# An economic comparison of forest recreation, timber and carbon fixing values with agriculture in Wales: a geographical information systems approach

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APPENDICES

# Appendix 1: Woodland Valuation Studies: Detailed Literature Review

In this appendix we present detailed review and commentary upon the woodland recreation valuation studies summarised in chapter 3. In addition to these we provide commentary upon two further studies: the 'expert valuation' approach pioneered by Helliwell (1967, 1969, 1978, 1990); and an analysis of the landscape amenity value of woodland undertaking using the hedonic pricing method by Garrod and Willis (1991a,b; 1992a,b,c). This latter study is of particular interest to the future development of this research as we intend to extend our CBA appraisal of woodland to include landscape impacts.

In keeping with the approach of chapter 3, these reviews are ordered chronologically with the above-mentioned additional studies included at the end of this appendix.

## A1.1: The Total Recreation Value of the Forestry Commission Estate: H.M. Treasury CBA Study

**Method:** ZTC

**Evaluation Unit:** National value

### Commentary

In 1971 an interdepartmental team of government economists under Treasury chairmanship undertook a cost-benefit analysis of all aspects of Forestry Commission activities. As part of this, monetary values were estimated for recreation and amenity benefits (no attempt was made to desegregate recreation from amenity and it is clear from the analysis that it is the former which is of prime interest).

The Treasury's report (published in 1972) recognises the high and growing value of non-priced recreation on the Commissions estate[1].

Monetary evaluation is introduced via a discussion of ZTC techniques. This discussion is somewhat piecemeal, highlighting three assumptions as critical:

i. The opportunity cost of time: the Treasury makes two interesting (and debateable) assertions; firstly that time spent on-site will correlate directly with travel time (an assertion we shall discuss subsequently with respect to our Thetford Forest experiment ... ity costs of time for short trips (the Treasury suggest ... ay be zero in which case basing recreation values up ... lead to an overestimation of benefits;

ii. The exogeneity of costs: ... t if individuals fix home locations so as to reduce re ... costs themselves will be endogenous to the system ... underestimate benefits. Again the Treasury makes ... nt evidence) that "we may safely assume that the fo ... onsidered have no such dominating influence on residential location";

iii. Single purpose trips: if trips are multipurpose then the use of full travel cost will lead to an overestimation of recreation benefits.

All of these assumptions/problems have been reviewed in detail earlier, however the Treasury's (forthright) views on each matter are of interest[2]. The Treasury's investigations did not extend to any new survey work. Instead it extrapolates the results of a[illegible] recreational study undertaken by the Department of the Environment (DoE). [illegible] approach is to be criticised as this latter study examined general outdoor recreation ra[illegible] forestry, used an unspecified variant of what is presumably the ZTC and was never pu[illegible], indeed even the survey year is not given, making it uncertain as to the base year of all

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[1] A notable policy statement is made here; "It would be wrong to deter visitors by levying charges in excess of the costs to which their visits gave rise" (p.23-24). This implies that any access-pricing policy should be based upon user costs rather than provider costs or any cost-benefit measure.

[2] The Treasury's analysis came under attack shortly after its publication (Wolfe, 1973, Anon, 1973). While the main focus of these criticisms was non-recreation values, Wolfe (1973) claims that national recreation values were higher than estimated due to the exclusion of private woodlands. However, the scope of the Treasury study is specifically confined to FC land and this criticism can therefore be discounted.

reported results. This makes an objective analysis of the DoE study impossible, the only details being those given in table A1.1.

Table A1.1: Results of DoE general outdoor recreation study

| Trip type | Median trip length (miles) | Median trip duration (hours) | Consumer Surplus of trip (£/person) |
|---|---|---|---|
| Whole day<br>Half day | 50<br>25 | 6 to 7<br>3 to 3.5 | 0.35<br>0.20 |

Source: Abstracted from HM Treasury (1972).

These benefit estimates were then applied to data collected as part of the Forestry Commission's 1968 summer visitor survey[3]. This survey classified sites according to the number of cars "likely to be found on a typical Sunday afternoon" (HM Treasury, 1972), arriving at the following classifications:

i. Concentrated use sites; over 15 cars
ii. Lesser use sites; between 5 and 15 cars
iii. 'Linear' sites; 4 cars parked per quarter mile

Separate visitor details were available for the New Forest, Dean Forest, Westonburt and Bedgebury arboreta[4]. Applying the DoE benefit estimates to these data allow the calculation of the informal recreation benefits detailed in table A1.2.

An attempt is then made to desegregate these national informal recreation estimates to a Forestry Commission Conservancy level using the conservancy visitor data collected in the 1968 survey. Results for this analysis are reported in table A1.3. An attempt is also made to calculate per hectare figures for which the Treasury assume that only land planted for at least 25 years (ie. pre 1945) will yield a consumer surplus. This is a crude analysis with no allowance for what will in fact be a gradual increase in value over time. Nevertheless it gives a general guide although figures will be grossly inflated for areas with high numbers of visitors where there are relatively few mature plantations.

This general approach is then extended to the analysis of campers. Forestry Commission receipts from camping totalled some £66,000 in 1969/70 however the Treasury recognise the likelihood of a considerable consumer surplus and in the absence of any clear information assume (boldly) that this is equal to half of the full day rate estimated by the DoE. This produces the results given as table A1.4.

[3]Survey date: 1st June to 30th September 1968.
[4]No further details of this survey are given.

Table A1.2: HM Treasury (1972) estimates of informal recreation consumer surplus values

| Site | Estimated Average Visit Duration (hrs) | Estimated Consumer Surplus (£/visit) | Annual Visits (million) | Total Consumer Surplus (£ million) |
|---|---|---|---|---|
| New/Dean etc | 3.0 | 0.20 | 2.2 | 0.44 |
| Concentrated use | 1.0 | 0.05 | 6.0 | 0.30 |
| Lesser use | 1.0 | 0.05 | 0.6 | 0.03 |
| Linear use | 1.0 | 0.05 | 6.7 | 0.34 |
| Total | | | 15.5 | 1.11 |
| Note: In addition the Forestry Commission report honesty box receipts of £70,000 p.a. | | | | |

Source: HM Treasury (1972)

Table A1.3: Day visits and consumer surplus per day visit and per hectare

| Conservancy | Total Day Visits 1968 (million) | Total Consumer Surplus[1] (£'000) | Area planted before 1945[2] ('000 ha) | Consumer surplus of land planted before 1945 (£/ha) |
|---|---|---|---|---|
| England | | | | |
| NW | 1.38 | 99.4 | 13.1 | 7.66 |
| NE | 1.40 | 100.8 | 19.0 | 5.31 |
| E | 2.24 | 161.3 | 21.2 | 7.61 |
| SE | 1.74 | 125.3 | 5.3 | 23.64 |
| New | 1.80 | 129.6 | 6.1 | 21.25 |
| Dean | 0.38 | 27.4 | 4.2 | 6.52 |
| Scotland | | | | |
| N | 0.71 | 51.1 | 20.5 | 2.49 |
| E | 0.32 | 23.0 | 20.4 | 1.13 |
| S | 0.22 | 15.8 | 9.5 | 1.66 |
| W | 1.24 | 89.3 | 15.5 | 5.76 |
| Wales | | | | |
| N | 0.85 | 61.2 | 14.6 | 4.19 |
| S | 1.04 | 74.9 | 13.7 | 5.47 |
| Total | 15.46 | 1,113.2 | 171.8 | 6.48 |

Notes 1. Assumes that the calculated national average consumer surplus per visit (£0.72) is valid for all sites.
2. 1 hectare = 2.471 acre.
3. It is somewhat unclear, however these figures appear to be at 1970 prices.

Source: HM Treasury (1972)

Table A1.4: HM Treasury (1972) estimates of camper recreation consumer surplus values

| Site | Campers Nights (p.a.) | Consumer Surplus per Camper Night (£) | Total Consumer Surplus (£) |
|---|---|---|---|
| New Forest | 330,000 | 0.175 | 87,500 |
| Elsewhere | 500,000 | 0.175 | 57,750 |
| Total | 830,000 | - | 145,250 |

Source: HM Treasury (1972)

The final recreational user category considered by the Treasury report is that of specialist users namely deer hunters, other hunters, fishermen, nature watchers and educational groups. While a net revenue of £70,000 p.a. is recorded for the general shooting/fishing group. Lack of data meant that no consumer surplus estimate could be made for any or all of these groups. This is a shortcoming as individual consumer surplus values for such groups are likely to be high. However the low number of specialist users means that aggregate values are not likely to be high.

Finally the Treasury team turn to forest amenity values. Here data is almost totally absent nevertheless, while avoiding any positive statement the Treasury declare that "it seems clear that there is no (amenity) debit to be deducted from the recreational benefits of forestry".

In summary, the slim and under-reported empirical basis of this study makes suspect the reliability of recreation benefit estimates. Nevertheless, per visit, aggregate, disaggregated and national consumer surplus estimates are reported and, given the weight of Treasury calculations, these are of importance.

## Summary Results

National recreational consumer surplus = £1,113,200 (1970 prices).
Conservancy and per hectare estimates given in table A1.3.

## Study Reference

H.M. Treasury (1972) *Forestry in Great Britain: An Interdepartmental Cost/Benefit Study*, HMSO, London.

## Supplementary References

Wolfe, J.N. (1973) Some considerations regarding forestry policy in Great Britain. *Report to the Forestry Committee of Great Britain*, Department of Economics, University of Edinburgh.

Anon (1973) Deficiencies in forestry study, *Timber Trades Journal*, 12th May 1973.

## A1.2: National Recreation Values: Predicting Visitor Numbers

**Method:** TC

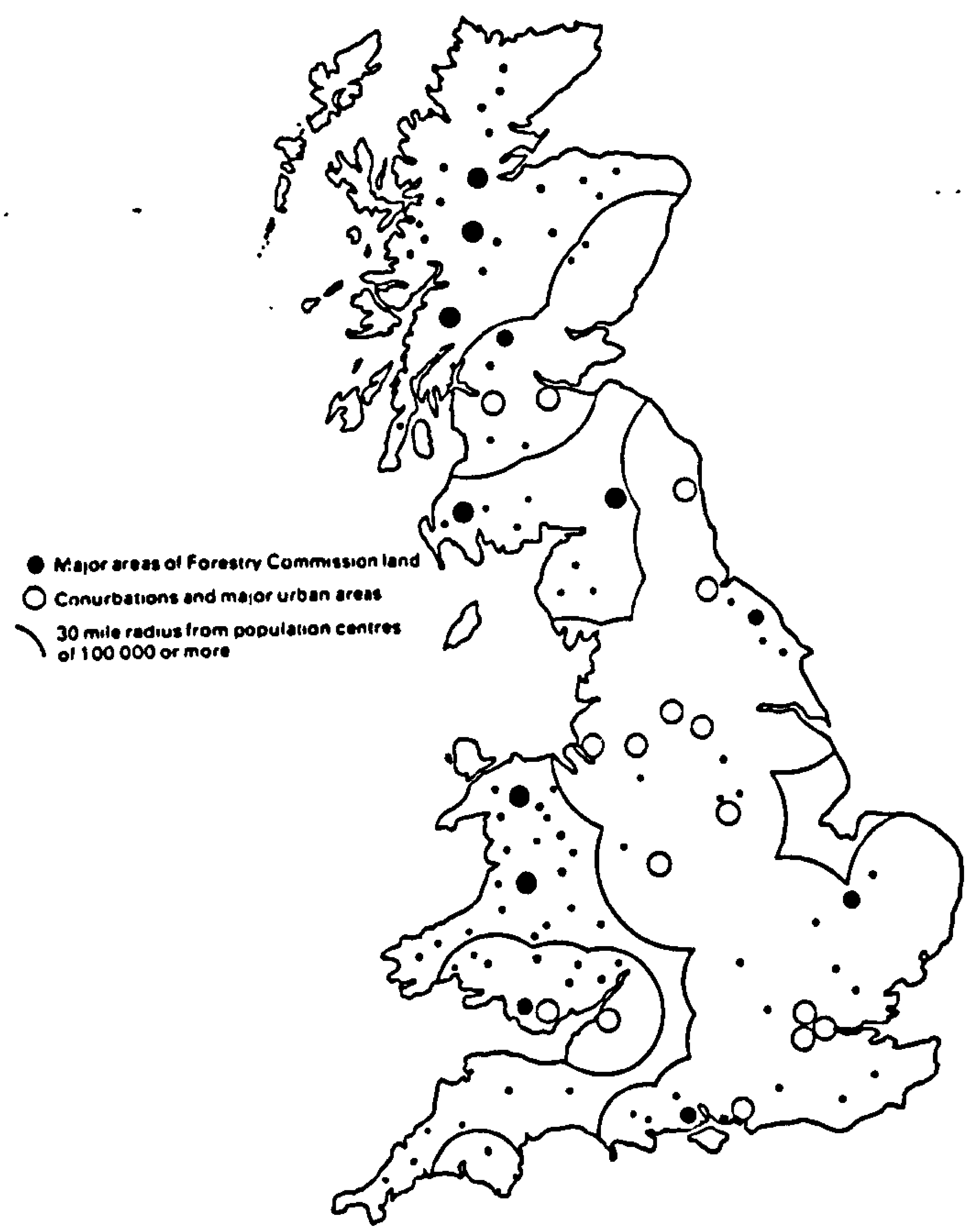
**Evaluation Unit:** National and per acre values

**Commentary**

The recreation estimates produced in this paper (Grayson et al., 1975) are strongly linked to those of the contemporary HM Treasury (1972) study and as such add little to the quantitative debate. However important observations are made regarding both the nature of recreation on the FC estate and regarding the relationship of visitor use to local population density.

The FC estate is characterised as consisting mainly of young[5] conifer plantations situated away from areas of high population density. This latter point is illustrated in figure A1.1 and is highlighted as a major problem for the maximisation of recreation benefit values[6].

Figure A1.1: Location of major forests and urban areas




Source: Grayson et al. (1975)

[5]Less than 25 years old (in 1972).

[6]Despite this early observation it is only in the 1990s that the Forestry Commission, jointly with the Countryside Commission, has significantly changed its planting emphasis in favour of lowland high population areas.

Grayson et al. point out that private woodlands[7] are often closer to urban populations, older and predominantly broadleaves. However in the absence of private incentives to provide informal recreation and consequent lack of public access, these are not seen as substitute goods. Estimates of visitor rates and recreation values are based upon the same sources as for HM Treasury (1972) although Grayson et al. report a range of results as detailed in tables A1.5 and A1.6.

Table A1.5: Estimates visitor numbers for the Forestry Commission estate, 1968

| Area | Estimates of seasonal total of day visits (million) | Estimates of lengths of stay (hours) | Implied visitor hours (millions) |
|---|---|---|---|
| New Forest | 1.8 | 2.2 | 4.0 |
| Forest of Dean | 0.4 | 2.5 | 1.0 |
| concentrated use sites | | | |
| weekdays | 3.0 to 6.0 | 1.0 | 3.0 to 6.0 |
| weekends | 1.0 to 3.0 | | |
| Less/linear sites | | 1.2 | 6.0 to 17.0 |
| weekends only | 4.0 to 11.0 | | |
| Average | | 1.3 | |
| Total | 10.2 to 22.2 | | 14.0 to 28.0 |

Source: Grayson et al. (1975)

Table A1.6: National and per acre consumer surplus[1] (£ 1971)

National informal recreation value[2] = £1.05 million

| Area | Consumer surplus[3] (£/acre) |
|---|---|
| East Scotland Conservancy (lowest) | 0.04 |
| South East England (highest) | 8.60 |
| Great Britain (average) | 2.50 |

1. Assumes consumer surplus of £0.05 per hour
2. Assumes mean total visitor hours of 21 million p.a.
3. Assumes that only plantations of age 25+ years give a reception value (some 420,000 acres in 1971)

Source: Grayson et al. (1975)

An interesting analysis is presented regarding the trade off between timber and recreation values. This consists of two case studies, the first being a cost benefit analysis of a hypothetical forest recreation area (using accurate cost estimates) which we summarise as table A1.7, and the second being a NPV calculation of optimal felling age with and without the consideration of supplementary recreation values, which we present as table A1.8.

[7]Grayson et al. also raise many of the same objections as HM Treasury (1972) regarding the travel cost methodology.

Table A1.7: Cost benefit analysis of converting a 5-acre timber area to recreational use

| Benefits | (£) | Costs | (£) |
|---|---|---|---|
| (60 car park spaces) * (100 use/space pa) * (3 people/car) = 18,000 visit pa<br>@ 1 hr/visit<br>@ CS of £0.05/hr<br><br>= Recreation value | <br><br><br><br><br><br><br>900 | Capital costs:<br>i. 60 spaces @ £25 each<br>ii. 5 acres foregone timber<br>iii. Path creation<br><br>Annualized @ 10% over 20 yrs<br>+ annual maintenance<br>= Annual cost equivalent | <br>15,000<br>200<br>500<br>2,200<br>260<br>150<br>410 |
| ∴ Net Benefit = £900 - £410 = £490 pa | | | |

Source: Abstracted from Grayson et al. (1975)

Table A1.8: Present value of timber and recreation values: Sitka Spruce (YC = 12) (£ 1971)

| Age of felling, years | 30 | 35 | 40 | 45 | 50 | 55 | 60 |
|---|---|---|---|---|---|---|---|
| Discounted wood revenue (DR) at market prices | 93.9 | 112.3 | 117.7 | 114.8 | 107.9 | 100.5 | 88.3 |
| DR foregone by adopting different felling age from forty | 23.8 | 5.4 | 0 | 2.9 | 9.8 | 17.2 | 29.4 |
| Marginal DR loss for each five year delay in felling | | | | 2.9 | 6.9 | 7.4 | 12.2 |
| Cumulative discounted recreation benefit at constant £20 per acre per year from year twenty-five | 75.8 | 122.9 | 152.1 | 170.3 | 181.5 | 188.5 | 192.9 |
| Total wood plus recreation benefits | 169.7 | 235.2 | 269.8 | 285.1 | 289.4 | 289.0 | 281.2 |

Source: Grayson et al. (1975)

Table A1.8 confirms that the addition of recreation benefits, accumulating from a plantation age of 25 years, leads to an increase in optimum felling age. While this is a general result[8] we are doubtful that the recreation benefit level assumed in table A1.8 can be justifiably attached to Sitka Spruce[9].

The most interesting addition to the literature provided by this paper is confined to a short appendix concerning the prediction of visitor rates. Analysis of the 1968 day visitor survey data is undertaken via three alternative regressions. The first and most complex of these attempts to construct a forest attractiveness index as follows:

[8]Bateman (1987) uses FC data to show the impact upon optimal felling age of a variety of benefit values, discount rates and discounting regimes for various species types and yield classes.

[9]Garrod and Willis (1992) highlight the negative externalities which may characterise such species.

(a) A trip attraction index is set up which postulates a linear negative relation between visits and distance such that visits fall to zero at some set distance (assumed as 30 miles straight line distance).
(b) This is then multiplied by the population in each of five concentric distance zones within the overall 30 mile radius. For simplicity an assumption of homogeneous population distribution was adopted.
(c) This product was then summed across all forests in each FC conservancy.
(d) The resulting measure was then weighted according to the plantation age distribution within each conservancy using weights of: 1 for woods of less than 25 years old; 3 for woods between 25 and 50 years old; and 5 for woods over 50 years old. This weighting should actually be done at the forest level (ie. before point (c)). However Grayson et al. claim that the computational pressures handling 300 forests were too great.
(e) This produces the conservancy (i) attractiveness index $ATTRACT_i$.

Regressing 1968 conservancy visitor numbers ($V_i$) in thousands against $ATTRACT_i$ and constraining the model to pass through the origin gives regression equation (A1.1)[10].

$$V_i = \underset{(0.33)}{3.77}\ ATTRACT_i \qquad (A1.1)$$

for which $R^2 = 0.66$

The degree of explanation afforded by equation (A1.1) is quite reasonable. A second approach examined the variable $AGE1_i$ being simply the ages of forests within a conservancy. Regression results for this model are given by equation (A1.2).

$$V_i = \underset{(0.45)}{4.09}\ AGE1_i \qquad (A1.2)$$

for which $R^2 = 0.49$

A refined age variable, $AGE2_i$, being forest area weighted by age and proportion of broadleaves was also tested as shown in equation (A1.3).

$$V_i = \underset{(0.30)}{2.69}\ AGE2_i \qquad (A1.3)$$

for which $R^2 = 0.57$

Clearly the assumptions underlying the construction of these explanation variables are too strong for us to have much confidence in the precise predictions of these models. Furthermore the simplicity of these models is to be criticised. As each explanatory variable appears individually significant the obvious next stage in such an analysis is to estimate a multiple regression model of the ATTRACT and at least one AGE variable. Such an analysis is not reported, nevertheless the work of Grayson et al. does strongly suggest that, given suitable data and computing power, further analysis might well be worthwhile. Such a conclusion supported our own GIS-based analysis of visitor arrivals.

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[10] Although not stated, given the levels of $R^2$, we conclude that numbers in parentheses are standard errors.

## Summary Results

National informal recreation value (1971) = £1.05 million p.a.
Average consumer surplus per acre = £2.50 p.a.

## Study Reference

Grayson, A.J., Sidaway, R.M. and Thompson, F.P. (1975) Some aspects of recreation planning in the Forestry Commission in Searle, G.A.C. (ed.). *Recreational Economics and Analysis: papers present at the Symposium on Recreational Economics and Analysis, London Graduate School of Business Studies, January 1972*, Longman, Essex.

## Supplementary References

Bateman, I.J. (1987) Forestry in the UK: A standard and social discounting approach to investment evaluation, *MSc thesis*, Department of Agricultural Economics, University of Manchester.

Garrod, G.D. and Willis, K.G. (1992) The environmental economic impact of woodland: a two-stage hedonic price model of the amenity value of forestry in Britain, *Applied Economics*, 24:715-728.

H.M. Treasury (1972) *Forestry in Great Britain: An Interdepartmental Cost/Benefit Study*, HMSO, London.

## A1.3: THE DALBY FOREST STUDY

**Method:** ZTC

**Evaluation Unit:** CS per visitor and CS per ha (unadjusted and adjusted) values.

**Commentary**

The Dalby Forest is located in the North Yorkshire Moors National Park about 12 miles inland from Scarborough. The forest is mostly owned by the Forestry Commission and contains a variety of recreational assets including two nature trails, five signposted footpaths, open spaces with picnic areas, a natural history museum and (its most distinctive feature) a forest drive for which a fee was charged via an honesty box (the fee being 20p up to May 1975 after which it was raised to 30p).

Between March 1975 and March 1976 some 2816 questionnaires were completed, however due to a lack of suitable data concerning holidaymakers the latter were excluded, as were specialist visitors (horseriders; rally drivers; etc), leaving a dataset of 1425 day trip visitors.

Everett constructs an unusual visit rate variable based not upon the number of day visitors but instead upon the number of day visitor's cars to produce the following visit rate dependent variable ($V_i$) for each zone i:

$$V_i = \frac{N_i}{P_i} \qquad \text{(A1.4)}$$

where:

$N_i$ = the number of day visitors cars from zone i visiting Dalby forest during the (annual) survey period

$P_i$ = population of zone i

Everett then moves to define his travel cost variable ($C_i$) for each zone based upon return trip distance and a petrol cost of £0.7134/gallon adjusting this for mean car engine size per zone.

A number of criticisms can be raised regarding these definitions. Basing the visit rate ($V_i$) variable upon cars rather than individuals causes problems both regarding the aggregation of these results and their comparison with those of other studies, we shall return to this problem in our discussion of results.

The definition of travel costs is also suspect. Everett's adjustment for mean car engine size in each zone implies some logicality in such a heterogeneous relationship which would in fact contravene one of the basic assumptions of the ZTC. Furthermore although Everett initially defines these travel costs as simply distance multiplied by miles per gallon (based on engine size) multiplied by price per gallon, he later estimates an on-site experience demand curve as showing the number of vehicles visiting Dalby Forest at various hypothetical entrance charges *above* that already being paid via the honesty box. This implies that existing charges have already been incorporated presumably as part of the variable $C_i$ (although this is uncertain and complicated by the fact that not all visitors pay the honesty box fee).

Everett uses these variables to estimate a 'whole-experience' and from that an 'on-site experience' demand curve[11]. Everett points out that a double log functional form, in common contemporary use[12], implies that at zero cost the visitation rate would be infinite. This is clearly inappropriate for the 'on-site' demand curve and Everett instead fits a form which can theoretically apply to both demand curves as shown in equation (A1.5):

$$V_i = a + \frac{b}{(C_i+k)} \qquad \text{(A1.5)}$$

where a, b and k are constants.

The vehicle visit rate ($V_i$) for each zone was weighted according to the proportion of vehicles in the whole sample which originated from that zone (i.e. zones with high vehicle visit rates were given high weightings). The resulting weighted least squares (WLS) regression equation was iterated with various values for the constant k so as to maximise the correlation coefficient (r) between actual and predicted number of vehicle visits. Equation (A1.6) gives maximum $r = 0.98$.

$$V = -0.233 + \frac{109.7}{(C+179.1)} \qquad \text{(A1.6)}$$

Figure A1.2 maps this estimated 'whole-experience' demand curve onto the observed vehicle visit-rate data. As can be seen the WLS routine means that zones with very low visit rate have relatively little impact upon the fitted curve which closely fits high visit rate zones.

The visitation rate for each zone is plotted against the mean travel cost for day visitors to are Dalby Forest Area based on data from the period March 1975 to March 1976. Each point shown is based on a variable number of visits: O represents over 500 visits; o represents over 100 visits and under 500 visits; • represents under 100 visits.

Everett then estimates the 'on-site' experience demand curve. This is achieved by raising the value C in equation (A1.6) to mimic the effects of imposing various entrance fees[13]. The resultant 'on-site' demand curve is illustrated in figure A1.3 and predicts 126,155 visitors at zero entry fee and a zero visitors at an entry charge of £2.59.

Given the unusual choice of dependent variable, reported results are in terms of consumer surplus per vehicle and must be subsequently adjusted to give per person values. In per vehicle terms Everett reports on-site consumer surplus for day trip vehicles of £68,928.

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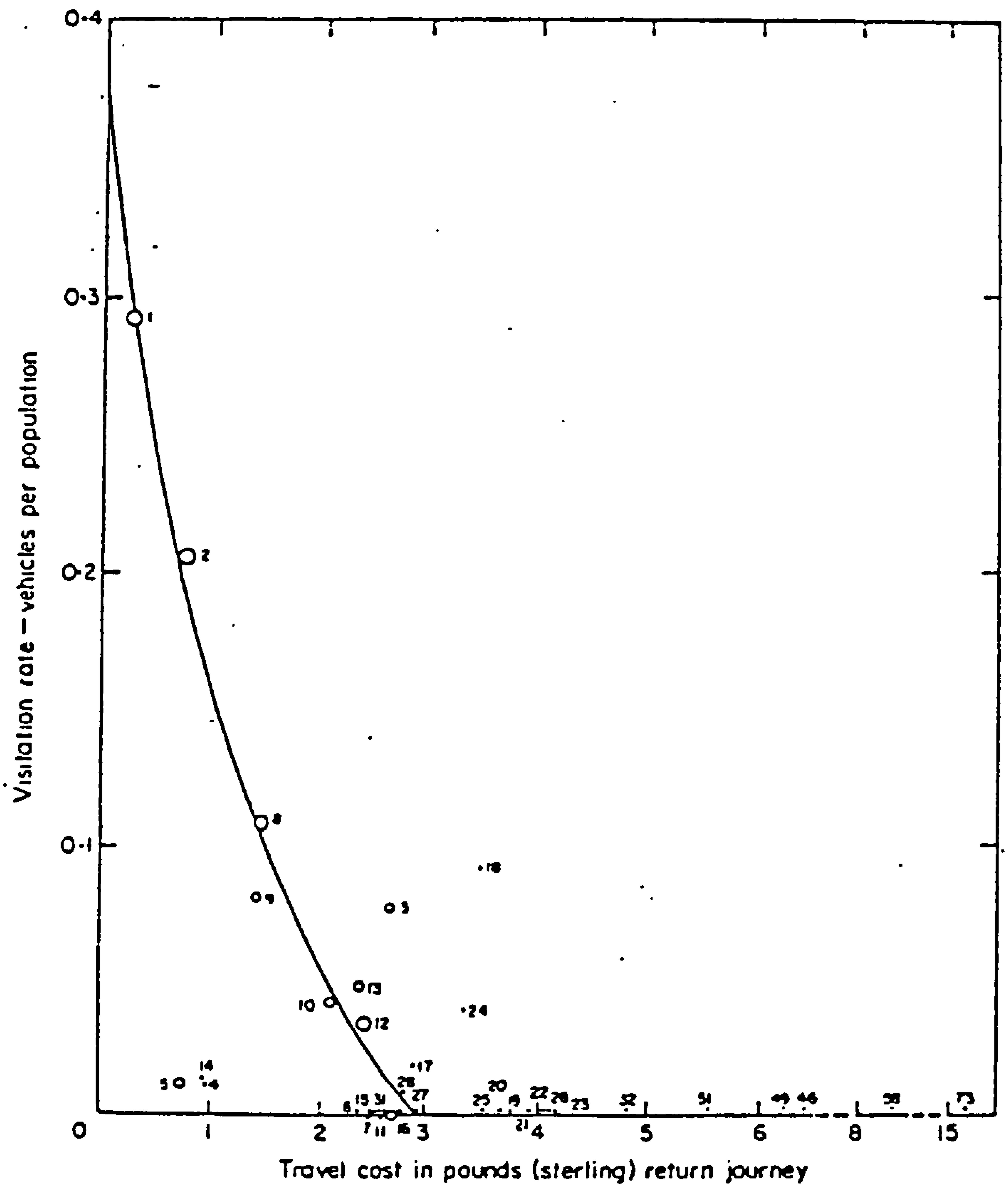
[11]Everett refers to the on-site demand curve as a 'simulated demand schedule'.

[12]See Kavanagh and Gibson (1971); Usher (1977).

[13]As detailed in chapter 2, this assumes that vehicle parties react in the same manner to increasing entrance fees as they do to increased travels costs.

Figure A1.2: Demand curve for the whole experience



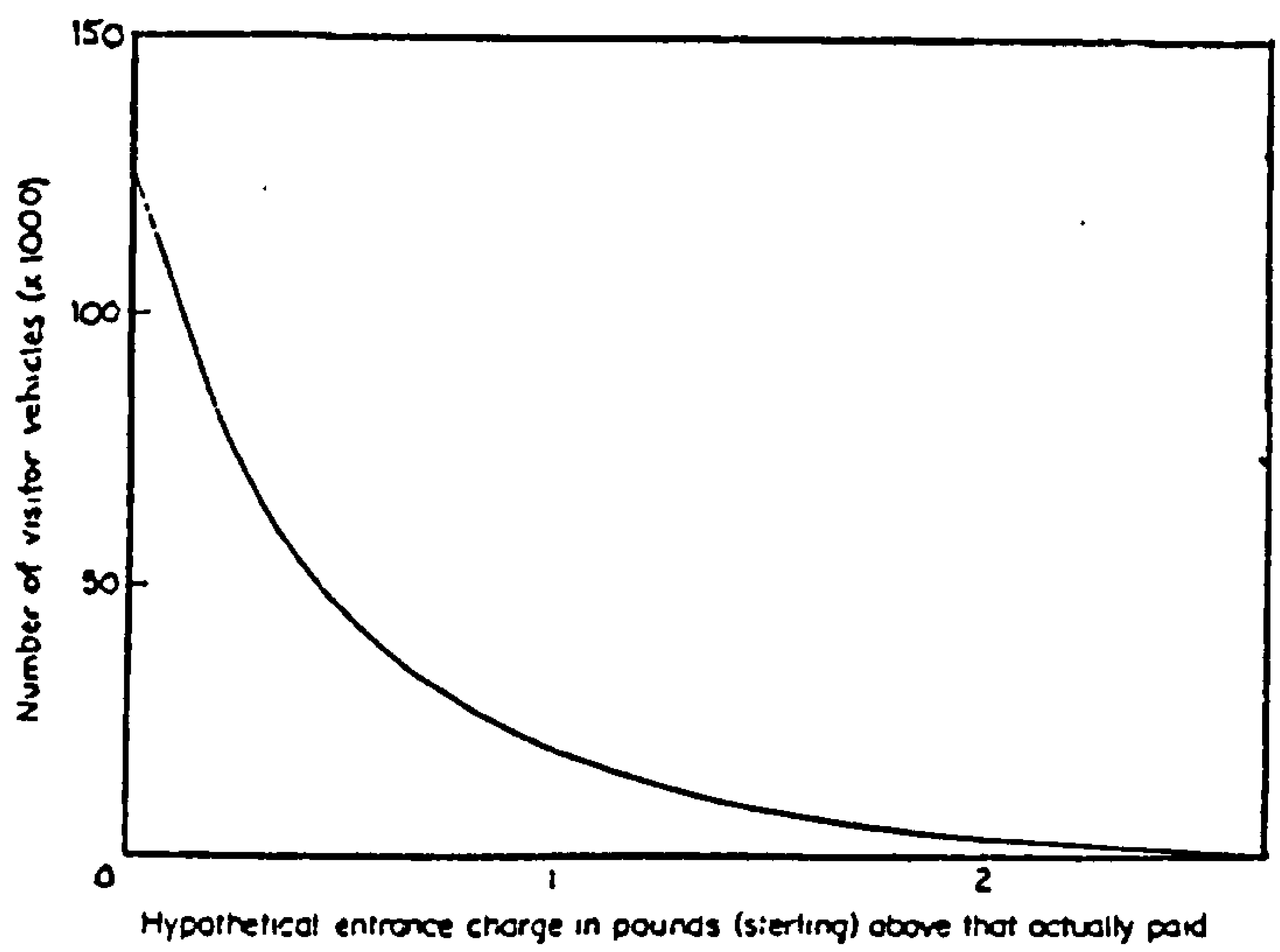

Key: O represents over 500 visits; o represents over 100 visits and under 500 visits; • represents under 100 visits.

The numbers relate to the following zones. Zones 1 to 28 are county districts and above 28 are counties.

| | | |
|---|---|---|
| 1 Ryedale | 13 Holderness | 25 Scunthorpe |
| 2 Scarborough | 14 Selby | 26 Craven |
| 3 Middlesbrough | 15 Harrogate | 27 Richmondshire |
| 4 Hambleton | 16 Leeds | 28 Doncaster |
| 5 Langborough | 17 Wakefield | 31 Durham |
| 6 Stockton-on-Tees | 18 Bradford | 32 Tyne and Wear |
| 7 Hartlepool | 19 Calderdale | 46 Cumbria |
| 8 York | 20 Kirklees | 49 Cheshire |
| 9 North Wolds | 21 Barnsley | 51 Nottinghamshire |
| 10 Beverley | 22 Sheffield | 58 Northamptonshire |
| 11 Boothferry | 23 Rotherham | 73 Kent |
| 12 Kingston-upon-Hull | 24 Glandford | |

Source: Everett (1979)

Figure A1.3: Demand curve for the on-site experience




Note: As with the whole experience demand curve there is uncertainty as to whether the travel cost variable used to map this curve includes existing (honesty box) entrance fees.

Source: Everett (1979).

Everett assumes that day visitor and holidaymakers have equal values for a visit (a questionable assumption) and states a ratio of all visitors to daytrip only visitors of 1.496. This implies an all-visitors consumer surplus of £103,116. To this Everett adds the annual entrance fees paid via the honesty box to reach a total value of £113,816[14]. An adjustment is then made for multi-purpose visits; 79.3% of respondents named visiting Dalby as the main purpose of their journey while the remaining 20.7% named another site. Everett therefore makes no adjustment to the first group but reduces consumer surplus for the second group by half i.e. he reasons that only 89.65% of the total recreational value is attributable to Dalby; that being approximately £102,000[15].

We face several problems in converting Everett's benefit estimate to a per visitor sum. His use of terminology is loose and at several points it is very difficult to determine whether he is referring to individual visitors or visiting vehicles. He refers to a figure of "53,200 day visitors during the year" and later states that the ratio of all cars to daytrippers cars (and therefore presumably all visitors to daytrip visitors) is 1.496. This would imply a total number of visitors of 80,000 pa. However Everett also states that "the total number of cars that visited the area during the survey period of March 1975 to March 1976, ... was estimated to be in the order of 80,000 vehicles". Clearly a car occupancy rate of approximately 1 is infeasible and we must conclude that Everett's "53,200 day visitors" refers to the number of day visitors *vehicles* and not to the number of individuals visits.

[14]Everett substracts from this £5000 for Forestry Commission recreation costs.
[15]Footnote 1 applies here also, Everett calculates this figure as £98,000.

This being so we are given no information regarding an appropriate car occupancy conversion rate. However, we can refer to such data as supplied by Willis (1988) in their study of six forest sites one of which was Dalby. Willis et al., report an average car occupancy rate of 3.10 persons[16]. Adopting this result then the 80,000 cars pa using Dalby in Everetts 1975/76 study equates to some 248,000 visits. Applying this to the whole site estimate of £102,000 produces an estimated consumer surplus per visit of £0.41[17] at 1979 prices. Benson and Willis (1992) report that this equates to a 1988 value of £1.93, being identical to their estimate of consumer surplus per visit at Dalby.

In an earlier paper, Everett (1977) devises an approach for disaggregating out the wildlife related aspects of monetary recreation value estimates. This approach presents respondents with a series of six questions from which a wildlife interest score (0-100%) is calculated. Everett (1979) applies this to the Dalby sample reporting a wildlife recreation score of 24.69% implying that some £25,000 of the total recreational value is due to wildlife although, following Price (1977), Everett shows that this value is not evenly distributed across the whole site. This procedure is somewhat subjective and we will not consider it further.

Everett discusses a variety of analytical issues. The omission of a time cost is justified on the grounds that 93.7% of respondents stated that they enjoyed the trip. Everetts wording of this question can be criticised however as being too stark and not allowing for the fact that travel time may still have a relative opportunity cost compared to other activities. This omission is therefore potentially serious.

Everett is aware of the travel cost endogeneity problem (see Turner et al.1992) in which proximity to the site influences home location which in turn reduces travel costs engendering an underestimate of true consumer surplus (see chapter 2). However he notes that 47.7% of respondents were first time visitors[18] while 92.8% visited less than 7 times in the past year. Indeed only two respondents said that they visited almost every day. From this Everett concludes (we feel quite reasonably) that any underestimate arising from this problem will be small.

The treatment of substitute sites is, Everett recognises, very cursory. Following our discussions of chapter 2 this can be seen to be a potentially serious omission. Similarly the analysis of socioeconomic factors can be criticised not for its absence but rather for its strange nature. Rather than attempting to investigate socioeconomic factors influencing actual visits, Everett asks the hypothetical question "Would you *like* to come more often than you do" (emphasis added) reporting significant $\chi^2$ analyses for various socioeconomic groups as follows (table A1.9).

While the analysis of table A1.9 is not in itself of great interest, Everett asked all those who stated that they would like to visit more, why they did not. Of these respondents some 41.4% gave reasons of cost/distance (supporting the inclusion of the cost variable in the tgf) while some 53.2% gave reasons of work/time constraints. The prevalence of this latter result indicates that TC models might be substantially improved via the inclusion of some appropriate work/time constraint parameter.

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[16]Average for all six sites sampled.

[17]For indexing purposes this figure is £0.41129.

[18]This would raise extreme problems for any ITC analysis (see chapter 2) and therefore supports our subsequent criticisms of Willis and Garrod (1991).

Table A1.9: $\chi^2$ analysis of visitation preferences

| Socioeconomic Group | Visit Preference[1] | $\chi^2$ | df | Significance Level |
|---|---|---|---|---|
| Pensioners | + ve | 14.55 | 1 | 1% |
| Skilled Manual | - ve | 4.79 | 1 | 5% |
| Income £2-£3K | - ve | 7.92 | 1 | 5% |
| Income £3-£5K | - ve | 4.61 | 1 | 5% |

Notes: 1. + ve = would like to visit more
- ve = would not like to visit more

In a further associated sub analysis Everett examined the basic assumption of socioeconomic homogeneity across sites. Again $\chi^2$ analysis techniques are used to show that both income and occupation differ significantly between zonal samples[19] concluding that this "suggests that socioeconomic groups may alter proportionately with different zones, and may have variable behaviour towards visitation thus violating the first basic assumption" of the ZTC approach.

Everett is therefore aware of many of the criticisms of analysis. Given the absence of reported data it is impossible for us to assess the depth of some of the more serious problems (e.g. time costs). However this study is notable for being the only UK study to attempt to produce meaningful per hectare consumer surplus figures by recognising that only a relatively small part of most Forestry Commission and other timber orientated forests is used for recreation[20]. The entire estate of Dalby Forest covers some 4500 ha. Dividing our revised total recreational sum of £102,000 over this yields a consumer surplus of £22.66 per hectare. However Everett defines the recreational area of the forest as the sum area of nature reserves, picnic areas, car parks, an area 50m either side of all footpaths and an area 100m either side of the forest drive. This yields a total recreational area of 625 ha equating to a consumer surplus of £163 per hectare.

In conclusion, this early study does have some problems however it also provides some excellent fundamental analysis.

## Summary Results (£ 1979)

ZTC consumer surplus per visitor = £0.41
Consumer surplus per hectare (unadjusted) = £22.66
Consumer surplus per recreation hectare = £163.20

## Study Reference

Everett, R.D. (1979) "The monetary value of the recreational benefits of wildlife". *Journal of Environmental Management*, 8:203-213.

[19] $\chi^2$ for income group with zone was 169.14 with 132 df giving significance at 1.5% level. $\chi^2$ for occupation with zone was 336.61 with 288 df giving significance at 2.5% level.

[20] One exception to this may be 'community woodlands' where recreation is a major focus (see subsequent discussion of Bishop (1992)).

## Supplementary References


Benson, J.F. and Willis, K.G. (1992) Valuing informal recreation on the Forestry Commission estate, *Bulletin 104*, Forestry Commission, Edinburgh.

Everett, R.D. (1977) A method of investigating the importance of wildlife to countryside visitors. *Environmental Conservation*, 4:227-231.

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Willis, K.G., Benson, J.F. and Whitby, M.C. (1988) Values of user benefits of forest recreation and wildlife. *Report to the Forestry Commission.* Department of Town & Country Planning, University of Newcastle upon Tyne.

# A1.4: GWYDYR FOREST (NORTH WALES) STUDY

**Methods:** ZTC/CV

**Evaluation Unit:** CS per predicted visitor group

**Commentary**

The data for this study was collected by Humphreys (1981) between June and October 1980 consisting of 237 interview questionnaires collected at five different locations within Gwydyr Forest[21]. Christensen (1985) then attempts to apply both ZTC and CV techniques to this data.

The ZTC analysis Christensen (1985) is well conducted and thorough (within the limitations of the data available). Christensen notes that, given that 73% of respondents were on holiday (rather than day trips) the standard Clawson ZTC approach is liable to overstate consumer surplus unless specific account is taken of the fact that holidaymakers are likely to visit several sites during their holidays. Christensen et al therefore proposes a 'revised Clawson method' (RCM) "in which travel-from-home costs were spread over the whole holiday" and "the allocated fraction of these costs plus the travel cost for the day" (Price et al, 1986) was entered as the respondent's visit travel cost. Of particular note is the attention which this work gives to the weighting of observations for use in bid curve analysis as developed theoretically in Christensen and Price (1982) and given empirical testing in Price et al (1986). Weighting approaches are adopted to combat the problems of heteroskedasticity and sampling bias[22]. This study also gives one of the few analyses of the effects of respecifying the definition of zones; two concentric systems are tested with 10 and 6 zones respectively, although Christensen (1985) recognises that non-concentric systems (eg. using postcode zones) are equally valid. Results for some of the many permutations of model specification report at given in table A1.10.

The results of table A1.10 show a wealth of diverse analyses. Although Christensen (1985) states that deciding which model performed best was problematic, in later papers the log form alone is reported and we shall follow their judgement. Examining results for the log linear model we can see a large divergence between results for the standard Clawson model and Christensen et al's RCM approach. This is not surprising as ignoring multiple site bias will clearly lead to overstatement of a site's consumer surplus (especially where 73% of visitors are on holiday). Comparison of the "zone pop." (Bowes and Loomis, 1980) and "pop./vis" (Christensen and Price, 1982) weightings for heteroskedasticity show that moving from one to the other makes relatively little difference to consumer surplus estimates. As the latter approach seems more thorough such results are to be preferred. Introduction of the Lucas (1963) weighting for sampling error almost halves consumer surplus estimates and again, given the prevalence of holidaymakers among the sample, a significant downward revision is to be expected. Finally it is interesting (and comforting) to note that respecification of zonal bands had relatively little impact upon consumer surplus estimates. Christensen (1985) suggests that, as we have no prior expectation of a 'correct' zonal specification, the average value over a series of respecifications would seem a logical choice

[21]OS reference: SH 770 590.

[22]See discussions of these papers with respect to the travel cost method (chapter 2).

of benefit measure.

Table A1.10: ZTC results for the Gwydyr Forest study: consumer surplus per predicted visitor group (pvg)[1]

| Functional Form | Weight[2] | CS/pvg (£) standard Clawson[3] | CS/pvg (£) revised Clawson (RCM)[4] | CS/pvg (£) RCM: plus Lucas weight[5] | CS/pvg (£) RCM: zones respecified[6] |
|---|---|---|---|---|---|
| Linear | zone pop. | 7.29 | 0.63 | 0.39 | 0.39 |
| | pop./vis | 7.39 | 1.22 | 0.40 | 0.42 |
| Log linear | zone pop. | 6.22 | 0.83 | 0.42 | 0.43 |
| | pop./vis | 5.91 | 0.84 | 0.36 | 0.38 |

Notes:

1. Christensen and Price (1982) argue that, with correctly specified models, the predicted visitor group (pvg) numbers provide a superior aggregation guide than say last years observed visitor numbers.
2. Weight designed to combat heteroskedasticity; the zone pop. (zonal population) weight follows Bowes and Loomis (1980); the pop./vis (zonal population/visit rate) follows Christensen and Price (1982) (see travel cost method description, chapter 2).
3. Model CLAW14 in Christensen (1985).
4. Model CLAW2 in Christensen (1985). This differs from the standard Clawson approach by the calculation of multiple site visitors (eg. holidaymakers) visit travel costs (see text).
5. Model CLAW17 in Christensen (1985). Along with heteroskedasticity weighting this model also employs a Lucas (1963) weighting system to counteract sampling bias (see chapter 2).
6. Model CLAW17 in Christensen (1985). As per model CLAW6 but with the latter 10 distance zones redefined into 6 zones.

Source: Abstracted from Christensen (1985).

While many of the reservations of chapter 2 still stand, nevertheless this study stands as a thorough application of the ZTC, which attempts to address many fundamental problems.

The CV analysis in this study is of a more cursory nature and can be criticised on the grounds of induced starting point and anchoring bias. Christensen (1985) asks respondents the following question;

"to help me assess how much you value Gwydyr as a recreational areas, I would like to ask you what you personally would be willing to pay as an entry fee".

Each respondent was then offered one of the following four prompts;

Option 1: no prompt
Option 2: "would you be willing to pay 25 pence?"
Option 3: "would you be willing to pay 1 pound?"
Option 4: "would you be willing to pay 2 pounds?"

Results from this discrete variable format experiment were unfortunately not analysed.

Instead Christensen (1985) follows up options 2-4 above with an open-ended "how much are you willing to pay?" question and reports results from all four options as per Table A1.11.

Table A1.11: Mean Willingness to Pay for Four Starting Point Subsamples

| Starting Point (£) | Mean WTP (£) |
|---|---|
| none | 0.446 |
| £0.25 | 0.385 |
| £1.00 | 0.851 |
| £2.00 | 1.396 |

Source: Christensen (1985)

Table A1.11 illustrates a very clear starting point bias. Indeed in an accompanying one way analysis of variance (ANOVA) test Christensen reports equation (A1.7) as the only fully significant model i.e. only the level of starting point was statistically significant ($p < 0.001$) in explaining the stated final WTP bid (although income was weakly significant; $p < 0.098$).

$$Y_{ij} = a_i + e_{ij} \qquad \text{(A1.7)}$$

where

| | | |
|---|---|---|
| $Y_{ij}$ | = | the willingness to pay of individual j when prompted by option i |
| $a_i$ | = | coefficient for prompting option i (i = 1 to 4) |
| $e_{ij}$ | = | random error term. |

While this seems clear cut, the analysis of such data is strictly speaking invalid given that answers to option 1 are to a standard open ended (continuous variable) CV question while answers to options 2 to 4 involve an iterative bidding game (despite there being only one iteration following the starting point) with three separate starting points the only strictly correct analyses would have been to examine responses to option 1 separately using continuous variable techniques and then analyse options 2 to 4 as three levels in a discrete choice experiment requiring logit (or probit as appropriate) analysis (see Bateman and Turner, 1992 and, for an applied study, Bateman et al., 1992).

This problem of a mixed continuous and discrete variable dataset is avoided by Price et al (1986). Here respondents are presented with eight discrete fee levels yielding the data reproduced in table A1.12[23].

[23]Few details are given regarding this data leaving some questions unanswered; what is the meaning of the 0 pence fee? how do we interpret the >500 pence level?; were these actually gathered in an iterative bidding game starting at zero and presented to all respondents? (in which case continuous variable analysis is more relevant).

Table A1.12: Respondents willing to pay a hypothetical entrance fee

| Fee (pence) | 0 | 20 | 50 | 100 | 150 | 200 | 300 | >500 |
|---|---|---|---|---|---|---|---|---|
| Number WTP at least that fee | 237 | 200 | 152 | 70 | 20 | 16 | 1 | 0 |

Source: Price et al (1986).

Price et al., (1986) present the above as discrete variable data in which case the continuous variable statistical analysis subsequently presented is invalid. The above data should correctly be analysed and mean WTP determined via a logit analysis[24]. Instead, the analysis presented details a double log function relating visits (V) to the sum of transport costs (c) and the stated entrance fee (f), the estimated function being equation (A1.8) below[25].

$$\ln(V) = a + b \ln(F + c) + e \qquad \text{(A1.8)}$$

Price et al., (1986) vary the level of c so as to estimate b at the models maximum explanatory power however, as the authors note, this occurs at an unrealistically low value of c (= £0.25). Details of this analysis are given in Table A1.13.

Table A1.13: Results of equation (A1.8) at varying levels of transport cost (c)

| Inserted value of c (pence) | Fitted value of b | $R^2$ |
|---|---|---|
| 1 | -1.334 | 0.833 |
| 10 | -1.618 | 0.889 |
| 25 | -1.807 | 0.891 |
| 50 | -2.028 | 0.878 |
| 100 | -2.372 | 0.852 |
| 200 | -2.942 | 0.813 |

Source: Price et al., (1986).

In defence of these results the coefficient of price elasticity of demand is correctly signed throughout and all models give similarly high degrees of explanation. However following on from the above criticism of analytical approach and the clear evidence of induced bias within the earlier CV study we cannot give much emphasis to these results.

[24]As per Bateman and Turner, 1992; Bateman et al, 1992; and chapter 2.

[25]Here a = scale parameter of demand; b = price elasticity of demand; and other variables as defined in the text. Note that Price et al (1986) use (V + 1) in place of (V) as the dependent variable to avoid ln(0) occurring However, this is unnecessary as all observations by definition have V>0.

## Summary Results

ZTC: Consumer surplus = £0.37 per predicted visitor group[26].

## Study References

Christensen, J.B. (1985) An economic approach to assessing the value of recreation with special reference to forest areas, *PhD thesis*, Department of Forestry and Wood Science, University College of North Wales, Bangor.

Christensen, J.B., Humphreys, S.K. and Price, C. (1985) A revised Clawson method: one part-solution to multidimensional disaggregation problems in recreation evaluation, *Journal of Environmental Management*, 20:333-346.

Humphreys, S.K. (1981) The socio-economic characteristics of respondents to recreation questionnaires in Gwydyr Forest, *unpublished BSc dissertation*, Department of Forestry and Wood Science, University College of North Wales, Bangor.

Price, C., Christensen, J.B. and Humphreys, S.K. (1986) Elasticities of demand for recreation site and recreation experience, *Environment and Planning A*, 18:1259-1263.

## Supplementary References

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Bateman, I.J., Willis, K.G., Garrod, G.D., Doktor, P., Langford, I. and Turner, R.K. (1992) *Recreation and Environmental Preservation Value of the Norfolk Broads: A Contingent Valuation Study*, report to the National Rivers Authority, pp.403.

Bowes, M.D. and Loomis, J.B. (1980) A Note on the Use of Travel Cost Models with Unequal Zonal Populations, *Land Economics*, 56:465-470.

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[26]This result is highlighted following the recommendation of the articles concerned. It derives from the log linear RCM with pop./vis heteroskedasticity weighting and Lucas sampling bias weighting and is the mean of the two zonal respecification models reported for this combination model.

## A1.5: THE TOTAL RECREATION VALUE OF THE FORESTRY COMMISSION ESTATE: THE NAO REPORT

**Method:** ZTC

**Evaluation Unit:** National value

**Commentary:**

The 1986 National Audit Office (NAO) report set out to provide the first comprehensive assessment of Forestry Commission activities since the HM Treasury CBA in 1972. A major focus of the NAO study is an examination of the financial trading loss incurred annually by the Commission and subsidised as grant-in-aid by the Government. The NAO report that, for the tax year 1985/86 annual grant-in-aid amounted to some £53 million against which an excess cash balance of £1.6 million and property/plantation disposal receipts of £17 million could be set. This left a net deficit of about £34.4 million.

The NAO examine a wide remit of social costs and benefits, in part to see if these wider economic returns outweigh the financial loss on the estate. Amongst these are the recreation and amenity/environmental aspects of forestry, however, in both cases the analysis is somewhat cursory and draws upon little new evidence.

Annual recreational use of the estate is estimated as being 20,000 visitor nights in cabins, 1.2 million visitor nights at the Commission's camp sites and some 24 million informal recreation visitors to the estate. This latter figure represents an increase of some 55% over that estimated in the Commission's 1968 visitor survey. The NAO report therefore estimates recreation values by simply inflating the Treasury's 1972 ZTC estimate[27] by the growth in visitor numbers and by interviewing price inflation to arrive at an estimate of "around £10 million per annum"[28]. The NAO comment that a sum "gives a capitalised (recreation) value of about £200 million for the whole estate" and that incorporating such a capital value within new investment analyses would "raise the rate of return by around 0.3 to 0.5 per cent, assuming the benefit arises from year 25 onwards"[29].

Turning to consider amenity and environmental benefits the lack of new research forces the NAO to conclude that "In the main there is no evidence which would enable the ecological (and amenity) consequences of forestry investment to be treated in economic terms as either a gain or a loss".

It can be seen that with the exception of some updated visitor information, the NAO report adds very little but indexing to what was said in the Treasury's 1972 CBA. However, the NAO report is nevertheless of considerable importance regarding the monetary evaluation of recreation and amenity in that its highlighting of the Forestry Commission's grant-in-aid deficit was the motivating impetus underlying much of the evaluation research sponsored by the Commission in the aftermath of the report and on to the present day.

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[27]Estimated at £1,113,200 at 1970 prices.

[28]Checking this procedure we arrive at an estimate of £9,475,260.

[29]The NAO warn that such a value is only justifiable "in specific cases where mature forests are easily accessible to large numbers of people".

## Summary Results (£1986)

National recreational consumer surplus = £10,000,000.

## Study Reference

NAO (National Audit Office), (1986) *Review of Forestry Commission Objectives and Achievements.* Report by the Comptroller and Auditor General, National Audit Office, HMSO, London.

### Supplementary Reference

H.M. Treasury (1972) *Forestry in Great Britain: An Interdepartmental Cost/Benefit Study*, HMSO, London.

# A1.6: A NATIONAL SURVEY OF SITE INFORMAL RECREATION VALUE FOR THE FORESTRY COMMISSION ESTATE

**Methods:** ZTC/ITC/CV

**Evaluation Unit:** CS per person per visit and national value

## Overview

This series of papers constitutes the most thorough monetary evaluation study of UK forestry to date. An initial study of six forest sites was undertaken in 1987, with 1,786 questionnaires being completed representing 6,169 visitors. A ZTC analysis was carried out upon this data (Willis, et al. 1988; Willis and Benson, 1989a). This study was expanded in 1988 (Willis and Benson, 1989b; Willis, 1990) with a further eight new sites being sampled (1,862 questionnaires representing 5,309 visitors) while data from the site survey by Hanley and Common (1987) was also incorporated. In total 4,796 questionnaires were utilised representing some 15,329 visitors. At one site questionnaire numbers were supplemented by Forestry Commission records of individual visitors. Again a ZTC analysis was performed upon this data to estimate visitor consumer surplus. In subsequent work (Benson and Willis, 1990, 1992; Willis 1991) these results were aggregated to produce national estimates for the non-market recreation value of the Forestry Commission estate. In a recent paper these results are used to argue the case for recreational forestry in populous lowland areas of Britain (Benson and Willis, 1993).

In a subsequent reconsideration the data was subjected to ITC and CV analyses (Garrod and Willis, 1991; Willis and Garrod, 1991). Results from these investigations were found to be considerably different to those obtained from the ZTC procedure. Because of the number and complexity of these studies the TC work will be analysed separately first to be followed by an analysis of the CV experiments.

## Commentary

The impetus for this work derives from the National Audit Office review of the Forestry Commission (NAO, 1986) and subsequent discussion of that report by the Public Accounts Committee (PAC, 1987). This report brought into question the shortfall of £34.4 million between the grant from H.M.Treasury to the Forestry Commission and the in monetary benefits which the Commission subsequently generated in terms mainly of timber sales. The NAO report recognised that state forestry also generated non-market benefits in particular via the recreational facilities provided for which the report notes (para 4.31);

> "a 'consumer surplus' which is estimated to be around £10 million per annum, worked out in terms of the cost of travelling to make use of them. Due to various assumptions in the calculation, it is possible that this surplus could be significantly greater and if recreational use continued to grow the benefit could increase even further".

The NAO recreation benefit estimate was recognised to be very approximate being a simple inflation indexing of figures given in the HM Treasury (1972) CBA which in turn were based upon a still earlier single unpublished Department of the Environment study of recreation demand. With this in mind and the clear prompting of the NAO report (both in terms of the good to be valued and an appropriate methodology) the Forestry Commission were quick to instigate research in this field and a contract was placed with the University of Newcastle Upon Tyne to conduct a travel cost investigation into the evaluation of the non-market recreation benefits of the Commissions estate.

## A1.6.1: THE TRAVEL COST ANALYSES

### A1.6.1.1: The initial six sites ZTC study

The initial study (Willis, et al. 1988; Willis and Benson 1989a) examined forests in England and Scotland. Sites where chosen according to satisfy the following criteria.

1. Substantial visitor use.
2. Some available data regarding annual visitation numbers.
3. To encompass a range of flora and fauna.

Using these criteria six forests where selected for analysis these being (names in brackets refer to the wider forest name and [cluster number] used in the subsequent studies).

1. Dalby (North York Moors [6]) in the Forestry Commissions North England Conservancy
2. Hamsterley (Durham [6]) in the North England Conservancy
3. Grizedale (South Lakes [8]) in the North England Conservancy
4. Clatteringshaws (Castle Douglas [11]) in the South Scotland Conservancy
5. Symonds Yat (Dean [13]) in the West England Conservancy
6. Thetford (Thetford [14]) in the East England conservancy

Travel cost estimates of consumer surplus varied from £1.26 (Grizedale) to £2.51 (Thetford) per visitor with a weighted mean of £1.90 per visitor across the six sites.

Estimates of annual consumer surplus per hectare ranged from £12.37/ha pa (Clatteringshaws) to £231.51/ha pa (Symonds Yat) with a weighted mean of £32/ha pa.

### A1.6.1.2: The extended fifteen site ZTC study

While these results were of interest, the relatively restricted range of forests sampled prevented aggregation to the national level and so in 1988 a further study was commissioned with this aim in mind (Willis and Benson, 1989b; Willis, 1991; Benson and Willis, 1992). While site selection in the earlier study had been via three simple criteria (which many forests would have satisfied), in the expanded study considerable care was taken to ensure that, the additional forests sampled, along with those already sampled, should form a representative cross section of the Forestry Commission estate so that national aggregation could proceed. Cluster analysis was used to classify forests into groups or clusters sharing similar characteristics and isolate a representative forest within each cluster for survey. Both her hierarchical and optimising clustering techniques were employed (Everitt, 1977; Everitt and Dunn, 1983) the latter allowing relocation of individual forests in the event of poor initial partitioning by identifying those variables which best characterise the individual forests within a group. The characteristics necessary to perform the cluster analysis are detailed in table A1.14 below, the data being assembled from the Forestry Commission's sub-compartment database (variables 1 to 18), Forestry Commission district managers (variables 19-26), the Commissions Annual Report for 1986-87 (variables 30) and population census data (variables 27 to 29).

Table A1.14: Variables used to determine representative Forest Districts in cluster analysis

| | |
|---|---|
| 1-5 | % broadleaves pre-1901, 1901-20, 1921-40, 1941-54, 1965 onwards |
| 6-10 | % larch, scots pine and corsican pine pre-1901, 1901-20, 1921-40, 1941-65, 1965 onwards |
| 11-15 | % other conifers pre-1901, 1901-20, 1921-40, 1941-65, 1965 onwards |
| 16-18 | % forest land in wind hazard class 1+2, 3+4, 5+6 |
| 19 | Number of car park spaces |
| 20 | Number of forest drives |
| 21 | Number of camp person-nights |
| 22 | Number of cabin person-nights |
| 23 | Number of walks |
| 24 | Length of walks (km) |
| 25 | Number of picnic places |
| 26 | Number of specialist recreational activities |
| 27 | Population density |
| 28 | Population 000s |
| 29 | Area (000s ha) |
| 30 | Commission land (000s ha) |

Source : Willis (1991).

While there is no single 'correct' method of cluster analysis[30] the analysis produced 14 clusters all of which made intuitive sense as separate entities. Details of the clusters chosen are given in table A1.15 along with the names of the forest districts classified within each cluster. Notice that clusters 1 to 4 each contain only one Forest District i.e. these four districts were distinct not only from each other but from all other districts nationally. The cluster analysis also served to highlight the single most representative district within each cluster which was then surveyed. Those districts which where surveyed are shown in italic type along with (in brackets) details of: (i) the number of questionnaires completed in each district and; (ii) the number of visitors enumerated through counting all persons accompanying the respondent.

[30]Kendall (1975) points out that the very concept of clustering is a subjective matter.

Table A1.15: Final cluster analysis classification of Forest Districts as sampling basis for questionnaire surveys of recreational visitors

*Cluster 1: New* (316; 898)
The New Forest growing stock includes a large proportion of older trees particularly broadleaves. Public use of the forest is high and many recreational facilities have been provided. Timber production is secondary to other uses of the forest.

*Cluster 2: Cheshire* (324; 881)
Cheshire Forest District has a large proportion of larch, SP and GP much of which is in the older age classes. This Forest District also has a very large population within its boundaries.

*Cluster 3: Loch Awe* (56; 150)
Loch Awe Forest District has a large proportion of young crops, mainly spruce, and high windthrow hazard classes. It differs from Cluster 9 in the high proportion of FC land within the FD boundary and the presence of a forest cabin development.

*Cluster 4: Brecon* (241; 661)
Brecon Forest District has a high proportion of middle aged crops, mainly spruce, but without extremes of windthrow hazard class. It differs from most Welsh forest districts in being well provided with forest walks.

| *Cluster 5:* | Rothbury | *Buchan* (201; 592) |
|---|---|---|
| | Llanwynno | Kincardine |
| | Rheola | Easter Ross |
| | Llandovery | Inverness |
| | Speyside | Angus |
| | Fife | Perthshire |
| | Lothian | |

This group comprises a number of forest districts largely in the eastern half of the country from north of Inverness to Northumberland plus an area in south Wales. Characteristic features include a below average amount of older broadleaves but an above average amount of non-spruce species. Windthrow hazard classes tend to be in the middle of the range.

| *Cluster 6:* | Marches | *Durham* (481; 1708) |
|---|---|---|
| | Gwent | *North York Moors* (387: 1319) |

Cluster 6 comprises four forest districts with a diversity of age classes and species including a higher than average proportion of older crops. although not in lowland England windthrow hazard classes in these districts are not high. Some recreational provision in the form of forest drives and overnight stays.

*Cluster 7: Aberfoyle* (1148; 3851) Cowal
This cluster covers two forest districts with large areas of young conifers, mainly spruce. Because they are in a tourist area and close to a large centre of population (Glasgow) many recreational facilities have been provided.

| *Cluster 8:* | North Lakes | Somerset |
|---|---|---|
| | Llanrwst | *South Lakes* (322; 721) |
| | Cornwall | |

Cluster 8 comprises forest districts in major tourist areas with a high proportion of older conifers particularly spruce and/or Douglas fir.

(contd)

Table A1.15 (cont)

*Cluster 9:* Border, Ayrshire, Dornoch, Nithsdale, Kintyre, Borders, Lockerbie, *Newton Stewart* (213; 705)

Cluster 9 comprises forest districts with extensive areas of young conifer species particularly spruce. Windthrow hazard class is high with large areas in hazard classes 5 and 6. Because of this many areas will be poorly roaded and non-thin will be common.

*Cluster 10:* Wester Ross, Strontian, Fort Augustus, *Lorne* (201; 522), Lochaber

Cluster 10 covers a number of forest districts also with large areas of young conifers but significant amounts of older conifers (planted 1921-40) are also present. Windthrow hazard classes tend not to be as high as in Cluster 9.

*Cluster 11:* Kielder, Mull, Afan, *Castle Douglas* (66; 775*)

These forest districts also have a high proportion of spruce but there is a greater range of age classes than in Cluster 9. Their most characteristic feature is that FC land comprises a large proportion of all land within the forest district boundary. Notable forest drives also exist.

*Cluster 12:* Aberystwyth, Newtown, Dolgellau, Llandrindod, Corris, *Ruthin* (310; 899), Brechfa

The forest districts in this cluster are all in Wales and have an above average proportion of crops in the 1921-40 and 1941-65 age classes.

*Cluster 13:* York, Weald, Northants, Chilterns, West Downs, *Dean* (276; 801), South Downs, Wiltshire

Cluster 13 comprises forest districts in lowland England with an above average proportion of broadleaves, and proximity to large populations.

*Cluster 14:* North Lincs, Suffolk, Sherwood, Midland, Moray, *Thetford* (254; 845), Dorset

The forest Districts in Cluster 14 are also to be found in lowland areas but with a higher proportion of pines. With the exception of Suffolk Forest District which lost many of its older crops in the storm of October 1987, stands of over 50 years of age are common.

* Questionnaire numbers supplemented by Forestry Commission records of origins of individual visitors at this site.

Source : Willis (1991)

Notice that the earlier study had already sampled forests in clusters 8,11,13, and 14 as well as two forests in cluster 6. This left nine clusters to be sampled however data for the 1987 survey of Queen Elizabeth Forest park in Aberfoyle Forest District (Hanley and Common, 1987 a/b; Hanley, 1989) was made available thus providing responses for cluster 7. Forest Districts for the remaining eight clusters were sampled between July and September 1988. Figure A1.4 illustrates the cluster boundary's and indicates the location of the Forest Districts Sampled.

The questionnaires employed were well constructed and a large database of relevant information was gathered. Table A1.16 gives descriptive statistics regarding the respondents interviewed by Willis et al during 1987 and 1988.

Table A1.16: Respondent characteristics 1987 and 1988[31]

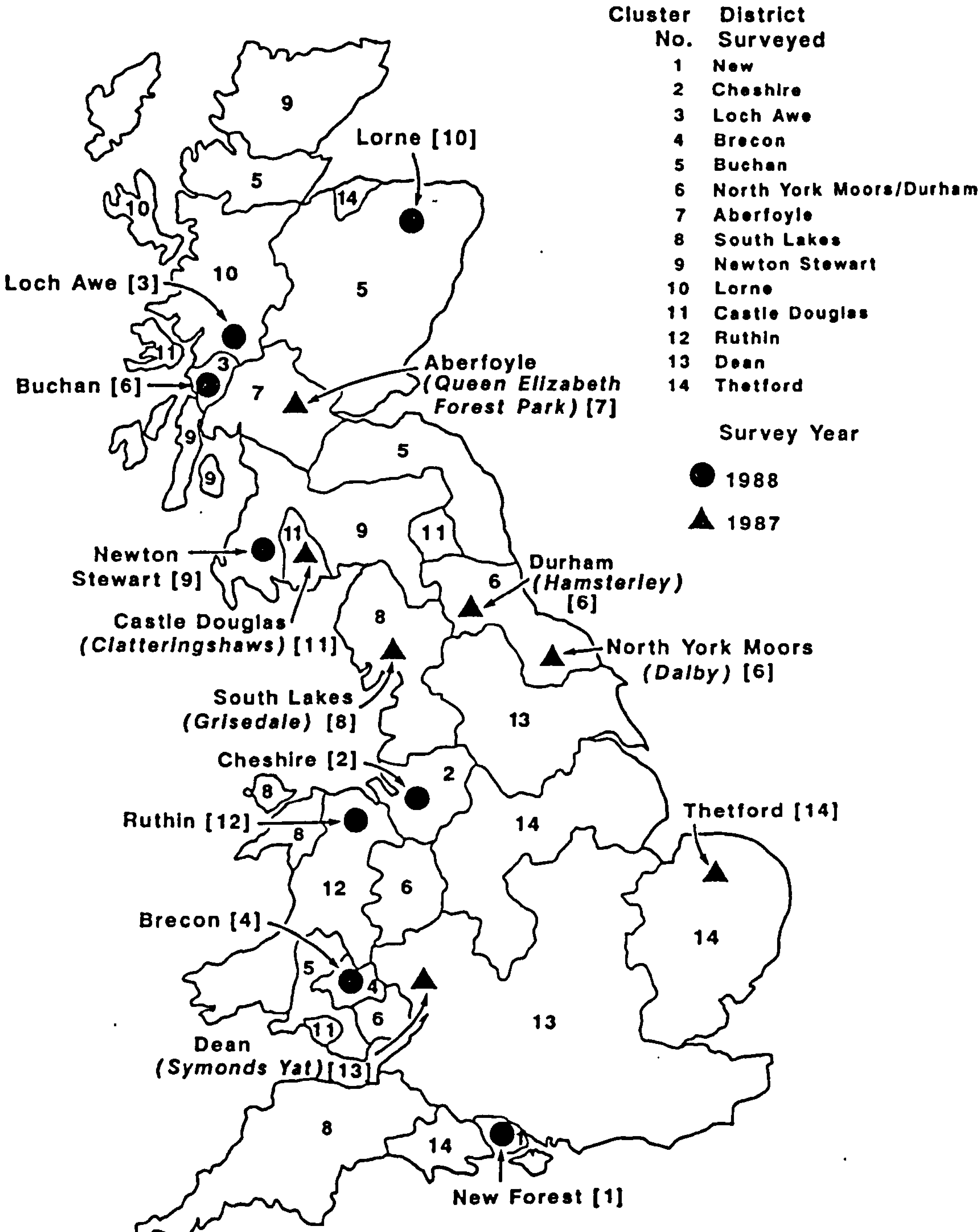
| Variable | 1987 Survey | 1988 Survey |
|---|---|---|
| Questionnaires completed | 1,786 | 1,862 |
| Visitors sampled | 6,169 | 5,309 |
| Age of respondent | 43.39 ± 14.99 | 43.39 ± 13.91 |
| Group size (interviews) | 3.22 ± 1.57 | 2.95 ± 1.43 |
| Car occupancy | 3.10 | 3.17 |
| Respondents not members of conservation organisation | 72.1% | 64.0% |
| Household income | £14,277 ± 8,483 | £16,347 ± 8,238 |
| Respondents on trip from home | 52.8% | 57.3% |
| Site visit length (hours) | 2.97 ± 1.81 | 2.44 ± 1.56 |
| Day trip length (hours) | 6.26 ± 2.38 | 5.43 ± 2.58 |
| Respondents travelling by car | 95.7% | 93.4% |
| Mean trip miles (return) | 58.59 ± 55.98 | 46.69 ± 39.57 |

± = plus or minus (indicating 95% CI)

Source: Willis and Benson (1989b)

[31] Excludes the 1148 questionnaires (3851 visitors) sampled by Hanley (1989) used as cluster 7.

Figure A1.4: Location map of Forest Clusters and sampled Forest Districts




First names = used in Willis & Benson 1989b and subsequent papers
*(italic names)* = used in prior reports and Hanley and Common (1987) and Hanley (1989) Aberfoyle survey conducted by Hanley and Common in 1987
Numbers refer to clusters. Numbers in square brackets refer to the cluster for which the survey site is representative

Source: Amalgamated from Willis and Benson (1989b) and Benson & Willis (1992)

In applying the ZTC, Willis and Benson (1989b, 1992) fit the general model given in equation (A1.9)

$$V_{ij}/N_i = f\,(TC_{ij}, T_{ij}, S_{ij}, A_{jk}) \qquad \text{(A1.9)}$$

where

$V_{ij}$ = number of visitors from zone i to forest j
$N_i$ = population of zone i
$TC_{ij}$ = travel costs from zone i to forest j
$T_{ij}$ = time costs from zone i to forest j
$S_{ij}$ = socioeconomic characteristics of visitors from zone i to forest j
$A_{jk}$ = attributes of forest j in relation to other substitute recreation areas k

A variety of definitions for the above explanatory variables were tested. Each site was analysed using 20 consecutive zones of 5 mile intervals with a further single >100 miles zone. Zonal population was determined via the Census of Population or the site survey as appropriate. This definition of $N_i$ was used to allocate respondents to zones and this define the dependent variable $V_{ij}/N_i$.

Travel costs were evaluated according to a variety of assumptions:

i Royal Automobile Club estimates of full running costs (petrol, maintenance, insurance and taxes) [33p/mile];
ii Travel costs as estimated by respondents [site average ranged from 17.7p/mile to 27.1p/mile with a mean for all sites of 22.p/mile];
iii Petrol costs only [8p/mile].

Three assumptions regarding the evaluation of time costs were employed:

i Following Department of Transport (1987) recommendations time costs were calculated at 43% of earnings with lower rates for children and non-earners;
ii Prior to their 1987 recommendations the Department of Transport evaluated non-working time at 25% of the wage rate. This assumption was also tested;
iii A zero time cost assumption was also tested.

Income data to operationalise the above measures were gathered as part of the questionnaire survey. Various socioeconomic variables were tested as follows:

i Households with professional/managerial head of household [PROF];
ii Households with skilled manual head of household [MAN];
iii Households with head of household in social classes 1 and 2 [SOC 1 +2];
iv Households with 1 or more cards [CARS].

Data for the above was gathered from the Census. Other socioeconomic variables were tested but excluded on the grounds of high multicollinearity with one of the above. However, the statement that "the correlation coefficient between all other independent variables was less than 0.6" (Benson and Willis, 1992) is hardly reassuring as it indicates that high multicollinearity still exists in the model.

The analysis of differing attributes between sites was carried out purely as a way of examining the impact of substitute sites rather than as an evaluation of the differing attributes within a site. Such intrasite characteristics have in some way been dealt with via clustering however the multiple-characteristic nature of cluster definitions makes the extrapolation of a value for a particular site attribute infeasible and in effect limits this study to an being an evaluation of recreation sites rather than recreation experiences. The work of Price et al (1986) is relevant here as he concludes that site demand may be considerably more elastic than demand for recreation experiences. The lack of attribute evaluation was explicitly addressed in subsequent Forestry Commission sponsored research by Hanley and Russell (1991a/b); see later discussion. In analysis only three substitute site variables proved even weakly significant; Further discussion is postponed until we consider the CV study.

i Length of time spent at the forest site.

ii Whether a substitute forest was named.

iii Whether any substitute recreation site was named.

A number of functional forms were tested including, amongst others, linear, semi-log and double log forms. Choice of functional form was made via comparison of $R^2$ measures of explanatory power and by examining the predictive ability of the model in estimating visitor numbers. Both of these tests can be criticised; comparison of $R^2$ statistics between functional forms with differing dependant variable (e.g. comparing linear with log forms) is invalid. Furthermore Christensen and Price (1982) show the heteroskedastic variances which habitually afflict travel cost observations mean that the correspondence between actual and predicted numbers of visits may not provide the best indication of an optimal model. In reanalysing this data, Willis and Garrod (1991) confirm the presence of heteroskedasticity in this data set via a Breusch-Pagan test. In the face of these criticisms and given the large impact upon consumer surplus estimates of alternate functional forms (e.g. Hanley, 1989), the non-reporting in any report prior to 1991 of results from any other functional form than that of the preferred semi-log (dependant variable) model is to be criticised. Instead it is reported that this model gave the highest $R^2$ values and that "the predicted numbers of visitors by the semi-log models were within +4.4% of actual visitor numbers on average over all forests, varying from +35.3% in Lorne to +0.2% at Thetford, and -5.8% at Brecon" (Benson and Willis, 1992). The first comparative analysis detailing the performance of three functional forms (linear; semi-log dependent; double log) applied to this data is given in Garrod and Willis (1991). Although results for only six sites are given, this analysis shows that the semi-log (dependent form does perform better in terms of predicted visitor rate equating to actual visitor rate than do either of the others (the linear form, not surprisingly, performing particularly poorly). Not withstanding the criticisms of Christensen and Price (1982) this does provide considerable support for the use of a semi-log (dependent) form. Table A1.17 reports results from this analysis.

Table A1.17: Alternative functional forms for ZTC analysis

| Forest | Linear | Functional Forms<br>Semi-Log (Dependent) | Log-Log |
|---|---|---|---|
| Brecon | | | |
| (1) | -177.1 | -5.7 | -12.6 |
| (2) | 0.17 | 0.54 | 0.27 |
| Buchan | | | |
| (1) | 138.8 | +13.3 | +47.1 |
| (2) | -0.13 | 0.75 | 0.47 |
| Cheshire | | | |
| (1) | 873.8 | -3.2 | +45.8 |
| (2) | 0.17 | 0.99 | 0.86 |
| Lorne | | | |
| (1) | -27308.2 | +35.3 | +432.6 |
| (2) | 0.12 | 0.92 | 0.76 |
| New Forest | | | |
| (1) | -8633.6 | -3.7 | +4.7 |
| (2) | 0.90 | 0.97 | 0.82 |
| Ruthin | | | |
| (1) | -358.2 | -4.1 | +6.7 |
| (2) | 0.20 | 0.96 | 0.63 |

(1) Overall percentage error = [(predicted visits - actual visits)/actual visits]*100
(2) Correlation coefficient between actual and predicted number of visits.

Source: Willis and Garrod (1991)

Because of high multicollinearity between $TC_{ij}$ and $T_{ij}$ the monetised time costs where added to travel costs to produce a 'full distance cost' variable ($C_{ij}$) which was found to be a highly significant explanatory variable at all sites. Of the socioeconomic variables, the income related social class variable SOC1 + 2 was only superior to the access variable CARS at two of the fifteen sites surveyed. This indicates that it is the transport rather than income constraint which is most binding upon visits and, given the zero price nature of informal forest recreation and the predominance of cars as visitors preferred mode of transport (see table A1.16), such results are not surprising . Lewis and Whitby (1972) in their TC study of reservoir recreation report a similar result. None of the attribute variables designed to test the impact of substitute sites, were found to be sufficiently significant to be instrumental in determining any of the site models. Comparable estimated trip generation functions for all 15 sites are reported as table A1.18 below.

Table A1.18: Estimated Trip Generation Function for 15 Forests

| Forest | Constant | Full distance cost | Cars | Social class (1+2) zone | $R^2$ (%) |
|---|---|---|---|---|---|
| New Forest | -6.9496<br>(1.1438) | -0.7021<br>(0.0408) | | 11.5027<br>(3.9138) | 0.9657 |
| Cheshire | -9.8929<br>(1.0529) | -0.5252<br>(0.0189) | 4.4685<br>(1.4985) | | 0.9908 |
| Loch Awe | -11.8110<br>(2.1167) | -0.3021<br>(0.0598) | 9.2899<br>(2.8914) | | 0.8241 |
| Brecon | -9.9515<br>(1.6266) | -0.3837<br>(0.0392) | 4.5087<br>(2.4549) | | 0.8518 |
| Buchan | -4.2843<br>(0.6820) | -0.4442<br>(0.0634) | | | 0.8033 |
| Durham | -11.6374<br>(2.2537) | -0.5911<br>(0.0515) | 13.6293<br>(3.5309) | | 0.9119 |
| N. York Moors | -6.7342<br>(2.5352) | -0.5491<br>(0.0543) | 5.0872<br>(3.3426) | | 0.9107 |
| Aberfoyle | -9.1030<br>(1.6896) | -0.3901<br>(0.0566) | 8.1693<br>(2.7381) | | 0.7513 |
| S. Lakes | -12.3680<br>(3.1062) | -0.7969<br>(0.0489) | | 20.6201<br>(6.4390) | 0.9498 |
| Newton Stewart | -2.2715<br>(0.7573) | -0.6221<br>(0.0666) | | | 0.8531 |
| Lorne | -4.9182<br>(2.0781) | -0.6937<br>(0.0517) | 6.0074<br>(2.8288) | | 0.9505 |
| Castle Douglas | -7.4233<br>(1.8953) | -0.4415<br>(0.0512) | 5.0778<br>(2.5171) | | 0.8505 |
| Ruthin | -6.5265<br>(0.3363) | -0.3963<br>(0.0333) | | | 0.9040 |
| Forest of Dean | -12.3965<br>(2.8328) | -0.4732<br>(0.0445) | 9.3891<br>(3.5707) | | 0.9110 |
| Thetford | -10.4823<br>(2.4350) | -0.3989<br>(0.0390) | 6.2448<br>(2.8788) | | 0.9417 |

Only results significant at 15% level included.
n = 21 in all cases. Standard deviation in brackets.

Source : Willis and Benson (1989a/b); Benson and Willis (1992)

Integration of the tgf's produced the 'standard model' consumer surplus per visit estimates shown in column [SM] of table A1.19. As can be seen this varied from £3.31 at Loch Awe to £1.34 at South Lakes. The Loch Awe estimate derives from the smallest site sample (56 questionnaires representing 145 visitors) and may therefore be more variable than other results. Overall these results indicate a weighted average consumer surplus for all forests of £2.00 per visit. The nomenclature of some reports (e.g. Benson and Willis, 1992) is somewhat loose, referring to "consumer surplus per visitor" when it is clear from the original reports (e.g. Benson and Willis, 1990) that the correct measure is "consumer surplus per visit" (p.50). The implications for aggregation purposes, of such terminology are highly significant.

Table A1.19: Consumer surplus per visit by forest under varying assumptions (£/visit; 1988 prices)

| Cluster No. | Forest district | [SM][2] Travel=33ppm Time=43% | [1] Travel=33ppm Time=25% | [2] Travel=33ppm Time=0% | [3] Travel=esti-mated Time=43% | [4] Travel=8ppm Time=0% | [5] Travel=8ppm Time=43% |
|---|---|---|---|---|---|---|---|
| 1 | New Forest | 1.43 | 1.40 | 1.36 | 0.93 | 0.33 | 0.40 |
| 2 | Cheshire | 1.91 | 1.87 | 1.81 | 1.25 | 0.44 | 0.54 |
| 3 | Loch Awe | 3.31 | 3.21 | 3.05 | 1.92 | 0.73 | 1.00 |
| 4 | Brecon | 2.60 | 2.56 | 2.50 | 1.70 | 0.61 | 0.71 |
| 5 | Buchan | 2.26 | 2.22 | 2.16 | 1.67 | 0.52 | 0.63 |
| 6 | Durham[1] | 1.64 | 1.77 | 1.73 | | 0.54 | |
| 6 | N. York Moors[1] | 1.93 | 1.87 | 1.84 | | 0.59 | |
| 7 | Aberfoyle | 2.72 | 2.59 | 2.37 | | 0.61 | 0.95 |
| 8 | South Lakes | 1.34 | 1.30 | 1.27 | | 0.41 | |
| 9 | Newton Stewart | 1.61 | 1.57 | 1.53 | 1.24 | 0.36 | 0.45 |
| 10 | Lorne | 1.44 | 1.40 | 1.35 | 1.10 | 0.33 | 0.42 |
| 11 | Castle Douglas | 2.41 | 2.36 | 2.54 | | 0.72 | |
| 12 | Ruthin | 2.52 | 2.47 | 2.40 | 1.72 | 0.58 | 0.70 |
| 13 | Forest of Dean | 2.34 | 2.19 | 2.13 | | 0.69 | |
| 14 | Thetford | 2.66 | 2.62 | 2.55 | | 0.76 | |

Weighted mean = 1.98[2]

Notes:
1. Two forest districts (Durham and North York Moors) were sampled within cluster 6.
2. The authors often refer to a weighted mean cs/visit of £2.00 (Benson & Willis, 1992; page v.) for their standard model [SM]. However the actual figure (and that used for aggregation) is £1.983. We calculate that use of the higher figure would result in an overstatement of aggregate benefits in excess of £430,000.
3. We argue that these figures represent 'whole experience rather than on-site only' values.

There is one further important distinction which Willis and Benson fail to make regarding these results; whether they refer to the on-site experience alone or whether they refer to the whole trip experience (see chapter 2 for fuller details). The approach taken is somewhat unclear on this point but it does appear that these results represent the simpler whole trip experience calculation. This distinction is important for two reasons; firstly as many visitors expressed positive utility for the trip as well as on-site time this means that the results obtained overestimate the value of the on-site experience i.e. the aggregate figures reported in Benson and Willis 1990; 1992 may refer not to the recreation value of the sites themselves, as claimed, but to the recreational value of the whole experience of visiting those sites. Secondly, if this is so then we should not expect a correspondence between results obtained from the ZTC, which relate to whole trip experience, and those obtained from CV questions, which relate to the WTP for the on-site experience alone. We should therefore be looking for TC results in excess of CV results[32], rather than an equivalence between the two (as sought for by Willis and Garrod (1991) as discussed subsequently).

Apart from results arising from the 'standard model' (full RAC car running costs of 33p/mile and time costs valued at 43% of wage rate) shown in table A1.18, five alternative

[32]This relationship is somewhat muddied by the fact that TC measures relate to use value only (of on-site or shore experience as appropriate) while CV measures may relate to an amalgam of use/option/non-use values depending upon the specification of the WTP question.

models were appraised to analyse the sensitivity of consumer surplus results to alterations in the assumption of the standard model[33]. Details of all models are as given in table A1.20 with consumer surplus per visit estimates being reported in the corresponding columns of table A1.19.

Table A1.20: Cost specifications for standard and alternative models

| Model | Assumptions | |
|---|---|---|
| | Travel Cost (p/mile) | Time Cost (% wage rate) |
| Standard model [SM] | 33 | 43 |
| Alternative [1] | 33 | 25 |
| Alternative [2] | 33 | 0 |
| Alternative [3] | Visitors estimate | 43 |
| Alternative [4] | 8 | 0 |
| Alternative [5] | 8 | 43 |

Clearly we will obviously get the order of consumer surplus estimates being [SM] > [1] > [2] and [SM] > [5] > [4] while other relationships are uncertain. In the event table A1.19 shows a consistent ordering of results for all forests being [SM] > [1] > [2] > [3] > [5] > [4]. On inspection we can see that varying time costs had relatively little impact upon consumer surplus estimates while varying travel costs had significant impacts. The authors point out that, a priori, time may be expected to have a more significant effect but that this may be diminished by its treatment as a subset of total costs ($C_{ij}$) rather than as a separate variable within the tgf.

The authors advocate the use of consumer surplus estimates from the standard model [SM] in preference to alternative models on the following grounds (Willis and Benson, 1989b; Benson and Willis, 1992);

i. They argue that respondents perceptions and statements regarding travel costs are based upon full rather than marginal (petrol only) cost per mile.
ii. They argue that respondents do not adopt differential costs toward recreation as opposed to non-recreation travel.
iii. Whilst respondent value that whole trip experience, the forest visit was valued proportionately more than the car journey, so that a positive time cost, of less than the full wage rate, can be justified, the time cost used in the standard model being that most recently advocated by a government department.
iv. "Given that entry fees at many National Trust, English Heritage and similar properties (which include gardens, parks, woodlands and forests) are closer to our higher estimate (£2.00), this figure seems realistic and plausible for car-borne forest visits of the kind studied in this project".

[33]The authors also test the argument (Vickerman, 1975) that the variable CARS may not be truly independent of the travel cost variable by omitting the CARS variable, reestimating the tgf and recalculating consumer surplus. However, the consequent change in consumer surplus was small and, as the CARS variable is, in most tgfs, the only proxy socioeconomic variable, it was considered valid for inclusion.

These justifications are open to some criticism. Arguments i and ii, which are similar, may well be true, however while respondents perceptions of travel cost well exceed pure marginal petrol costs of 8p/mile, the reported range of site average expressed travel costs (from 17.7p/mile to 27.1p/mile with a mean for all sites of 22.8p/mile) does not support the adoption of the 33p/mile assumption used in the 'standard model'. Table A1.21 gives details of respondents estimates of car running costs for the eight forest districts where this information was elicited.

Table A1.21: Respondents estimates of car running costs

| Forest district | Estimated car travel cost (p/mile) | confidence interval (+) (p/mile) | Sample size |
|---|---|---|---|
| Brecon | 20.85 | 9.31 | 47 |
| Buchan | 23.77 | 11.02 | 135 |
| Cheshire | 21.77 | 7.51 | 128 |
| Loch Awe | 17.74 | 11.85 | 38 |
| Lorne | 27.08 | 19.36 | 119 |
| New Forest | 21.02 | 14.45 | 266 |
| Newton Stewart | 25.21 | 15.75 | 150 |
| Ruthin | 21.92 | 10.91 | 61 |
| All sites | 22.79 | 13.91 | 944 |

Source: Willis and Benson (1989b)

Given the uncertainty surrounding the value of time, and in particular leisure time (see chapter 2) argument iii above is reasonable although one would not want to make such uncertainty the mainstay of any strong result. However, argument iv is weak. Firstly the comparison of goods is invalid, informal forest recreation is of the essence unpriced and indeed its public goods nature may be endogenous to its value, comparisons with priced goods are therefore chalk and cheese. Secondly, we have argued that the values estimated represent whole-experience rather than on-site values (with which the comparison to National Trust entry fees is being made). Thirdly, if such a comparison between goods were valid, then the necessity of undertaking a three year TC study would disappear. Surely this is not an argument which the authors would push too strongly!

While we can accept the authors choice of functional form, it would seem that their choice of the 'standard model' [SM] results as the most accurate is less defencible. Indeed, following the authors own arguments it would seem that the most logical model is that using time costs valued at 43% of wage rates (as this is a government recognised figure) and travel costs calculated as visitors perceived costs (average of 22.8p/mile) ie. model [3] in table A1.19. One problem with this approach is that data for such an analysis was only collected at certain sites. However an approximation can be calculated by examining the ratio of consumer surplus results for models [3] and [SM] for these sites. The weighted average of this ratio can then be used to extrapolate for the remaining other seven sites. Table A1.22 calculates this weighted ratio ([3]/[SM]) as 0.690 and uses this to estimate consumer surplus per visit at the seven sites where perceived costs were not elicited. These results together with those of model [3] from consumer surplus estimates for all sites under the assumption of perceived travel costs and 43% wage rate time costs and are recorded in table A1.22 as model [3*]. An all sites weighted average consumer surplus was then calculated as being £1.48 per visit. We would argue that this represents a more defencible result than the weighted average of £1.98 obtained from the [SM] model and preferred by Willis and Benson.

Table A1.22: Calculation of the whole sample weighted mean consumer surplus per visit for model [3] (producing model [3*])

| Cluster No. | Forest district | Sample size | % of total sample | % of model [3] sample | CS/visit [SM] (£) | CS/visit [3] (£) | Ratio [3]/[SM] | CS/visit [3*] (£) |
|---|---|---|---|---|---|---|---|---|
| 1 | New Forest | 316 | 6.59 | 16.97 | 1.43 | 0.93 | 0.650 | 0.93 |
| 2 | Cheshire | 324 | 6.76 | 17.40 | 1.91 | 1.25 | 0.654 | 1.25 |
| 3 | Loch Awe | 56 | 1.17 | 3.01 | 3.31 | 1.92 | 0.580 | 1.92 |
| 4 | Brecon | 241 | 5.03 | 12.94 | 2.60 | 1.70 | 0.654 | 1.70 |
| 5 | Buchan | 201 | 4.19 | 10.79 | 2.26 | 1.67 | 0.739 | 1.67 |
| 6 | Durham | 481 | 10.03 | | 1.64 | | | 1.13[2] |
| 6 | North York Moors | 387 | 8.07 | | 1.93 | | | 1.33[2] |
| 7 | Aberfoyle | 1148 | 23.94 | | 2.72 | | | 1.88[2] |
| 8 | South Lakes | 322 | 6.71 | | 1.34 | | | 0.92[2] |
| 9 | Newton Stewart | 213 | 4.44 | 11.44 | 1.61 | 1.24 | 0.770 | 1.24 |
| 10 | Lorne | 201 | 4.19 | 10.79 | 1.44 | 1.10 | 0.764 | 1.10 |
| 11 | Castle Douglas | 66 | 1.38 | | 2.41 | | | 1.66[2] |
| 12 | Ruthin | 310 | 6.46 | 16.65 | 2.52 | 1.72 | 0.683 | 1.72 |
| 13 | Forest of Dean | 276 | 5.75 | | 2.34 | | | 1.61[2] |
| 14 | Thetford | 254 | 5.30 | | 2.66 | | | 1.84[2] |
| Total | | 4796 | 100.00 | | | | | |
| Model [3] total | | 1862 | | 100.00 | | | | |
| Weighted mean | | | | | 1.98 | | 0.690[1] | 1.48[3] |

Notes: 1.Calculated by multiplying the ratio [3]/[SM] by the decimal % of model [3] sample column and then finding the (weighted) mean.
2.Calculated by multiplying the site [SM] CS/visit for sites where perceived costs were elicited by the weighted average of the ratio [3]/[SM] to 7 decimal places (0.6901678) and then rounded.
3.Calculated by weighting the site [3*] CS/visit by its decimal % of total sample (across all sites). Calculated to 7 decimal places (1.481469) and then rounded.

### A1.6.1.3: Aggregation of the ZTC study results

The third stage of this study, and the last sponsored by the Forestry Commission, involved the aggregation of site-level results to produce a national estimate of the informal recreation value of the Commission's estate (Benson and Willis, 1990; Willis, 1990; Willis, 1991; Benson and Willis, 1992). However, here the authors faced considerable problems regarding annual visitation data. Firstly very little explicit woodland visit data was available and secondly much related tourism data suffered from definitional problems and was therefore unusable.

Growth in general countryside recreation visits was rapid during the period from the late 1960s to late 1970s (Countryside Commission, 1980), but more stagnant in the 1980s (Bovaird, et al., 1984). A similar pattern may characterise forestry recreation visits however data is sparse and its variability high. The Forestry Commission's 1968 visitor survey (Grayson, Sidaway and Thompson, 1975) estimated total summer visits at between 10.2 and 22.2 million implying an annual total of between 15 and 32 million (Benson and Willis, 1992). A further survey in 1977 (Collings, 1977) estimated annual visits at 24 million. As part of their aggregation process, Benson and Willis (1990) asked Forestry Commission District Managers to estimate day visits during 1988. The resulting estimate of 26.7 million annual visitors represented a modest 13.3% increase over 1977 estimates. However, while this seems quite reasonable, analysis between districts show very large increases and decreases over 1977 figures questioning the validity of such estimates. Benson and Willis (1990, 1992) draw up Countryside Commission and British Tourist Authority sources to suggest that the estimated growth between 1977 and 1978 and their total visits estimate of 26.7 million, are likely to be underestimates of true growth and thus defencible for aggregation purposes as lower bound estimates.

While such an approach may be defensible in aggregate (and given the lack of available data the authors had little choice), the variability and potential error of district visitor numbers means that we must treat district aggregates with some circumspection. Benson and Willis's district and national aggregation estimates are reproduced in table A1.23. These results were circulated using the 'standard model' [SM] estimates of consumer surplus per visit. Following our objections to this approach, the final three columns of table A1.23 have been added to recalculate these aggregate results using our preferred perceived costs + 43% wage rate model which was denoted [3*] in table A1.22.

The results of table A1.23 show that using their preferred [SM] model produces a national aggregate consumer surplus estimate for informal recreation on the Forestry Commission estate of £53 million per annum. However adopting our calculated and preferred [3*] model reduces this sum by over 30% to just under £37 million per annum. Benson and Willis (1992) claim that, because of the possibility of understatement of forest visit numbers then their estimate is "very conservative" and easily outweighs the £10 million informal recreation estimate quoted by the NAO (1986). Our interpretation of these results is more cautious. Firstly our preferred [3*] model produces significantly lower results than that emphasised by the authors. Secondly the entire study hinges upon the empirical strength of the ZTC analysis carried out. Ironically it is subsequent work by Willis et al which raises some of the most fundamental questions concerning this analysis. We now turn to consider this work.

Table A1.23: Calculation of aggregate cluster and national consumer surplus according to two models

| Cluster No. | No. of Districts | District Sampled | Sample Size | Total visits pa ('000) | Total ha ('000) | Visits/ ha pa | CS/visit[1] [SM] (£) | CS/ha [SM] (£) | Total CS [SM] (£'000) | CS/visit[1] [3*] (£) | CS/ha [3*] (£) | Total CS [3*] (£'000) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | New Forest | 316 | 8000 | 27 | 296.3 | 1.43 | 424 | 11440 | 0.93 | 276 | 7440 |
| 2 | 1 | Cheshire | 324 | 224 | 1 | 224.0 | 1.91 | 428 | 428 | 1.25 | 280 | 280 |
| 3 | 1 | Loch Awe | 56 | 10 | 34 | 0.3 | 3.31 | 1 | 33 | 1.92 | <1 | 19 |
| 4 | 1 | Brecon | 241 | 150 | 8 | 18.9 | 2.60 | 49 | 390 | 1.70 | 32 | 255 |
| 5 | 13 | Buchan | 201 | 2137 | 217 | 9.8 | 2.26 | 22 | 4830 | 1.67 | 16 | 3569 |
| 6 | 4 | Durham/N.Y. Moors | 868[2] | 1154 | 45 | 25.6 | 1.79[3] | 46 | 2066 | 1.22[3] | 31 | 1408 |
| 7 | 2 | Aberfoyle | 1148 | 650 | 59 | 11.0 | 2.72 | 30 | 1768 | 1.88 | 21 | 1222 |
| 8 | 5 | South Lakes | 322 | 1855 | 47 | 39.5 | 1.34 | 53 | 2486 | 0.92 | 36 | 1707 |
| 9 | 8 | Newton Stewart | 213 | 294 | 235 | 1.2 | 1.61 | 2 | 473 | 1.24 | 2 | 365 |
| 10 | 5 | Lorne | 201 | 740 | 156 | 4.7 | 1.44 | 7 | 1066 | 1.10 | 5 | 814 |
| 11 | 4 | Castle Douglas | 66 | 652 | 110 | 5.9 | 2.41 | 14 | 1571 | 1.66 | 10 | 1082 |
| 12 | 7 | Ruthin | 310 | 561 | 68 | 8.2 | 2.52 | 21 | 1414 | 1.72 | 14 | 965 |
| 13 | 8 | Forest of Dean | 276 | 5621 | 57 | 98.6 | 2.24 | 221 | 12591 | 1.61 | 159 | 9050 |
| 14 | 7 | Thetford | 254 | 4678 | 57 | 82.1 | 2.66 | 218 | 12443 | 1.84 | 151 | 8608 |
| Total | 67 | | 4796 | 26726 | 1121 | | | | 52999 | | | 36783 |
| Mean | | | 320 | | | | 1.98 | 47 | | 1.48 | 33 | |

Notes: 1.We argue that these figures may represent 'whole experience' rather than 'on-site only' values.

2.Sum of two districts; Durham (481) and North York Moors (387).

3.Weighted mean of two sampled districts.

### A1.6.1.4: The comparative ITC/ZTC study

In 1991 Willis and Garrod published a comparative study conducting an ITC analysis upon the data collected for six of the Forest Districts and contrasting these results with those of the earlier ZTC study (Garrod and Willis, 1991; Willis and Garrod, 1991).

The comparative study begins by reviewing the ZTC analysis. Analysis of three different functional forms for the tgf is reported (see table A1.17 previously) confirming the choice of a semi-log (dependent) form. ZTC tgf regression results are reported for each of the six sites chosen for this comparative analysis, however here a certain ambiguity arises. The reported coefficients and $R^2$ results and consequent consumer surplus estimates are exactly the same as those reported in earlier studies (Willis and Benson, 1989b) for much larger sample sizes. While we might except very similar results, exact repetition is statistically infeasible. This problem somewhat detracts from the 'comparative' thrust of this later work.

One interesting re-analysis of the ZTC work is a jack-knife test of the stability of the tgf travel cost coefficient. The jack-knife approach (Mosteller and Tukey, 1977) omits each observation in turn comparing the consequent regression equation with the original (all observations) equation and thereby testing the stability and significance of coefficients. Results for this analysis are reported in table A1.24 and show that the travel cost coefficient is extremely stable (and indeed remains significant at the 5% level throughout the jack-knife procedure). The problem of potential mis-specification was also investigated by re-estimating the model excluding all explanatory variables other than travel cost. Again the travel cost coefficient stayed moderately stable with exclusion of other variables causing, on average, a 10% variation in estimated consumer surplus, a variation which was considered acceptable.

Table A1.24: Standard model, jack-knife and excluded variable estimates of the travel cost coefficient

| Forest District | Standard model: travel - cost coefficient | Jack-knife: travel - cost coefficient | Travel cost coefficient: All other variables excluded |
|---|---|---|---|
| Brecon | -0.3837 | -0.3973 | -0.3519 |
| Buchan | -0.4442 | -0.4905 | - |
| Cheshire | -0.5252 | -0.4886 | -0.5386 |
| Lorne | -0.6937 | -0.7452 | -0.7308 |
| New Forest | -0.7021 | -0.7082 | -0.7072 |
| Ruthin | -0.3963 | -0.4040 | - |

Note: Ruthin and Buchan have single variable standard models therefore the excluded variable analysis is not necessary.

Source: abstracted from Willis and Garrod (1991).

The ITC analysis related individuals number of site visits per year to a variety of explanatory variables including visit costs (calculated, as per the ZTC analysis, to avoid multicollinearity, as the sum of travel and time costs); perception of substitutes; measures of the contribution of the visit to the whole trip experience; party size; and certain socio-economic variables including age and income.

A variety of functional forms were tested in the OLS regression procedure. A Breusch-Pagan test confirmed the presence of heteroskedasticity which in turn led to the rejection of quadratic and semi-log (independent) forms. A double-log form was rejected on theoretical grounds as the authors note, "it implies infinite visits per individual at zero cost and generates infinites consumer surplus whenever demand is inelastic" (Willis and Garrod, 1991). While this is a seemingly obvious objection, it is interesting that few commentators have noted this. However, the authors subsequent rejection of the semi-log (dependent) form is less convincing as they note that "though implying finite visits at zero cost, (this form) was abandoned after providing estimates of consumer surplus which were far higher than yielded by other travel-cost studies at UK forest sites" (ibid). Such statements do not constitute statistical tests, indeed since this was the first application of the ITC approach to UK woodland (for which the authors are to be applauded) the lack of any reported diagnostic tests between functional forms is unfortunate, particularly given the major impact upon consumer surplus estimates which changes in functional form entail. However, conversation with Guy Garrod indicated that the overall degree of explanation of ITC tgf's was low for all functional forms.

In the light of these results Willis and Garrod adopt a linear functional form for their ITC model. This choice is most surprising and questionable. Not only is such a functional form incompatible with basic economic theory (the implication being a constant marginal utility for visits; a problem which the authors acknowledge), but also the heteroskedasticity problem signalled earlier will afflict the linear form (potentially less than quadratic forms) such that the OLS estimator will no longer BLUE. This is a serious criticism and considerably detracts from the analysis presented.

Quite separate from discussions regarding an appropriate functional form for TC analysis several commentators (eg Balkan and Kahn, 1988), have questioned the appropriateness of OLS techniques for regression analysis of recreation survey data. The OLS approach relies upon observations having a normal probability density function (pdf). Clearly data from a recreation survey does not conform to this assumption in that non-visitors are truncated out of the sample: Willis and Garrod (1991) follow earlier analysts such as Smith and Desvouges (1985) in complimenting their OLS results with estimates obtained from a maximum likelihood routine[34]. Here the model for forest recreation is as shown in equation (A1.10):

$$V_{ji} = \beta_j X_{ij} + e_{ji} \qquad \text{(A1.10)}$$

where

$i$ = indexes individuals

$j$ = indexes forests

$V_{ji}$ = visits to forest j by individual i (per annum)

$\beta_j$ = coefficient vector

$X_{ij}$ = all explanatory variables ($C_{ji}$, $Y_i$, etc)

$e_{ji}$ = IID disturbances: N $(0, \sigma^2)$

Given this model the maximum likelihood estimator is based upon the pdf of $V_{ji}$ which can be constrained (ie. truncated) normal such that $V_{ji} > 0$ (ie. to allow for the truncation of non-visitors) as shown in equation (A1.11).

$$f(V_{ji}) = \begin{cases} \dfrac{(1/\sigma)\emptyset[(V_{ji}-B_jX_{ji})/\sigma]}{(1-\phi[-B_jX_{ji}/\sigma])} & \text{if } V_{ji} > 0 \\ 0 & \text{otherwise} \end{cases} \qquad \text{(A1.11)}$$

[34]For and excellent introduction to likelihood analysis see Pickles (1985).

where

$\emptyset(.)$ = standard normal density function

$\phi(.)$ = standard normal distribution function

Table A1.25 gives details of estimated travel cost coefficients and consumer surplus for three permutations of TC approach and estimation technique:

i) ZTC (OLS); a ZTC approach estimated via OLS techniques
ii) ITC (OLS); an ITC approach estimated via OLS techniques
iii) ITC (TML); and ITC approach estimated via truncated maximum likelihood techniques

Table A1.25: Travel cost coefficients and consumer surplus estimates for three estimation techniques

| | ZTC (OLS) | | ITC (OLS) | | ITC (TML) | |
|---|---|---|---|---|---|---|
| Forest District | Travel Cost Co-efficient | Consumer Surplus per visit (£) | Travel Cost Co-efficient | Consumer Surplus per visit (£) | Travel Cost Co-efficient | Consumer Surplus per visit (£) |
| Brecon | -0.384 | 2.60 | -0.358 | 1.40 | -0.757 | 0.66 |
| Buchan | -0.444 | 2.26 | -0.996 | 0.50 | -2.515 | 0.20 |
| Cheshire | -0.525 | 1.91 | -1.259 | 0.40 | -8.408 | 0.06 |
| Lorne | -0.694 | 1.44 | -0.327 | 1.53 | -0.522 | 0.96 |
| New Forest | -0.702 | 1.43 | -0.215 | 2.32 | -4.280 | 0.12 |
| Ruthin | -0.396 | 2.52 | -0.386 | 1.29 | -0.566 | 0.88 |

Notes:
1. Visit costs for all results calculated as the sum of travel costs (at full running costs of 33p/mile) and time costs (at 43% wage rate)
2. ZTC (OLS) results use a semi-log (dependent) functional form
3. ITC (OLS) and ITC (TML) results use a linear functional form

Source: Abstracted from Willis and Garrod (1991).

As can be seen from the results detailed in table A1.25, the more inelastic the demand curve the lower the estimated consumer surplus. Willis and Garrod (1991) also report ITC results for a model based upon petrol only (8p/mile) travel costs (with time costs as 43% wage rates) which, naturally, produces even lower consumer surplus estimates. However, as these are less defensible assumptions we shall not discuss such a model further (this is also in line with the authors treatment).

Willis and Garrod (1991) use the visitor data collected by Benson and Willis (1990) to produce aggregate consumer surplus estimates. Using the ITC (TML) per visit estimates gives an aggregate annual consumer surplus for the six study sites of £3.4 million per year for the same sites (Willis, 1990). The ITC (TML) procedure produces annual estimates equivalent to just over 16% of those produced by the ZTC approach. Extending this result to the whole Forestry Commission estate would reduce estimated national informal recreation benefit to just £8.7 million per annum.

Willis and Garrod (1991) attempt to chose between the differing results of the ZTC and

ITC approaches by comparing these two results with those obtained from CV questions asked during the surveys (discussed below). They argue that CV WTP measures (ie. compensating variation measures) should lie just below (but not far below) the Marshallian consumer surplus measures provided by revealed preference measures such as those provided by TC. Following this line, Willis and Garrod note that the CV results (shown in the last column of table A1.25) are much closer to the ITC results than the ZTC results and therefore conclude that "ITC provides the closest travel-cost approximation of the true consumer surplus" (ibid).

This conclusion can be criticised upon practical, empirical and theoretical grounds. The obvious practical query is that if the test of accuracy is purely to be in terms of the relationship of TC measures to the CV measure, then why perform TC analysis at all, a simpler approach being just to undertake a CV study. In reality CV is far from flawless and so cannot be used as a perfect measuring rod. Empirically such an assertion is also flawed; Willis and Garrod are arguing that the ITC provides a true consumer surplus measure because it exceeds the CV (compensatory variation) measure. However, upon inspection we can see that in half the cases this is not so, indeed average CV WTP exceeds that of the ITC measure. However it is in theoretical terms and counts that the Willis and Garrod argument is most flawed. Firstly their comparison of compensating variation and consumer surplus measures is theoretically framed in terms of Willis's private goods type differences if they are looking for a small difference between these measures. However, the theoretical advances of Randall and Stoll (1980) and especially Hanemann (1991) show that, for public goods such as non-priced recreation, the difference between the consumer surplus and compensating variation may be very considerable. Hanemann's (1991) synthetic data example demonstrates the feasibility of a magnitude difference between WTP (compensating variation for a welfare gain) and WTA (equivalent variation for a welfare gain of 5 times, implying consumer surplus 2.5 times above compensating variation. Therefore the similar magnitudes of ITC (TML) and CV measures cannot be seen as necessary support for the validity of the former. Indeed the magnitude difference between ZTC and CV measures (ranging from 2.0 to 5.7 across the six sites) cannot be ruled out of feasibility.

A second important theoretical criticism of the Willis and Garrod (1991) analogy between the ITC (TML) and CV measures is that in two distinct ways they do not correspond to the same good:

(i) The ITC measure is one of the pure use value while the CV measure, by dint of its expressed preference nature, is an amalgam of, at very least, the use and option value held by visitors. Indeed we can argue that it is an amalgam of visitors use, option and non-use (bequest and existence) values (Pearce and Turner, 1990). The link between the (CV) compensating variation measure of this use and option good with the (TC) consumer surplus measure of the use-only good is uncertain.

(ii) We have argued that the ZTC results may represent 'whole-experience' rather than 'on-site only' values. This argument may also extend to the ITC. However responses to the CV WTP question (discussed in detail subsequently) clearly only apply to the on-site experience. This is a confusing factor running contrary to the influence of factor (i) above in that it should influence TC results to be above CV results. We have no clear a priori grounds for expecting one factor to be stronger than the other, however it does tend to invalidate the comparison of results as a strong test of validity.

### A1.6.1.5: The TC studies: concluding remarks

If we have no a-priori grounds for preferring one or other of the ZTC or ITC measures, and the results themselves offer no direct guidance, can we then decide which of theses analyses has been conducted more rigorously? Although no details were given in earlier articles, the predicted versus actual visitor rates comparison of ZTC functional forms reported in Willis and Garrod (1991) does support the choice of the semi-log (dependent) form. We have raised some reservations about this test and the predictive ability of this form is in some cases weak (correlation coefficient of just 0.54 reported for Brecon in table A1.17). However, overall this test works quite well and despite the objections of Christensen and Price (1982) it is difficult to envisage and alternative test, given the multitude of forms being examined.

Although we disagree with Willis and Benson's (1989b) preference for results from their 'standard model' [SM] and propose instead our own revised (perceived travel cost) model [3*], accepting this revision the analysis has clearly been undertaken extremely thoroughly. Rejecting completely the revised model [3*] results could therefore only be justified upon the grounds that the ZTC approach itself is completely flawed. This is not an unsustainable attack; as our review of the TC showed (chapter 2), their are many serious problems inherent in any TC analysis. Furthermore we do not accept the multitude of US applications of the method as necessary proof of its integrity[35]. We can frame our conclusion therefore in terms of a null hypothesis[36] being; $H_0^Z$: "Results from the ZTC analysis are valid". We conclude that, despite reservations, we do not have sufficient evidence to reject this hypothesis.

Turning to consider the ITC analysis, an immediate strength is that this utilizes the same rigorous dataset as did the ZTM analysis. Furthermore, following Brown and Nawas (1973) and our own analysis (chapter 2), we should expect the ITC approach to allow for superior definition of the set of explanatory variables. Despite this, Willis and Garrod (1991) clearly experienced great difficulty in isolating a suitable functional form[37], indeed we feel that their analysis is weak at this point. Their rejections of the quadratic and semi-log (independent) forms on grounds of heteroskedasticity are quite reasonable. However, such a decision must then rule invalid their subsequent choice of a linear form (which is anyway incompatible with theory). Their rejection of the semi-log (dependent) form simply for providing consumer surplus estimates which were higher than those yielded by other studies in the UK literature does not constitute a valid statistical test. The lack of diagnostic rejection of this form implies that it may have been statistically valid, in which case results (not reported) would be most interesting.

The problems engendered by the unrealistic and statistically biased nature of the linear form employed outweighs the authors commendable and theoretically correct preference for the TML estimation procedure. This criticism is more serious than that levelled at the ZTC analysis and if we formulate a new null hypothesis; $H_0^I$: "Results from the ITC analysis are valid" we have greater grounds for rejecting $H_0^I$ than we had for rejecting $H_0^Z$.

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[35]Indeed we would argue that the TC *may* work reasonably well in the USA while at the same time failing in the UK context. It may be that the discrete nature of US sites, characterised both by few surrounding substitutes and by long travel distances, may make the TC operational while the cluster of nearby substitute sites and relatively low travel distances which characterise UK sites makes it unoperational. In personal communications with between the author and staff at H.M. Treasury the latter indicated that they would not accept benefit estimates produced via the TC although the reasoning for these statements was not made explicit.

[36]It may seem odd to refer to a positive statement as being a null hypothesis. However, Maddala (1988, p.21) refers to this as an acceptable, standard approach.

[37]This extreme difficulty raises the possibility of the dataset containing a high proportion of first time or once-annually visitors. This implies problems for the ITC (but not ZTC) approach (see Freeman, 1979; Bowes and Loomes, 1980; Bateman, 1993). *In extremis*, such a problem makes the ITC inoperable.

## A1.6.2: THE CV ANALYSES

Both the 1987 survey (Willis, et al., 1988) and the 1988 survey (Willis and Benson, 1989b) asked respondents CV questions. The 1987 survey asked respondents two WTP questions; firstly what would they be WTP a simple entrance fee (ie. use value), and secondly what would they be WTP as a 'maximum entrance fee' which ensured conservation of the site in the future (ie. use plus option value). In both cases the payment vehicle was a car parking fee. Per capita entrance and maximum entrance fees were then calculated by dividing per car per visit figures by the mean car occupancy rate. Results are given in table A1.26.

Table A1.26: WTP entrance fee at six sites (1987 survey and prices)

| Site | Average entrance fee (use value) (WTP/person/visit) £1 | Average maximum entrance fee (use + option value) (WTP/person/visit) £ |
|---|---|---|
| Castle Douglas (Clatteringshaws) | 0.37 | 0.80 |
| South Lakes (Grizedale) | 0.39 | 0.86 |
| North York Moors (Dalby) | 0.53 | 1.03 |
| Durham (Hamsberley) | 0.31 | 0.56 |
| Thetford | 0.23 | 0.41 |
| Dean (Symonds Yat) | 0.28 | 0.63 |

Source: Willis, et al., (1988)

This early study is also notable for preceding certain US articles (eg Walsh et al, 1990) in asking respondents to disaggregate their bids into various categories, results being as table A1.27.

Table A1.27: Disaggregated willingness to pay

| Value Category | % |
|---|---|
| Wildlife | 36 |
| Landscape | 34 |
| Information and facilities | 16 |
| Recreation | 14 |

Note: Average WTP = £0.33/visitor

Source: Willis, et al., (1988)

While these results were reasonably stable between sites, their interpretation is difficult. The categories are somewhat overlapping (eg wildlife is part of the landscape; facilities may include recreational facilities) and certainly their relationship to categories of use/option/existence value is difficult to assess (Bateman, 1992).

The 1988 survey presented respondents with one of two WTP questions as follows:

Version A: (Q11A)

"There is no entry fee or parking charge here. Would you be willing to make a donation to help towards the costs of keeping the forest open for visitors?" (YES/NO)

(If 'YES'): How much would you give" (£)

(Check it per person, per group etc.)

Version B: (Q11B)

"There is no entry fee or parking charge here. What do you think would be a fair charge per person to help towards the costs of keeping the forest open for visitors?" (£)

Following either version the respondent was then asked the following:

Version A and B: (Q12)

"Would you pay even more to ensure that the forest is conserved for the future?" (YES/NO)

(If 'YES'): "How much extra (above previous sum) would you pay on each visit?" (£)

The Q11A and Q11B questions differ in a number of respects. They were designed to test the impact of any payment vehicle bias. However, following Bateman et al., (1991)[38] we can see that the format of these questions has also allowed the possibility of other biases arising. Firstly while Version A (Q11A) validates zero bids (via the YES/NO WTP anything at all question) before asking for a WTP bid, Version B (Q11B) does not. Many recent studies (eg. Bateman et al., 1992) have adopted the former approach arguing that if respondents are not explicitly allowed the right to refuse to bid, then they may feel compelled to state some positive amount even if, in reality, they would refuse to pay or go elsewhere, etc. A second bias arises, again in Q11B from the use of the wording "What do you think would be a fair charge?" This does not have the same meaning as a conventional WTP question as here the respondent can construe this as a request for their idea of a socially acceptable norm other than their personal WTP. This wording may have serious and uncertain consequences. It may be that respondents, freed from the constraints of personal evaluation, may drastically free-ride, so reducing mean WTP. What is certain is that, instead of these two questions adequately assessing the impact of a change in vehicle, there are in fact three separate differences between Q11A and Q11B and as such the analysis is underidentified and inoperable. To be feasible, each bias check requires just one alteration in question format[39].

Q12 is designed to estimate pure option value and as such it is reasonable well-worded. Possible objections are: (i) that use and option value are not perceived as separable and that answers to Q11 A/B contain an option value element; (ii) that Q12 is in fact an 'extra information' question where respondents perceive their previous WTP bids as somehow insufficient and therefore react to this extra information rather than to the good in question. However, overall the question seems to reasonable.

The results for Q11A and Q11B are given as table A1.28. As can be seen mean WTP via an entrance charge (column 1) is lower than via the donation vehicle (column 2) at all sites. Furthermore refusals to pay were 12% for an entrance charge compared to just 1% for the donation vehicle. (7% of entire sample). Following the objections we raised above we cannot, with certainty, attribute these differences to vehicle bias, indeed they accord to the

[38]See also Mitchell and Carson (1989) and Bateman and Turner (1992, 1993).

[39]See our second Thetford Forest study described in chapter 4.

proposed free-rider behaviour we suggested earlier. The table also details three measures irrespective of payment vehicle: (i) mean WTP for all respondents (column 3) which varies from £0.43 to £0.73 per person per visit with an all sites mean of £0.53; (ii) mean WTP of all respondents who were not aware of substitute sites (column 4) and; (iii) mean WTP for respondents who were aware of substitute sites (column 5). The latter was generally higher than the former, implying a logical link between the awareness of substitutes and WTP for a site. However, due to the high standard deviations of these figures, the differences between them were found not to be statistically significant.

Table A1.28: Willingness to pay via donation or entrance fee (£ (1989) per visit and 95% confidence interval; non-payers included as zeros). Sample rise in parentheses.

| Forest District | (A) Mean WTP (donation) | (B) Mean WTP (charge) | (A+B) Mean WTP (all) | Mean WTP (all) if no substitute | Mean WTP (all) if substitute |
|---|---|---|---|---|---|
| Brecon | 0.53±0.40 (103) | 0.40±0.30 (109) | 0.46 | - (1) | 0.45±0.31 (155) |
| Buchan | 0.68±0.45 (91) | 0.45±0.38 (92) | 0.57 | 0.72±0.39 (9) | 0.54±0.39 (120) |
| Cheshire | 0.57±0.41 (131) | 0.38±0.32 (151) | 0.47 | 0.42±0.54 (13) | 0.44±0.35 (152) |
| Loch Awe | 0.54±0.29 (15) | 0.45±0.33 (16) | 0.50 | 0.20±0.21 (5) | 0.56±0.31 (12) |
| Lorne | 0.88±0.90 (84) | 0.57±0.39 (89) | 0.72 | 0.71±0.73 (69) | 0.75±0.72 (91) |
| New | 0.52±0.53 (140) | 0.35±0.35 (148) | 0.43 | 0.60±0.62 (11) | 0.42±0.37 (131) |
| Newton Stewart | 0.87±0.42 (99) | 0.59±0.49 (101) | 0.73 | 0.70±0.69 (8) | 0.65±0.39 (101) |
| Ruthin | 0.53±0.37 (123) | 0.37±0.31 (150) | 0.44 | 0.70±0.87 (4) | 0.43±0.34 (217) |
| All sites | 0.63±0.52 (786) | 0.43±0.37 (857) | 0.53 | 0.64±0.67 (120) | 0.50±0.41 (980) |

A: includes some bids per group as well as per person
B: per person

Note: Refusal rates: A = 1%, B = 12%, All = 7%

Source: Willis and Benson (1989b)

Reported results for the option value question (Q12) are given in table A1.29, Willis and Benson (1989b) state of these that: "The answers to Q12, when compared to those of Q11 and those obtained in 1987, suggest that respondents were bidding an extra sum per group rather than per person; of this is so, the mean willingness to pay extra per person was 39p (given a mean group size of 2.95)." The need for such analysis and conversion suggests that the wording of Q12 received somewhat loose interpretation by either respondents or interviewers (or both).

A further confusion arises because, whereas the results of table A1.28 are given including all non-payers as zeros, the reported results of table A1.29 (columns 5 and 6) are calculated only from those who were WTP some extra amount. Bateman et al., (1992) argue that this will lead to confusion in the interpretation of results and instead advocate the calculation of means for the whole sample with non-payers included as zeros. Such a calculation has been performed on this data with per person revised mean extra WTP being given in the last column of table A1.29.

Table A1.29: Willingness to pay an extra sum per visit to ensure site conservation (option value)
(£ (1989) per visit and 95% confidence interval)

| Forest | N | payers | non-payers | Mean Extra WTP of those WTP some extra (per group) | Mean Extra WTP of those WTP some extra (per person) | Revised Mean WTP (non-Payers as zero's) (£ per group) | Revised Mean WTP (non-payers as zero's) (£ per person) |
|---|---|---|---|---|---|---|---|
| Brecon | 241 | 188 | 53 | 0.75±0.92 | 0.25±0.31 | 0.59±0.72 | 0.20±0.24 |
| Buchan | 201 | 149 | 52 | 0.87±0.90 | 0.29±0.31 | 0.64±0.67 | 0.22±0.23 |
| Cheshire | 324 | 209 | 115 | 1.15±1.50 | 0.39±0.51 | 0.74±0.97 | 0.25±0.33 |
| Loch Awe | 56 | 25 | 31 | 1.74±1.22 | 0.59±0.41 | 0.78±0.54 | 0.26±0.18 |
| Lorne | 201 | 138 | 63 | 1.30±1.99 | 0.44±0.67 | 0.89±1.37 | 0.30±0.46 |
| New Forest | 316 | 279 | 37 | 1.51±2.10 | 0.51±0.71 | 1.33±1.85 | 0.45±0.63 |
| Newton Stewart | 213 | 158 | 55 | 1.79±2.79 | 0.61±0.95 | 1.33±2.07 | 0.45±0.70 |
| Ruthin | 310 | 240 | 70 | 0.71±1.00 | 0.24±0.34 | 0.55±0.77 | 0.19±0.26 |
| All Sites Mean | | | | 1.16±1.74 | 0.86±0.59 | 0.86±1.30 | 0.29±0.44 |
| All Sites Total | 1862 | 1387 | 475 | | | | |

Source: Extrapolated from data given in Willis and Benson (1989b)

A bid function was estimated in order to investigate WTP responses. Only results for a linear functional form are reported (Willis and Benson, 1989b; Willis 1990; Willis and Garrod, 1991; Garrod and Willis, 1991; Benson and Willis, 1992) and there is no mention of any other functional form being investigated (which is somewhat surprising). Furthermore only entrance charge observations were investigated using the model specified in equation (A1.12).

$$WTP = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + ..... + \beta_n X_n \qquad (A1.12)$$

where

| | | |
|---|---|---|
| WTP | = | willingness to pay per capita as an entrance charge |
| $X_1$ | = | Income |
| $X_2$ | = | Time spent at forest |
| $X_3$ | = | Visit costs (travel and time cost) |
| $X_4$ | = | % of whole days' enjoyment attributable to the forest |
| $X_5$ | = | Visits to forest in past year (number) |

| | | |
|---|---|---|
| $X_6$ | = | Is forest sole purpose of trip? (1/0) |
| $X_7$ | = | First trip to forest? (1/0) |
| $X_8$ | = | Substitute forest named? (1/0) |
| $X_9$ | = | Substitute recreation site named? (1/0) |

Because of severe missing data problems there were only 207 observations with all necessary data complete. A standard OLS regression provided only a weak model ($R^2 = 0.08$) with only three variables were significant at even the 15% level ($X_2$, $X_8$, $X_9$). Interestingly the intercept value $\beta_0$ was £0.38, equal to the mean WTP per person. A jack-knife regression analysis was also undertaken confirming the stability of coefficient estimates. However this proved to be a similarly weak model. Results for both regressions are given as table 1.30. Estimated coefficients for $X_2$ and $X_8$ are correctly signed, indicating an increase in WTP of £0.05 for each extra hour spent on site and a decrease in WTP of £0.18 if a respondent indicated awareness of a substitute forest site. However, the sign on $X_9$ (awareness of a substitute recreation site) is incorrect and disturbing given its relative strength in the jack-knife analysis (although this is not the case in the standard OLS regression).

Table A1.30. Willingness to pay regression results
(dependent variable = WTP per person via an entrance charge).

| OLS Regression ($R^2 = 0.0880$) | | | | |
|---|---|---|---|---|
| Independent Variable | Coefficient Estimate | Standard Error | t-ratio | Prob> T |
| Site visit length | 0.0556 | 0.0186 | 2.9802 | 0.0032 |
| Substitute forest | -0.1761 | 0.0837 | -2.1050 | 0.0365 |
| Other substitute | 0.1912 | 0.1182 | 1.6177 | 0.1072 |
| Jack-knife Regression ($R^2 = 0.0875$) | | | | |
| Independent Variable | Coefficient Estimate | Standard Error | t-ratio | Prob> T |
| Site visit length | 0.0586 | 0.0618 | 0.9485 | 0.3440 |
| Substitute forest | -0.1848 | 0.1785 | -1.0348 | 0.3019 |
| Other substitute | 0.2000 | 0.1437 | 1.3924 | 0.1653 |

Source: Willis and Benson (1989b); Willis and Garrod (1991)

In conclusion, the CV analysis has certain problems arising from underidentification of the multiple biases inherent in the WTP question formats used. There is also a slight uncertainty about the 'unit of account' (person/group/household) although this may not be serious. Finally, the bid curve analysis as reported is very limited.

## A1.6.3: CONCLUSIONS

We have raised criticisms of all three facets of this study (ZTC/ITC/CV) undertaken by Willis et al. The major criticisms are as follows;

a) ZTC

There is no clear definition of whether the values obtained represent 'on-site' or 'whole experience' values (see chapter 2). While this in no way invalidates the analysis, if they are 'whole experience' values then we should not expect an equivalence between TC and CV WTP (which are on-site) values. While not reported in the original ZTC reports (Willis and Benson, 1989b, Willis, 1990), the analysis of functional form given in Willis and Garrod (1991) does give support for the adoption of a semi-log (dependent) functional form in the ZTC analysis. However, we take issue with Willis et al's preference for their 'standard model' [SM] cost assumption (full running travel costs + 43% wage rate time costs). We propose our own preferred model [3*] using a revised cost assumption (perceived travel costs + 43% wage rate time costs) which results in a considerable downward revision of consumer surplus values.

b) ITC

The uncertainty regarding the 'whole experience'/'on site' nature of ZTC analysis extends to the ITC analysis. Furthermore, we have grave reservations concerning the chosen (linear) functional form which both contradicts theoretical expectation and is subject to problems of heteroskedasticity. While the use of TML (as well as OLS) regression techniques is commendable, the functional form problem makes the resultant consumer surplus estimates highly suspect.

c) CV

The CV WTP values correspond by definition to the on-site experience. However, we have reservations concerning the wording of the two versions of elicitation question employed. Rather than these providing a check upon vehicle bias, we find that three potential biases are present making the analysis of individual bias effects inoperable. However statistical tests found no significant differences in WTP between the two approaches so that we can overlook these problems.

In conclusion (contrary to Willis and Garrod, 1991) it would seem most defensible to dismiss the ITC results, concentrating instead upon those from the ZTC and CV analysis. Relationships between these two measures are, a-priori, uncertain. If the ZTC measure relates to the use-value whole-experience then this should raise its value above that of the CV WTP on-site use value measure (as observed). The observed relationship between ZTC and CV values are therefore defensible although, given that on average (across all sites) visitors attributed 71.7% of the days enjoyment to the forest visit (Willis and Benson, 1989b) the gap between ZTC and CV values is wider than we would expect with use and use + option value estimates being respectively 36% and 55% of our preferred ZTC measure.

## Summary Results

Table A1.31 summarises results for ZTC, ITC and CV analyses at each site and for all sites. Following our commentary and criticisms we would emphasise the results obtained from the ZTC[3*] model and from the CV use and option value analyses. Weighted means for WTP use value, option value and use + option value are also calculated and reported.

Table A1.31: Summary results from three analyses: consumer surplus per person per visit (£ 1988 prices).

| | | ZTC | | ITC | | CV | | |
|---|---|---|---|---|---|---|---|---|
| Cluster No. | Forest District | [SM] (£) | [3*] (£) | OLS (£) | TML (£) | Mean WTP Use[1] (£) | Mean WTP Option [2] (£) | Mean WTP Sum[3] (£) |
| 1 | New Forest | 1.43 | 0.93 | 2.32 | 0.12 | 0.43 | 0.45 | 0.88 |
| 2 | Cheshire | 1.91 | 1.25 | 0.40 | 0.06 | 0.47 | 0.25 | 0.72 |
| 3 | Loch Awe | 3.31 | 1.92 | | | 0.50 | 0.26 | 0.76 |
| 4 | Brecon | 2.60 | 1.70 | 1.40 | 0.66 | 0.46 | 0.20 | 0.66 |
| 5 | Buchan | 2.26 | 1.67 | 0.50 | 0.20 | 0.57 | 0.22 | 0.79 |
| 6 | Durham/N.Y. Moors | 1.79[4] | 1.22[4] | | | | | |
| 7 | Aberfoyle | 2.72 | 1.88 | | | | | |
| 8 | South Lakes | 1.34 | 0.92 | | | | | |
| 9 | Newton Stewart | 1.61 | 1.24 | | | 0.73 | 0.45 | 1.18 |
| 10 | Lorne | 1.44 | 1.10 | 1.53 | 0.96 | 0.72 | 0.30 | 1.02 |
| 11 | Castle Douglas | 2.41 | 1.66 | | | | | |
| 12 | Ruthin | 2.52 | 1.72 | 1.29 | 0.88 | 0.44 | 0.19 | 0.63 |
| 13 | Forest of Dean | 2.24 | 1.61 | | | | | |
| 14 | Thetford | 2.66 | 1.84 | | | | | |
| Mean | | 1.98 | 1.48 | 1.26[5] | 0.45[5] | 0.53[6] | 0.29[6] | 0.82[6] |

Notes: 1. Mean of donation and entrance fee bids (Q11A and Q11B) with non-payers included as zeros
2. Mean extra WTP to conserve sites with non-payers included as zeros
3. Sum of use and option bids with non-payers included as zeros
4. Weighted mean of two sites
5. Weighted mean of six sites
6. Weighted mean of eight sites.

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# A1.7: QUEEN ELIZABETH FOREST PARK (ABERFOYLE) STUDY

**Methods:** ZTC/CV

**Evaluation unit:** per person per visit

**Commentary**

In 1986 the Forestry Commission agreed to fund a study of one of their forests with the intention of evaluating the non-market wildlife, landscape and recreation resources therein. This study was therefore designed to complement the national scale study conducted by Willis et al., which was more (although not exclusively) concerned with recreation benefits.

An initial one-week pilot survey was undertaken in Easter 1987 (Hanley and Common, 1987a) wherein 170 completed questionnaires were elicited. This was followed by a six week survey between June and August of the same year (Hanley and Common, 1987b; Hanley 1989). Here sample size is reported as 1148 questionnaires completed. In both the pilot and main study, ZTC and CV techniques were applied to the data. As pilot results are roughly in line with those of the main study we shall concentrate upon the latter.

Main survey sampling was undertaken at two sites in the forest; the David Marshall Lodge (DML) visitor centre and the Achray Forest Drive (AFD). While some questionnaires were completed in face to face interviews, others were self completed by on-site respondents who then posted these into on-site boxes provided by the Forestry Commission (the proportion of self-fill to face-to-face interviews is not reported).

## A1.7.1: THE CONTINGENT VALUATION STUDY

The CV exercise attempted to estimate separate values the wildlife, landscape amenity and forest drive assets of the forest as well as for the whole forest itself. This was attempted by presenting each respondent with all of the following questions (abstracted from the questionnaire):

Q.1.a) Suppose the Forestry Commission decided to construct a hide, from which you could watch wildlife (for instance, deer, squirrels and birds) at close quarters. If the only way to fund this project was an entrance fee, what would be the most you would be prepared to pay, per person per visit? (Please circle one)

£0 £0.50 £1.00 £1.50 £2.00 £2.50 £3.00

Other (please state)

b) If your answer is 'nothing', why is this?

Q.2.a) Currently a charge of £1 is made for use of the forest drive, a Forestry Commission private road which takes in 7 miles of woodland wildlife and views. If the only way to keep this drive open was to increase the fee, what is the most you would be willing to pay in total, per car per visit? (Please circle one)

£0 £1.00 £1.50 £2.00 £2.50 £3.00 £3.50

Other (please state)

b) If your answer is 'nothing', why is this?

Q.3.a) The trees surrounding the David Marshall Lodge (which include oak, spruce, silver birch and larch), are of quite high timber value. Suppose the Commission was faced with the choice of either felling

the trees this year or else increasing the entry fee to the Lodge area. How much would you be willing to pay in total, per person per visit, to save the trees? (Please circle one)
£0 £0.50 £1.00 £1.50 £2.00 £2.50 £3.00
Other (please state)

b) If your answer if 'nothing', why is this?

Q.4.a) Suppose the government was considering selling the Queen Elizabeth Forest Park to a private forestry company. This would mean people would no longer be able to visit it. If the only way to prevent this happening was for the Forestry Commission to raise money by selling day tickets to visitors, how much would you be willing to pay, per person per visit? (Please circle one)
£0 £0.50 £1.00 £1.50 £2.00 £2.50 £3.00 £3.50 £4.00
Other (please state)

b) If your answer is 'nothing', why is this?

Source: Hanley (1989)

To test for anchoring effects the sample was systematically divided with some facing open-ended WTP questions (i.e. not presented with the lists of possible bids indicated in the questions above) while the remainder were presented with the payment card range of bids indicated above. WTP results for the whole sample CV exercise (including face to face/self-fill and open-ended/payment card respondents) are reported in table A1.32 below.

Table A1.32: Contingent valuation results

| Descriptive Statistics | WTP for wildlife | WTP for forest drive | WTP for landscape | WTP for whole forest |
|---|---|---|---|---|
| Mean (£/visit/person) | 0.84 | 1.58[1] | 0.800 | 1.25 |
| Standard deviation | 0.57 | 0.72 | .59 | 0.87 |
| Range (£/visit/person) | 0-5.00 | 0-5.00 | 0-5.00 | 0-10.00 |
| No. of protest bids | 89 | 121 | 156 | 158 |
| No. of non-protest bids | 1059 | 1027 | 992 | 990 |

Notes: n = 1148
All sums are in £(1989) prices
1. For an estimated 3.45 visitors per car, the mean bid is £0.45 per visitor.

Source: Hanley (1989)

Analysis was then extended to sub-samples examining whether WTP bids differed between self-fill and face-to-face respondents being reported as table A1.33.

Table A1.32: Comparison of bids by data collection method

| | Interview | | Self Fill | |
|---|---|---|---|---|
| Bid for: | Mean (£) | St Dev | Mean (£) | St Dev |
| Hide | 0.87 | 0.62 | 0.84 | 0.53 |
| Forest Drive | 1.56 | 0.75 | 1.60 | 0.71 |
| Landscape | 0.73 | 0.58 | 0.86 | 0.60 |
| Forest | 1.35 | 0.91 | 1.16 | 0.84 |

Source: Hanley (1989)

Table A1.33 shows mean WTP bids for self-fill and face-to-face to be reasonably similar. Bid figures are only significantly different (at the 5% level) for the landscape and whole forest questions, although in opposite directions. Hanley then moves to consider the impact of question format upon WTP bid with results reported as per table A1.34.

Table A1.34: Open versus closed ended responses

| | Open-Ended | | Closed-Ended | |
|---|---|---|---|---|
| Bid for: | Mean Bid (£) | St Dev | Mean Bid (£) | St Dev |
| Wildlife Hide | 0.81 | 0.61 | 0.89 | 0.54 |
| Forest Drive | 1.58 | 0.82 | 1.59 | 0.64 |
| Landscape | 0.74 | 0.63 | 0.85 | 0.56 |
| Whole Forest | 1.24 | 0.99 | 1.25 | 0.76 |

Source: Hanley (1989)

The results of table A1.34 show that for all assets considered, responses to open-ended WTP questions lie below those for payment card questions with the difference in response between the two approaches being the most (15%) for the landscape attributes of the forest.

Means for the whole sample will necessary lie between the means of these opposing approaches. Hanley therefore uses whole sample mean WTP in the calculation of aggregate WTP sums given as table A1.35.

Table A1.35: Aggregate WTP results (CV)

| Forest Resource | Mean WTP(£)[1] | Visitor Days p.a.[2] | Aggregate WTP p.a. (£) |
|---|---|---|---|
| Wildlife | 0.84 | 145,000 | 121,800 |
| Forest drive | 0.45 | 24,500 | 11,025 |
| Landscape | 0.80 | 145,000 | 116,000 |
| Whole forest | 1.25 | 145,000 | 181,250 |

Notes: 1. Whole sample mean WTP per person per visit.
2. Forestry Commission estimates.

The determinants of WTP were investigated via estimation of a bid function. A number of equations for individual assets and the whole forest were estimated, however results were weak in that explanatory power was low and expected explanatory variables were found to be insignificant. Hanley (1989) reports the best fit function as given in table A1.36.

Table A1.36: Whole forest WTP bid function: semi log form

Dependent variable = $\ln(WTP_{Whole\ Forest})$

| Variable | Coefficient (T-statistic) | Variable | Coefficient (t-statistic) |
|---|---|---|---|
| Constant | 0.1788<br>(3.64) | Age of respondent | -0.0219<br>(-3.41) |
| Miles travelled to site | 0.00008<br>(0.34) | Holidaymaker or day visitor | -0.0219<br>(-1.05) |
| No. of substitute sites visited | -0.0117<br>(-1.74) | Meanderer or purposeful tripper | -0.0048<br>(-0.23) |
| Visits per annum | -0.0029<br>(1.83) | Member of conservation society | 0.048<br>(2.07) |
| Income | -0.0000009<br>(-0.66) | Interviewed or self-fill response | -0.098<br>(-5.01) |
| Size of party | 0.00048<br>(0.24) | Mode: open or closed ended questions | 0.038<br>(1.98) |

Notes: $R^2 = 4.5\%$; n = 990; Figures in brackets are t-statistics, critical value for two-sided t-test at 90% level = 1.67

Source: Hanley (1989)

In retrospect there are a number of criticisms which can be raised concerning the CV part of this study. Most fundamentally the construction and format of the WTP is problematic. The use of payment card WTP questions has already been highlighted as liable to induce anchoring bias[40]. However, in the light of results given in table A1.34 we can conclude that, while anchoring bias has occurred, it does not appear to have been of a major magnitude. More crucial is the hypothesis that the form of WTP questioning (asking four successive questions about essentially differing assets) has induced an ordering effect into responses[41]. Along with any mental accounting/part-whole problems which have not been addressed, this is liable to result in the inflation of WTP sums for assets placed at the top of that list (i.e. wildlife) compared to assets placed at the bottom of the list (i.e. the whole forest). The testing of such a hypothesis is problematic without access to the source data. However, even the analysis of means gives some support for such a contention. The first question asks WTP for wildlife eliciting a whole sample mean WTP of £0.84 per visit. The second questions asks WTP for the forest drive, however this is complicated by the fact that it also mentions that an entrance fee of £1 is already in force thus undoubtedly influencing responses. Such problems are not present with the third 'landscape' WTP question and here mean WTP is lower (£0.80) than for the first 'wildlife' question. The most serious evidence of ordering and part-whole effects is given by responses to the fourth 'whole forest' WTP question. Even if respondents did not use the forest drive (most did) then the whole forest asset must at least comprise the wildlife and landscape assets they had already given bids for. Nevertheless mean WTP for the whole forest (£1.25/person/visit) is very significantly less than the sum of the parts previously evaluated and strongly supports the contention that part-whole and/or ordering effects are having an impact here.

The lack of a significant relationship between WTP and expected explanatory variables (table A1.36) is interesting and supports the contention of Bateman et al (1992)[42] that for non-unique assets with accessible substitutes, CV responses correspond more to the respondents conception of a 'fair price' rather than true WTP[43]. However, the weakness of the entire model is worrying. Nevertheless these criticisms do not necessarily imply that these results have no value. Instead we argue that Hanley's estimate of WTP for the whole forest (£1.25/person/visit), depressed as it is likely to be by ordering and mental account influences, can be seen as a lower bound estimate of true WTP.

## A1.7.2: THE TRAVEL COST STUDY

A travel cost analysis was carried out on the 319 questionnaires who stated that the visit to Queen Elizabeth Forest Park was the main reason for their day out[44]. A ZTC analysis was undertaken attempting to estimate a trip generating function (tgf) relating zonal visit rate to standard explanatory variables. Travel costs were calculated to represent the marginal cost of making one additional trip by using round trip running costs (petrol plus entry fee) rather than full costs (including sunk costs such as insurance). Travel time costs were approximated however these were found to be statistically insignificant in determining trips. An attempt

[40]See chapters 2, 4, and Bateman et al., (1992).

[41]See Bateman et al (1991); Bateman and Turner (1992).

[42]See also our study of woodland recreation benefits in Thetford Forest described in chapter 4.

[43]Bateman et al (1992) extend this argument to consider CV WTP responses of non-users faced with non-unique substitutable assets and argue that in such cases, WTP responses represent conceptions of a 'fair' charitable donation.

[44]Sample selected to avoid the problem of meanderers and multiple visitors (see chapter 2). However, this does limit the general applicability of resulting estimates.

was initially made to consider the impact of substitute sites however the data collected proved insufficient to operationalise such an analysis.

Due to the lack of firm theoretical guidance as to an appropriate functional form for the tgf (other than a linear form being inappropriate due to the first derivative being a constant), four functional forms were estimated with consumer surplus being calculated for each. Results of this analysis have been discussed previously but are reported below for convenience as table A1.37.

Table A1.37: Estimated trip generating functions and corresponding consumer surplus estimates

| Equation | $R^2$ | Consumers' surplus per capita |
|---|---|---|
| (1) $V_i/P_i = 0.478 - 0.329\ TC_i + 0.05\ TC_i^2$<br>(4.06) (3.47) (3.11) | 34% | £0.32 |
| (2) $V_i/P_i = 0.1523 - 0.146 \ln TC_i$<br>(3.91) (3.05) | 24% | £0.56 |
| (3) $\ln (V_i/P_i) = -2.6 - 0.6\ TC_i$<br>(6.06) (3.41) | 37% | £1.70 |
| (4) $\ln (V_i/P_i) = -2.76 - 1.7 \ln TC_i$<br>(8.39) (4.18) | 37% | £15.13 |

Notes:

$V_i/P_i$ = Per capita visits p.a. from zone i

$TC_i$ = Round trip petrol plus entry costs per respondent from zone i

Figures on brackets are t-statistics

It was assumed that trip costs were shared equally by the members of the respondents party.

(t-statistics in parentheses)

Source: Hanley (1989)

A Breusch-Pagan test confirmed the presence of heteroskedasticity within the data[45]. Following Maddala (1977)[46] one solution is to transform $V_i/P_i$ by taking logs however this rules out the quadratic and semi-log (independent) tgf's. Of the remaining functions, Hanley (1989) rejects the double log from as "the very high per capita consumers surplus estimate from the latter seems inconsistent with other travel cost work on UK sites". The preferred semi-log (dependent) tgf yields a consumer surplus estimate of £1.70/person/visit which is reported to equate to an annual recreation value of £160,744. Both of these figures relate approximately to mean values obtained from the CV experiment.

As before, the ZTC arm of this study can be criticised on a number of grounds not least because of incomplete reporting of results. The analysis was repeated using full travel cost values. However, while consequent and much higher consumer surplus estimates are reported, tgf's and associated diagnostic statistics are not[47]. This leaves the reader uncertain as to which approach performed better; certainly the full cost tgf's of the pilot study (Hanley and

[45]Strong (1983) suggests that this is typical of ZTC data.

[46]See p.265, however note the caveat raised by Christensen and Price (1982) discussed in Bateman (1993).

[47]Calculation of aggregate values for the ZTC analysis is also not made explicit although some adjustment to account for the exclusion of all non-pure visitors (meanderers) *should* have been performed.

Common, 1987a) achieve a much higher degree of explanation than the marginal cost equivalents reported in the main study (see Hanley 1989 and table A1.37 above).

While the case for rejecting the quadratic and semi-log (independent) tgf's is conventionally acceptable, the case made out by the author for preferring the semi-log (dependent) over double-log form is less convincing. A more convincing argument would be to follow Everett (1979) and note that the double log form implies infinite visits at zero costs, an argument which might be feasible for a 'whole experience' demand curve but not one which could be extended to any extrapolated 'on-site experience' demand curve, i.e. we can find a theoretical (if not statistical) reason for rejecting the double log in favour of the semi-log (dependent) functional form. Furthermore, as we have previously argued that the CV estimate of mean WTP (£1.25/person/visit) may be downwardly biased, this does compare favourably to the preferred semi-log (dependent) ZTC consumer surplus estimate (£1.70/person/visit) arguing additionally that this relationship is correctly ordered for a comparison of compensating variation (CV) and consumer surplus (TC) measures.

### Summary Results

CV: £1.25/person/visit
ZTC: £1.70/person/visit

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Bateman, I.J., Willis, K.G., Garrod, G.D., Doktor, P., Langford, I. and Turner, R.K. (1992) Recreation and environmental preservation value of the Norfolk Broads: a contingent valuation study. *Report to the National Rivers Authority*, Environmental Appraisal Group, University of East Anglia, pp.403.

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# A1.8: THE CENTRAL SCOTLAND WOODLANDS PROJECT

**Method:** CV

**Evaluation unit:** capitalised per household values

**Commentary:**

In 1990 the Scottish Office and Scottish Enterprise jointly commissioned Nick Hanley and Ecotech Ltd to undertake a two-stage appraisal of the potential of monetary evaluation techniques as aides to decisionmaking regarding non-priced assets. The first stage of this report (Hanley and Ecotec, 1990) consisted of methodological exposition and theoretical appraisal of various methods. This report highlighted in particular the potential for practical application of the CV and stage two of the project (Hanley and Ecotec, 1991) accordingly undertook seven practical CV studies. Two of these concerned the proposed Central Scotland Woodland Project (CSWP) which aims to substantially increase tree cover in the central belt of Scotland (Scottish Office, 1989).

## A1.8.1: The First Study

In the first CSWP CV study respondents were asked payment card format[48] once-off (capitalised) household WTP questions. For half the questionnaires the payment vehicle was specified as via poll tax while for the remainder a trust fund was used. In all cases respondents were asked to specify their WTP for three mutually exclusive projects:

i WTP to cover 30% of the area in trees
ii WTP to cover 20% of the area in trees
iii WTP to cover 10% of the area in trees.

The study was conducted via a postal survey with addresses being selected at random from the electoral register. 1200 questionnaires were sent out in November and December 1990 with 600 of these being followed by one reminder. In total 230 useable responses were received, details being given as table A1.38.

Table A1.38: Response rate to first CSWP survey (mail CV survey)

| Payment Vehicle | Questionnaires Sent Out | Questionnaires Completed | Response rate |
|---|---|---|---|
| Poll Tax | 600 | 125 | 20.8% |
| Trust Fund | 600 | 105 | 17.5% |
| Total Study | 1200 | 230 | 19.2% |

Source: Hanley and Ecotec (1991)

[48] Details of the payment card range are not given in the relevant publications.

The authors recognise that this is only a modest response highly prone to response bias. This may have been improved with more rigorous reminders; Bateman et al (1992) uses 3 mailings in a non-user CV study of the Norfolk Broads, achieving a response rate of 35%.

Of the 230 responses received, 81 respondents refused to give a positive bid for any of the scenarios. Of these 33 indicated that they would value the forest but refused to pay for it, ie. 14% of the entire sample appeared to be pure free riders. A further 41 gave objections to the payment vehicle as their reason for refusing to pay (18% of total sample). This latter figure is worrying indicating a potentially poor specification of the scenario. Univariate WTP results for the whole sample are given as table A1.39[49].

Table A1.39: Univariate WTP results: first CSWP survey
(£ per household; once-off payment)

| Variable | N | Mean £ | Median £ | Std Dev £ | SE Mean £ | 95% CI £ |
|---|---|---|---|---|---|---|
| WTP 30% | 226 | 16.35 | 5.00 | 25.63 | 1.70 | 12.99-19.71 |
| WTP 20% | 218 | 13.21 | 5.00 | 21.31 | 1.44 | 10.37-16.06 |
| WTP 10% | 217 | 10.58 | 5.00 | 18.40 | 1.25 | 8.12-13.04 |

where:
WTP 30% = bid for 30% forest cover
WTP 20% = bid for 20% forest cover
WTP 10% = bid for 10% forest cover
N = number of bids, including all zeros

Source: Hanley and Ecotec (1991)

Hanley et al., then examine any payment vehicle bias by partitioning the dataset according to the bid vehicle used. WTP results by poll tax or trust fund vehicle are detailed in table A1.40.

[49] WTP results excluding all zeros were also calculated. However, these can be criticised as heavily biased and are not considered here.

Table A1.40: Comparing WTP under different bid vehicles: first CSWP survey (£ per household; once-off payment)

| 1. Poll Tax bids | | | | |
|---|---|---|---|---|
| Variable | Mean £ | Std Dev £ | SE Mean £ | 95% CI £ |
| WTP 30% | 17.94 | 27.37 | 2.48 | 13.04-22.85 |
| WTP 20% | 13.97 | 22.02 | 2.03 | 9.95-17.98 |
| WTP 10% | 10.76 | 18.20 | 1.68 | 7.43-14.09 |
| | | | | |
| 2. Trust Fund bids | | | | |
| Variable | Mean £ | Std Dev £ | SE Mean £ | 95% CI £ |
| WTP 30% | 14.48 | 23.42 | 2.3 | 9.93-19.04 |
| WTP 20% | 12.32 | 20.51 | 2.05 | 8.25-16.39 |
| WTP 10% | 10.37 | 18.72 | 1.87 | 6.65-14.09 |
| Note: both the above tables include protest bids | | | | |

Source: Hanley and Ecotec (1991)

As can be seen, for all scenarios, WTP via the poll tax vehicle is higher (and, as seen, attracts more responses) than for the trust fund vehicle. Although the authors profess some surprise at this, such a result accords directly with the experience of Bateman et al., (1992) who found a consistent preference to pay via taxation vehicles than a variety of trust funds[50]. Despite popular conceptions of tax aversion, such a response is entirely logical reflecting the public's recognition that tax payments inhibit free riding by others and, with government backing, may be more reliable at providing the goods described than are charitable trusts.

Bid functions were also estimated for the 30% forest cover WTP responses. The reported whole sample bid function is reproduced as table A1.41.

[50]Our first Thetford forest study, discussed in chapter 4, also confirms such a result with respect to the specific poll tax vehicle.

Table A1.41: Whole sample bid function: first CSWP survey

| Dependent Variable: WTP for 30% woodland cover | | | |
|---|---|---|---|
| Variable | Coefficient | T-stat | Prob Value |
| constant | -0.09 | -0.01 | .995 |
| TYPE | -6.358 | -1.95 | .053 |
| CONSERV | 1.390 | 0.24 | .811 |
| INC | 3.1922 | 5.65 | .000 |
| AGE | 1.052 | 0.94 | .350 |
| EDUC | 1.3729 | 1.57 | .118 |
| SEX | -4.714 | -1.43 | .156 |
| AREA | 0.8708 | 1.77 | .078 |
| n = 197 $R^2$ (adj) = 25.1% F = 10.40 | | | |

Notes:
TYPE = Bid vehicle type (poll tax = 1; trust fund = 2)
CONSERV = Member of conservation group (yes = 1; no = 2)
INC = Pre-tax household income
EDUC = Level of education attained
SEX = 1 if male; 2 if female
AREA = Location code of respondent

Source: Hanley and Ecotec (1991)

Of the above explanatory variables only TYPE, INC and AREA are clearly significant and a re-estimation to exclude doubtful variables (particularly CONSERV and AGE) would be useful. The functional form, being linear, is also highly questionable.

Bid functions were also estimated for data partitioned according to bid vehicle as detailed in table A1.42 below.

Both of the bid functions in table A1.42 have higher powers of explanation and more acceptable (semi log dependent) functional forms than the whole sample bid function reported in table A1.41. However, as before, insignificant explanatory variables are retained in the reported model.

In summary, this is a small scale study with some significant limitations, the low response rate being an immediate problem. The results only apply to a partial afforestation scheme and furthermore several key variables (eg. visit rate to similar assets; intention to visit; etc) were not collected. Following Bateman et al., (1992) one approach to the analysis of results would be to assume that all non-respondents have a zero WTP and aggregate accordingly across the population.

Table A1.42: Bid functions partitioned by bid vehicle: first CSWP survey

| *Dependent Variable: Ln Poll Tax bids* | | |
|---|---|---|
| Variable | Coefficient | T Stat |
| CONSERV | -0.143 | -0.41 |
| INCOME | 0.185 | 4.93 |
| AGE | 0.198 | 2.39 |
| EDUC | 0.015 | 0.24 |
| SEX | 0.164 | 0.70 |
| $R^2$ (adj) = 37% F = 8.82 | | |
| *Dependent Variable: Ln Trust Fund bids* | | |
| Variable | Coefficient | T Stat |
| CONSERV | -0.1514 | -0.35 |
| INC | 0.1426 | 3.67 |
| AGE | -0.078 | -1.07 |
| EDUC | 0.042 | 0.76 |
| SEX | -0.435 | -1.84 |
| $R^2$(adj) = 27% F = 5.4 | | |

Source: Hanley and Ecotec (1991)

## A1.8.2: THE SECOND STUDY

Building directly upon its predecessor, the second CSWP CV study adopted a face-to-face interview approach to address the problem of non-response bias. However, while the first study had suggested that a trust fund payment vehicle would elicit more 'protest' and zero bids than a poll tax vehicle, after a small pilot sample (just 12 interviews) the latter was dropped on the grounds (ironically) that it produced too many protest bids.

In March 1991 301 face-to-face interviews were completed at eight locations throughout the CSWP proposed planting area. The format used was a once and for all payment to a specially created trust fund set up to provide 30% tree cover in the study area. Along with the data previously collected (age, income and education) questions were also asked regarding preference/use of woodlands (just over 50% did visit woodland); current visits to the area (40% do visit) and probability of future visits to the CSWP (65% said they would).

No less than 158 respondents (52.6%) refused to pay anything for the site of which 90 (30%) were genuine zero bids and 68 (22.5%) were free riders/protest bids. While the authors feel this is reasonable it compares poorly with many contemporary studies (eg. Bateman et al., 1992) and indicates a partial failure of the study probably originating from a poor choice of payment vehicle. Furthermore in calculating mean WTP bids in excess of £100 were arbitrarily reduced to £101. No reasonable justification is given for this decision.

Univariate WTP results are detailed in table A1.43[51].

Table A1.43: Univariate WTP results: second CSWP survey

| *Variable: WTP per household; once and for all* | | | | | | |
|---|---|---|---|---|---|---|
| N | Mean £ | Median | St Dev | SE Mean | Min | Max |
| 301 | 9.34 | 3.00 | 18.79 | 1.08 | 0 | 101 |

Note: includes zeros; all bids >£100 were coded as £101

Source: Hanley and Ecotec (1991)

A bid curve was estimated for all non-protest bids being reported as table A1.44 below.

Table A1.44: Bid function for non-protest WTP bids: second CSWP survey

| *Dependent Variable: LnWTP** | | |
|---|---|---|
| Variable | Coefficient | T-value |
| constant | -0.0837 | -0.09 |
| distance | 0.0048 | 0.71 |
| visfor | 0.2267 | 0.85 |
| probvis | -0.2083 | -1.59 |
| freqpass | 0.1752 | 1.82 |
| opin | 0.0945 | 0.20 |
| conserv | -0.5166 | -1.94 |
| inc | 0.1404 | 4.03 |
| age | 0.1936 | 2.54 |
| educ | 0.0876 | 1.59 |
| $R^2$ (adj) = 36.2% F = 4.72 | | |

Notes:
distance = distance from nearest boundary of CSWP in miles
visfor = dummy (1,2) for if visit FC forests (1 = yes)
probvis = likelihood of visiting CSWP (1-5, 1=almost a certainty to 5=very unlikely
freqpass = frequency of passing area (1-5, 1=every day, 5=less frequently than once a month)
opin = opinion on whether CSWP should go ahead (1=yes, 2=no)
conserv = membership of conservation organisation (1=yes, 2=no)
inc = income
age,educ = self explanatory

Source: Hanley and Ecotec (1991)

[51] As before univariate WTP results for the sample excluding all zero bids were calculated. Interestingly, mean WTP for the subgroup of CSWP residents is £24.31 (excluding all zeros) while for those resident outside the CSWP area mean WTP (excluding zeros) is £12.07.

Again the number of non-significant explanatory variables being included is to be criticised although the F test result is significant. However other coefficients and diagnostic statistics are as expected with the exception of the 'freqpass' variable[52].

Finally an analysis of the WTP/expected demand relationship is conducted showing that, as expected, WTP rises with expected demand. Table A1.45 gives details.

Table A1.45: Option price WTP and expected demand: second CSWP survey

| Probability of visiting | N | Mean non-protest WTP £ |
|---|---|---|
| 1. Almost a certainty | 45 | 26.53 |
| 2. Very likely | 36 | 11.76 |
| 3. Quite likely | 83 | 8.70 |
| 4. Quite unlikely | 5 | 2.80[1] |

Note: all zero WTP bids have been excluded from the above analysis
[1] not significantly different from zero at the 95% level

Source: Hanley and Ecotec (1991)

In conclusion while the second survey avoids the problems of non-response, the high proportion of free-rider/protest zero bids is disturbing. The choice of payment vehicle is likely to have been a contributing factor here. The calculation of mean WTP sums is rather unusual and appears to be a reaction to poor design rather than prompted by theoretical considerations. Nevertheless the results obtained can be defended as lower bound estimates of true WTP[53] although interpretation of once-and-for-all bids within decision frameworks poses an additional complication.

## Summary Results

*First Study*

CV: WTP 30% afforestation = £16.35/household (once and for all payment)
WTP 20% afforestation = £13.21/household (once and for all payment)
WTP 10% afforestation = £10.58/household (once and for all payment)

Note: mail survey response rate = 19.2%

*Second Study*
CV: WTP = £9.34/household (once and for all payment).

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[52]Note the rather odd definitions of categorical variables used in table A1.44 where, for example, a high frequency of passing the site is given a lower category score than that for low frequency of passing the site.

[53] The absence of information regarding the payment card used has to be a further qualifying constraint upon this statement.

## Study References

Hanley, N.D. and Ecotec Ltd (1990) *Valuation of Environmental Effects: Final Report Stage One.* Industry Department for Scotland and the Scottish Development Agency, Edinburgh.

Hanley, N.D. and Ecotec Ltd (1991) *The Valuation of Environmental Effects: Stage Two Final Report.* The Scottish Office Industry Department and Scottish Enterprise, Edinburgh.

## Supplementary References

Bateman, I.J., Willis, K.G., Garrod, G.D., Doktor, P., Langford, I.H. and Turner, R.K. (1992) Recreation and environmental preservation value of the Norfolk Broads: a contingent valuation study, *Report to the National Rivers Authority*, Environmental Appraisal Group, University of East Anglia.

Scottish Office (1989) *Central Scotland Woodlands*, Scottish Office, Edinburgh.

## A1.9: THE COSTS OF FORESTRY DEVELOPMENT: THE FLOW COUNTRY STUDY

**Method:** CV

**Evaluation unit:** capitalised per household preservation (use+non-use) values

**Commentary**

The 'Flow Country' is an extensive area of blanket bog located in Northern Scotland. Its distinctive landscape provides a home for large populations of rare birds and is of great ecological importance. However, the character of the area is threatened by ongoing large scale afforestation which displays the natural fauna and flora. Hanley and Craig (1991a/b) calculate the market benefits of this afforestation (mainly timber) and compare these with market costs (e.g. establishment costs; opportunity costs of any displaced agriculture; etc) and non-market costs. This latter item consists of both the user and non-user value of the Flow Country in its non-developed state. All items were then analysed via a Krutilla-Fisher decision model (Krutilla and Fisher, 1975, 1985; Porter, 1982) as given in equation (A1.13).

$$NPV_D = -C_o + \int_{t=o}^{\infty} D_t\, e^{-(r+\delta)t}\, .dt - \int_{t=o}^{\infty} P_t\, e^{-(r-\rho)t}\, .dt \qquad (A1.13)$$

where

| | | |
|---|---|---|
| $NPV_D$ | = | net present value of development |
| $C_o$ | = | year zero establishment costs |
| $D_t$ | = | net development benefit, year t |
| $P_t$ | = | net preservation benefit, year t |
| r | = | real discount rate (6% used) |
| $\delta$ | = | real growth rate of technology |
| $\rho$ | = | real growth rate of preservation benefits |
| t | = | time (years) |

Non-monetary preservation benefits were evaluated via a postal CV survey. 400 questionnaires were sent out producing, after one reminder, 159 replies (40% response rate) of which 129 were usable (32% usable response rate). Respondents were asked to state their household maximum WTP as a single once-and-for-all payment. Univariate WTP results are summarised in table A1.46.

Table A1.46: Summary WTP[1] results (excluding all 'protest' votes)

| Sample | Mean WTP (£/household) | 95% CI | | Sample Size |
|---|---|---|---|---|
| | | Upper (£/household) | Lower (£/household) | |
| Whole sample[2,3] | 16.79 | 20.76 | 12.82 | 100[4] |
| Users only[2] | 24.59 | 34.27 | 16.74 | 32[5,6] |
| Non-users only[2] | 12.15 | 16.26 | 09.24 | 58[5,6] |
| First mail-out[2] | 17.48 | 22.60 | 12.35 | 62[5] |
| Second mail-out[2] | 13.81 | 20.99 | 06.64 | 38[5] |

Notes: 1.WTP per household as a once and for all question
2. Excludes protest votes
3. Additional results: standard deviation = £19.69; s.e. mean = 2.00; minimum WTP = £0; maximum WTP = £100 (one bid of £1000 excluded)
4. Includes 22 non-protest zero bids
5. Includes an unspecified number of non-protest zero bids
6. There is a reporting error here in that these should sum to 100

Source: Abstracted from Hanley and Craig (1991a/b).

Hanley and Craig investigate the determinants of WTP by estimating the bid curve given as equation (A1.14) using OLS techniques.

$$\underset{}{WTP} = \underset{(.97)}{3.41} + \underset{(1.53)}{5.67}\ USER + \underset{(2.52)}{11.0}\ CONSERV + \underset{(2.44)}{0.000477}\ INCOME \qquad (A1.14)$$

$R^2 = 0.26$ $\qquad$ $F = 10.48$

where

| | | |
|---|---|---|
| WTP | = | household WTP (£), a once and for all sum |
| USER | = | 1 if user, 0 otherwise |
| CONSERV | = | 1 if member of conservation group, 0 otherwise |
| INCOME | = | household pretax income (£) |

Note: Figures in parenthesis are t statistics.

Tests for multicollinearity and heteroskedasticity proved negative, however the estimated bid curve can be queried on several points. The OLS estimation technique is inappropriate for a truncated dependent variable and so a Tobit approach was employed. However, this had little impact upon estimates of mean WTP. The linear form of the reported curve is surprising, although a non-linear relationship between income and WTP was investigated (and rejected). A general test of functional form is not reported. It is also uncertain (but doubtful) as to whether the USER coefficient is significant.

The reported whole sample mean WTP of £16.79 is also open to criticism. By omitting all 29 protest votes, mean WTP is considerably inflated. Treating all protests as zero's reduces mean WTP to £12.49. While the correctness of either approach is perhaps debatable it is clearly inappropriate to use the unadjusted upper amount for aggregation purposes as it implies that non-protest respondents are representative of the whole population. Nevertheless this is the approach taken, producing a net sum of £66 million which Hanley and Craig annualise at 6% to some £4 million p.a. Bateman et al (1992) argue that a more defensible lower-bound approach is to assume that all non-respondents have a zero WTP. Adopting such an assumption and including the protest votes as zeros lowers mean WTP per household to just £3.27 equating to an aggregate capitalised sum of just under £13 million and a 6% annualised equivalent of just under £800,000 per annum.

Interestingly adopting our lower bound approach would not, in this case, change the results of Hanley and Craig's overall analysis. These show that, due to the discounting of long delayed forestry returns, and the poor productive quality of Flow Country land, then even ignoring preservation benefits, $NPV_D$ is negative. Including preservation benefits, even with our adjustment and $\rho = 0$ will only reinforce this result.

## Summary Results

Household once and for all WTP to preserve wetlands by preventing afforestation
= £16.79 (mean of non-protest respondents)
or = £12.49 (including all respondents; protest votes taken as zero's)
or = £3.27 (treating protests and non-responses as zero's).

## Study References

Hanley, N.D. and Craig, S. (1991a) Wilderness development decisions and the Krutilla-Fisher model: the case of Scotlands Flow Country. *Discussion Paper in Economics 91/11*, Department of Economics, University of Stirling.

Hanley, N.D. and Craig, S. (1991b) Wilderness development decisions and the Krutilla-Fisher model: the case of Scotlands Flow Country. *Ecological Economics*, 4:145-164.

## Supplementary References

Bateman, I.J., Willis, K.G., Garrod, G.D., Doktor, P., Langford, I. and Turner, R.K. (1992) Recreation and environmental preservation value of the Norfolk Broads: a contingent valuation study. *Report to the National Rivers Authority*, Environmental Appraisal Group, University of East Anglia, pp.403.

Krutilla, J.V. and Fisher, A.C. (1975, 1985) *The Economics of Natural Environments*. John Hopkins Press, Baltimore.

Porter, R.C. (1982) The new approach to wilderness preservation through cost-benefit analysis. *Journal of Environmental Economics and Management*, 9:59-80.

## A1.10: TESTING FOR INFORMATION EFFECTS: A WOODLAND PRESERVATION STUDY

**Method:** CV

**Evaluation unit:** capitalised per household preservation (use+non-use) values

**Commentary**

The study attempts to assess the impact of extra information given in a CV questionnaire upon respondents WTP bids. Hanley and Munro (1991) postulate that information may potentially affect responses via three routes.

i. If the benefits of a site/asset are uncertain then information will affect the probabilities surrounding the uncertainty.

ii. Information should reduce the hypothetical nature of scenarios.

iii. If respondents act strategically (eg. free-riding) then the provision of information, in heightening awareness of asset benefits, should reduce such behaviour.

Hanley and Munro define WTP as the difference between the net benefits of visiting the preferred site and those of the most valued substitute site (analogous to the opportunity cost of the visit) as shown in equation (A1.15).

$$WTP_i = (V_1 - C_1) - (V_2 - C_2) \qquad (A1.15)$$

where

$WTP_i$ = willingness to pay for site i
$V_i$ = expected utility at site i
$C_i$ = generalised travel cost of visiting site i
1 = preferred site
2 = best substitute site

Following the three routes outlined above, the provision of information is postulated, a priori, to result in the following changes in WTP.

i. Positive information regarding the site in question, or negative information regarding substitutes, will lead to an increase in WTP for the site in question

ii. If the information is such that the credibility of a negative change scenario (eg. asset degradation) is strengthened then this should result in a reduction in st zero bids. This in turn is likely to increase overall WTP.

iii.. If uninformed respondents have an initially lower WTP than prior-informed respondents then the provision of information should raise WTP for the latter more than the former, ie. bid variance will decrease[54]. In this case mean WTP will increase. However if uniformed WTP initially exceeds informed WTP then impacts upon variance are less certain.

Hanley and Munro set out to test these assertions via a postal CV survey regarding the

[54]This argument follows Boyle (1989).

proposed development of parts of Birkham Wood (Yorkshire) to make way for the planned Harrogate-Knaresborough by-pass. The Department of Transport has outlined three route options as outlined in table A1.47.

Table A1.47: Route options for the Harrogate-Knaresborough by-pass

| Route Option | Monetary Cost | Impact upon Birkham Wood |
|---|---|---|
| P | Lowest | Wood bisected |
| A | Mid | 5% of wood severed |
| B | Highest | Unaffected |

Source: Hanley and Munro (1991)

1000 questionnaires were posted to addresses in the wider district. Non-respondents were sent reminders 10 days after posting. Following a further 10 days of random sampling of 20 non-respondents were contacted via telephone to ascertain reasons for non-response.

Questionnaires were divided equally into four types according to the bid question asked. These were:

Group 1: This group were told the basic route option/monetary cost information given in table A1.47 and were also given the additional information that the site was "a woodland of national importance". They were then asked for their maximum WTP as a once-and-for-all sum to preserve the woodland intact (a payment card was used).

Group 2: The same route and additional information was given to this group who were then asked to state the minimum amount they would be willing to accept as a once-and-for-all compensation payment for the damage done to the wood if route P rather than either of the others was to go ahead (again a payment card was used).

Group 3: Identical to group 1 (WTP) but the additional information statement was omitted.

Group 4: Identical to group 2 (WTA) but the additional information statement was omitted.

Some 365 usable responses were received (a reasonable reply rate) of which 160 were WTP format responses. Of those non-respondents contacted, most were classified as protests although non-use of the proposed by-pass may also have been a contributing factor.

Very unfortunately, Hanley and Munro fail to report any results from the WTA format questionnaire (groups 2 and 4). This is a serious omission and considerably detracts from the usefulness of this work. Considering those results reported (groups 1 and 3) univariate WTP sums are given as table A1.48 below.

Table A1.48: WTP univariate results

| Group[1] | Sample size (n) | Mean WTP[2] (£) | st. dev. (£) | s.e. mean (£) | 95% CI Upper (£) | 95% CI Lower (£) | Zero bids (No.) |
|---|---|---|---|---|---|---|---|
| 1+3 | 160 | 12.89 | 20.93 | 1.65 | 16.18 | 9.61 | 67 |
| 1 | 77 | 12.66 | - | 2.8 | - | - | 34 |
| 3 | 82 | 13.08 | - | 1.65 | - | - | 33 |

Notes: 1. Group 1 = with extra information; Group 3 = no extra information
2. WTP as once-and-for-all payment

Source: Abstracted from Hanley and Munro (1991)

These results appear to run contrary (or at least not support) all of the a-priori expectations raised by Hanley and Munro. Firstly, rather than raising WTP, the 'extra information' group (group 1) actually have a lower mean WTP than that of the group without extra information (group 3). Secondly, there are more zero bids for group 1 than group 3. While this is not a significant difference it does reject the notion that this extra information increased credibility and thereby zero bids. Thirdly bid variance is higher for group 1 than group 3, contrary to the assertions of Bishop (1989).

The apparent negative relation between information and WTP could be produced by other differences between the groups and to test this Hanley and Munro fit a bid curve for the entire WTP sample (groups 1 and 3). Results for this estimation are given as table A1.49.

Table A1.49 details a linear bid function estimated by OLS techniques. Both this functional form and regression technique are open to criticism (as noted previously). Accepting this, the estimated coefficients of all the significant explanatory variables are in accordance with theory (F-statistic rejects at 95% confidence the $H_0:B_i = 0$ for all i). It could be argued that this also applies to the information variable however the reported t-statistic shows this variable to be entirely insignificant. Calculating a two sample t-test very firmly fails to reject (t=0.13) the $H^o$: (WTP group 1) = (WTP group 3).

These results might be seen as support for the assertion that varying information does not affect WTP. However, we (and Hanley and Munro) reject such a conclusion. The difference in information levels between groups 1 and 3 is minimal such that the two sub-groups can, with statistical validity, be treated as one. However it does not follow from this that further increments in information would continue to have such negligible effects. In this same study Hanley and Munro assess the impact of larger information changes upon evaluations of heathland preservation values, concluding here that significant impacts are observable. This accords with our reading of the literature as summarised in Bateman and Turner (1993).

Table A1.49: Bid Function

| Variable | Coefficient | t-statistic |
|---|---|---|
| Constant | -22.00 | -2.27 |
| Familiarity | 2.292 | 1.62 |
| Conserve | 6.61 | 2.35 |
| Income | 0.00039 | 2.33 |
| AppRtP | 1.957 | 0.68 |
| Visits | 0.710 | 2.91 |
| AppByP | 3.168 | 1.27 |
| User rate | 0.771 | 0.62 |
| Pref 1 | 7.788 | 3.35 |
| Info | 0.196 | 0.12 |
| r-sq(adjusted) - 25.2% | F = 6.62 | |

Notes:
Familiarity = categorical variable; score of 1-5 for familiarity with Bypass controversy (1 = totally unfamiliar; 5 = very informed)
Conserve = number of conservation groups respondent is member of (0 = none, 1 = one or two, 2 = three or more)
Income = before tax household income
AppRtP = approve of route P? (0 = yes, 1 = no)
Visits = frequency of visits to Birkham Wood
AppByP = approve of Bypass (0 = yes, 1 = no)
User rate = rate of use of Bypass
Pref 1 = first preference route (0 = P, 1 = A, 2 = B)
Inf = level of information provided in the CV instrument. Information differed across respondents at what we took to be a marginal level. The dummy variable takes a value of zero with the extra information, and two without it.

Source: Hanley and Munro (1991)

## Summary Results

Once and for all WTP to preserve Birkham Wood = £12.89 per household.

## Study Reference

Hanley, N.D. and Munro, A. (1991) Design bias in contingent valuation studies: the impact of information, *Discussion Paper in Economics 91/13*, Department of Economics, University of Stirling.

## Supplementary References

Bateman, I.J. and Turner, R.K. (1993) Valuation of the environment, methods and techniques: the contingent valuation method, in Turner, R.K. (ed) *Sustainable Environmental Economics and Management: Principles and Practice*, Belhaven Press, London.

Boyle, K. (1989) Commodity specification and the framing of contingent valuation questions, *Land Economics*, 65:57-63.

# A1.11: THE VALUATION OF FOREST CHARACTERISTICS: A NATIONAL STUDY

**Methods:** HTC, CV

**Evaluation unit:** per household per visit; per person per visit; woodland characteristic values

**Commentary**

## A1.11.1: OVERVIEW

Following the work of Willis et al., (see section A1.6) regarding the monetary evaluation of recreational sites, the Forestry Commission became interested in determining which features of a woodland influenced site value. Such an analysis was deemed important for the planning of future forests and cost effective redevelopment of the present estate so as to maximise recreational benefits. The forest-characteristic cluster analysis of Willis and Benson (1989) did not permit any realistic back analysis from benefit estimates to characteristic levels and so a specific piece of research was required. Lee (1990) conducted various qualitative surveys regarding preferences for various forest attributes, however a monetary evaluation study was clearly preferable for decision-making purposes. In early 1991, the Forestry Commission placed a contract for such research with Nick Hanley and Robin Ruffell at the University of Stirling.

The Hanley and Ruffell (1991, 1992) approach was to employ three separate methods:

1. A hedonic travel cost method (HTC) as outlined in chapter 2 and detailed below;
2. A CV approach in which respondents were presented with 3 pairs of photographs of different forest scenes, and, for each pair, asked their WTP for their preferred scene;
3. A second CV approach in which respondents were asked their WTP for a forest with set forest and journey characteristics.

A common questionnaire was designed such that each interview would yield sufficient data to operationalise each of these three analyses.

Sample sites were selected on the basis of their constituent forest characteristics. The Forestry Commission's sub-compartment database provides a wealth of data regarding all Commission land within a 3 km radius of each sub-compartment centre. *A priori* expectations were used to isolate six relevant forest characteristic variables as defined in table A1.50.

A common and major problem for any HTC study is the existence of high multicollinearity between characteristic variables. Table A1.51 reports of multicolinearity at seriously high levels between certain characteristics (eg; mean height (hm) and proportion of broadleaves (pb); proportion of broadleaves (pb) and conifer diversity (cd); etc).

Table A1.50: Forest characteristics derived from the Forestry Commission sub-compartment database

| Variable | Definition | Range |
|---|---|---|
| hm | Mean height of all trees | 3.5-20.9 |
| hd | Height diversity of all trees (measured by Shannon[1] index) | 0-1.57 |
| pb | Area of broadleaves as % of total forest area | 0-95.2% |
| cd | Diversity of conifer species (measured by Shannon[1] index) | 0-1.723 |
| pw | Dummy variable for presence of water feature (lakes, streams, etc)[2] | |
| | Percentage of forest as open space (no trees) | 0.1 |
| po | | 0.1-100% |

Notes: 1. Shannon index = $-P_i (\ln P_i)$ where $P_i$ is the proportion in the 8th class, the classes being: 0-1.5m; 1.5-5m; 5-10m; 10-20m; 20+m.

2. Due to inaccuracies in the Forestry Commission database (ignores non-FC water features) this was constructed by Hanley and Ruffell.

Source: Hanley and Ruffell (1991, 1992)

Table A1.51: Zero-order correlation matrix for forest characteristic variables

| | hm | hd | pb | cd | pw | po |
|---|---|---|---|---|---|---|
| hm | 1.0 | | | | | |
| hd | -0.24 | 1.0 | | | | |
| pb | 0.54 | -0.39 | 1.0 | | | |
| cd | 0.40 | -0.06 | 0.42 | 1.0 | | |
| pw | -0.19 | 0.11 | -0.21 | -0.26 | 1.0 | |
| po | 0.13 | -0.09 | 0.24 | -0.02 | 0.10 | 1.0 |

Notes: 484 sites; variables defined in Table A1.50

Source: Hanley and Ruffell (1992)

The optimum strategy in such situations would appear to be to choose sites which show high values of a particular characteristic but significantly lower values of others, especially those where there appears to be a high multicollinearity problem. However, Hanley and Ruffell (1992) state that, "given the very large number of possible combinations of sites, this was too intensive in computing time" (a decision which will have an unquantifiable effect upon the robustness of results). Instead they rank sites by characteristic levels and choose that site on each characteristic list which has the highest characteristic level. Once this is completed for all (six) characteristic the process is repeated but with the provision that the next chosen site must be in a different geographic area as "Avoiding pairs of sites in the same geographic area (defined as FC Forest Districts) avoids high covariances, since there are strong district similarities in UK forests". This implies intra-district homogeneity and inter-district heterogeneity, an assertion which is somewhat at variance with certain of the cluster definition of Willis and Benson (1989).

Using this approach Hanley and Ruffell isolate 60 sites for sampling surveys of which took place between June and August 1991. Each site was surveyed for a maximum of 2 days or until the chosen maximum of 30 responses had been elicited. At 3 sites no responses were forthcoming while sample sizes at the remaining 57 sites varied from 30 down to just 1. This made the operation of certain tests infeasible however the total sample size of 1041 was generally adequate.

The questionnaire elicited information regarding all the standard socio-economic variables necessary to allow the estimation of conventional bid curves. tgfs (visit type; reason for visit; frequency; distance travelled; length of stay; enjoyment of visit/journey; substitute perception; party structure; education; income; WTP).

Visitor perception of the levels of seven forest characteristic variables were also elicited, these being;

1. Forest height diversity
2. % of broadleaves
3. % of open space
4. Presence of water features (1/0)
5. Quality of views
6. Quality of walking facilities
7. Quality of other facilities.

These perceptions were quantified via a preferred 5 point scale with the exception of the 'water feature' question for which a simple yes (1) or no (0) answer was elicited. Data was also collected from interviewers to assess their perceptions.

The general results show that while interviewers and interviewees perceived forests characteristic levels in an extremely similar manner, these perceptions were almost completely uncorrelated with information from the Commission's sub-compartment database indicating that the latter is unsuitable for the assessment of such characteristics. While this is perhaps not surprising (given that the database ignores non-FC land and reports on a full sub-compartment basis, ie it does not give extra weight to areas of heaving recreational use), it does bring into question the site selection procedure employed by Hanley and Ruffell and suggests that a perceptions orientated approach may have been more appropriate (eg by asking District Managers to suggest suitable sites).

Regarding other general respondent characteristics, respondents where found to have a similar demographic profile to the 1989 Family Expenditure Survey although with significantly higher income and educational background. This is a trend similar to other surveys of informal recreation and suggests that some adjustment would be required before results could be generalised to the UK population.

## A1.11.2: THE HEDONIC TRAVEL COST STUDY

The hedonic travel cost method (HTC) is briefly discussed in chapter 2 and reviewed by Bateman (1993a/b) with respect to the work of Brown and Mendelsohn (1984) and Smith and Desvousges (1986). However, the model employed by Hanley and Ruffell also owes much to the earlier work of Vaughan and Russell (1982) which we can briefly review. This is, as with all of the above, a two stage approach in which the first stage involves the estimation of a standard travel cost tgf of the form given in equation (A1.16).

$$V_{iq} = \beta_{io} + \beta_{i1} X_{iq1} + \dots + \beta_{ik} X_{iqk} + e_{iq} \qquad \text{(A1.16)}$$

where $V_{iq}$ = Visits per year to site i from zone q (either zonal averages or individual visits pa)

$X_{iq}$ = Socioeconomic characteristics of the visiting population (travel cost, income, zonal population etc)

Equation (A1.16) is estimated for each site in the sample and the resulting estimated coefficients used as dependent variables in the second stage as shown in equation (A1.17).

$$\beta_{il} = \alpha_{il} Z_{il} + ..... \alpha_{iL} Z_{iL} + \eta_{il} \qquad (A1.17)$$

where

$Z_i$ = the 'various measures of site characteristics which are invariant across the zones' (Vaughan and Russell, 1982)

l = 0 to k

This two step approach requires a large number of zones (for step 1) and sites (step 2) ie the approach has very high data requirements. However, Vaughan and Russell note that, if the estimates of $B_{il}$ are robust then (A1.17) can be substituted into (A1.16) to produce a one step procedure. The advantage of such a substitution is that the revised one-step model is that data can be pooled from a number of sites which, together with using individual rather than zonal average visitation rates, considerably reduces data requirements. However, two main disadvantages of the one-step approach are:

a) Whereas the two-step model allows for the treatment of high multicollinearity between characteristic level variables by their exclusion from (A1.16), the one-step version is susceptible to such multicollinearity.
b) Noting that (A1.16) and (A1.17) have separate error terms ($e_{iq}$ and $\eta_{il}$ respectively) means that the one-step version will have a composite error term which will be subject to heteroskedasticity and its associated problems (see chapter 2).

It is interesting to note that in adopting such an approach, Hanley and Ruffell (1991) do not report statistical tests regarding the above problems although it is noted (p.89) that "there are no particular problems of multicollinearity". This could be due in part to the somewhat ad hoc nature of the particular one-stage model employed. Rather than following the full substitution of (A1.17) into (A1.16), Hanley and Ruffell only include a selection of the cross-product terms which such substitution would imply. While including travel cost, income, age, frequency, forest characteristics and reasons for visit as separate variable, only the cross product terms of characteristics/travel cost and reason for visit/travel cost are included. This represents a considerable reduction in terms below that strictly required by theory[55]. However, Hanley and Ruffell (1991) justify this by noting that, "in view of the objectives of this study, it is important that the possibility of the characteristics affecting the (consumer) surplus is investigated but less important to look at their effect on the other coefficients". Furthermore, cross product terms between travel costs and reasons for visiting were

[55]See as an example the discussion of Smith and Desvousges (1986) and the final form of their estimated model in their (Appendix B) in Bateman (1993a).

considered to be "as important in determining the slope of the demand function as in determining its intercept" and were therefore also included in the one-stage model which was formulated as given in equation (A1.18).

$$\begin{aligned} \ln(\text{VISA}) = \; & \beta_1 + \beta_2 TC + \beta_3 \ln(\text{INCOME}) + \beta_4 AGE \\ & + \beta_5 \ln(\text{LENGTH}) + \sum_{j=1}^{6} \beta_{j+5} CHAR_j \\ & + \sum_{j=2}^{17} \beta_{j+10} WHY_j + \sum_{j=1}^{6} \beta_{j+27} CHAR_j.TC \\ & + \sum_{j=2}^{17} \beta_{j+32} WHY_j.TC + e \end{aligned} \quad \text{(A1.18)}$$

where

| | | |
|---|---|---|
| VISA | = | Household visits to site in past 12 months |
| TC | = | Round trip visit costs (£) |
| INCOME | = | Household disposable income (£ pa) |
| AGE | = | Respondent age (years) |
| LENGTH | = | Number of days per annum when the respondent was resident in the local area |
| CHAR | = | Perceived level (see previous) of six forest characteristics:<br>1. Mean height of trees (hm)<br>2. Height diversity (hd)<br>3. % broadleaved (pb)<br>4. Conifer diversity (cd)<br>5. Presence of water feature (pw)<br>6. % open space (po) |
| WHY | = | Dummies (1/0) for 17 main-purpose-of-visit codes:<br>1. Walking (WHY 1)<br>2. Picnic/BBQ/lunch (WHY2)<br>3. Dog walking (WHY3)<br>4. Special features eg playground (WHY4)<br>5. Visit forest (WHY5)<br>6. Views/scenery (WHY6)<br>7. Break in journey (WHY7)<br>8. Visit area in general (WHY8)<br>9. Entertain children (WHY9)<br>10. Cycling (WHY10)<br>11. See water feature (WHY11)<br>12. Fresh air/peace and quiet (WHY12)<br>13. Water sport (WHY13)<br>14. Visit forest centre (WHY14)<br>15. Fauna eg birds (WHY15) |

16. Photography (WHY16)
17. Other (WHY17)

e = Random error

Following Smith and Desvousges (1986),Willis and Benson (1989) and others, a semi-log (dependant) functional form was fitted. Although the lack of functional form testing is perhaps unfortunate, Hanley & Ruffell (1991) make the valid point that the common inclusion of a linear income term implies rising income elasticity and therefore a log form (implying constant income elasticity) is preferable. Another interesting point is the use of a household rather than individually based dependent variable which allows the use of the more realistic household (rather than computed individual) visit costs.

To avoid multicollinearity problems, household visit costs were defined as the sum of travel plus time costs (as per Willis and Benson, 1989). Travel costs were calculated as measured round trip distance multiplied by marginal (petrol) costs per mile (using an AA estimate of 13.567 p/mile). Perceived distance was found to give similar results but with a slightly inferior fit. In calculating time costs, on site time was argued to have a zero opportunity cost (positive costs were found to have little impact upon results). Travel time was costed on the basis of responses to the question"Was the journey here part of the enjoyment of your day out?" If respondents answered yes then a zero opportunity cost was assumed while those who answered no were assigned costs according to the standard DTp procedure (discussed with reference to Willis and Benson 1989) at 43% of household wage rate. The DTp estimates, updated to 1991, give an average figure of £2.68 per hour, However, this was adjusted for each respondent household by the ratio of their income to the national average (in the 1988 Family Expenditure Survey) adjusted for the purposefulness of the visit. 32% of the sample stated that the forest visit was not the main purpose of their trip and these 'meanderers' were asked to rate the importance of the trip on a scale from 1 (unimportant) to 5 (very important). Weights of 0.0 to 0.4 in steps of 0.1 were apportioned to these scale points and then applied to calculated visit costs. In a separate analysis all meanderers were omitted.

An interesting innovation is the inclusion of the LENGTH time constraint variable set at 365 for residents and the length of local stay for non-residents. This allows for the time constraints upon holidaymakers. The use of the log form, ln(LENGTH) allows an estimate of the time elasticity of visits, a value of 1 implying visit numbers exactly proportional to time available while a value $0<\ln(LENGTH)<1$ implying and (expected) declining marginal utility of visits.

An attempt was made to allow for substitution impacts by asking respondents to state the cost of visiting a substitute site. However, 45% were unable to give a price while a further 25% gave a price of zero. This analysis therefore failed and was excluded from the model. Given our discussions of chapter 2, this is a potentially serious omission.

Income was included as a 12 band variable with households being allocated the mid-point of each band and the adjustment from gross to disposable income being via the ratio reported in the 1988 Family Expenditure Survey.

Finally a variety of visit-purpose dummy variables were set up (see notes to equation (A1.18)). The commonest of these was walking (WHY1) and by omission of this in (A1.18) (notice that the summation of $WHY_j$ and $WHY_j.TC$ variables run from j=2) the estimated coefficients of the other visit dummies measure differences from WHY1 (Walking).

Hanley and Ruffell (1991) use OLS regression techniques to estimate (A1.18) while Hanley and Ruffell (1992) report results from both OLS and ML estimation procedures (the latter approach allowing explicit incorporation of the truncation of non-visitors). However, while the earlier report gives coefficient estimates for all of the 49 parameters entailed in (A1.18), the later report uses only 34 parameters (even though the same equation is reported). The 1992 model differs from its predecessor in the following respects:

a) Redefined 'reason-for-visit' variables, being amalgamations of several of the visit codes used previously as follows:
WHYA = WHY1 + 2 + 4 + 9 + 10 + 13 + 14 (ie walkers and facility users)
WHYB = WHY3 (dog walkers)
WHYC = WHY5 + 6 + 8 + 11 + 15 + 16 (forest enthusiasts)
WHYD = WHY7 + 12 (break in journey)
WHYE = WHY17 (other);

b) A consequent reduction in the WHYX.TC combination terms (17 down to 5);

c) Introduction of four characteristic interaction terms all being interactions with the proportion of broadleaves (pb) term as follows:
pb.hm (mean height)
pb.hd (height diversity)
pb.pb (proportion of broadleaves; squared term)
pb.cd (conifer diversity);

d) Introduction of four triple combination terms all being combinations of the above interaction terms and trip costs (tc);

e) Inclusion of a new variable IMPORT with which to assess meanderers/purposeful visitors. This is a categorical variable based upon the 1 to 5 score given by respondents outlined above (presumably with visitors for whom the forest visit is of prime importance now classified as 5, although this is not explicitly stated).

The results for these competing OLS (1991 and 1992) models and the ML (1992) model are given as table A1.52. With the exception of the standard socioeconomic variables, only results significant at the 5% level are reported.

The immediate and most striking difference between Hanley and Ruffell's 1991 model (OLS1) and those of their 1992 paper (OLS2 and ML) is the marked non-significance of the TC variable in the former (although the sign is as expected). This finding casts considerable doubt over the OLS1 results, however, in both the 1992 models the TC variable is correctly signed and significant. The non-significance of the income variable is, we feel, not surprising, indicating that other constraints such as time are more binding. This assertion is very strongly supported by estimates of the ln(LENGTH) variable which is the most strongly significant of all variables in all three models. The estimated coefficient on ln(LENGTH) indicates diminishing marginal utility in both OLS models but indicates increasing marginal utility in the ML model, a result which is somewhat surprising. The AGE variable is also significant and positively signed in all models, a result which may indicate that older respondents (eg pensioners) may have more leisure time. However, we would expect this relationship to be complex and would recommend the testing of a possible quadratic relationship.

The IMPORT variable was not used in OLS1 but was found to be highly significant in OLS2 and ML. However, this is hardly surprising as it merely implies that people who like forests tend to visit them more often! There is a question here regarding the meaningfulness of such a variable and the consequences upon the model of its inclusion. However, it can be defended as expressing the purposefulness of visits. This leads us to consider the various purpose-of-visit (WHYX) variables, the most clearly significant of which is the walking-the-dog dummy (WHY3; WHYB) providing in all models the strongest positive variable influencing visits. The significant positive and negative signs upon respectively WHY7 (break in journey) and WHY13 (water sports) in OLS1 are also to be expected. However, the significant negative sign on WHY17/WHYE ('other purposes') is more difficult to explain and may indicate either an omitted purpose or that these were generally purpose-less visits and should have been classified along with break-in journey responses. The significance of these highlighted purpose variables is such that the combination WHYX.TC variables are also significant. However, examination of the F-statistics F(why) and F(why.tc) shows that the combination variables are of lesser significance (although still above 5%) than are the uncombined WHYX explanatory variables (strong rejection of the null hypothesis that coefficients not different from zero).

Table A1.52: HTC regression results

| Variable[1] | Model | | | | | |
|---|---|---|---|---|---|---|
| | OLS (1991)[2] | | OLS (1992)[3] | | ML (1992)[3] | |
| | Coefficient | \|t\| | Coefficient | \|t\| | Coefficient | \|t\| |
| constant | -1.09 | 1.62 | -1.10 | 1.27 | -10.73 | 6.08 |
| TC | -0.0425 | 1.02 | -0.347 | 2.61 | - 0.438 | 1.98 |
| Ln(INCOME) | 0.0065 | 0.11 | -0.0399 | 0.67 | 0.0133 | 0.14 |
| AGE | 0.0078 | 3.20 | 0.0068 | 2.68 | 0.0122 | 3.07 |
| Ln(LENGTH) | 0.306 | 15.23 | 0.301 | 15.39 | 1.23 | 25.67 |
| IMPORT | n/a | n/a | 0.710 | 6.73 | 2.26 | 10.49 |
| PO | 0.0950 | 2.41 | 0.0852 | 2.10 | 0.320 | 4.31 |
| WHY3;WHYB | 2.18 | 14.92 | 2.00 | 14.64 | 3.14 | 14.40 |
| WHY7;WHYD | -0.570 | 2.44 | -0.207 | 1.02 | -0.547 | 1.58 |
| WHY13 | 1.971 | 3.77 | n/a | n/a | n/a | n/a |
| WHY17;WHYE | -0.536 | 2.94 | -0.469 | 2.73 | -0.557 | 2.52 |
| HM*TC | 0.0025 | 0.14 | 0.179 | 2.62 | 0.292 | 2.15 |
| HM*PB*TC | n/a | n/a | -0.0592 | 2.75 | 0.0861 | 1.90 |
| WHY3*TC; WHYB*TC | -0.161 | 4.35 | -0.146 | 4.01 | -0.274 | 4.42 |
| WHY7*TC; WHYD*TC | 0.0906 | 2.02 | 0.0941 | 2.48 | 0.287 | 3.86 |
| WHY17*TC; WHYE*TC | 0.0413 | 2.09 | 0.0300 | 1.66 | 0.473 | 1.28 |
| No of obs | 974 | | 974 | | 974 | |
| $R^2$ | 0.54 | | 0.546 | | - | |
| $R^2$ (adj) | n/k | | 0.530 | | - | |
| $F(R^2)$ | 22.47 | | 34.27 | | - | |
| F(char) | 3.53 | | n/k | | n/k | |
| F(char.tc) | 0.83 | | n/k | | n/k | |
| F(why) | 21.19 | | n/k | | n/k | |
| F(why.tc) | 2.85 | | n/k | | n/k | |
| S.E.R. | n/k | | 0.956 | | 1.235 | |
| armse | n/k | | 45.89 | | 47.11 | |
| Explanatory variables | 49 | | 34 | | 34 | |
| of which sig | 10 | | 11 | | 11 | |

Notes: 1.Variables as defined previously in text and notes to (A1.18). All figures in bold type are significant at the 5% level. All variables which are insignificant in all three models are not reported (with the exception of INCOME)
2.Hanley and Ruffell (1991)
3.Hanley and Ruffell (1992)
4.n/a = variable not used in model
5.n/k = statistic not reported
6.The F-statistics are for joint tests of the null hypothesis that the variables listed in brackets are not significantly different from zero:
'char' = the set of forest characteristics
'char.tc' = the interaction terms between forest characteristics and TC
'why' = the set of reason-for-visit dummies
'why.tc' = the interaction terms between these dummies and TC
7.SER = ML estimate of the standard error of the regression/standard deviation of the disturbance
8.Prmse = root mean squared error in y (not log y)

Source: Abstracted from Hanley and Ruffell (1991,1992)

Turning to consider the stated focus of this study, the forest characteristic variables, it is notable that in all three reported models only one uncombined characteristic has a significant impact upon visits, namely the perceived proportion of open space(po). Coefficients are small but positive for both OLS models and somewhat larger in the ML model. Ironically this implies that, although forests are valued, continuous forest is less preferable to patches of trees. Certainly it supports higher per hectare valuations for woodland pockets (eg Bishop, 1992) than for large forests (Willis and Benson, 1989) although of course the comparative size of such resources also leads to the same relationship.

The non-significance of other uncombined characteristic variables is perhaps surprising particularly as the (not significant) signs on such variables sometimes run counter to expectations (eg, height diversity negative in all models; proportion of broadleaves negative in OLS2). The most supportive interpretation is therefore to ignore all statistically insignificant results.

Just one of the dual combined variables (HM*TC) was found to be significant in the 1992 models. Similarly just one triple combined variable (HM*pB*TC) was found to be significant although only in the OLS2 model. In both cases it is the significance of the TC term which is important and it is interesting to note that the F-statistic F(chars.tc) is the only one reported to fail to reject the null hypothesis (coefficients not significantly different from zero). Hanley and Ruffell (1992) concede that "these are disappointing results and give little basis for deriving implicit prices".

In comparing the overall models, OLS2 appears to be preferable to OLS1 on several counts. The non-significance of the TC variable in OLS1 conflicts not only with the other models but with virtually all other ITC studies. One explanation would be if TIC was collinear with certain of the variables in OlS1 that are either amalgamated or omitted in OLS2. Both OLS1 and OLS2 have identical functional forms making $R^2$ comparisons valid. While both record $R^2$ of 0.54 the OLS2 model has $R^2$ (adj) = 0.53 while $R^2$ (adj) for OLS1 is not reported. However, given the higher number of insignificant variables in OLS1 it almost certainly has an inferior $R^2$ (adj). Furthermore $F(R^2)$ for OLS2 is considerably higher than for OLS1. We therefore have a preference for OLS2 over OLS1. Diagnostic statistics give little indication of whether the OLS2 or ML model is more valid. However as the mean of the dependent variable (annual visits) is close to the zero visits truncation point then OLS estimates are likely to suffer severe truncation bias and therefore our preference(and that of

Hanley and Ruffell) is for the ML model.

Using results from the ML model allows us to calculate household consumer surplus estimates for differing forest characteristic levels. Results for such an analysis are given as table A1.53 below. Here Hanley and Ruffell give household consumer surplus for differing characteristics mapped against differing levels of pb (proportion of broadleaves) characteristic. While a priori this may seem reasonable, in the light of regression results such an analysis is suspect, indeed given the non-significance of all characteristic coefficient estimates, except those for po, we have to treat all the results of table A1.53 with extreme caution.

Table A1.53: Household consumer surplus at various characteristic levels (£)

| | hm | | | hd | | | pb | cd | | | pw | po |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pb | mean | 1 | 4 | mean | 1 | 4 | - | mean | 1 | 4 | - | - |
| 0 | | | | | | | | | | | 6.04 | |
| 1 | 4.33 | 4.59 | 4.51 | 2.90 | 9.08 | 2.16 | 15.51 | 4.50 | 9.66 | 3.66 | 4.30 | 6.53 |
| 2 | 5.28 | 82.64 | 3.64 | 3.59 | 11.20 | 2.70 | 7.12 | 4.87 | 13.48 | 3.79 | | 5.78 |
| 3 | 6.78 | -5.17 | 3.06 | 4.71 | 14.61 | 3.59 | 4.86 | 5.30 | 22.30 | 3.93 | | 5.18 |
| 4 | | | | 6.83 | 21.02 | 5.36 | 3.83 | 5.81 | 64.51 | 4.08 | | 4.69 |
| 5 | | | | 12.41 | 37.46 | 10.58 | | | | | | 4.29 |

Note: The table shows the values of the surplus for differing values of the characteristics. Where there is an interaction term, pb is held at its mean (2.90), its minimum (1) and its maximum (4) to show how the variation depends on pb.

Source: Hanley and Ruffell (1992)

Using the ML coefficients and holding characteristic scores at existing mean levels across the whole sample gives a mean consumer surplus per visit of £5.00 per household or £2.19 per adult. This latter figure accords well with many other recent studies (eg, Hanley, 1989; and Willis, 1992). Household consumer surplus was also calculated for various user groups, results being as given in table A1.54.

Excepting the problems of coefficient significance, the results of table A1.54 do appear logical and are in line with contemporary studies.

Table A1.54: Consumer surplus per visit (£)

| User | Consumer Surplus per Household per Visit (£) | Consumer Surplus per Adult Visitor per Visit (£) |
|---|---|---|
| Whole sample mean | 5.00 | 2.19 |
| Forest enthusiasts | 5.70 | - |
| Walkers/facility users | 5.66 | - |
| Dog Walkers | 2.22 | - |

Source: Hanley and Ruffell (1992)

## A1.11.3: THE CV PHOTOGRAPH STUDY

It was initially intended to check all HTC characteristic level valuations by means of asking respondents to state their WTP for different types of forests as illustrated in photographs. This was to be achieved by presenting respondents with pairs of photographs with only one characteristic varying between each photo in a pair. Unfortunately after piloting only pairs illustrating the extremes of three characteristics were found to be suitable:

a) Presence/absence of water feature (pw) (photo 1: no water feature; photo 2: water feature)

b) Proportion of broadleaves (pb) (photo 3: conifer only; photo 4: mixed forest)

c) Height diversity (hd) (photo 5: uniform heights; photo 6: diverse heights)

For each pair of photographs respondents were asked to state which one they preferred and then asked the WTP question; "How much extra would you be willing to pay to visit the forest you like best rather than the other".

In their first report, Hanley and Ruffell (1991) detail WTP for the majority preferred photos. However this ignores WTP for the minority preferred photos, some of which attracted substantial votes. Therefore in their 1992 report the authors calculate 'net WTP' amounts by treating WTP for minority preference photos as negative sums against the majority preference photo. Results for this latter analysis are given as table A1.55.

All the net WTP figures reported are significantly different from zero. However, this analysis can be criticised on a number of points. Firstly the phrasing of the question is rather loose in that it is not made clear whether payments are per person or per household. As there are incremental figures, either explanation is feasible and therefore this lack of clarity is unhelpful. The TWP question also fails to specify a payment vehicle. Again we can presume that respondents infer this to be via entrance fees. However, again the lack of clarity is unfortunate. Elicitation is prompted via a payment card, the problems of which we have reviewed elsewhere (Bateman and Turner, 1992). These may not be too serious given the wide range of suggested sums (£0 to > £25.00 via 18 steps)[56].

The most likely cause of bias is however the nature of the photographs themselves. Hanley and Ruffell recognise that "it was not possible to find pairs of photos which held constant all forest characteristics, and all photographic aspects, except the characteristic being studied". This is particularly true of the first pair (presence of water feature) where photo 2 (with water feature) clearly shows mixed species while photo 1 (without water feature) is dominated by conifer. A second problem is also recognised as the authors state, "we have no way of measuring the 'amount' of characteristic in each photo." ie marginal measures are not calculable from these results.

[56]This large number of steps may not necessarily be without problems if respondents tend to opt for amounts early on in a list (see Bateman and Turner, 1992).

Table A1.55: Net willingness to pay results

| Characteristic being valued | Photograph | Respondents preferring | | Net WTP | |
|---|---|---|---|---|---|
| | | No. | % | Amount (£) | 95%CI (£) |
| Presence of water feature (pw) | 1. No water feature | 87 | 9.5 | | |
| | 2. Water feature | 831 | 90.5 | 0.69 | 0.61-0.78 |
| Sub totals | | 918 | 100.0 | | |
| Proportion of broadleaves (pb) | 3. Conifer only | 50 | 5.7 | | |
| | 4. Mixed forest | 834 | 94.3 | 0.49 | 0.41-0.56 |
| Sub totals | | 884 | 100.0 | | |
| Height diversity (hd) | 5. Uniform heights | 221 | 24.6 | 0.33 | 0.26-0.41 |
| | 6. Diverse heights | 678 | 75.4 | | |
| Sub totals | | 899 | 100.0 | | |

Source: Abstracted form Hanley and Ruffell (1992)

## A1.11.4: THE CV BID CURVE STUDY

As a final analysis a conventional CV study was undertaken with received bids being regressed on a variety of explanatory variables, amongst which were the characteristic levels of the site at which respondents were sampled.

Phrasing of the elicitation question was a considerable improvement upon that of the previous photographic analysis. An open-ended format was employed in which respondents were informed of the payment vehicle (entrance fee) and the bid unit (WTP per adult per visit).

The recording of bids was also clear with protest bids[57] being separated from zero bids Univariate WTP results are summarised in table A1.56.

[57]Of protest bids over one-third felt that forests should be open access, while over 20% felt charging (ie exclusion) was infeasible.

Table A1.56: Univariate willingness to pay results

| WTP/adult visit (£) | |
|---|---|
| Mean | 0.93 |
| Median | 0.75 |
| 95% CI | 0.87-0.98 |
| sd | 0.79 |
| Range | 0-5.00 |
| Useable sample size of | 924 |
| which: Protests | 71[1] (7.7%) |
| Zero bids | 74 (8.0%)[2] |

Notes: 1. Recorded as 69 in Hanley & Ruffell (1991)
2. 8.7% of the 853 non-protest bids

Source: Hanley and Ruffell (1992)

These responses were analysed by the fitting of a bid curve. This utilised many of the explanatory variables of the HTC tgf. However, certain other variables were included as follows:

a) Weather Variables:

| | | |
|---|---|---|
| RAIN1 | = | 1 if dry, 0 otherwise |
| TEMP1 | = | 1 if hot, 0 otherwise |
| TEMP2 | = | 1 if warm, 0 otherwise; |

b) Trip characteristic variables:

| | | |
|---|---|---|
| DAY | = | 1 if interview on weekend, 0 otherwise |
| RESIDENT | = | 1 if daytripper (usually a local resident); 0 otherwise |
| DIST | = | How far visitors had travelled to site |
| TRAVTIME | = | Length of travel time |
| STAYTIME | = | Length of time on site |
| VIEWS | = | Surveyors rating of views (1-5) |
| WALKS | = | Surveyors rating of walks (1-5) |
| VISFACIL | = | Surveyors rating of visitor facilities (1-5) |
| INFO | = | 1 if information board, 0 otherwise |
| TRAILS | = | 1 if marked trails, otherwise |
| PRICE | = | Car parking fee, in pence (generally 0) |

Regression results obtained by both OLS and ML techniques are detailed in table A1.57. Both the reported regressions use a linear functional form. In their earlier report Hanley and Ruffell (1991) detail three OLS regressions in which successively more insignificant variables are omitted (53, 34 and 24 variables respectively). However, there is little change in diagnostic statistics across these three models.

Both of the models shown above come from the 1992 report and (like all 1991 models) use a linear form. Omission of any functional form analysis is somewhat surprising. Truncation problems mean that the ML model should be preferable to the OLS model, however a different functional form may well have improved the fit further.

Considering significant variables within the ML results, standard factors include the constant and income[58] as well as age and visit rate (VISA). The latter is negatively signed indicating that regular visitors who would pay most often would only be willing to do so at relatively low entrance fees. The same factor appears to influence the sign on the RESIDENT, DAY AND WHY3[59] variables and we wonder about the potentially high multicollinearity between these similar variables. The signs on VIEWS, VISFACIL and WHY5 are all logical, however, 'incorrect' signs occur for TEMP1 and PRICE. The former may possibly arise from forest overcrowding on hot days and may require some explicit investigation of congestion effects, however we have no explanation of the coefficient on PRICES.

The only significant characteristic level variable is that of mean height (hm). None of the other characteristic variables are significant although Hanley and Ruffell note that signs do conform to a priori expectations. Nevertheless, given these are the focus variable of the study, these results are disappointing. Hanley and Ruffell feel that much of this may be due to measurement error.

Finally a small sample test of potential vehicle bias was conducted at a single site (Achray Forest, Alberfoyle), not otherwise sampled. Respondents were asked WTP questions using one of four payment vehicles:

a) Open ended
b) Bidding game
c) Payment card
d) Dichotomous choice

[58]We comment on these factors further in our study of Thetford forest. It is interesting that income is not significant in the HTC tgf.

[59]Hanley & Ruffell (1992) note that "dog walkers are on average WTP £0.78 less than walkers".

Table A1.57: Bid survey regression results

| | OLS | | with truncation (ML) | |
|---|---|---|---|---|
| variable | coeff | \|t\| | coeff | \|t\| |
| constant | -74.3 | 1.77 | -458.2 | 3.61 |
| rain1 | 9.94 | 1.22 | 28.2 | 1.26 |
| temp1 | **-29.5** | **2.70** | **-69.4** | **2.18** |
| temp2 | -12.5 | 1.60 | -30.2 | 1.55 |
| day | **15.1** | **2.76** | **34.5** | **2.37** |
| resident | **-16.6** | **2.92** | **-32.0** | **2.28** |
| dist | 0.0553 | 0.53 | 0.120 | 0.46 |
| travtime | 0.0448 | 0.85 | 0.0761 | 0.77 |
| staytime | 0.0482 | 1.73 | 0.0822 | 1.29 |
| why3 | **-21.5** | **2.61** | **-78.4** | **2.83** |
| why4 | **23.9** | **2.18** | 34.2 | 1.52 |
| why5 | **25.2** | **2.12** | **39.3** | **2.06** |
| why9 | -30.0 | 1.85 | -71.5 | 1.15 |
| why10 | -17.4 | 1.09 | -33.1 | 0.86 |
| import | 11.7 | 1.77 | 25.8 | 1.63 |
| visa | -0.0912 | 1.62 | -0.497 | 2.77 |
| age | **-0.421** | **2.33** | **-1.05** | **2.20** |
| income | **0.00123** | **4.02** | **0.0024** | **3.58** |
| hm | **38.3** | **1.99** | **122.7** | **2.30** |
| hm*pb | -10.3 | 1.53 | -31.3 | 1.74 |
| hd | 5.27 | 0.65 | 29.6 | 1.12 |
| hd*pb | -0.414 | 0.17 | -5.67 | 0.74 |
| pb | 12.6 | 0.83 | 36.2 | 0.80 |
| pb*pb | 0.756 | 0.28 | 3.79 | 0.48 |
| cd | -7.13 | 0.54 | -32.8 | 0.93 |
| cd*pb | 0.944 | 0.25 | 7.71 | 0.71 |
| pw | 8.10 | 1.09 | 7.28 | 0.37 |
| po | 2.68 | 0.97 | 7.91 | 0.92 |
| views | **14.1** | **4.85** | 34.8 | **4.36** |
| walks | -2.03 | 0.70 | -4.61 | 0.57 |
| visfacil | **10.2** | **3.66** | 27.7 | **3.73** |
| info | 9.66 | 1.18 | 25.4 | 1.22 |
| trails | -14.4 | 1.65 | -38.3 | 1.85 |
| price | **0.334** | **3.12** | **0.667** | **2.78** |
| no. of obs. | 859 | | 859 | |
| $R^2$ | 0.269 | | - | |
| $R^2$(adj) | 0.240 | | - | |
| $F(R^2)$ | **9.20** | | - | |
| s.e.r. | 68.1 | | 101.8 | |
| rmse | 68.1 | | 128.3 | |

Notes: Results which are significant at the 5% level are shown in bold type
Dependent variable: WTP in pence

OLS results provided on handwritten sheet with report
ML results assume that WTP is truncated at 0 and that error is lower truncated normal. Note that this is not equivalent to Tobit which assumes that WTP is censored at 0
rmse = root mean squared error in WTP
s.e.r. = ML estimate of the standard error of the regression/standard deviation of the disturbance

Source: Hanley and Ruffell (1992)

No details are given regarding the calculation of means. This is unfortunate as Bateman and Turner (1992) show that logit/probit or other discrete variable approaches are essential in such exercises. Univariate WTP results are detailed in table A1.58.

Table A1.58: Univariate WTP results: vehicle bias tests

| WTP bid vehicle | Useable responses | Mean WTP (£) |
|---|---|---|
| Open ended | 28 | 0.90 |
| Bidding game | 18 | 1.21 |
| Payment card | 21 | 1.39 |
| Dichotomous choice | 23 | 1.49 |
| Total | 90 | |
| Weighted mean | | 1.23 |

Source: Hanley and Ruffell (1991)

The ordering of means, specifically those of the open-ended, bidding game and dichotomous choice vehicles, is the same as found by Bateman et al., (1992) in their large sample (n=3206) CV study of the Norfolk Broads. Furthermore the mean of the open ended vehicle test is similar to that of the whole sample study (n=859; mean WTP = £0.93) which shares a similar format WTP question. However, Hanley and Ruffell (1991,1992) argue that the means reported do not differ significantly. Rather than reporting results (an omission) they test this by assigning the elicitation vehicles as separate dummy variables and re-running the previously estimated bid curve function on this new data (n=90). Such a test fails to confirm a significant difference in means across bid vehicles. However, we would question the validity of such a test (as well as preferring the much simpler $\chi^2$ approach). While the open-ended approach yields a truncated continuous variable the dichotomous choice method yields a discrete variable. Compiling a dependent variable as simply a list of these sums invalidates the subsequent use of an OLS regression based upon such a dependent variable. Furthermore the use of such a small sample is obviously questionable.

## A1.11.5: CONCLUSION

We have reservations regarding all three of the sub-analyses contained in this study. The variant HTC model presented by Hanley and Ruffell is highly prone to problems of multicollinearity (which is certainly present) and heteroskedasticity (of which we are not told). The approach of, say, Smith and Desvousges (1986) while admittedly complex and demanding of data, nevertheless produces a stronger model if it can be operationalised. Given this weakness, the analysis has been carried out carefully and the ML model does appear to give a priori, reasonable results. However with regard to the focus of the study, viz the estimate of implicit prices for forest characteristic levels, the HTC model cannot be considered robust and the results produced must be treated with extreme caution.

The CV photograph study also gives results which seem, a priori, reasonable. However only a restricted number of characteristic variables were examined and we have raised criticisms about the validity of the photographic descriptions of these characteristics. the interpretation of these results for decision making purposes is also somewhat problematic.

The CV bid curve analysis seems reasonable. However, here we raise concerns regarding possible multicollinearity (of which no details are given) and question the use of linear forms alone. WTP results for site visits seem quite reasonable (particularly as these are option use rather than just use values). However, again given level variables, the estimation of implicit prices for forest characteristics from these results is not defensibly feasible.

## Summary Results

### i. HTC Study

| | WTP/household/visit (£) | WTP/adult/visit (£) |
|---|---|---|
| Mean | 5.00 | 2.19 |
| Forest enthusiasts | 5.70 | - |
| Walkers/facility users | 5.66 | - |
| Dog walkers | 2.22 | - |

### ii. CV Photograph Study

| Characteristic | Mean WTP for Characteristic[1] (£) |
|---|---|
| Water feature | 0.69 |
| More broadleaves | 0.49 |
| More height diversity | 0.33 |

Note: 1. Not clear whether this is per person or per household.

### iii. CV Bid Curve Study

Major study: mean WTP/adult/visit = £0.93
mean WTP/household/visit = £2.12[1]

Minor Study: vehicle bias analysis[2]:

| Vehicle | Mean WTP/adult/visit (£) |
|---|---|
| Open ended | 0.90 |
| Bidding game | 1.21 |
| Payment card | 1.39 |
| Dichotomous choice | 1.49 |

Note: 1. Imputed using the adults:household ratio given in HTC results
2. Small sample size

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# A1.12: ASSESSING THE BENEFITS OF TWO URBAN FRINGE 'COMMUNITY' FORESTS

**Methods:** CV, time cost

**Evaluation unit:** per person per visit and use+option values and per person per annum

## Commentary

In July 1989 the Countryside and Forestry Commissions launched a joint national programme to create Community Forests on the outskirts of major towns and cities in England and Wales[60]. This programme consists of three initial 'lead project' forests being the 'Great North Forest' (south Tyne and Wear/north-east Durham); the 'Forest of Mercia' (south Staffordshire); and 'Thames Chase' (east of London). In February 1991 the project was expanded by the announcement of plans for nine further forests in England and potentially several Welsh forests (created upon the auspices of the Countryside Council for Wales) of which at least two would be in South Wales (see map figure A1.5).

The Countryside Commission (1989a/b) state that each Community Forest will cover an area of approximately 10,000-15,000 ha of which 30-60% of the land will be planted with a mixture of mainly broadleaf trees. These forests are seen as providing a number of public benefits specifically;

1. Conservation of habitat and species
2. Educational benefits
3. Leisure opportunities
4. Timber production
5. General environmental enhancement.

Bishop sets out to estimate the benefits of these planned forests by examining two existing urban fringe woodlands; Derwent Walk Country Park (DWCP), a 161 ha linear park (built around an 18 km disused railway track) in Tyne and Wear; and Whippendell Wood (WW) a 67 ha site near Watford, north London. Bishop (1990) argues that these provide good comparisons with the proposed community forests such that benefits estimates will be transferable. This assertion is somewhat contentious in that the Community Forests will be more dispersed and cover a considerably wider area than the sites considered in this study.

During the summer and winter of 1989 a sample of 100 respondents was collected at each of the study sites. The initial aim was to conduct both CV and ZTC experiments. However, the latter analysis proved inoperable for four main reasons;

i. A majority of respondents (over 50% at WW and over 60% at DWCP) came from the local (5km radius) area making zone definition difficult;
ii. Over 50% had zero travel costs (walkers/cyclists);
iii. Travel time costs for this group may be positive, zero or negative;
iv. Much of the travel time (especially at DWCP) was within the site.

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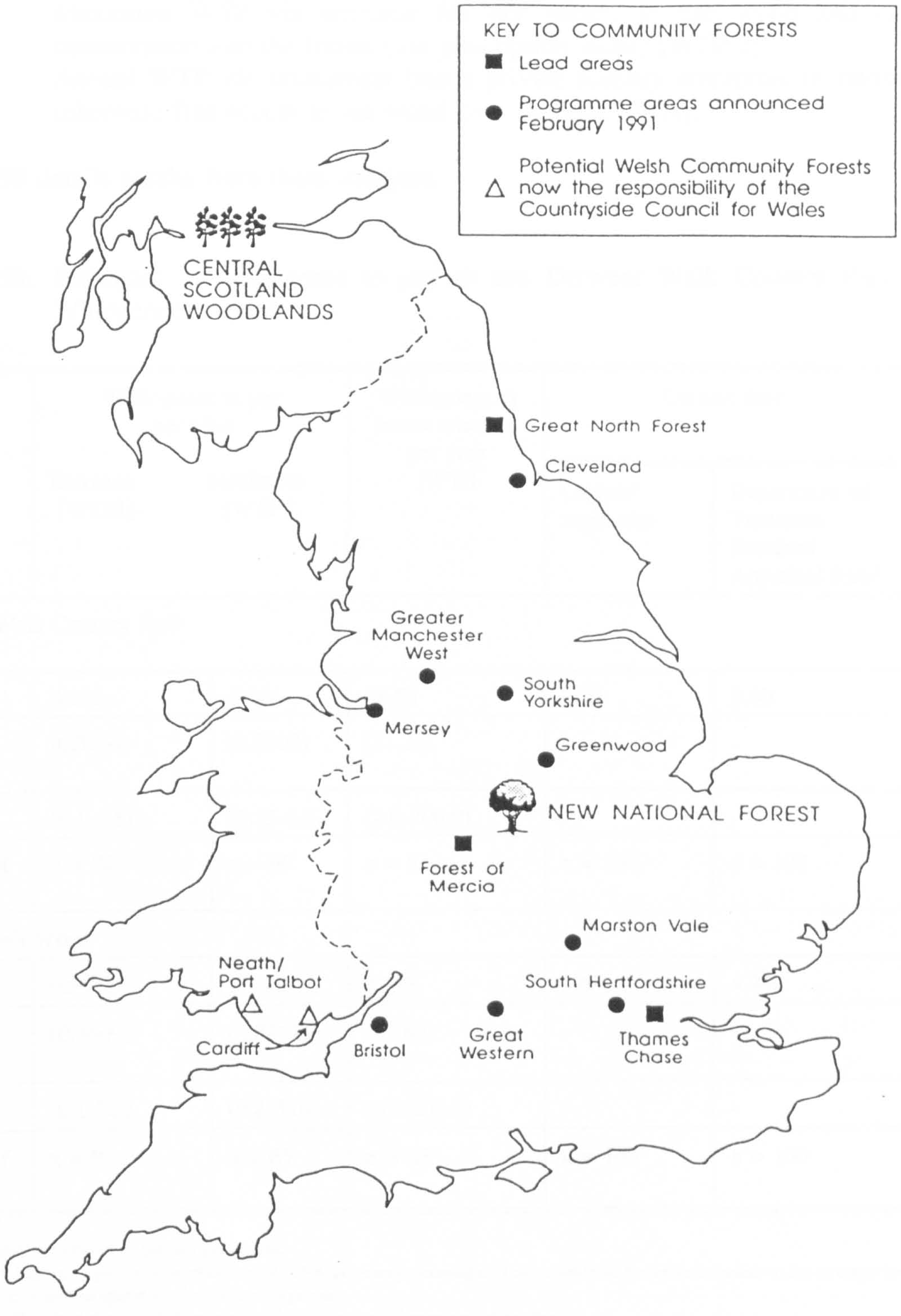
[60] This programme is in addition to initiatives to create a new Midlands forest (Countryside Commission 1990), a Welsh Valleys forest (Forestry Commission, 1991) and the planned Central Scotland Woodland Project (Scottish Office, 1989).

Figure A1.5: Britain's Planned New Forests




Source: Bishop (1992)

As a result of these difficulties the ZTC analysis was abandoned in favour of a simple evaluation of on-site time using standard appraisal time rates (as used in Department of Transport studies) and leisure wage rates (calculated as 25% of national average earnings). Objections to such approaches have been reviewed previously.

The CV study comprised three open-ended WTP scenarios presented to each respondent (Bishop and Stabler, 1991):

i. WTP in entrance fee per person [WTP 1];
ii. Maximum WTP via entrance fee per person to use wood and ensure conservation into the future (use plus option value) [WTP 2];
iii. Annual WTP via investment into a private forestry enterprise in return for otherwise free access to the wood over the year [WTI].

Table A1.59 details results from these analyses.

Table A1.59: Estimates of willingness to pay to use Derwent Walk Country Park and Whippendell Wood[1]

| Site | Willingness to pay per visit: Entrance [WTP1] | Willingness to pay per visit: Maximum [WTP2] | Willingness to invest amount per year [WTI] | On site time: Leisure[2] wage rate | On site time: Department of Transport Standard Appraisal Rate[3] |
|---|---|---|---|---|---|
| Derwent Walk Country Park | | | | | |
| Mean | 0.422 | 0.966 | 18.53 | 2.29 | 3.60 |
| Standard deviation | (0.3204) | (1.0708) | (31.30) | - | - |
| Range | (0.1-1.5) | (0.15-5.0) | (2.0-200.0) | - | - |
| Number of cases | n = 76 | n = 69 | n = 53 | n = 100 | n = 100 |
| Whippendell Wood | | | | | |
| Mean | 0.5425 | 1.3363 | 27.03 | 3.63 | 4.24 |
| Standard deviation | (0.3809) | (1.2711) | (29.89) | - | - |
| Range | (0.1-2.0) | (0.2-5.0) | (4.0-200.0) | - | - |
| Number of cases | n = 81 | n = 65 | n = 67 | n = 100 | n = 100 |

Notes: [1] Values expressed in pounds per capita.
[2] The leisure wage rate was calculated as 25% of average earnings. The estimate in the table is based on the average length of time of visit mulitplied by the leisure wage rate.
[3] The Standard Appraisal Rate is the value of time used in transport studies.

Source: Bishop (1990)

The time cost benefit estimates of table A1.59 are calculated by multiplying time spent on site by the leisure wage and standard appraisal time rates previously discussed. Their validity therefore relies upon the validity of these time rates. Certainly comparison of imputed time values with states WTP would tend to question the validity of the former and we will not pursue these further here.

The CV results of table A1.59 are logical given the goods corresponding to each scenario and show that, for all measures, WTP is lower for DWCP than for WW (with the proportional difference increasing as the values concerned increase, viz: WTP1 22% lower; WTP2 28% lower; WTI 31% lower). Bishop (1992) explains this as a consequence of lower salaries (15%) in Tyne and Wear compared to London.

However, the questionnaire employed can be criticised on a number of points. Firstly very little socioeconomic data is collected and Bishops (1992) assertion that "Whippendell Wood ..... was found to be used less by lower income groups than the Derwent Walk Country Park", does not appear to be substantial by data. Secondly although it is not made explicit, the WTP results duplicated above appear to have excluded all zero bids and are therefore upwardly biased and somewhat suspect. Similarly the wording of the WTP2 question suggests that the previous (WTP1) sum is insufficient to conserve the woodland for the future and thereby provides an upward anchoring bias.

Thirdly, while the WTP1 question does mention that payments should be per person, this qualifier is dropped from the WTP2 and it is arguable that both questions may lead to respondent confusion as to whether the bid should reflect personal or household WTP. Fourthly the (not noted) increase in bid variability at both sites between the WTP1 and WTP2 questions indicates an increased uncertainty in responses to the latter question.

Bishop (1992) notes that responses to WTP1 and WTP2 questions show an inverse relationship with visit frequency whereas answers to the WTI question show no relationship with frequency. Bishop implies that this latter absence of relationship is unexpected but argues that the former (negative) relationship arises because regular users will have to pay any entrance fee more often than infrequent visitors. However, an alternative unifying explanation would be that both frequent and infrequent users hold some (perhaps similar) psychological norm regarding a 'reasonable' personal annual payment for the woodland. When asked to value the woodland in terms of an entrance fee, users implicitly divide this norm amount by their predicted number of annual visits, thus explaining the negative relationship between visit frequency and the WTP1 and WTP2 measures observed by Bishop. However, when asked for their WTI (annual WTP) the implicit divisor for all respondents is unity and as this norm amount is similar across all groups of users then no relationship between visit frequency and annual WTP will emerge (as observed)[61]. If this proposed relationship was perfectly mechanistic then we should expect that the ratio of mean annual WTP to mean entrance fee WTP would be exactly equivalent to the average number of visits per person per annum. Re-analysing Bishop's (1992) data we can see some support for such a hypothesis as detailed in table A1.60.

Table A1.60: Testing the annual norm hypothesis

| Site | Ratio WTI/WTP1 | Ratio WTI/WTP2 | Visits/person p.a. |
|---|---|---|---|
| Derwent | 43.91 | 19.18 | 33.33 |
| Wippendell | 49.83 | 20.23 | 5.88 |

[61] Note that our CV/TC Thetford Forest experiment supports and extends such an interpretation suggesting that this 'norm' payment may alter between user and non-user groups.

As can be seen from table A1.60 the ratio of annual to entrance fee payments does approximate the number of annual visits for DWCP but not for WW. However, visitor estimates in both cases are noted as being suspect and it is likely that a specifically tailored questionnaire and visitor survey would be required to investigate our 'norm' payment hypothesis further.

Bishop (1992) calculates aggregate site values for various estimates of visitor numbers. As he subsequently concentrates upon the lower bound of these estimates only the aggregate benefits based upon these numbers are reported in table A1.61 below.

Table A1.61: Estimates of total annual user benefits at Derwent Walk Country Park and Whippendell Wood (£ p.a.)

| Site | WTP Scenario | | | Educational value |
|---|---|---|---|---|
| | WTP1 | WTP2 | WTI | |
| Derwent | | | | |
| Total | 126,000 | 289,830 | 166,770 | 5,267 |
| Per hectare | 781 | 1,789 | 1,036 | 33 |
| Whippendell | | | | |
| Total | 43,400 | 106,904 | 367,608 | - |
| Per hectare | 648 | 1,596 | 5,487 | - |

Notes: Based on lower bound visit estimates of 300,000 p.a. at DWCP (upper bound = 500,000 p.a.) and 80,000 at WW (upper bound = 100,000). Corresponding estimates of visitor numbers are 9,000 (15,000) at DWCP and 13,600 (17,000) at WW.

The educational value reported in table A1.61 was calculated via a survey of school and local educational records so as to estimate the annual cost of educational trips to DWCP (no records were available for WW and then taking the lower bound assumption that benefits were just equivalent to costs.

Bishop concludes his 1992 paper by comparing his results with those for seven other British forests as detailed in table A1.62.

Table A1.62: A comparison of the estimated user benefits of urban fringe and rural woodlands/forests

| Site | Site area (ha) | Total no. visitors (1000 per year) | Visitors (per hectare per year) | Total benefit: total visitors x max. entrance fee (per hectare per year)[1] (£) | Average entrance fee (WTP) (per person per visit) (£) | Average maximum entrance fee (per person per visit)[2] (£) | Average entrance fee 1990 prices (£) | Average maximum entrance fee 1990 prices (£) |
|---|---|---|---|---|---|---|---|---|
| Derwent Walk Country Park[a] | 161 | 300 | 1863.00 | 1845.00 | 0.42 | 0.97 | 0.46 | 1.06 |
| Whippendell Wood[a] | 67 | 80 | 1194.00 | 1596.00 | 0.54 | 1.34 | 0.59 | 1.46 |
| Castle Douglas (Clattershaws)[b] | 5,870 | 32 | 5.45 | 4.36 | 0.37 | 0.80 | 0.46 | 0.99 |
| South Lakes (Grizedale)[b] | 3,500 | 80 | 22.86 | 19.66 | 0.39 | 0.86 | 0.48 | 1.06 |
| North York Moors (Dalby)[b] | 4,500 | 130 | 28.88 | 29.75 | 0.53 | 1.03 | 0.66 | 1.27 |
| Durham (Hamsterley)[b] | 2,086 | 122 | 58.48 | 32.75 | 0.31 | 0.56 | 0.38 | 0.69 |
| Thetford (Thetford)[b] | 20,000 | 102 | 5.1 | 2.09 | 0.23 | 0.41 | 0.28 | 0.51 |
| Dean (Symonds Yat)[b] | 1,440 | 158 | 109.7 | 69.13 | 0.28 | 0.63 | 0.35 | 0.78 |

Notes: 1 Based on mean maximum entrance fee bids

2 Per capita entrance and maximum entrance fee bids have been calculated by dividing per car per visit figures by average car occupancy rate. The mean maximum entrance fee per site was calculated by adding to mean entrance fee respondents' mean extra payment bids to conserve the site in the future.

Source: [a] Bishop (1992). Data at 1990 prices

[b] Willis et al., (1988), names in brackets are as per Willis et al (1988). Data at 1987 prices.

Bishop notes the conformity in the relationship of WTP1 to WTP2 (approximately 1 to 2) across these studies. He notes further the apparently very large per hectare value of urban fringe woodland compared to those for rural forests stating that this is "primarily a result of increased annual visitor numbers to, and the smaller site area of, the two urban fringe woodlands". We would take issue with the second of these points, arguing instead that the equation of rural forest size with the recreation area of such forests is erroneous and leads to, possibly major, understatement of the per hectare value of the recreational sectors of such forests. A further assertion[62] is also open to criticism. Bishop states that;

> "The average bid amounts for urban fringe woodlands were higher than the non-urban fringe sites by a factor of about 38%, suggesting that the urban fringe woodlands have a higher perceived value than more distant woodlands".

An immediate problem with this assertion is the omission to take into account inflationary impacts in the years intervening this and comparative studies. To account for this the two final

[62] Bishop also states that woodland benefits exceed costs by a factor of three, however details are not given.

columns have been added to table A1.62 bringing all results to 1990 prices. Comparing results at constant 1990 prices now shows WTP entrance fee at urban-fringe woodlands as being less than 15% larger than that for rural woodlands[63].

## Summary Results

| CV | WTP entrance fee (use value) (£/person/visit) | WTP entrance fee ensuring future conservation (use + option price) (£/person/visit) | WTP annual subscription (£/person pa) |
|---|---|---|---|
| Derwent Walk Country Park | 0.422 | 0.966 | 18.53 |
| Whippendell Wood | 0.5425 | 1.3363 | 27.03 |

## Study References


Bishop, K.D. (1990) Multi-purpose woodlands in the countryside around towns, *PhD thesis*, University of Reading.

Bishop, K.D. (1992) Assessing the benefits of community forests: an evaluation of the recreational use benefits of two urban fringe woodlands. *Journal of Environmental Planning and Management*, 35(1):63-76.

Bishop, K.D. and Stabler, M.J. (1991) The concept of community forests in the UK: the assessment of the benefits, *unpublished paper*, presented at the annual conference of European Association of Environmental and Resource Economists, June 10-14th, 1991, Stockholm School of Economics, Sweden.


## Supplementary References


Countryside Commission (1989a) Forests for the community, *CCP 270*, Countryside Commission, Cheltenham.

Countryside Commission (1989b) Forests for the community, *CCP 272*, Countryside Commission, Cheltenham.

Countryside Commission (1990) A new national forest, *CCP 328*, Countryside Commission, Cheltenham.

Forestry Commission (1991) *Valleys Forest/Coed Y Cymoedd*, Forestry Commission, Neath.

Hanley, N.D. (1989) Valuing rural recreation benefits: an empirical comparison of two approaches, *Journal of Agricultural Economics*, 40(3):361-374.

Scottish Office (1989) *Central Scotland Woodlands*, Scottish Office, Edinburgh.

Willis, K.G. and Benson, J.F. (1989) Values of user benefits of forest recreation: some further site surveys. *Report to the Forestry Commission*, Department of Town & Country Planning, University of Newcastle upon Tyne.

Willis, K.G., Benson, J.F. and Whitby, M.C. (1988) Values of user benefits of forest recreation and wildlife, *Report to the Forestry Commission*, Department of Town & Country Planning, University of Newcastle upon Tyne.


[63] based on unweighted means.

# A1.13: RECREATION BENEFITS IN THREE COMMUNITY FORESTS

**Method:** CV

**Evaluation unit:** WTP per person per visit and per year

## Commentary

In preparation for the implementation of the Community Forest programme, the Forestry Commission conducted in-house CBA's of the first three projects being the Forest of Mercia, Thames Chase and the Great North Forest. As part of these analyses CV studies of recreation value were undertaken for each site. Face-to-face interviews of roughly 300 residents within 5 miles of each proposed forest were conducted during early 1992 (Whiteman and Sinclair, 1994). Standard sample selection protocols were adhered to.

Prior to the survey all households were mailed an information leaflet concerning the Community Forest programme and proposed local provision. Upon interviewing approximately one-third of respondents claimed to have read this leaflet fully while a further third had at least glanced at it. This gives some prior information base.

Alongside WTP information the questionnaire gathered data concerning existing use of countryside resources and planned use of the community forest as well as all standard socioeconomic variables.

Reasons for refusing to pay for the forest were elicited and divided into genuine and protest zeros. Those who stated that their reason for refusing to pay was either that the forest was not worth paying for or that they would not use it, were deemed as genuine zero's while those giving other reasons were felt to be giving protest responses. This is a somewhat conservative definition of genuine zero bidding (see Bateman et al., 1993) and runs the risk of questioning the validity of overall results. Table A1.63 details results from this analysis.

Constraints upon sample size precluded the use of a dichotomous choice elicitation format and so an open-ended approach was adopted for each of the three studies. A taxation payment vehicle was selected for reasons of realism and credibility. Table A1.64 details average willingness to pay per person per visit for each forest excluding protest zero bids.

Table A1.63: Reasons for giving a zero bid

| Reason | Forest of Mercia | Thames Chase | Great North Forest |
|---|---|---|---|
| Do not think it is worth paying any more | 19 | 33 | 31 |
| Would rather see the money spent elsewhere | | | |
| | 13 | 29 | 48 |
| Would agree to something being spent but not if it meant higher taxes | | | |
| | 27 | 18 | 24 |
| Would not use the forest | | | |
| Did not think the question was sensible | 0 | 23 | 1 |
| Don't know | 2 | 2 | 3 |
| | 24 | 31 | 43 |
| Total number of zero bids | 85 | 136 | 150 |
| Genuine zero bids | 19 | 56 | 32 |
| Protest zero bids | 66 | 80 | 118 |
| Protest bids as a percentage of the entire sample | 22% | 26% | 40% |

Source: Whiteman and Sinclair (1994)

Table A1.64: Average willingness to pay per person per visit (£, 1992) including only genuine zero bids

| Bid (£/visit) | Forest of Mercia | Thames Chase | Great North Forest |
|---|---|---|---|
| Mean | 1.00 | 0.68 | 0.92 |
| Standard error | 0.16 | 0.14 | 0.18 |
| Weighted mean | 1.00 | 0.71 | 0.81 |
| Median | 0.50 | 0.50 | 0.50 |
| Total number of bids | 231 | 220 | 168 |

Source: Whiteman and Sinclair (1994)

Whiteman and Sinclair (1994) also report annual equivalents of the WTP results given in table A1.64. These are calculated by multiplying WTP per person per visit by expected annual use of the forest. This multiplication of two hypothetical numbers must be treated with some caution although it seems a reasonable predictor of the relevant magnitudes involved[64]. Results for this exercise are given in table A1.65.

[64]This is similar to our approach in our study of a hypothetical Community Forest near Wantage (see chapter 4).

Table A1.65: Average annual value for the three community forests

| £/Year/Resident | Forest of Mercia | Thames Chase | Great North Forest |
|---|---|---|---|
| Mean<br>Standard error | 8.51<br>1.04 | 8.80<br>1.35 | 9.46<br>1.23 |
| Weighted mean | 7.70 | 9.79 | 8.66 |
| Median | 3.00 | 3.00 | 2.00 |
| Total number of valuations | 231 | 220 | 168 |

Source: Whiteman and Sinclair (1994)

Various tests of validity are reported including a comparative validity test detailing results from many of the studies reviewed previously. A bid curve analysis for annual WTP is also reported. Table A1.66 reports the best fitting model from this analysis. Unfortunately certain variables insignificant at the 5% level have been retained. However, in general, individual relationships are as expected although all the models yield (typically) low levels of overall explanation.

Table A1.66: Best-fit regression model for annual WTP

Dependent variable: Annual WTP

| | Forest of Mercia | | Thames Chase | | Great North Forest | |
|---|---|---|---|---|---|---|
| Independent Variables | Coefficient | t-statistic | Coefficient | t-statistic | Coefficient | t-statistic |
| Constant | 79.44 | 0.17 | 946.73 | 1.86 | -890.02 | -1.51 |
| Income | 321.81 | 3.93 | 138.89 | 1.57 | 276.60 | 2.26 |
| Membership of a Conservation Group | - | - | 1 220.60 | 2.58 | 1 524.08 | 2.64 |
| Household size | - | - | -212.85 | -1.65 | - | - |
| Sex | - | - | - | - | 559.71 | 2.21 |
| Satisfaction with existing area | -476.46 | -4.42 | -158.46 | -1.11 | -86.54 | -0.55 |
| Existing use of countryside | 2.32 | 1.26 | 8.89 | 3.97 | 4.66 | 2.84 |
| Library Activities | | | | | | |
| Dog walk | 440.84 | 1.96 | - | - | - | - |
| Waymarked walk | 276.56 | 1.26 | 477.47 | 1.48 | 545.15 | 2.17 |
| Other walk | 281.19 | 1.34 | - | - | - | - |
| Picnic/barbecue | 858.50 | 3.60 | 516.81 | 1.36 | - | - |
| Use play area | - | - | 768.70 | 1.87 | - | - |
| Ride a bike | - | - | 1 052.88 | 1.31 | 1 322.55 | 1.95 |
| Forest drive | - | - | -848.49 | -2.07 | - | - |
| Observe nature | 365.40 | 1.61 | -785.77 | -2.30 | - | - |
| Adjusted R-squared | | 0.20 | | 0.18 | | 0.19 |
| Number of observations | | 227 | | 180 | | 155 |

Source: Whiteman and Sinclair (1994)

Finally total annual WTP was calculated as detailed in table A1.67.

Table A1.67: Total value for three Community Forests

| | Annual adult visitor numbers (millions) | Mean value per visit (£) | Mean annual value placed on the forest | |
|---|---|---|---|---|
| | | | per adult (£) | total (£ millions) |
| Forest of Mercia | 20 | 1.00 | 7.70 | 9.85 |
| Thames Chase | 15 | 0.71 | 9.79 | 8.01 |
| Great North Forest | 19 | 0.81 | 8.66 | 6.14 |

Source: Whiteman and Sinclair (1994)

## Conclusions

Overall this appears to be a competent study yielding interesting results as summarised below.

## Summary Results

| | Forest of Mercia | Thames Chase | Great North Forest | Weighted mean |
|---|---|---|---|---|
| WTP per person per visit (£) | 1.00 | 0.71 | 0.81 | 0.85 |
| WTP per person per annum (£) | 7.70 | 9.79 | 8.66 | 8.70 |
| Sample size | 231 | 220 | 168 | - |

## Study Reference

Whiteman, A. and Sinclair, J. (1994) *The Costs and Benefits of Planting Three Community Forests: Forest of Mercia, Thames Chase and Great North Forest*, Policy Studies Division, Forestry Commission, Edinburgh.

## Supplementary Reference

Bateman, I.J., Langford, I.H., Willis, K.G., Turner, R.K., Garrod, G.D. (1993) The impacts of changing willingness to pay question format in contingent valuation studies: an analysis of open-ended, iterative bidding and dichotomous choice formats, *CSERGE GEC Working Paper 93-05*, Centre for Social and Economic Research on the Global Environment, University of East Anglia and University College London.

## A1.14: RECREATION VALUE OF MARSTON VALE COMMUNITY FOREST

**Method:** CV

**Evaluation unit:** WTP per visit and per year (not specified if per person or per household)

**Commentary:**

Only partial details of this study were made available and therefore our commentary is somewhat circumspect. Marston Vale is the site of a proposed Community Forest. Residents in the surrounding area were interviewed and presented with open-ended questions regarding WTP per visit and per year for the forest. One of the failings of the study as seen is that it is not made clear as to whether responses are in per household or per person terms. This limits the use of this study for our wider analysis.

Respondents were presented with various payment vehicles. Per visit amounts were elicited via boat hire, nature trail and entrance fee vehicles while per annum amounts were elicited both by these and a trust fund vehicle. Table A1.68 details univariate results for these analyses.

Table A1.68: WTP results

| Vehicle | Sample size[1] | Mean WTP (£) | SE (£) | 95% CI (£) |
|---|---|---|---|---|
| Per visit measures | | | | |
| Boat hire | 50 | 1.97 | 0.146 | ± 0.29 |
| Nature trail | 68 | 1.52 | 0.098 | ± 0.20 |
| Entrance fee | 79 | 1.34 | 0.096 | ± 0.19 |
| Per annum measures | | | | |
| Boat hire | 94 | 4.14 | 0.804 | ± 1.60 |
| Nature trail | 95 | 3.03 | 0.413 | ± 0.82 |
| Entrance fee | 89 | 4.60 | 0.701 | ± 1.40 |
| Trust fund | 85 | 6.00 | 0.710 | ± 1.42 |
| Maximum[1] | 100 | 9.15 | 0.879 | ± 1.75 |

Note: [1] The maximum WTP response given to any CV question by a respondent

Source: Abstracted from Maxwell (1992)

The WTP sums given in the upper half of table A1.68 are significantly above the per person per visit results recorded in the other studies received. This may be due to two factors:

i) The per visit figures given may well be per household rather than per person in which case these results are in line with those of other studies
ii) The boat hire (and to some extent the nature trail) payment vehicle is for a mixture of private and public recreational goods whereas the other studies reviewed looked at the recreational

public good alone. Accordingly we would expect both higher absolute values and the observed ordering of goods across payment vehicles.

Bid function analysis was carried out although the resulting regressions were not available. Overall degrees of significance and explanation for each payment vehicle is detailed in table A1.69.

Table A1.69: Overall tests of significance and coefficients of determination for annual WTP regression equations

| Payment vehicle | Overall tests of significance | | Coefficients of determination | |
|---|---|---|---|---|
| | F | sig F | $R^2$ | $R^2$ (adj) |
| Boat hire | 6.11 | 0.0000 | 0.38 | 0.32 |
| Nature trail | 5.94 | 0.0002 | 0.33 | 0.28 |
| Entrance fee | 3.57 | 0.0015 | 0.27 | 0.20 |
| Trust fund | 4.13 | 0.0004 | 0.31 | 0.24 |
| Maximum[1] | 5.06 | 0.0000 | 0.32 | 0.26 |

Note: 1. The maximum WTP given by a respondent to any CV question

Source: Maxwell (1992)

For a relatively small scale project, the results of table A1.69 are quite creditable. However, we are concerned that as each respondent was asked WTP via several payment vehicles, the probability that answers have affected each other is high.

## Summary Results

Uncertain because of a lack of clarity in specifying results[65].

## Study Reference

Maxwell, S. (1992) Valuation of rural environmental improvements: a case study of the Marston Vale Community Forest Project using contingent valuation methodology, *MSc Thesis*, Department of Land Use, Silsoe College, Cranfield Institute of Technology.

[65] This may well be rectified in the full report to which we did not have access.

## A1.15: VALUING WOODLAND WALKS IN WINDSOR

**Method:** CV

**Evaluation unit:** WTP per visit and per year (not specified if per person or per household)

**Commentary:**

This study, described as a pilot for a subsequent wider analysis, was carried out in summer 1993 at an urban fringe woodland in Windsor Forest. The site encompassed a car park, heritage centre with refreshment facilities and several woodland paths. The study set out to estimate the recreational value of these paths.

A bidding game was used although no details of starting point(s) are given. Three payment vehicles were employed: a per visit entrance fee; an annual sum paid via Council Tax; and to a charitable fund. Results are summarised in table A1.70 which also gives some details regarding the distribution of final bids.

Table A1.70: WTP for woodland paths by payment vehicle[1]

| Payment vehicle | Bid distribution | | Mean WTP |
|---|---|---|---|
| | WTP band | % | |
| Entrance fee per visit | Nothing<br>£0.10-£0.50<br>£0.51-£1.00<br>£1.01-£2.00<br>> £2.00 | 20<br>26<br>25<br>18<br>11 | £1.18 |
| Council tax per annum | Nothing<br>£0.10-£3.00<br>£3.01-£5.00<br>£5.01-£15.00<br>>£15.00 | 28<br>19<br>12<br>23<br>18 | £9.40 |
| Charitable donation once-and-for-all | Nothing<br>£0.10-£10.00<br>£10.01-£25.00<br>£25.01-£50.00<br>>£50.00 | 31<br>30<br>19<br>14<br>6 | £21.02 |

Note: 1. Not specified if this is per person, per party or per household

Source: Abstracted from Tranter et al., (1994)

A major problems with this study is inadequate reporting[66]. As with the study by Maxwell (1992) it is uncertain whether results are per person per party or per household. Similarly space

[66]The published article consists of a brief two-page summary. Hopefully, full details will be published elsewhere (may be forthcoming in AES proceedings).

limitations meant that regression analyses are not detailed although the following comment is of interest:

> "Statistical analysis revealed a strong relationship between the entrance fees people stated they were willing to pay and:
> • the distance they had travelled; and
> • their leisure budget
>
> Similarly, a strong relationship existed between the addition to the Council Tax that people said they were willing to pay and:
> • their monthly leisure budget;
> • the number of times they used the paths in the year; and
> • their assessment of the quality of the path system"
>
> (Tranter et al., 1994)

While these comments are of interest and relevant to our own applied work, the absence of detail means that further commentary is difficult.

## Summary Results

Uncertain because of a lack of clarity in published results[67].

## Study Reference

Tranter, R.B., Bennett, R.M. and Beard, N.F. (1994) Valuing woodland walks, *Countryside Recreation Network News*, 2(2):4-5.

[67]This may be amended in future publications.

# A1.16: WOODLAND LANDSCAPE AMENITY VALUES: A HEDONIC PRICING STUDY

**Method:** HPM

**Evaluation unit:** household and national values

**Commentary**

## A1.16.1: A WELSH BORDERS/CENTRAL ENGLAND WOODLAND AMENITY STUDY

This initial study (Garrod and Willis, 1991a; 1992a) examined an area of 4800 $km^2$ of the Welsh Borders and central England. In order to prevent violation of the single market assumption central to the HPM (see Bateman, 1993) all urban areas were excluded so as to concentrate upon the rural housing market as a single entity. This restriction together with the limited size of the study area probably meant that there was no violation of the single market assumption.

Data was gathered from four sources

i. Building society mortgage data; giving information upon house price, 1km grid reference, structural variables etc. The file used contained nearly 2000 observations for the period 1985-89, covering 13 local authorities and providing over 100 variables although key variables such as age, site area gardens and utilities were omitted.
ii. Ordnance Survey (OS) maps (1:50000 series); provides data on approximate cover of land by forestry, water, buildings, parkland, etc. Also accessibility, services, potential view (ie. whether a 1 km square overlooked a wooded or urban area), topography, infrastructure, etc.
iii. Small area census (1981); detailing average resident age, population density, etc.
iv. National Outline Manpower Information System (NOMIS); detailing local employment characteristics, etc.

The study itself is, in traditional HPM terms, incomplete in that, while the hedonic price function itself is estimated, for reasons explained subsequently, it was not possible to then estimate demand functions for any of the environmental characteristics under examination. While the subsequent national study remedies this, the initial study in many ways users a more complete data set and so this omission is somewhat unfortunate.

The hedonic price function used is as given in equation (A1.19):

$$P_i = f\,(\,AC_i, B_i, CC_i, LAD_i, S_i, SE_i, Y_i, Q_i\,) \qquad \text{(A1.19)}$$

where

$P_i$ = the market price of property i

| | | |
|---|---|---|
| $AC_i$ | = | vector of variables indicating the proximity of public services to property i |
| $B_i$ | = | vector of external variables which may effect the value of property i |
| $CC_i$ | = | vector of countryside characteristics neighbouring property i |
| $LAD_i$ | = | local authority district of property i |
| $S_i$ | = | vector of structural characteristics of property i |
| $SE_i$ | = | vector of socioeconomic characteristics of the district containing property i |
| $Y_i$ | = | year in which property i was purchased |
| $Q_i$ | = | quarter in which property i was purchased. |

In testing for an appropriate functional form, Garrod and Willis (1991a; 1992a) firstly discuss the suitability of a Box-Cox quadratic model as given in equation (A1.20).

$$P^{\gamma} = a_o + \Sigma\, a_j\, X_j^{\pi} + 0.5\, \Sigma_j\, \Sigma_i\, b_{ji}\, X_j^{\pi}\, X_i^{\pi} \qquad \text{(A1.20)}$$

where

$$P^{\gamma} = \begin{cases} (P\gamma - 1)/\gamma & \text{for } 0< \gamma <0 \\ \ln P & \text{for } \gamma = 0 \end{cases}$$

$$X_j^{\pi} = \begin{cases} (X_i^{\pi} - 1)/\Pi & \text{for } 0< \Pi <0 \\ \ln X_i & \text{for } \Pi = 0 \end{cases}$$

This model is sufficiently general to include most conventional functional forms as the following special cases[68];

| | | |
|---|---|---|
| linear: | $\Pi = \gamma = 1$ | and $b_{ji} = 0$ for all j,i |
| semi-log dep: | $\Pi = 1, \gamma = 0$ | and $b_{ji} = 0$ for all j,i |
| double log: | $\Pi = \gamma = 0$ | and $b_{ji} = 0$ for all j,i |
| quadratic: | $\Pi = \gamma = 1$ | |

A number of objections have been raised regarding the use of quadratic forms for HPM models. In such form each marginal (implicit) price is more dependent upon other coefficients than for the other standard functional forms. Thus omitted variable bias will have a multiplied effect upon these quadratic function price estimates and Cropper et al., (1988) advise against quadratic forms where mis-specification is suspected. The omission in this study of variables such as plot size and age is a relevant factor here. Furthermore similar studies (eg. Cassel and Mendelsohn, 1985; Willis and Nicholson, 1991) have noted that the use of second order terms introduces additional multicollinearity thereby reducing the significance and accuracy of first order terms without significantly improving model fit.

[68] For further details regarding functional forms for HPM models see Garrod and Allenson (1991)

Garrod and Willis therefore reject the quadratic form (setting $b_{ij}$ to zero for all i,j in (A1.20)) and compare standard forms against a simplified linear Box-Cox model as given in equation (A1.21).

$$P^{\gamma} = a_o + \Sigma a_j X_j^{\pi} \qquad \text{(A1.21)}$$

where

$$P^{\gamma} = \begin{cases} (P_i^{\gamma} - 1)/\gamma & \text{for } \gamma \neq 0 \\ \ln P_i & \text{for } \gamma = 0 \end{cases}$$

and $X_j$ = characteristic j at property i

The above model[69] was estimated for values of $\gamma$ between -1.0 and 1.0 at intervals of 0.1[70]. Results for special functional forms and for the optimum alternative Box-Cox linear model are given as table A1.71.

**Table A1.71: Alternative forms for the hedonic price function[1]**

| | Form of hedonic price function | | | |
|---|---|---|---|---|
| | Linear | Semi-log | Double-log | Box-Cox ($\gamma$=0.1) |
| $R^2$ | 0.6672 | 0.7682 | 0.7771 | 0.7678 |
| $R^2$ (adj.) | 0.6605 | 0.7630 | 0.7770 | 0.7625 |
| *F*-value | 98.88 | 147.02 | 154.17 | 147.52 |
| Focus variables[2] | 3 | 7 | 6 | 7 |
| Total variables[2] | 35 | 40 | 39 | 40 |
| *N* | 1762 | 1826 | 1766 | 1826 |

Note: 1. OLS regression based on N observations (given in table)
2. All variables have coefficients significant at the 10% significance level

Source: Garrod and Willis (1992a)

As can be seen from table A1.71 it is the double-log form which yields the maximum degree of explanation. However Garrod and Willis are also concerned to maximise the number of 'focus' (that is environmental characteristic) explanatory variables in their model and thus prefer the semi log form ($\gamma$ = -0.1) there may be a case for a second, finer line search (increments of say 0.05) however estimates are unlikely to change markedly from such a refinement and are therefore acceptable.

[69] Note that we have rewritten Garrod and Willis' (1992a) original form of (A1.21) into one consistent with equation (A1.20) and which allows operation of a Box-Cox iterative fitting routine (unlike their original).

[70] The treatment of $\pi$ within the estimation of the Box-Cox model is not made clear, however the stated preference for a semi log (dependent) model indicates, for the results reported as table A1.72, that $\pi$ = 1.

Empirical results for the estimated semi log hedonic price function are given in table A1.72 along with variable definitions (dependent variable = ln house price). The explanatory variables have been grouped as per Graves et al (1988) as either 'focus' (those of particular policy interest), 'free' (those known to affect property price but not of policy interest) and 'doubtful' (those which may or may not affect the dependent variable). Definitions of the explanatory variables (including those investigated but found to be insignificant) are given in note 1 at the end of this commentary.

In estimating the hedonic price function, none of the continuous focus variables proved significant even at the 10% level used for table A1.72. This lack of continuous focus variables prevents differentiation of the hedonic price function ie. calculation of implicit marginal prices. This in turn prevents the estimating of demand functions for the environmental characteristics. However, as can be seen, seven discrete focus variables proved significant. Of these the most relevant to this study is FOR20, indicating whether a property was located in a 1km square with at least 20% woodland cover[71]. Given that the coefficients of a semi-log equation represent the marginal cost of each characteristic[72], the coefficient on FOR20 indicates that the proximity of at least 20% woodland cover should raise house price by 7.1%. This finding is roughly in line with those of two comparable US studies; Morales (1980) who estimates a house price increment for trees of 6%; and Anderson and Cordell (1988) who estimate this increment as between 3.5 to 4.5%.

The sign and magnitude of other focus variables is as expected except for the negative sign on WVIEW (whether the 1km square commands a woodland view). Garrod and Willis only comment that this element was found in all estimated functions and conclude that "while a significant tract of woodland within 1 km has a positive benefit to property values (cf. FOR20 variable), its presence as a significant element of a view has the opposite effect". We find this rather unsatisfactory. However, fortunately, Garrod and Willis' subsequent national study (discussed below) points to a logical explanation by noting a positive house price relation with broadleaves and a negative relation with conifers. Given that broadleaves may be more concentrated around housing relative to their concentration elsewhere, the disparity between nearby and distant forest effects found in the initial study (Garrod and Willis 1991a; 1992a) may be consistent with these subsequent findings (Garrod and Willis 1991b; 1992b; 1992c). We now turn to discuss these latter studies.

---

[71] This level was presumably set via a series of respecifications so as to maximise significance.

[72] The average percentage change in house value for a unit change in the characteristic.

Table A1.72: Estimated hedonic price function: Welsh Borders/Central England study

| | Coefficient | *t*-ratio |
|---|---|---|
| *Focus variables* | | |
| FOR20 | 0.07104 | 2.53 |
| RIVER | 0.04897 | 2.74 |
| SETT | 0.08341 | 5.34 |
| WET | -0.18005 | -1.75 |
| WVIEW | -0.07346 | -3.10 |
| UVIEW | -0.05795 | -3.55 |
| GRAD | -0.00302 | -2.50 |
| *Free variables* | | |
| ROOMS | 0.06932 | 11.08 |
| BATHS | 0.14664 | 6.21 |
| DET | 0.20635 | 5.20 |
| DETBUN | 0.20392 | 4.58 |
| SEMI | -0.11551 | -3.03 |
| TERR | -0.20068 | -5.30 |
| TENURE | 0.31328 | 8.06 |
| DOUB | 0.24517 | 8.03 |
| SING | 0.06875 | 4.32 |
| FULLCH | 0.06517 | 3.61 |
| PARTCH | 0.06381 | 2.52 |
| FLOOR | 0.00028 | 6.09 |
| YEAR86 | 0.03554 | 1.76 |
| YEAR87 | 0.20846 | 9.34 |
| YEAR88 | 0.49631 | 18.33 |
| YEAR89 | 0.60704 | 16.34 |
| TQTR | 0.08321 | 5.14 |
| LQTR | 0.11819 | 7.35 |
| BMKT1 | -0.44311 | -6.07 |
| BMKT2 | -0.90490 | -25.05 |
| BMKT5 | -0.35198 | -4.26 |
| BMKT8 | -0.30502 | -9.99 |
| BMKT11 | -0.55928 | -6.67 |
| BMKT12 | -0.15869 | -5.22 |
| BMKTRM | -0.15180 | -3.76 |
| *Doubtful variables* | | |
| DIST1 | -0.24948 | -5.75 |
| DIST4 | 0.16357 | 5.60 |
| DIST6 | -0.06180 | -2.02 |
| DIST13 | -0.07487 | -2.68 |
| RETD | 0.04181 | -8.72 |
| ROAD | 0.02785 | 3.66 |
| RAIL | -0.05426 | -2.77 |
| UNEM | -0.00623 | -2.20 |

Note: Variable definition given in note at end of this commentary.

Source: Garrod and Willis (1992a)

## A1.16.2: A NATIONAL WOODLAND AMENITY STUDY

This study utilised the Nationwide Building Society's 1988 mortgage database of some 300,000 properties throughout Britain. From this a sample of over 1000 properties was selected. All properties were in rural locations. This factor was both essential for the countryside characteristics nature of the study and as an attempt to present the sample as representing different areas with a single non-segmented market (a vital assumption of the HPM discussed in Bateman (1993)). Garrod and Willis (1991b; 1992b) argue that "with the improvements in road and rail travel over the last few decades[73]" and "the increased demand for rural housing in the form of second homes or retirement cottages", that "there is a single, continuous market for rural housing in Great Britain". This is the most fundamental, and unfortunately the most debateable, assumption of this work. That rural properties in Scotland can be assumed to be in the same market as those in the rural areas of the South East is highly questionable. While the desirability of modelling British demand is obvious we cannot be certain that such a single study approach is theoretically valid. However, in the absence of empirical (if not intuitive) information to the contrary we cannot reject out of hand this approach.

Sample properties were distributed around Britain as indicated by table A1.73. As can be seen, this distribution was particularly suitable for our wider study in that properties in Wales represented by far the biggest single area grouping.

**Table A1.73: The geographical distribution of the housing data set**

| Region | Properties | Percentage |
|---|---|---|
| East Anglia | 17 | 1.65 |
| East Midlands | 39 | 3.78 |
| Northern England | 31 | 3.01 |
| Outer Metropolitan | 95 | 9.21 |
| Outer South East | 141 | 13.68 |
| Scotland | 154 | 14.94 |
| South West | 151 | 14.65 |
| Wales | 312 | 30.26 |
| West Midlands | 72 | 6.98 |
| Yorkshire and Humberside | 19 | 1.84 |
| Total | 1031 | |

Source: Garrod and Willis (1992b)

In addition to the house price and structural characteristics provided by the building society, other variables were added from the small area census and NOMIS databases as per the previous study. However, the prior use of OS maps to provide environmental (and some neighbourhood) characteristics proved infeasible for the national study. In its place data was taken from the Forestry Commissions (FC) sub-compartment database which was aggregated to 1km squares to be compatible with the building society data. This provided extensive data regarding the Commissions holdings including 6 planting age groups for each of three tree species types as well as the total amount of FC plantation in each square. However, the abandonment of the OS source entailed considerable data losses, specifically no record of

[73] Evidence of an improvement in the rural rail network is particularly hard to find.

non-FC woodland was available which consequently voided any woodland-view variable. Furthermore, certain of the 'doubtful' neighbourhood variables, found to be significant in the earlier study, were now unavailable[74].

In the first stage of the study a hedonic price function was specified as given in equation (A1.22):

$$P_h = P_h\ (FC_i,\ Q_i,\ S_i,\ SE_i,\ R) \qquad \text{(A1.22)}$$

where

| | | |
|---|---|---|
| $P_h$ | = | house price |
| $FC_i$ | = | vector of countryside characteristics in the neighbourhood of property i (obtained from FC database) |
| $Q_i$ | = | quarter of the year in which property i was purchased |
| $S_i$ | = | vector of structural characteristics of property i |
| $SE_i$ | = | vector of socio-economic characteristics of the local authority containing property i |
| $R_i$ | = | region in which property i is located |

In testing for an appropriate functional form for (A1.22) a Box-Cox quadratic form is rejected for the reasons rehearsed in the previous study. A linear transformation is therefore specified as given in (A1.23):

$$P^{\theta} = a_o + \Sigma\ a_j\ X_j^{\pi j} + u \qquad \text{(A1.23)}$$

where

$$P^{\theta} = \begin{cases} (P^{\theta} - 1)/\theta & \text{for } \theta \neq 0 \\ \ln P & \text{for } \theta \neq 0 \end{cases}$$

$$X_j^{\pi j} = \begin{cases} (X_j^{\pi j} - 1)/\pi & \text{for } \pi \neq 0 \\ \ln X_j & \text{for } \pi \neq 0 \end{cases}$$

and $X_j$ = explanatory variables[75]

Theoretically each $\pi_j$ can take a separate value within each fitted function. However such a position was considered unfeasible given the computational limitations imposed by the large number of explanatory variables used. Garrod and Willis (1991b; 1992b) therefore adopt the simplifying constraint that $\pi_j = \pi$ for all $X_j$. The explanatory variables ($X_j$) were

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[74] Bateman (1994) discusses the advantages of applying GIS software to the HPM, an approach which would overcome the problems outlined here.

[75] All dummy variables remain untransformed.

initially selected upon the basis of a stepwise regression model set to exclude variables at a 10% significance level. Both $\pi$ and $\theta$ were then varied between -2.0 and 2.0 at intervals of 0.05 allowing an intensive line search for the optimal model. A maximum degree of explanation of $R^2$ = .7555 (adjusted $R^2$ = .7481) was found using $\theta$ = 0.05 and $\pi$ = 0.35. Results for this regression are reported as table A1.74 below.

Table A1.74: Estimated hedonic price function: national study

| | Coefficient | t-ratio |
|---|---|---|
| Intercept | 12.2942 | 35.64 |
| *Focus variables* | | |
| BROAD* | 0.0126 | 2.73 |
| CON40* | -0.0938 | -2.95 |
| *Free variables* | | |
| BATHS | 0.5529 | 6.07 |
| DETAT | 0.5920 | 9.92 |
| BPB* | -0.4087 | -4.87 |
| TERR | -0.3755 | -7.37 |
| GAR | 0.3392 | 6.77 |
| FULLCH | 0.2318 | 4.22 |
| PARTCH | 0.1593 | 1.78 |
| FLOOR* | 0.0259 | 3.02 |
| SQTR | -0.1152 | -2.31 |
| LQTR | 0.2091 | 4.17 |
| BMKT1 | -1.9579 | -7.48 |
| BMKT2 | -1.4982 | -18.64 |
| BMKT8 | -0.6702 | -7.91 |
| BMKTRM | -0.2972 | -3.89 |
| *Doubtful variables* | | |
| DIST4 | 0.3994 | 2.36 |
| DIST6 | -0.4417 | -5.01 |
| DIST7 | -0.3853 | -3.78 |
| DIST10 | -0.2824 | 2.37 |
| DIST11 | 0.5702 | 5.79 |
| DIST12 | -0.5292 | -4.49 |
| RETD* | 0.1869 | 4.80 |
| PDEN* | 0.0711 | 3.58 |
| AG* | 0.0496 | 1.82 |
| NOCAR* | -0.0750 | -1.81 |
| UNEM* | -0.1287 | -3.89 |
| * transformed using Box-Cox transformation with $\pi$ = 0.35 | | |

Note: Variable definitions given in note at end of commentary

Source: Garrod and Willis (1992b)

The estimated hedonic price function was tested for excluded variable bias by omitting single explanatory variables in turn and re-estimating. Garrod and Willis report that coefficients deviated by, on average, 5%, however, any extreme results within this analysis are not reported.

Analyses of outlier effects and multicollinearity were also undertaken via a jack-knife regression routine in which 189 groups of 5 observations were in turn removed and the model re-estimated. This suggested evidence of multicollinearity within non-focus variables (eg. DETAT and BATHS) making coefficients for these somewhat unreliable. However, this problem did not seem to extend to focus variables.

Only two focus variables, BROAD (% of FC land in km square under broadleaves) and CON40 (% of FC land in km square under conifers (not larch, scots or Corsican pine) planted before 1940) proved significant at the 10% level. Using the mean values of all other variables, Garrod and Willis use focus variable coefficients to calculate that a 1% increase in house price while the same increase in CON40 results in a £141 reduction in house price. Furthermore, if the increase in BROAD was at the expense of CON40 then these sums are additive. Although statistically insignificant a variable composed of those conifers excluded from CON40 (and planted pre-1920) was found to have very little effect upon house prices.

The inclusion of significant continuous focus variables in the hedonic price function permits the estimation of marginal implicit prices for these variables via differentiation (as per Bateman, 1993). This in turn allows the estimation of a demand function for either of the focus variables. Given the difficulties of examining an apparent 'bad' such as CON40, Garrod and Willis fit a demand curve for BROAD. Given the problems of a simultaneous determination of demand and supply for this characteristic, Garrod and Willis (1992b) assert that the market for BROAD should be treated as one of elastic supply arguing that "This derives from the fact that for a particular good, an individual household's demand would not normally affect the price function which clears the market" and that "this mean that the incorporation of the supply side variables into a simultaneous estimation system to estimate the demand parameters is unnecessary". Arguments concerning the correct specification of this second stage function have been fully rehearsed. The stance taken by Garrod and Willis runs directly contrary to that of Freeman (1979) who argues that an assumption of inelastic supply is more defensible. We however argue that the most thorough approach is that taken by Nelson (1978) and Jud and Watts (1981) who specify a simultaneous demand and supply system. However, we recognise that there is considerable debate regarding this point and that the Garrod and Willis approach is, at very least, defensibly feasible. Their general demand equation is therefore as given in (A1.23):

$$Z_a = Z_a\,(W_{Za}, SOC, SUB, COM) \qquad \text{(A1.23)}$$

where

$Z_a$ = demand for characteristic a
$W_{Za}$ = implicit price of characteristic a = $\delta P_h/\delta Z_a$
SOC = vector of local socioeconomic characteristics
SUB = vector of local substitute characteristics
COM = vector of local complementary characteristics

Although no functional form diagnostics are reported, a double log form is chosen to estimate (A1.23) with the reported results being given as per table A1.75.

Examining table A1.75 we can see that at 0.82, the income elasticity of demand for broadleaf woodland is marginally inelastic[76]. Garrod and Willis (1991b; 1992b) face two problems in interpreting these results. Firstly the exclusion of non-FC woodland means that an aggregate figure for the whole of Britain is not calculable. Secondly the absence of a 'without forestry' dataset makes the calculation of absolute amenity values problematic. The authors sidestep the latter problem with regard to broadleaves by constructing a scenario where an initially very low number of broadleaves (ie. virtually a greenfield site) is massively increased. General amenity values are examined by constructing scenarios in which CON40 conifers are replaced by non CON40 trees. Results for these comparative analyses are given as table A1.76.

Table A1.75: The demand for broadleaved woodland

| Independent variables | Coefficient | t-ratio |
|---|---|---|
| lnINCOME | 0.8197 | 9.47 |
| lnKIDS | 0.4687 | 4.90 |
| lnCON | -0.2763 | -10.45 |
| lnLARP | 0.2013 | 5.34 |
| lnMEAN AGE | 0.3214 | 2.89 |
| lnPRICE | -1.7600 | -17.07 |

$R^2$ = 0.3155
$R^2$ (adjusted) = 0.3114
n = 1031

Source: Garrod and Willis (1992b)

In an extension to this work Garrod and Willis (1992c) attempt to estimate the national aggregate amenity value of the FC estate. The FC has holdings across over 17,000 1 km OS grid squares, of these less than 900 are populated with a total of 156,226 households. In order to produce an aggregate value a simplifying assumption was made that the marginal price of each type of woodland could be multiplied by the percentage of FC forested land in each 1 km square taken up by that type of woodland in order to produce an estimate of its total value. This is a debateable assumption but one which, in the absence of any superior information, provides an acceptable approximation to amenity value[77]. The aggregation equation was therefore as given in equation (A1.24)[78];

$$\text{VALUE}_i = \text{H HOLDS}_i * [\{(\text{LARP20}_i * £20.33) + (\text{BROAD}_i * £49.22) - (\text{CON40}_i * £166.36)\} * (\text{FC AREA}_i/10000)] \quad \text{(A1.24)}$$

[76] However, it exceeds that for structural variables estimated as 0.60 for the same dataset (Nicholson & Willis, 1991).

[77] The authors have kindly supplied their individual 1 km amenity totals dataset for future further analysis.

[78] The slight variations in marginal price between equation (A1.24) and other studies (including Garrod and Willis, 1992c) are not explained.

where

| | | |
|---|---|---|
| $VALUE_i$ | = | total FC woodland amenity value in square i |
| $H\ HOLDS_i$ | = | number of households in square i |
| $LARP20_i$ | = | % of FC forested land under larch, Scots pine or Corsican pine in square i planted before 1920 |
| $BROAD_i$ | = | % of FC forested land under broadleaves in square i |
| $CON40_i$ | = | % of FC forested land under non-LARP conifers in square i planted before 1940 |
| $FC\ AREA_i$ | = | FC forested area in square i (ha's) |

Table A1.76: Amenity values for selected species changes[1]

| | | | | | |
|---|---|---|---|---|---|
| **Base Case: Sitka Spruce, yield class 16** | | | | | |
| | Wood | | | | |
| IRR (%)<br>NPV (£) | 6.6<br>705 | | | | |
| **Scenario 1: Broadleaved planting on greenfield site, oak, yield class 6** | | | | | |
| | Wood | Wood + a50 | Wood + a26 | Wood + a16 | Wood + a0 |
| IRR (%)<br>NPV (£) | 3.1<br>-537 | 4.4<br>-202 | 6.7<br>491 | 11.1<br>1222 | *<br>3118 |
| **Scenario 2: Corsican Pine, yield class 14, replaces Sitka Spruce** | | | | | |
| | Wood | Wood + a50 | Wood + a26 | Wood + a16 | Wood + a0 |
| IRR (%)<br>NPV (£) | 6.4<br>570 | 6.7<br>798 | -<br>- | -<br>- | -<br>- |
| **Scenario 3: Broadleaved, oak, yield class 6, replaces Sitka Spruce** | | | | | |
| | Wood | Wood + a50 | Wood + a26 | Wood + a16 | Wood + a0 |
| IRR (%)<br>NPV (£) | 3.1<br>-537 | 6.7<br>911 | 12.4<br>3910 | 22.8<br>7068 | *<br>15273 |

Notes: [1] 1988 prices.
Discount rate 3%: the rate sanctioned by H.M. Treasury (1991) and used by the Forestry Commission at the time of analysis (Major, 1989).
a0 = amenity value accruing immediately after initial planting
a16 = amenity value accruing 16 years after initial planting
a26 = amenity value accruing 26 years after initial planting
a50 = amenity value accruing 50 years after initial planting
* = not reported (probably not calculable due to instability)

Source: Garrod and Willis (1992b)

Summing over all households living in 1 km OS squares with some FC forested land produces an estimated total of FC amenity value of £353,323[79]. This figure can be criticised according to the weakness of the simplifying assumptions[80]. However, as an order of magnitude approximation the sum is defensible.

## A1.11.3: CONCLUSIONS

In conclusion, these studies are to be commended as a first attempt to tackle an important and difficult problem. However, specific criticisms are:

i. Potential for missing explanatory variables (eg. lot size, etc) to have affected regression coefficients, although tests suggest that this may not be a problem for focus variables;
ii. Lack of continuous variables in the hedonic price function of the initial study, preventing calculation of an implicit price and estimation of the characteristic demand function;
iii. Lack of species variables in the early study which, we believe, resulted in the contrary signs between the 'presence of woodland' and 'woodland view' variables;
iv. Assumption of elastic supply in the national study demand estimation. This is controversial although we recognise that opinion is divided;
v. Absence in the national study of non-FC woodland variables as well as certain views and neighbourhood variables used (and found significant) in the earlier study;
vi. The nature of the (simplistic) assumption underlying the analysis of aggregate FC amenity benefits. However, we recognise that this is an estimation of magnitudes and an alternative assumption is not apparent.

**Summary Results**

| | |
|---|---|
| Initial study: | Presence of 20%+ of woodland in household 1 km square raises house price by 7.1%. |
| National study: | 1% increase in broadleaves raises house price by £42.81<br>1% increase in conifers (excluding larch, Scots pine and Corsican pine) reduces house price by £141<br>1% increase in larch, Scots pine or Corsican pine increases house price by £20.33[81]. |
| Aggregation study: | total amenity value of FC land = £353,323. |

[79] The nature of this value is not made clear but we have to presume from the nature of HPM valuations that this is a capitalised sum. As such Garrod and Willis' (1992c) subsequent comparison of this with annual recreation benefits is invalid.

[80] For which this author is partly to blame.

[81] Result not significant at 10% confidence limit.

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**Note 1: Variables for initial inclusion in the regional model**

1.1 Focus Variables

FOR20 = 0-1 variable, over 20% woodland in kilometre square; RIVER = 0-1 variable, river or canal in kilometre square; SETT = 0-1 variable named settlement in kilometre square; WOODS = per cent land covered by woodland in kilometre square; WATER = per cent land covered by open water in kilometre square; ORCH = per cent land covered by orchards in kilometre square; PARK = per cent land covered by parkland or ornamental gardens in kilometre square; WET = 0-1 variable, wetlands in kilometre square; WVIEW = 0-1 variable, whether kilometre square commands an urban view; GRAD = predominant gradient slope in kilometre square; HEIGHT = average height above seal-level of kilometre square; WASPECT = 0-1 variable, predominant westerly aspect in kilometre square; SASPECT = 0-1 variable, predominantly southerly aspect in kilometre square; CABLE = 0-1 variable, overground cable in kilometre square.

1.2 Free Variables

ROOMS = number of bedrooms and reception rooms; BATHS = number of bathrooms; DET = 0-1 variable, detached house (greater than one storey); DETBUN = 0-1 variable, detached bungalow; SEMI = 0-1 variable, semi-detached house; TERR = 0-1 variable, terraced house; FLAT = 0-1 variable, flat; TENURE = 0-1 variable, freehold; DOUB = 0-1 variable, double garage; SING = 0-1 variable, single garage; SPAC = 0-1 variable, own parking space; FULLCH = 0-1 variable, full central heating; PARTCH = 0-1 variable, part central heating; FLOOR = total floor area (square metres); YEAR86 = property purchased in 1986; YEAR87 = property purchased in 1987; YEAR88 = property purchased in 1988; YEAR89 = property purchased in third quarter of year; LQTR = property purchased in fourth quarter of year; BMKT1 = 0-1 variable, property has sitting tenant; BMKT2 = 0-1 variable, property is council owned; BMKT5 = 0-1 variable, property is being built by mortgage applicant; BMKT8 = 0-1 variable, property requires improvements; BMKT11 = 0-1 variable, property under community leasehold; BMKT12 = 0-1 variable, property value under-estimated; BMKTRM = 0-1 variable, property sold below market value for other reasons.

1.3 Doubtful Variables

DIST1 = property in Northavon Local Authority District (LAD); DIST2 = property in North Wiltshire LAD; DIST3 = property in Thamesdown LAD; DIST4 = property in Cotswold LAD; DIST5 = property in Stroud LAD; DIST8 = property in Leominster LAD; DIST9 = property in South Herefordshire LAD; DIST10 = property in Malvern LAD; DIST11 = property in West Oxfordshire LAD; DIST12 = property in Vale of the White Horse LAD; DIST13 = property in Monmouth LAD; POPLN = population density of LAD; RETD = population over 60 years of age in LAD (%); PROF = population in professional or managerial positions in LAD (%); CARS = households with two or more cars in LAD (%); ROAD = kilometres of major road (B-roads and above) in kilometre square; RAIL = kilometres of rail track in kilometre square; UNEM = yearly proportion of workforce unemployed in LAD (%); AGRIC = yearly proportion of workforce in agriculture in LAD (%); SKILL = yearly proportion of workforce in skilled labour in LAD (%); KMSEC = kilometres from nearest secondary school; KMPRI = kilometres from nearest secondary school; KMPOST = kilometres from nearest post office; KMURB = kilometres from nearest town; POST = 0-1 variable, post office in kilometre square; PUB = 0-1 variable, pub in kilometre square; INDUST = 0-1 variable, major industrial facility in surrounding 3 square kilometres; GOLF = 0-1 variable, golf course in surrounding 3 square kilometres; CPNT = 0-1 variable, whether kilometre square contains National Trust or Country Park Land.

**Note 2: Variables for initial inclusion in the national model**

*Focus Variables*

| | | |
|---|---|---|
| BROAD | = | Percentage of Forestry Commission forested area in km square taken up by broadleaved woodland; |
| LARP20 | = | Percentage of Forestry Commission forested area in km square taken up by larch, Scots pine and Corsican pine planted before 1920; |

| | | |
|---|---|---|
| CON40 | = | Percentage of Forestry Commission forested area in km square taken up by conifers (excluding larch, Scots pine and Corsican pine) planted before 1940. |

*Free Variables*

| | | |
|---|---|---|
| ROOMS | = | number of bedrooms and reception rooms; |
| BATHS | = | number of bathrooms; |
| BPB | = | number of bedrooms per bathroom; |
| DETAT | = | 0-1 variable, detached house; |
| BUN | = | 0-1 variable, bungalow; |
| TERR | = | 0-1 variable, terraced house; |
| FLAT | = | 0-1 variable, flat; |
| TENURE | = | 0-1 variable, freehold; |
| GARAGE | = | 0-1 variable, garage; |
| SPACE | = | 0-1 variable, own parking space; |
| FULLCH | = | 0-1 variable, full central heating; |
| PARTCH | = | 0-1 variable, part central heating; |
| FLOOR | = | total floor area (square metres); |
| SQTR | = | 0-1 variable, property purchased in second quarter of year; |
| TQTR | = | 0-1 variable, property purchased in third quarter of year; |
| LQTR | = | 0-1 variable, property purchased in fourth quarter of year; |
| BMKT2 | = | 0-1 variable, property is council owned; |
| BMKT8 | = | 0-1 variable, property required improvements; |
| BMKTRM | = | 0-1 variable, property sold below market value for other reasons; |

*Doubtful Variables*

| | | |
|---|---|---|
| DIST4 | = | property in the East Anglian region of England; |
| DIST6 | = | property in Wales; |
| DIST7 | = | property in Scotland; |
| DIST10 | = | property in the East Midlands region of England; |
| DIST11 | = | property in the Outer Metropolitan region of Southern England; |
| DIST12 | = | property in the Northern region of England; |
| POPLN | = | population density of LAD; |
| RETD | = | population over 60 years of age in LAD (%); |
| PROF | = | population in professional or managerial positions in LAD (%); |
| 2CARS | = | households with two or more cars in LAD (%); |
| NOCAR | = | households with no cars in LAD (%); |
| UNEM | = | yearly proportion of workforce unemployed in LAD (%); |
| AGRIC | = | yearly proportion of workforce in agriculture in LAD (%). |

## A1.17: AN EXPERT APPRAISAL APPROACH TO THE VALUATION OF WOODLAND LANDSCAPE AMENITY

**Method:** Expert appraisal

**Evaluation unit:** per hectare values

**Commentary:**

The 'Helliwell system', developed by Rodney Helliwell through a series of papers spanning 25 years (Helliwell; 1967, 1969, 1978, 1990), proposes a unique approach to monetary evaluation based upon EIA-style expert assessment coupled with a monetary conversion factor. Helliwell isolates seven major woodland characteristic factors as follows:

| | |
|---|---|
| i | Size of woodland |
| ii | Position in landscape |
| iii | Viewing population |
| iv | Presence of other trees and woodland |
| v | Composition and structure of the woodland |
| vi | Compatibility in the landscape |
| vii | Special factors |

In assessing a particular woodland (or proposed woodland) the expert assessor considers each of the above factors in turn awarding them an integer mark on a scale from 0 to 4 points such that higher scores correspond to a higher quality of a particular characteristic. For example, regarding the size of woodland:

| | | | | |
|---|---|---|---|---|
| small | = | 0.1 to 0.5 ha | = | 1 point |
| medium | = | 0.5 to 2 ha | = | 2 points |
| large | = | 2 to 10 ha | = | 3 points |
| very large | = | 10 to 40 ha | = | 4 points |

Table A1.77 details the resulting matrix of factors and points scores. Further details are given in Helliwell (1990).

Under this system, woodland areas of less than 0.1 ha should be evaluated as single trees (for which Helliwell gives a different score matrix) and areas over 40 ha should be evaluated as more than one unit. The total woodland points score is then calculated by multiplying together all the points scores for all seven factors. This gives a score in points per hectare which can then be multiplied by woodland size. If a particular woodland is unacceptable in some way (eg. a highly rectangular composition) then it can be given a zero score for the relevant factor resulting in a zero total assessment score. Monetary evaluation is then achieved by multiplying the total assessment score by an agreed monetary conversion factor which currently stands at £25 per point (Helliwell, 1990).

Helliwell (1990) gives a variety of example assessments, one of which concerns an 8 ha Beech woodland clothing the top of a low hill ridge (pp.29-30). Details of the assessment and monetary evaluation are given in table A1.77.

Table A1.77: The Helliwell system: amenity factors and points score definitions

| Factor | Points | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| i. Size of woodland | very small | small | medium | large |
| ii. Position in landscape | secluded | average | prominent | very prominent |
| iii. Viewing position | few | average | many | very many |
| iv. Presence of other trees and woodland | area more than 25% wooded | area 5-25% wooded | area 1-5% wooded | area less than 1% wooded |
| v. Composition and structure of the woodland | dense plantation or blatantly derelict woodland | even-aged pole-stage crops with mixed species | semi-mature or uneven-aged woodland with fairly large trees | mature or uneven-aged woodland with large trees |
| vi. Compatibility | just acceptable | acceptable | good | excellent |
| vii. Special factors | none | one | two | three |

Source: Helliwell (1990).

Table A1.77: The Helliwell System: Example Assessment

| Factor | Assessment | Points Score |
|---|---|---|
| 1. Size | Large | 3.5 |
| 2. Position in landscape | Prominent | 3 |
| 3. Viewing population | Average | 2 |
| 4. Presence of other trees/woodland | 1-5% | 3 |
| 5. Composition and structure | Mature; uneven aged | 4 |
| 6. Landscape compatibility | Excellent | 4 |
| 7. Special factors | One (public access) | 2 |

Total score = 3.5 x 3 x 2 x 3 x 4 x 4 x 2 = 252 points/ha
Monetary evaluation = 252 x 25 = £6,300/ha

Source: Helliwell (1990)

The Helliwell assessment system derives from extensive personal knowledge and consultation with respected bodies and has been formerly adopted by the UK Arboricultural Association for the assessment of woodland amenity. The points score approach clearly has use in the comparative assessment of alternative woodland amenity options. However, Bateman (1992) notes that "this system cannot be classed as a true monetary evaluation method, since it makes no reference to individuals expressed or revealed preferences". The weak link in the Helliwell system, from the point of economic theory, is the determination of the monetary conversion factors. Helliwell (1990) states that this conversion factor should be "realistic and accepted as such by a wide spectrum of users" and continues to state that "After consultation within and outside the Arboricultural Association, a conversion factor of £10 is recommended for individual trees and £25 for woodlands, as at 1st January 1990". In effect the conversion factor is set so as to give results which seem intuitively reasonable. To some extent this gives credit to the points system in that if this did not ably reflect what assessors perceive as a reasonable ordering of projects then the consequent monetary values would themselves not seem reasonable.

However, the assessments of 'experts' may well be at variance with the valuations of individuals. A recent experiment which supports such a conclusion is given by Lee (1990) who surveyed both experts and individuals regarding their preferences for various forest landscape attributes. Non-expert members of the public strongly preferred 'diversity' and 'wilderness' factors. These results were quite strongly at variance with the preferences of 'experts' (particularly regarding diversity) and thereby undermine the central assumption of the Helliwell approach, viz, that expert evaluation corresponds to consumer evaluation. The Helliwell system bypasses the preferences of individuals and, in so doing, cannot be regarded as a theoretically valid system of monetary evaluation. As such, this approach is not pursued further in this study.

### References


Helliwell, D.R. (1990) *Amenity Valuation of Trees and Woodland*, Arboricultural Association, Romsey.
Helliwell, D.R. (1978) The assessment of landscape preferences, *Landscape Research*, 3(3):15-17.
Helliwell, D.R. (1969) Valuation of wildlife resources, *Regional Studies*, 3:41-47.
Helliwell, D.R. (1967) The amenity value of trees and woodlands, *Aboricultural Journal*, 1:128-131.


### Supplementary References


Bateman, I.J. (1992) The United Kingdom, in Jones, T. and Wibe, S. (eds) *Forestry: Market and Intervention Failure*, Earthscan, London.
Lee, T.R. (1990) Attitudes towards and preferences for forestry landscapes. *Report to the Forestry Commission Recreation Branch*, Forestry Commission, Edinburgh.

# Appendix 2: Details of Forest Research

## A2.1 INTRODUCTION

This appendix presents analysis details from the studies of woodland recreation summarised in chapter 4. Questionnaires used in our field work are also reproduced. Researchers who wish to use these questionnaires should seek permission from the author (although this will usually be given free of charge for bona-fide academic research).

## A2.2 THETFORD 1 STUDY

### A2.2.1: THETFORD FOREST CV/TC QUESTIONNAIRE

Questionnaire for Thetford Forest project

"I am [interviewer's name] from the University of East Anglia, and am carrying out a survey on recreational activities in Thetford Forest. Would it be possible to ask you a few questions? Information you provide will be anonymous and confidential, and used only for statistical purposes."

I. A. Where is your normal place of residence?

City/Town/Village
County

B. Where did you stay last night (if different from above)?

City/Town/Village
County

II. How many miles have you travelled to reach the forest today?

III. Which of these statements best describes you?

| | |
|---|---|
| I am on a part-day visit from home | 1 |
| I am on a day visit from home | 2 |
| I am staying away from home for a weekend | 3 |
| I am staying away from home for longer than a weekend | 4 |
| I am on a touring holiday | 5 |

IV. Is your trip today just to visit Thetford Forest? (Y/N)

If "No" then ask:

A. where else have you been/will you go? (Press for details)

B. Is it by chance that you arrived at Thetford Forest? (If "Yes", go to CV.)

V. What are the attractions of this site?

| | |
|---|---|
| Walks | 1 |
| Scenery | 2 |
| Beauty of trees | 3 |
| Observed wildlife | 4 |
| Peace and quiet | 5 |
| Picnic sites | 6 |
| Children's play area (Lynford Stag only) | 7 |
| Ease of access | 8 |
| Other (please specify) | 9 |

VI. A. Can you estimate how much of your enjoyment today (including the journey and any other visits made), is due to your time at Thetford Forest? Give your score out of 100%.

B. Do you rate your journey time as enjoyable? (Y/N)

If "Yes", give your score out of 100%.

VII. A. (For all interviewees): Are there any alternative locations, within reach on a day trip basis from your present place of residence, which you would judge to be as good as this one? (Y/N)

If "Yes", what would your alternative site(s) be?

VIII. A. (For holidaymakers only): From your permanent residence, what other similar attractions/facilities are you aware of?

IX. How did you travel to this site today?

| | |
|---|---|
| Car | 1 |
| Motorbike | 2 |
| Train + Other | 3 |
| Bus + Other | 4 |
| Cycle | 5 |
| Other (please specify) | 6 |

If by car/motorbike, what is the size of the engine? (If not known, state make and model.)

If not by car/motorbike, how much did your journey cost in fares?

X. How long did today's journey to this site take?

| | |
|---|---|
| 0-15 minutes | 1 |
| 16-30 minutes | 2 |
| 31-60 minutes | 3 |
| 1- 2 hours | 4 |
| 2- 3 hours | 5 |
| 3- 4 hours | 6 |
| Over 4 hours | 7 |

XI. Please could you give me some information about the people you are with, including yourself?

| Age group | Nº of people | |
|---|---|---|
| | Male | Female |
| 0- 4 | 1 | 10 |
| 5-11 | 2 | 11 |
| 12-15 | 3 | 12 |
| 16-25 | 4 | 13 |
| 25-35 | 5 | 14 |
| 36-45 | 6 | 15 |
| 46-55 | 7 | 16 |
| 56-65 | 8 | 17 |
| Over 65 | 9 | 18 |

XII. What are the occupations of the adults in your household?

XIII. Could you indicate which of the following categories your annual household income falls into?

| | |
|---|---|
| 0- 4,999 | 1 |
| 5,000- 7,499 | 2 |
| 7,500- 9,999 | 3 |
| 10,000-12,499 | 4 |
| 12,500-14,999 | 5 |
| 15,000-17,499 | 6 |
| 17,500-19,999 | 7 |
| 20,000-22,499 | 8 |
| 22,500-24,999 | 9 |
| 25,000-27,499 | 10 |
| 27,500-29,999 | 11 |
| 30,000-39,999 | 12 |
| 40,000+ | 13 |

XIV. How often, on average, do you visit

| | A. this site | B. the forest |
|---|---|---|
| Daily | 1 | 9 |
| At least twice a week | 2 | 10 |
| Weekly | 3 | 11 |
| Fortnightly | 4 | 12 |
| Monthly | 5 | 13 |
| Every three months | 6 | 14 |
| Yearly | 7 | 15 |
| First visit | 8 | 16 |

XV. How long do you intend to stay in the forest?

| | |
|---|---|
| Up to one hour | 1 |
| 1-2 hours | 2 |
| 2-3 hours | 3 |
| 3-4 hours | 4 |
| 4-5 hours | 5 |
| Over 5 hours | 6 |

XVI. Which of the following ways led you to visit this particular site?

| | |
|---|---|
| Previous visit | 1 |
| By-chance finding | 2 |
| Followed road markings | 3 |
| Saw it on Thetford Forest Park map | 4 |
| Found out about it through visitor centre at Brandon | 5 |
| Found out about it through visitor centre elsewhere | 6 |
| Saw an advertisement | 7 |
| Word of mouth through friend or relative | 8 |
| Other (please specify) | 9 |

XVII. Which other parts of the forest do you enjoy visiting?

* * *

*Contingent valuation questions:*

The purpose of this study is to estimate how much people value the recreational activities and opportunities provided by a natural environment.

Rather than asking for statements such as "valued" and "highly valued", I am attempting to find a monetary valuation of the forest. I would like to ask you a few questions about the amount of money you would be willing to pay, to safeguard the recreational activities at this site [Note: randomise interviewee's into following 4 versions of Q.18].

PER-VISIT EXPERIMENT: LOW-RANGE PAYMENT CARD VERSION

18. At present, this site is supported largely through taxes. Supposing that funding were not available to maintain this site in its present form, and the only way to fund such preservation were through an entrance fee, what would be the most you would be prepared to pay, per person per visit?

0 £0.50 £1.00 £1.50 £2.00 £2.50 £3.00 Other (specify)

If the amount you said earlier were not enough to safeguard this site, would you pay anything more? (Y/N)

If "Yes", what is the maximum additional amount (i.e. on top of the sum given in your previous answer) you would be prepared to pay before you would forgo the current level and quality of your recreation at this site?

PER-VISIT EXPERIMENT: HIGH-RANGE PAYMENT CARD VERSION

18. At present, this site is supported largely through taxes. Supposing that funding were not available to maintain this site in its present form, and the only way to fund such preservation were through an entrance fee, what would be the most you would be prepared to pay, per person per visit?

£2.00 £2.50 £3.00 £3.50 £4.00 £4.50 £5.00 Other (specify)

If the amount you said earlier were not enough to safeguard this site, would you pay anything more? (Y/N)

If "Yes", what is the maximum additional amount (i.e. on top of the sum given in your previous answer) you would be prepared to pay before you would forgo the current level and quality of your recreation at this site?

PER-ANNUM EXPERIMENT: TAX VEHICLE

18. At present, these sites are supported largely through taxes. The average amount each household pays each year towards ALL of the Forestry Commission land is £2.70 (6p of which is received by Thetford Forest). If the £2.70 were not enough to preserve the sites in their present condition:

a) Would you be willing to pay increased taxes to maintain them in this condition? (Y/N)

b) Given that any increase in taxes would be distributed amongst the total forested area, how much more per year in taxes would you be willing to pay?

If the amount you said earlier were not enough to safeguard these sites, would you pay anything more? (Y/N)

If "Yes", what is the maximum additional amount (i.e. on top of the sum given in your previous answer) you would be prepared to pay before you would forgo the current level and quality of recreation at these sites?

PER-ANNUM EXPERIMENT: POLLTAX VEHICLE

18. At present, these sites are supported largely through taxes. The average amount each household pays each year towards ALL of the Forestry Commission land is £2.70 (6p of which is received by Thetford Forest). If the £2.70 were not enough to preserve the sites in their present condition:

a) Would you be prepared to pay an increased Community Charge to maintain them in this condition, given that an increased charge would be directed solely towards Thetford Forest? (Y/N)
b) How much more per year would you be prepared to pay?

If the amount you said earlier were not enough to safeguard these sites, would you pay anything more? (Y/N)

If "Yes", what is the maximum additional amount (i.e. on top of the sum given in your previous answer) you would be prepared to pay before you would forgo the current level and quality of recreation at these sites?

THANK YOU FOR YOUR HELP

## A2.2.2: NORWICH CV QUESTIONNAIRE

Complementary questionnaire for project,
to be undertaken in Norwich

"I am [interviewer's name'], from the University of East Anglia, and am carrying out a survey on how people value their natural environment. I am particularly interested in perceptions of Thetford Forest. Would it be possible to ask you a few questions? Information you provide will be anonymous and confidential, and will only be used for statistical analysis."

1. Where is your normal place of residence?
   City/Town/Village
   County

Here is a map showing the relationship of Norwich to Thetford Forest. There is a distance of about 30 miles between the two.

2. a) Have you heard of this forest? (Y/N)

It is an area of 20,000 hectares, that's about three times bigger than Norwich, including suburbs. It belongs to the Forestry Commission, and is planted mainly with coniferous trees. (Show photos.)

The Commission encourages visitors to the forest, providing walks and picnic facilities, as well as more specialist recreational activities, such as cycling and orienteering.

I have here some photographs of a section of the forest, the arboretum, which has been planted with over a hundred different species of tree. This is another popular site for visitors.

b) Have you heard of the arboretum? (Y/N)

Also, here are some photographs of Lynford Stag, a visitors' site with facilities for picnicking and walking, or just relaxing.

c) Are you aware of this site? (Y/N)

3. How often, on average, do you visit the a) forest b) arboretum c) Lynford Stag

| | a) forest | b) arboretum | c) Lynford Stag |
|---|---|---|---|
| Daily | 1 | 10 | 19 |
| At least twice a week | 2 | 11 | 20 |
| Weekly | 3 | 12 | 21 |
| Fortnightly | 4 | 13 | 22 |
| Monthly | 5 | 14 | 23 |
| Every three months | 6 | 15 | 24 |
| Yearly | 7 | 16 | 25 |
| Other (please specify) | 8 | 17 | 26 |
| Never | 9 | 18 | 27 |

I would now like to ask you some questions on the arboretum and on Lynford Stag.

4. The arboretum and Lynford Stag have a number of attractions; which of the following would you particularly value?

| | the arboretum | Lynford Stag |
|---|---|---|
| Walks | 1 | 10 |
| Scenery | 2 | 11 |
| Beauty of trees | 3 | 12 |
| Wildlife habitats | 4 | 13 |
| Peace and quiet | 5 | 14 |
| Children's play area (Lynford Stag only) | 7 | 16 |
| Ease of access | 8 | 17 |
| Other (please specify) | 9 | 18 |

*Contingent valuation questions*

The purpose of this study is to estimate how much people value the recreational activities and opportunities provided by a natural environment.

Rather than asking for statements such as "valued" or "highly valued", I am attempting to find a monetary valuation of the forest. I would like to ask you a few questions about the amount of money you would be willing to pay to safeguard the recreational opportunities at the two sites outlined to you earlier [Note: randomise interviewee's into following 4 versions of Q.5].

PER-VISIT EXPERIMENT: LOW-RANGE PAYMENT CARD VERSION

5. At present, these sites are supported largely through taxes. Supposing that funding were not available to maintain these sites in their present form, and the only way to fund such preservation were through an entrance fee, what would be the most you would be prepared to pay, per person per visit?

0 £0.50 £1.00 £1.50 £2.00 £2.50 £3.00 Other (specify)

If the amount you said earlier were not enough to safeguard these sites, would you pay anything more? (Y/N)

If "Yes", what is the maximum additional amount (i.e. on top of the sum given in your previous answer), you would be prepared to pay before you would forgo the current level and quality of your recreation at these sites?

PER-VISIT EXPERIMENT: HIGH-RANGE PAYMENT CARD VERSION

5. At present, these sites are supported largely through taxes. Supposing that funding were not available to maintain these sites in their present form, and the only way to fund such preservation were through an entrance fee, what would be the most you would be prepared to pay, per person per visit?

£2.00 £2.50 £3.00 £3.50 £4.00 £4.50 £5.00 Other (specify)

If the amount you said earlier were not enough to safeguard these sites, would you pay anything more? (Y/N)

If "Yes", what is the maximum additional amount (i.e. on top of the sum given in your previous answer), you would be prepared to pay before you would forgo the current level and quality of your recreation at these sites?

PER-ANNUM EXPERIMENT: TAX VEHICLE

5. At present, these sites are supported largely through taxes. The average amount each household pays each year towards ALL of the Forestry Commission land is £2.70 (6p of which is received by Thetford Forest). If the £2.70 were not enough to preserve the sites in their present condition:

a) Would you be willing to pay increased taxes to maintain them in this condition? (Y/N)

b) Given that any increase in taxes would be distributed amongst the total forested area, how much more per year in taxes would you be willing to pay?

If the amount you said earlier were not enough to safeguard these sites, would you pay anything more? (Y/N)

If "Yes", what is the maximum additional amount (i.e. on top of the sum given in your previous answer) you would be prepared to pay before you would forgo the current level and quality of recreation at these sites?

PER-ANNUM EXPERIMENT: POLL-TAX VEHICLE

5. At present, these sites are supported largely through taxes. The average amount each household pays each year towards ALL of the Forestry Commission land is £2.70 (6p

of which is received by Thetford Forest). If the £2.70 were not enough to preserve the sites in their present condition:

a) Would you be prepared to pay an increased Community Charge to maintain them in this condition, given that an increased charge would be directed solely towards Thetford Forest? (Y/N)

b) How much more per year would you be prepared to pay?

If the amount you said earlier were not enough to safeguard these sites, would you pay anything more? (Y/N)

If "Yes", what is the maximum additional amount (i.e. on top of the sum given in your previous answer) you would be prepared to pay before you would forgo the current level and quality of recreation at these sites?

6. It has been found in studies of this kind that people have a lot of different reasons for answering as they do.

Which of these reasons best describes why you answered the way you did?

| | |
|---|---|
| Not enough information | 1 |
| Did not want to place a monetary value | 2 |
| Objected to the way the question was presented | 3 |
| That is what it is worth | 4 |
| Other (please specify) | 5 |

Finally I should like to ask you a couple of questions regarding your household. This is merely to ensure that we have interviewed a representative cross-section of people. The information gathered will only be used for statistical purposes.

7. What are the occupations of the adults in your household?

8. Could you indicate which of the following categories your annual household income falls into?

| | |
|---|---|
| 0- 4,999 | 1 |
| 5,000- 7,499 | 2 |
| 7,500- 9,999 | 3 |
| 10,000-12,499 | 4 |
| 12,500-14,999 | 5 |
| 15,000-17,499 | 6 |
| 17,500-19,999 | 7 |
| 20,000-22,499 | 8 |
| 22,500-24,999 | 9 |
| 25,000-27,499 | 10 |
| 27,500-29,999 | 11 |
| 30,000-39,999 | 12 |
| 40,000+ | 13 |

Thank you for your time. The results of this survey are for research purposes only, and do not reflect the Forestry Commission's intentions.

End of questionnaire.

* * *

## A2.2.3: ITC STUDY: DETAILS OF ANALYSIS

Defining the variables

Table A2.1 gives details of the base-data variables elicited from the on-site survey of visitors to Thetford Forest.

Table A2.1: Definition of explanatory variables

| Column | Name | Description |
|---|---|---|
| c1 | DISTRAV | Return journey distance (continuous) |
| c2 | DISCAT | 1-7; distance categories (miles) 0-10, 10-20, 21-40, 41-60, 61-80, 81-100, 101+ |
| c3 | MODETRAV | 1-6 |
| c4 | ENGSIZE | cubic capacity (continuous) |
| c5 | JOYTRIP% | % of enjoyment due to journey |
| c6 | TIMESITE | Time on site (minutes) (continuous) |
| c7 | TIMEJOR | Journey time (minutes) (continuous) |
| c8 | EMPLOY | 1 = employed 0 = unemployed |
| c9 | INCOME | continuous |
| c10 | VISFORPA | Visits (days pa) (continuous) |
| c11 | NAT/ART | Dummy variable; whether respondent prefers natural or man-made recreation facilities |
| c12 | PENSION | 1 = Pensioner age 0 = otherwise |
| c13 | AGE | 1, 2, 3. 18-35, 35-60, 60+ |
| c14 | SEX | 1 = Male 0 = Female |
| c15 | NUMPARTY | Number in party |
| c19 | ALTERNTV | Alternative site stated: 1 = yes 0 = no |
| c50 | LNDISTRV | ln c1 (ln distance travelled) |
| c51 | CAR/OTH | 1 = car 0 = other |
| c52 | WALK/OTH | 1 = walk 0 = other |
| c53 | OTH/WALK | 0 = walk 1 = other |
| c54 | LNJORTIM | ln c7 (ln journey time) |
| c55 | JOBTYPE | 0 = Includes unemployed, armed forces,unskilled 1 = other |
| c57 | LNINCOME | ln c9 (ln income) |
| c59 | LNVISFOR | ln c10 (ln forest visits pa) (continuous) |
| c60 | CATVISFR | Visits to forest pa (category variable 1-8) |
| c100 | WEEKINC | Weekly income in pounds |
| c101 | HOURINC | Hourly income in pence |
| c102 | JORHOUR | Journey time in hours |

Note: Column number (prefixed by lower case letter "c") refers to database identifier column.

Table A2.2: Defining the dependent variable: zero order correlation matrix

| Cost Variable[1] | LNVISFOR | VISFORPA |
|---|---|---|
| INCOME | 0.386 | 0.354 |
| LNINCOME | 0.378 | 0.330 |
| TRCPET | -0.587 | -0.383 |
| LNTRCPET | -0.650 | -0.564 |
| TRCPERC | -0.587 | -0.383 |
| LNTRCPER | -0.650 | -0.564 |
| TRCFULL | -0.587 | -0.383 |
| LNTRCFUL | -0.650 | -0.564 |
| WALK0c61 | -0.593 | -0.385 |
| LNc71 | -0.609 | -0.587 |
| WALK0c63 | -0.593 | -0.385 |
| LNc73 | -0.592 | -0.593 |
| WALK0c65 | -0.593 | -0.385 |
| LNc75 | -0.585 | -0.594 |
| c61+c103 | -0.411 | -0.231 |
| c63+c103 | -0.523 | -0.322 |
| c65+c103 | -0.545 | -0.341 |
| c61+c104 | -0.507 | -0.308 |
| c63+c104 | -0.563 | -0.358 |
| c65+c104 | -0.571 | -0.366 |
| LNc110 | -0.498 | -0.330 |
| LNc111 | -0.575 | -0.417 |
| LNc112 | -0.594 | -0.443 |
| LNc113 | -0.562 | -0.400 |
| LNc114 | -0.612 | -0.473 |
| LNc115 | -0.623 | -0.492 |
| c71+c103 | -0.419 | -0.235 |
| c73+c103 | -0.532 | -0.327 |
| c75+c103 | -0.553 | -0.345 |
| c71+c104 | -0.516 | -0.313 |
| c73+c104 | -0.570 | -0.361 |
| c75+c104 | -0.578 | -0.369 |
| LNc130 | -0.507 | -0.339 |
| LNc131 | -0.588 | -0.433 |
| LNc132 | -0.606 | -0.462 |
| LNc133 | -0.575 | -0.416 |
| LNc134 | -0.623 | -0.495 |
| LNc135 | -0.631 | -0.515 |

Note: 1. Full definitions of the cost variables are given in table A2.5.

Initial investigations analysed the correct definition of the dependent variable (the individual's number of visits to the site per annum). In particular we wished to select a dependent variable which was best correlated with the explanatory variables shown in table A2.1. Table A2.2 gives a correlation matrix relating these explanatory variables to both a linear and log-linear dependent variable (VISFORPA and LNVISFOR respectively).

The zero order correlation matrix (table A2.2) suggests that a log dependent variable might be most appropriate. This was tested by comparing trip generation functions for a linear and log dependent variable regressed against a measure of cost (all the different measures of cost are highly collinear so the choice of which to use did not matter for this particular analysis). Table A2.3 reports the linear dependent variable model, while the log dependent tgf is reported as table A2.4.

Table A2.3: Single variable trip generation function: Linear dependent variable

Dependent variable = VISFORPA

| Predictor | Coef | Stdev | t-ratio | p |
|---|---|---|---|---|
| Constant | 78.36 | 10.88 | 7.20 | 0.000 |
| TRCPET | -0.12285 | 0.02628 | -4.67 | 0.000 |

s = 78.07   $R^2$ = 14.7%   $R^2$ (adj) = 14.0%

where:

VISFORPA = individuals visits to the forest per annum (continuous).
TRCPET = travel cost, petrol only (8p/mile)

Table A2.4: Single variable trip generation function: Log-linear dependent variable

Dependent variable = LNVISFOR

| Predictor | Coef | Stdev | t-ratio | p |
|---|---|---|---|---|
| Constant | 3.3208 | 0.2092 | 15.88 | 0.000 |
| TRCPET | -0.0041279 | 0.0005051 | -8.17 | 0.000 |

s = 1.500   $R^2$ = 34.5%   $R^2$(adj) = 33.9%

The log-dependent variable model (table A2.4) clearly performs significantly better than its linear counterpart (table A2.3) and was adopted for further investigation. A series of single variable tgf's were then estimated to examine the best specification for the cost variable. Table A2.5 details full results from these analyses. Many cost definitions produce very similar (or identical) level of explanation. As discussed in chapter 2, this poses a serious problem for the TC modeller in that alternate cost specifications lead to considerable variation in subsequent consumer surplus estimates. We see this as one of the major methodological problems of TC and highlight this again in our subsequent Thetford 2 study.

Table A2.5: Single parameter models; dependent variable = lnvisfor (c59)
All costs unadjusted for enjoyment of journey and expressed in pence.

| Col. | Name | Description | Coef | t-ratio | Model $R^2$ (adj) % |
|---|---|---|---|---|---|
| c61 | TRCPET | Travel cost, petrol only 8p/mile | -0.0041279 | -8.17 | 33.9 |
| c62 | LNTRCPET | ln c61 | -0.0059 | -9.63 | 41.8[1] |
| c63 | TRCPERC | Travel cost, perceived cost at 23p/mile | -0.0014358 | -8.17 | 33.9 |
| c64 | LNTRCPER | ln c63 | -1.0059 | -9.63 | 41.8[1] |
| c65 | TRCFULL | Travel cost, full cost @ 33p/mile | -0.0010007 | -8.17 | 33.9 |
| c66 | LNTRCFUL | ln c65 | -1.0059 | -9.63 | 41.8[1] |
| c71 | WALK0c61 | 8p/mile; walkers @ 0p | -0.0041106 | -8.30 | 34.6 |
| c72 | LNc71 | ln 8p/mile (added 1p on); walkers @ 0p | -0.64010 | -8.65 | 36.6 |
| c73 | WALK0c63 | 23p/mile; walkers @ 0p | -0.0014298 | -8.30 | 34.6 |
| c74 | LNc73 | ln 23p/mile; walkers @ 0p | -0.54567 | -8.28 | 34.5 |
| c75 | WALK0c65 | 33p/mile; walkers @ 0p | -0.0009965 | -8.30 | 34.6 |
| c76 | LNc75 | ln 33p/mile; walkers @ 0p | -0.51834 | -8.16 | 33.9 |
| c103 | TTCFULL | Travel time cost @ full wage rate (c102* c101) | -0.0008768 | -1.67 | 1.4 |
| c104 | TTC43% | Travel time cost @ 43% wage rate (c102* c101* 0.43) | -0.002039 | -1.67 | 1.4 |
| c110 | c61+c103 | 8p/mile + full time cost (A1) | -0.0015621 | -5.07 | 16.2 |
| c111 | c63+c103 | 23p/mile + full time cost (A2) | -0.0010354 | -6.92 | 26.8 |
| c112 | c65+c103 | 33p/mile + full time cost (A3) | -0.0008041 | -7.32 | 29.1 |
| c113 | c61+c104 | 8p/mile + 43% wage time cost (B1) | -0.0027317 | -6.62 | 25.1 |
| c114 | c63+c104 | 23p/mile + 43% wage time cost (B2) | -0.0012634 | -7.67 | 31.1 |
| c115 | c65+c104 | 33p/mile + 43% wage time cost (B3) | -0.0009181 | -7.83 | 32.1 |
| c116 | LNc110 | ln A1 (above) | -1.0622 | -6.47 | 24.2 |
| c117 | LNc111 | ln A2 (above) | -1.1445 | -7.92 | 32.5 |
| c118 | LNc112 | ln A3 (above) | -1.1448 | -8.31 | 34.7 |
| c119 | LNc113 | ln B1 (above) | -1.1385 | -7.66 | 31.1 |
| c120 | LNc114 | ln B2 (above) | -1.1314 | -8.73 | 37.0 |
| c121 | LNc115 | ln B3 (above) | -1.1157 | -8.97 | 38.3 |
| c130 | c71+c103 | 8p (0 walkers) + full time cost (C1) | -0.0015945 | -5.19 | 16.9 |
| c131 | c73+c103 | 23p (0 walkers) + full time cost (C2) | -0.0010469 | -7.08 | 27.7 |
| c132 | c75+c103 | 33p (0 walkers) + full time cost (C3) | -0.0008101 | -7.47 | 30.0 |
| c133 | c71+c104 | 8p (0 walkers) + 43% wage time cost (D1) | -0.0027686 | -6.78 | 26.0 |
| c134 | c73+c104 | 23p (0 walkers) + 43% wage time cost (D2) | -0.0012679 | -7.82 | 32.0 |
| c135 | c75+c104 | 33p (0 walkers) + 43% wage time cost (D3) | -0.0009193 | -7.98 | 32.9 |
| c136 | LNc130 | ln C1 (above) | -1.0764 | -6.64 | 25.2 |
| c137 | LNc131 | ln C2 (above) | -1.1390 | -8.19 | 34.0 |
| c138 | LNc132 | ln C3 (above) | -1.1231 | -8.59 | 36.2 |
| c139 | LNc133 | ln D1 (above) | -1.1401 | -7.92 | 32.5 |
| c140 | LNc134 | ln D2 (above) | -1.0805 | -8.98 | 38.3 |
| c141 | LNc135 | ln D3 (above) | -1.0383 | -9.16 | 39.3[2] |

Notes : 1. Best fitting assumption
2. Second best assumption
Sample size for all models = 129

Three definitions of cost: c62 (LNTRCPET); c64 (LNTRCPER); and c66 (LNTRCFUL) all perform equally well in explaining visits. Of these c66 (LNTRCFUL) is preferred because this is the full cost (travel) assumption corresponding to the slight dominance of c141 (LNc135) over its group of comparable models in table A2.5. Full details of the single variable tgf using LNTRCFUL are given in table A2.6.

Table A2.6: Best fitting single variable trip generation function

Dependent variable = LNVISFOR

| Predictor | Coef | Stdev | t-ratio | p |
|---|---|---|---|---|
| Constant | 8.7487 | 0.7121 | 12.29 | 0.000 |
| LNTRCFUL | -1.0059 | 0.1044 | -9.63 | 0.000 |

s = 1.409   $R^2$ = 42.2%   $R^2$(adj) = 41.8%   N = 129

All the costs given in table A2.5 were then adjusted for individuals evaluations of the importance of their visit to Thetford Forest proportional to their entire day's enjoyment. Table A2.7 details the single variable tgf's estimated in this analysis. Generally these adjusted cost definitions did not fit the data as well as the unadjusted cost variables and the latter were used for further analysis. While this results in the strongest statistical model, such an approach can be criticised as liable to lead to an overestimate of consumer surplus due to the site under investigation. Although, in this case we have reason to believe that any resultant error was small (a significant majority of visitors were only visiting Thetford during the day they were interviewed), we subsequently felt that this was not best practice and adjusted costs were used in our later Thetford 2 ITC experiment.

Regression analysis

Using LNTRCFUL as our cost variable and relabelling it as LNCOST for simplicity, a stepwise regression analysis was undertaken to identify other explanatory variables which were initially defined in linear form. Setting F = 4.0 (i.e. 5% significance level) as the test value for entering the model only one other explanatory variable, INCOME, was identified. This did not appear unusual as it strongly echoed the findings of Willis and Benson (1988, 1989) who report two variable best-fit models (being visit cost and a socioeconomic variable) in their studies of nature reserves and woodland. Furthermore as LNTRCFUL has zero time cost rather than some positive percentage of wage rates, there is no collinearity problem in also including an income variable in the tgf. Table A2.8 details results from the stepwise analysis.

Table A2.7: Single parameter models; dependent variable = lnvisfor (c59)
All costs adjusted for enjoyment of journey (c150) and expressed in pence.

| Col. | Name | Description | Coef | t-ratio | Model $R^2$ (adj) % |
|---|---|---|---|---|---|
| c301 | TRCPET (adj) | Travel cost, petrol only 8p/mile [adjusted] | -0.0044550 | 7.96 | 32.9 |
| c302 | LNTRCPET (adj) | ln c301 [adjusted] | -0.70373 | 7.50 | 30.3 |
| c303 | TRCPERC (adj) | Travel cost, perceived cost at 23p/mile [adjusted] | -0.0015496 | 7.96 | 32.9 |
| c304 | LNTRCPER (adj) | ln c63 (adjusted) | -0.60029 | 7.01 | 27.5 |
| c305 | TRCFULL (adj) | Travel cost, full cost @ 33p/mile [adjusted] | -0.0010800 | 7.96 | 32.9 |
| c306 | LNTRCFUL (adj) | ln c65 (adjusted) | -0.56953 | 6.86 | 26.6 |
| c307 | WALK0c61 (adj) | 8p/mile walkers @ 0p (adjusted) | -0.0044295 | 8.00 | 33.2 |
| c308 | LNc71 (adj) | ln 8p/mile (added 1p on) [adjusted] | -0.59053 | 7.37 | 29.6 |
| c309 | WALK0c63 (adj) | 23p/mile walkers @ 0p (adjusted) | -0.0015407 | 8.00 | 33.2 |
| c310 | LNc73 (adj) | ln 23p/mile walkers @ 0p (adjusted) | -0.49382 | 7.00 | 27.5 |
| c311 | WALK0c65 (adj) | 33p/mile walkers @ 0p (adjusted) | -0.0010738 | 8.00 | 33.2 |
| c312 | LNc75 (adj) | ln 33p/mile walkers@ 0p (adjusted) | -0.46662 | 6.89 | 26.8 |
| c313 | TTCFULL (adj) | Travel time cost @ full wage rate (c102* c101) [adjusted] | -0.0018637 | 3.09 | 6.3 |
| c314 | TTC43% (adj) | Travel time cost @ 43% wage rate (c102* c101* 0.43) [adjusted] | -0.004334 | 3.09 | 6.3 |
| c315 | c61+c103 (adj) | 8p/mile + full time cost (A1) [adjusted] | -0.0019496 | 5.96 | 21.4 |
| c316 | c63+c103 (adj) | 23p/mile + full time cost (A2) [adjusted] | -0.0011569 | 7.23 | 28.8 |
| c317 | c65+c103 (adj) | 33p/mile + full time cost (A3) [adjusted] | -0.0008850 | 7.48 | 30.2 |
| c318 | c61+c104 (adj) | 8p/mile + 43% wage time cost (B1) [adjusted] | -0.0030931 | 7.04 | 27.7 |
| c319 | c63+c104 (adj) | 23p/mile + 43% wage time cost (B2) [adjusted] | -0.0013759 | 7.69 | 31.4 |
| c320 | c65+c104 (adj) | 33p/mile + 43% wage time cost (B3) [adjusted] | -0.0009959 | 7.78 | 31.9 |
| c321 | LNc110 (adj) | ln A1 (above) [adjusted] | -0.6007 | 5.93 | 21.2 |
| c322 | LNc111 (adj) | ln A2 (above) [adjusted] | -0.56249 | 6.19 | 22.7 |
| c323 | LNc112 (adj) | ln A3 (above) [adjusted] | -0.54346 | 6.22 | 22.9 |
| c324 | LNc113 (adj) | ln B1 (above) [adjusted] | 0.6575 | 6.48 | 24.4 |
| c325 | LNc114 (adj) | ln B2 (above) [adjusted] | -0.58584 | 6.54 | 24.8 |
| c326 | LNc115 (adj) | ln B3 (above) [adjusted] | -0.55977 | 6.51 | 24.6 |
| c327 | c71+c103 (adj) | 8p (0 walkers) + full time cost (C1) [adjusted] | -0.0019624 | 6.02 | 21.7 |
| c328 | c73+c103 (adj) | 23p (0 walkers) + full time cost (C2) [adjusted] | -0.0011588 | 7.30 | 29.2 |
| c329 | c75+c103 (adj) | 33p (0 walkers) + full time cost (C3) [adjusted] | -0.0008849 | 7.54 | 30.6 |
| c330 | c71+c104 (adj) | 8p (0 walkers) + 43% wage time cost (D1) [adjusted] | -0.0031017 | 7.11 | 28.1 |
| c331 | c73+c104 (adj) | 23p (0 walkers) + 43% wage time cost (D2) [adjusted] | -0.0013731 | 7.74 | 31.7 |
| c332 | c75+c104 (adj) | 33p (0 walkers) + 43% wage time cost (D3) [adjusted] | -0.0009928 | 7.83 | 32.2 |
| c333 | LNc130 (adj) | ln C1 (above) [adjusted] | -0.6008 | 5.97 | 21.4 |
| c334 | LNc131 (adj) | ln C2 (above) [adjusted] | -0.56114 | 6.25 | 23.1 |
| c335 | LNc132 (adj) | ln C3 (above) [adjusted] | -0.54135 | 6.30 | 23.4 |
| c336 | LNc133(adj) | ln D1 (above) [adjusted] | -0.6556 | 6.54 | 24.8 |
| c337 | LNc134 (adj) | ln D2 (above) [adjusted] | -0.58033 | 6.64 | 25.3 |
| c338 | LNc135 (adj) | ln D3 (above) [adjusted] | 0.55286 | 6.63 | 25.3 |

Table A2.8: Stepwise regression of LNVISFOR on LNCOST and various linear socioeconomic variables

| Step | 1 | 2 |
|---|---|---|
| Constant | 9.110 | 8.010 |
| LNCOST<br>t-ratio | -1.06<br>-9.76 | -0.98<br>-8.70 |
| INCOME<br>t-ratio | | 0.00005<br>2.13 |
| S<br>$R^2$ | 1.36<br>44.90% | 1.34<br>46.99% |

where:

LNVISFOR = natural log number of visits to forest per annum
LNCOST = natural log of travel cost at full cost (33p/mile) rate and zero time cost (LNTRCFUL in previous tables)
INCOME = Respondent's annual income (pence)
Sample size = 129 of which 10 had missing observations.

Appropriate functional form was determined by re-running the stepwise across both linear and log-linear definitions of our explanatory variables to produce the tgf detailed in table A2.9.

Table A2.9: Stepwise regression of LNVISFOR on LNCOST and various linear and log-linear socioeconomic variables

| Step | 1 | 2 |
|---|---|---|
| Constant | 9.3303 | 0.6271 |
| LNCOST<br>t-ratio | -1.07<br>-9.31 | -1.00<br>-8.68 |
| LNINCOME<br>t-ratio | | 0.89<br>3.00 |
| S<br>$R^2$ | 1.39<br>42.54% | 1.35<br>46.67% |

where:

LNINCOME = Natural log of respondents annual income (pence)
Sample size = 129 of which 10 had missing observations.

The model detailed in table A2.9 is comparable with that of table A2.8 as both use the same dependent variable. $R^2$ is virtually identical as is the t-ratio on the respective cost variables. However, the significance of the income variable in table A2.9 (selected by the stepwise regression procedure to be the natural log variable LNINCOME) is considerably higher than previous. The model given in table A2.9 also has the theoretical advantage of not mixing log and linear explanatory variables when both are money measures. We therefore prefer the above model and report the full regression equation as table A2.10. This shows that the cost variable is by far the strongest predictor of visits, but that the income variable is also significant. The overall degree of explanation is very satisfactory, considerably exceeding those for the Willis and Garrod (1991) tgf's[1] and exceeding that of all but two of the 22 OLS tgf's reported by Smith and Desvousges (1986) in their studies of water based recreation in the US.

Table A2.10: Best fit trip generation function

Dependent variable = LNVISFOR

| Predictor | Coef | Stdev | t-ratio | p |
|---|---|---|---|---|
| Constant | -5.548 | 4.252 | -1.30 | 0.194 |
| LNCOST | -0.9422 | 0.1121 | -8.41 | 0.000 |
| LNINCOME | 1.0135 | 0.2899 | 3.50 | 0.001 |

s = 1.378 $R^2$ = 45.1% $R^2$(adj) = 44.2% n = 129

Analysis of variance

| SOURCE | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Regression | 2 | 196.778 | 98.389 | 51.78 | 0.000 |
| Error | 126 | 239.432 | 1.900 | | |
| Total | 128 | 436.210 | | | |

| SOURCE | DF | SEQ SS |
|---|---|---|
| LNCOST | 1 | 173.548 |
| LNINCOME | 1 | 23.230 |

Note: All explanatory variables are defined in pence.

Our zero time cost definition of trip costs obviated any multicollinearity problems with our best-fit tgf which also did not reveal any significant outlier effects. Accordingly this model was used for calculating consumer surplus estimates.

Calculating consumer surplus

Here, for brevity we shall label our dependent variable (LNVISFOR) as lnQ; the cost variable (LNCOST) as lnC; and the income variable (LNINCOME) as lnY.

In order to integrate the tgf given in table A2.10 we need to rearrange to have C as a function of Q and Y so as to allow an integration of C with respect to Q. This integration function is given as table A2.11.

[1] pers comm. Guy Garrod (see appendix 1).

Table A2.11: Best-fit (double-log) integration function

Dependent variable = lnC

| Predictor | Coef | Stdev | t-ratio | p |
|---|---|---|---|---|
| Constant | 10.046 | 2.492 | 4.03 | 0.000 |
| lnQ | -0.33022 | 0.04366 | -7.56 | 0.000 |
| lnY | -0.1817 | 0.1830 | -0.99 | 0.323 |

s = 0.8151 $R^2$ = 38.3% $R^2$(adj) = 37.3% n = 126

In order to integrate the equation given in table A2.11 a mean value for Y is needed. Means for this and other relevant variables are given in table A2.12. Values for Y and C are given in pence (to minimise rounding errors and problems with logarithms), while Q is expressed in visits per annum. Descriptive statistics regarding the party size (PARTY) are also included to allow subsequent conversion of consumer surplus from a per party to a per individual basis.

Table A2.12: Descriptive statistics for tgf variables

| Var. | n | mean | med. | st dev | se mean | min | max | Q1 | Q3 |
|---|---|---|---|---|---|---|---|---|---|
| Q | 126 | 36.33 | 4.00 | 79.98 | 7.13 | 1.00 | 365.00 | 1.00 | 26.00 |
| C | 126 | 1474 | 1133 | 1154 | 103 | 62 | 6416 | 552 | 2185 |
| Y | 126 | 1084325 | 875000 | 528401 | 47074 | 500000 | 2125000 | 625000 | 1125000 |
| PARTY | 126 | 3.143 | 3.00 | 1.396 | 0.124 | 1.00 | 7.00 | 2.00 | 4.00 |

We can rewrite the equation given in A2.11 in straight line notation as:

$$\ln C = a + b \ln Q + c \ln Y$$

Note that, strictly speaking, the double-log form implies an infinite consumer surplus as infinite visits are predicted at zero costs. Therefore we integrate the function from C = 1p. This is defensible as the lowest observed value of C is 62p. From tables A2.11 and A2.12 we observe the following values:

$a = 10.046$

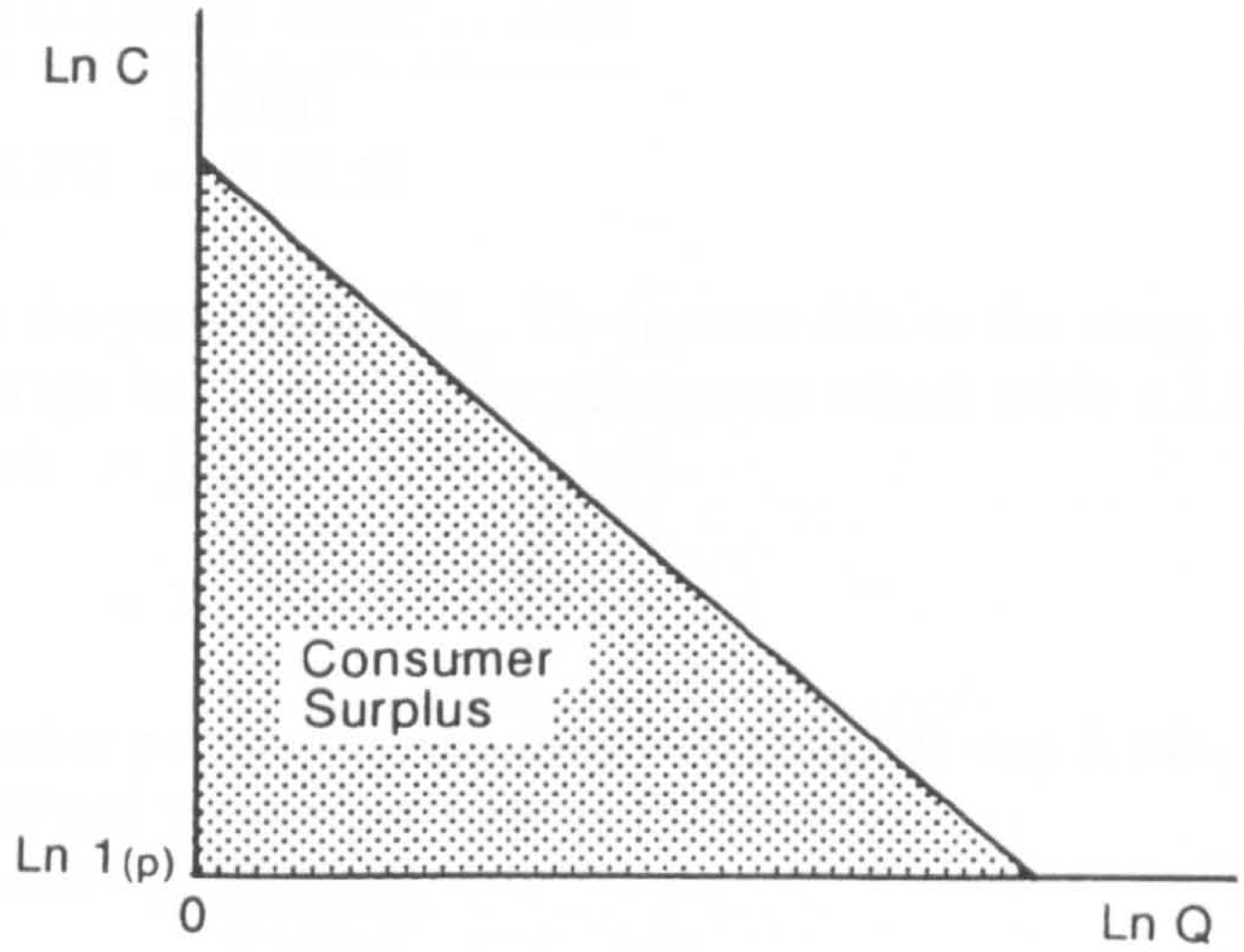
$b = -0.33022$

$c = -0.1817$

mean $Y = 1084325$

The integration of our rewritten equation can be illustrated as finding the area of the shaded triangle in figure A2.1.

Figure A2.1: Diagrammatic representation of the integration problem: double-log tgf




Therefore from our rearranged function, when lnQ = 0 we have:

$$\ln C = a + c \ln Y$$

$$\therefore C = \frac{e^{a + c \ln Y}}{100}$$

Note that the denominator in the above allows us the convert from pence (used in the best fit model) to pounds. Similarly, when lnC = 0

$$\therefore \quad 0 = a + b \ln Q + c \ln Y$$

$$b \ln Q = -(a + c \ln Y)$$

$$\ln Q = -\frac{(a + c \ln Y)}{b}$$

$$\therefore \quad Q = \frac{e^{(a + c \ln Y)}}{(100).\, e^{-b}}$$

$$= [e^{(a + c \ln Y)} . e^{b}]\,(100)$$

$$= \frac{e^{(a + c \ln Y + b)}}{100}$$

As previously, the use of the denominator in the above allows us to convert from pence to pounds. We now have the two points where the function cuts the axes in figure A2.1, therefore the area of the shaded triangle (which is the party total consumer surplus per annum; $CS_{pa}$) is given by:

$$CS_{pa} = \frac{1}{2} . \frac{e^{(a + c \ln Y + b)} . e^{(a + c \ln Y)}}{(100*100)}$$

$$= \frac{1}{2} . \frac{e^{2(a + c \ln Y) + b}}{10000}$$

$$= \frac{e^{2(a + c \ln Y) + b}}{2.10^{4}}$$

$$= \frac{e^{2(a + c \ln Y) + b}}{20{,}000}$$

Substituting in our coefficient values and holding the value of Y at its mean gives us:

$$CS_{pa} = \frac{e^{2(10.046 + (-0.1817[\ln 1084325])) + (-0.33022)}}{20{,}000}$$
$$= 122.5251 \quad = £122.53$$

This gives us the party total $CS_{pa}$. To convert this to the mean CS per party per visit we divide by the average number of visits per annum which table A2.12 shows to be 36.33.

$$\therefore \text{ mean CS/party/visit} = \frac{122.5251}{36.33}$$
$$= 3.3725599 \quad = £3.37$$

The mean number per party (excluding two outliers) was 3.143, therefore we can also calculate the mean CS per person per visit as follows:

$$\therefore \text{ mean CS/person/visit} = \frac{3.3725599}{3.143}$$
$$= 1.0730385 \quad = £1.07$$

The above calculation makes no distinction between adults and children. In the Thetford 1 study we did not collect information regarding the structure of parties (an omission corrected in the Thetford 2 study). Therefore the following analysis was conducted using such data collected in Bateman et al. (1992) which found the average party to consist of 2.8 adults and 0.7 children. Therefore if we treat one child visitor as the equivalent of 0.5 adult visitors, then this increases mean CS/person/visit to £1.19. Similarly if we omit children the mean CS/person/visit increases to £1.34.

The impact of changing functional form

The sensitivity of consumer surplus estimates to changes in functional form was examined.

*Semi-log (dependent) functional form*

A semi-log (dependent) tgf for the total sample is given in table A2.13.

Table A2.13: Semi-log (dependent) trip generation function: full sample model

Dependent variable = LNVISFOR

| Predictor | Coef | Stdev | t-ratio | p |
|---|---|---|---|---|
| Constant | 2.1791 | 0.3689 | 5.91 | 0.000 |
| COST | -0.0008195 | 0.0001131 | -7.25 | 0.000 |
| INCOME | 0.00000092 | 0.00000025 | 3.70 | 0.000 |

$R^2$ = 39.9%  $R^2$ (adj) = 39.0%  n = 129

where:

COST = variable (c75+c104) as defined in table A2.2

COST and INCOME are defined in pence.

Six high leverage observations were identified in table A2.13 and omitted to produce the tgf given in table A2.14

Table A2.14: Semi-log (dependent) trip generation function: omitting outliers

Dependent variable = LNVISFOR

| Predictor | Coef | Stdev | t-ratio | p |
|---|---|---|---|---|
| Constant | 2.3727 | 0.3768 | 6.30 | 0.000 |
| COST | -0.0009490 | 0.0001280 | -7.42 | 0.000 |
| INCOME | 0.00000088 | 0.00000025 | 3.56 | 0.001 |

$R^2 = 40.9\%$ $R^2(adj) = 39.9\%$ n = 123

For purposes of integration, the model given in table A2.14 was rearranged as:

$$\ln Q = f(C,Y)$$

The regression equation estimated for this model is given as A2.15.

Table A2.15: Semi-log (dependent) integration function

Dependent variable = lnQ

| Predictor | Coef | Stdev | t-ratio | p |
|---|---|---|---|---|
| Constant | 2.3727 | 0.3768 | 6.30 | 0.000 |
| C | -0.0009490 | 0.0001280 | -7.42 | 0.000 |
| Y | 0.00000088 | 0.00000025 | 3.56 | 0.001 |

s = 1.428 $R^2 = 40.9\%$ $R^2(adj) = 39.9\%$ n = 123

The necessary means for integrating the equation given in table A2.15 are detailed in table A2.16.

Table A2.16: Descriptive statistics for tgf variables: semi-log (dependent) functional form.

| Var. | n | mean | med. | st.dev | se mean | min | max | Q1 | Q3 |
|---|---|---|---|---|---|---|---|---|---|
| lnQ | 127 | 2.027 | 1.386 | 1.843 | 0.164 | 0.000 | 5.900 | 0.000 | 3.258 |
| C | 127 | 1371.4 | 1063.0 | 1025.8 | 91.0 | 32.6 | 4672.1 | 523.7 | 2122.8 |
| Y | 127 | 1080709 | 875000 | 528814 | 46925 | 500000 | 2125000 | 625000 | 1125000 |
| Q | 127 | 39.51 | 4.00 | 84.71 | 7.52 | 1.00 | 365.00 | 1.00 | 26.00 |
| PARTY | 127 | 3.087 | 3.000 | 1.363 | 0.121 | 1.000 | 7.000 | 2.000 | 4.000 |

Note: All money values are expressed in pence (as per our integration equation). The descriptive statistics given in table A2.16 for variables common to table A2.12 will differ marginally from the latter due to a slight redefinition of the sample

The values given in table A2.16 can now be substituted into the integration equation given in table A2.15 as follows:

$$\ln Q = 2.3727 - 0.0009490\ C + 0.00000088\ (1080709)$$

which we can rewrite as:

$$\ln Q = -kC + K$$

where:

$$k = 0.0009490$$

and $K = 2.3727 + 0.00000088\ (1080709) = 3.32372$

In order to find the limits of the integration we need to determine that level of visits ($Q'$) corresponding to the zero cost solution. Setting $C = 0$ we have:

$$\ln Q' = K - k(0)$$
$$= 3.32372$$
$$\therefore Q' = 27.7635$$

We can now proceed with the integration as follows:

$$\ln Q = -kC + K$$
$$kC = -\ln Q + K$$
$$C = -\frac{1}{k}\ln Q + \frac{K}{k}$$

now we can denote $K' = \frac{K}{k} = \frac{3.32372}{0.000949} = 3502.3393$

and we can denote zero visits as $Q_o$

$\therefore$ the integral is:

Consumer surplus per party of all visits pa

$$= \int_{Q_o}^{Q'} -\frac{1}{k}\ \ln Q.dQ + \int_{Q_o}^{Q'} K'.dQ$$

$$= -\frac{1}{k}\Big[\ Q.\ln Q - Q\Big]_{Q_o}^{Q'} + K'\Big[Q\Big]_{Q_o}^{Q'}$$

$$= -\frac{1}{k}\{(Q'.\ln Q'-Q')-(Q_o\ln Q_o)\}+K'(Q'-Q_o)$$

$$= -\frac{1}{k}\{(Q_o.\ln Q_o-Q_o)-(Q'.\ln Q'-Q')\}+(Q'-Q_o)$$

Now we have:

| | | |
|---|---|---|
| $k$ | = | 0.000949 |
| $K$ | = | 3.32372 |
| $K'$ | = | 3502.3393 |
| $Q'$ | = | 27.7635 |
| $Q_o$ | = | 0 |

Substituting these values in the above we get:

Consumer surplus per party of all visits pa

$$= \frac{1}{0.000949} * \{(0) - [(27.7635*\ln 27.7635)-27.7635]\} + 3502.3393*(27.7635 - 0)$$

$$= 1053.7408*(-64.514662) + 97237.197$$

$$= 292.55465$$

$$= £292.55$$

To convert this to a per visit basis we need to divide through by the average number of visits per annum, which was 39.51.

$\therefore$ consumer surplus per party per visit $= \frac{292.55465}{39.51} = 7.4045723$

$= £7.40$

Similarly if we wish to convert to a per-person basis we can divide through by the mean number of persons per party, which was 3.087.

$\therefore$ consumer surplus per person per visit $= \frac{7.4045723}{3.087} = 2.3986305$

$= £2.40$

This makes no differentiation between adults and children. Following the same adjustment procedure as for the double log model then assuming 1 child = 0.5 adults reduces party size to 2.7783, implying CS/person/visit = £2.67. Similarly omitting children reduces party size to 2.4696, implying CS/person/visit = £3.00.

*Linear functional form*

A linear functional form was also investigated yielding the tgf given in table A2.17. High leverage point effects were again examined. Given that our earlier analysis had indicated the statistical unsuitability of a linear form, it was not surprising that a number of unusual observations were identified. Table A2.18 details the re-estimated tgf arising from the omission of ten such "outliers". As can be seen this does not lead to much improvement in the explanatory power of the model although it is interesting that coefficient estimates remain fairly stable.

Table A2.17: Linear trip generation function: full sample model

Dependent variable = VISFORPA

| Predictor | Coef | Stdev | t-ratio | p |
|---|---|---|---|---|
| Constant | 21.78 | 19.28 | 1.13 | 0.261 |
| COST | -0.021894 | 0.005911 | -3.70 | 0.000 |
| INCOME | 0.00004517 | 0.00001306 | 3.46 | 0.001 |

$R^2 = 21.1\%$ $R^2(adj) = 19.9\%$ n = 129

Table A2.18: Linear trip generation function: omitting outliers

Dependent variable = VISFORPA

| Predictor | Coef | Stdev | t-ratio | p |
|---|---|---|---|---|
| Constant | 28.97 | 19.86 | 1.46 | 0.147 |
| COST | -0.026719 | 0.006747 | -3.96 | 0.000 |
| INCOME | 0.00004366 | 0.00001309 | 3.34 | 0.001 |

R-sq = 22.2%  R-sq(adj) = 21.0%  n = 119

The tgf given in table A2.18 was used for integration purposes in conjunction with the means detailed in table A2.19.

Table A2.19: Descriptive statistics for tgf variables: linear functional form.

| Var. | n | mean | med. | st.dev | se mean | min | max | Q1 | Q3 |
|---|---|---|---|---|---|---|---|---|---|
| Q | 127 | 39.51 | 4.00 | 84.71 | 7.52 | 1.00 | 365.00 | 1.00 | 26.00 |
| C | 127 | 1371.4 | 1063.0 | 1025.8 | 91.0 | 32.6 | 4672.1 | 523.7 | 2122.8 |
| Y | 127 | 1080709 | 875000 | 528814 | 46925 | 500000 | 2125000 | 625000 | 112500 |
| PARTY | 127 | 3.087 | 3.000 | 1.363 | 0.121 | 1.000 | 7.000 | 2.000 | 4.000 |

Note: All money values are expressed in pence (as per integration equation). The descriptive statistics given in table A2.16 for variables common to table A2.12 will differ marginally from the latter due to a slight redefinition of the sample

We can rewrite the equation given in table A2.18 as:

$$Q = a + bC + cY$$

Setting Y to its mean value (1080709), then when C = 0 we have:

$$Q = 28.97 - (0) + 0.00004366\ (1080709)$$
$$= 76.088912$$

Similarly when Q = 0 we have:

$$0 = 28.97 - 0.026719C + 0.00004366\ (1080709)$$
$$\therefore 76.08891 = 0.026719C$$
$$\therefore C = 2847.7455$$
$$= £28.48$$

Following the same (area) integration approach adopted previously gives us:
Total party CS per annum = £1083.4093
The average number of visits per party per annum is 39.51,

$$\therefore \text{Av party CS/visit} = \frac{1083.4093}{39.51}$$
$$= 27.421141 = £27.42$$

The average party size is 3.087 persons,

$\therefore$ Av CS/person/visit $= \frac{27.421141}{3.087}$

$= 8.8827799 = £8.88$

As before, this figure makes no differentiation between adults and children. Adopting the same adjustment procedure as before, treating 1 child = 0.5 adult implies CS/person/visit = £9.87, while omitting children implies CS/person/visit = £11.10.

Summary results

We have conducted a number of analyses as part of this study, including consideration of the appropriate definition of costs, functional form and party definition. The latter two analyses are summarised in table A2.20. In terms of statistical robustness, while the linear form is clearly inferior, the difference between the double and semi-log (dependent) models is less pronounced although the former performs detectably better.

## A2.3: THE WANTAGE WTP/WTA CV STUDY: DETAILED ANALYSIS

This study set out to assess valuations of a proposed (hypothetical) community woodland scheme near to Wantage, Oxfordshire[2]. Specific aims were to determine[3]:

1. The willingness to pay of the local community for the provision of a forest. This was achieved via a household CV study. As the site is presently not available respondents are current potential future rather than current users.

2. The willingness to accept compensation of local farmers on whose land the proposed woodland could feasibly be located, thereby assessing uptake of recreational-access, woodland schemes.

### A2.3.1: HOUSEHOLD WTP SURVEY: METHODOLOGY

Wantage is a rural town in Oxfordshire with a population of 11,495 adults as recorded in the 1991 electoral register. It is 15 miles from any cities and although there are recreational facilities within this distance there are no nearby open-access woodlands. The town therefore provides a discrete sample population for which some demand for additional recreational facilities is likely.

[2]Chosen so as to minimise survey costs as this was the home of our research assistant, Emily Diamand, who collected the data, contributed significantly to the sample selection process and punched all data, for which we are grateful.

[3]A side issue was to test the feasibility of applying the CV to a small scale planning issue such as this.

Table A2.20: Thetford 1 ITC study: consumer surplus estimates

| Functional form[1] | $R^2$ adj (%) | Constant | | Cost variable | | Income variable | | CS/party /visit | CS/person/visit | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | coeff. | t-ratio | coeff. | t-ratio | coeff. | t-ratio | 1 child = 1 adult | 1 child = 1 adult | 1 child = 0.5 adults | children omitted |
| Double log (A2.10) | 44.2 | -5.548 | -1.30 | -0.9422 | -8.41 | 1.0135 | 3.50 | £3.37 | £1.07 | £1.19 | £1.34 |
| Semi log (A2.14) | 39.9 | 2.3727 | 6.30 | -0.0009490 | -7.42 | 0.00000088 | 3.56 | £7.40 | £2.40 | £2.67 | £3.00 |
| Linear (A2.18) | 21.0 | 28.97 | 19.86 | -0.026719 | -3.96 | 0.00004366 | 3.34 | £27.42 | £8.88 | £9.87 | £11.10 |

Note: 1. Numbers in brackets refer to the tables giving full details of each respective equation.
2. Defined with journey costs at 33p/mile and zero time costs, the latter obviating collinearity problems with the income variable.

The survey covered the four census wards of the town, including the connected village of Grove. Out of these areas a stratified sample of 400 households was selected by targeting every twenty-ninth household on the electoral role. This method is consistent with that recommended by Tunstall et al. (1988) in their review of CV sampling procedure. Between July and September of 1991 each selected household was visited and the 'head of household' interviewed[4]. If there was no response on the first visit, the household was revisited on two separate later occasions; the second visit being at a different time of day and, if necessary, a third was carried out at least one week later. Of the 400 households visited, 29 were unobtainable after three visits, a further 37 refused to answer the questionnaire and a further 9 interviews yielded incomplete questionnaires. A useable sample of 325 responses was therefore collected.

**A2.3.1.1: Household questionnaire design**

An initial questionnaire was tested in a pilot survey of 30 households not selected for use in the main study. The pilot was undertaken in order to:

1. Clarify the meaning of the contingent market description with respect to the respondents' understanding of it, in order to avoid market mis-specification (Mitchell and Carson, 1989). At this point set responses to interviewee questions regarding the market scenario were developed;
2. Assess the level of non-response to an OE valuation question as a contemporary article had highlighted this as a problem (Eberle and Hayden, 1991). Levels of non-response were found to be acceptable and therefore the format was retained;
3. Assess instrument bias. Initially only an annual trust fund payment vehicle was used. After the pilot a second vehicle, a per-visit entrance fee, was included to provide some comparison.

The main survey questionnaire was refined in the light of findings from the pilot and a full copy is given at the end of this section. Initial questions asked respondents how long they had lived in the area. This was both to provide data on a potential explanatory variable and to accustom respondents to the interview process. Subsequent questions asked respondents to name sites of recreation that they had visited on a day trip basis during the last year and to state their preferences with respect to urban or rural sites. These questions were included to encourage consideration of preferences for competing recreation facilities and to establish a measure of familiarity with the proposed good.

Following this the contingent market and payment vehicle were introduced via a 'constant information statement' which was read out verbatim to all respondents. Households were then asked whether or not they would be prepared to pay towards provision of the wood. Such a 'payment principle' question was included mainly as a way of validating zero bids as it was felt that directly presenting respondents with a WTP question might intimidate those who hold zero values (Harris et al., 1989). Respondents who answered 'no' to this question were asked to state their reasons for such a response whilst those who answered positively were asked the WTP questions[5].

[4]Problems regarding the definition of "head of household" are recognised. Selection was necessarily a matter for the interviewers discretion and it is not felt that any serious error was incurred here. All those interviewed were at least 18 years of age.

[5]It was subsequently felt that the motivations behind positive responses should also be investigated and such an analysis was built into the Thetford 2 CV experiment.

Two WTP questions were used. Firstly respondents were asked how much they were WTP per household per annum (referred to subsequently as the 'per-annum' question). Secondly, respondents were then asked how much they would be WTP per adult per visit as a car parking fee (referred to subsequently as the 'per-visit' question). Here then all respondents who were WTP some amount were presented with, in turn, both the annual and per-visit format question. Ideally we would want to either use separate samples for each format or vary the order in which questions are presented so that any ordering or anchoring effects might be assessed. However such an analysis was not undertaken because we were a-priori uncertain of obtaining sufficient sample size (this problem was rectified in the subsequent Thetford 2 study).

After the valuation questions, respondents were asked to assess their expected use of such a woodland. This was included both to provide a potential explanatory variable for analysis of the bid function and to indicate the level of use and of non-use valuation included in willingness to pay figures. This indirect method was considered preferable to asking respondents to divide their valuation into subcategories of existence, use and option value (as per Loomis et al., 1984) which we considered to be a highly suspect procedure liable to allow respondents to inflate the altruistic motivations of their valuations.

At this point in the questionnaire half of the sample were given extra information about the likely costs of the scheme and asked if they wished to change their WTP response (although revised bids are not used in the following analysis). This was included to examine the possibility of an information effect as highlighted by Freeman, (1993) and Bergstrom et al., (1990).

Finally all respondents were asked questions regarding their household characteristics in order to establish socioeconomic factors affecting willingness to pay.

### A2.3.2: Survey of farmers: methodology

The study also examined the levels of payment required by local farmers for them to undertake the proposed woodland scheme i.e. their WTA compensation. The relatively small local farming population posed an immediate problem regarding sample size.

Farm addresses were taken from the local telephone directory. Initially addresses were restricted to those within a three mile radius of the town in order to maintain consistency with the scenario presented in the household survey. However, this failed to produce an acceptable sample size and a six-mile radius was finally adopted. Just over forty farms were contacted by mail to request a face to face interview. A considerable proportion of farms refused to be interviewed, the main reason being that, as interviews coincided with the harvest season (the surveys being conducted between July and October 1991), farmers faced heavy workloads and were not available for interview[6]. Because such refusals were for reasons unconnected with the content of the questionnaires (as distinct from say household refusals to pay for woodland) the farmer participation rate is not seen as a serious problem for the validity of the survey. In total nineteen farm interviews were completed. Whilst we recognise and accept problems regarding such a sample size, we would highlight the difficulty of assembling a large sample here and feel that the results can be accepted as generally indicative of farmers attitudes.

[6]A second reason, given by four farmers, was that they had already participated in other research surveys and were unwilling to devote further time.

### A2.3.2.1 Farm questionnaire design

Due to the limited availability of respondents it was impossible to conduct a pilot survey of farms. Initial questions were related to the value of present agricultural production and associated costs. This data provided a comparison between the expressed value of the woodland as given in the household survey, and the current value due to agricultural production. Furthermore, by initially establishing the value of the land on the farm, it was hoped to focus the farmer's attention on an acceptable and reasonable level of compensation for income loss due to the removal of land from present production. Such an approach was designed to minimise any tendency to overstate compensation requirements. After these questions the contingent market and payment conditions were introduced to the respondent in the following manner:

> "The purpose of this survey is to assess the feasibility in this region of planting an area of mixed woodland for recreational purposes. As you may know, under the Farm Woodland Scheme the government provides grants for planting areas of at least 3 hectares on farms. The scheme being examined in this survey would allow participating farmers to take up these grants, but in addition to receive further payments from a local woodland trust. These extra payments would be conditional on the woodland being accessible to the public (with a small area allocated for parking space). The land would remain your property but you or your subcontractor would be expected to provide basic maintenance."

This scenario proved to be similar to that embodied in the Forestry Commission's subsequent Community Woodland Scheme.

The respondents were then asked to state a minimum level in pounds per annum per hectare (or acre), which would be acceptable to them in order to commit land into such a scheme. They were also asked how much land they would allocate to the scheme at the payment level stated. It should be noted that respondents were not told the payment levels available under existing schemes. This was in order to avoid the possibility of such information providing an anchoring point for the valuations given. However, it was clear from the interviews that some of the farmers had prior knowledge of the scheme and levels of payment and this may have affected responses.

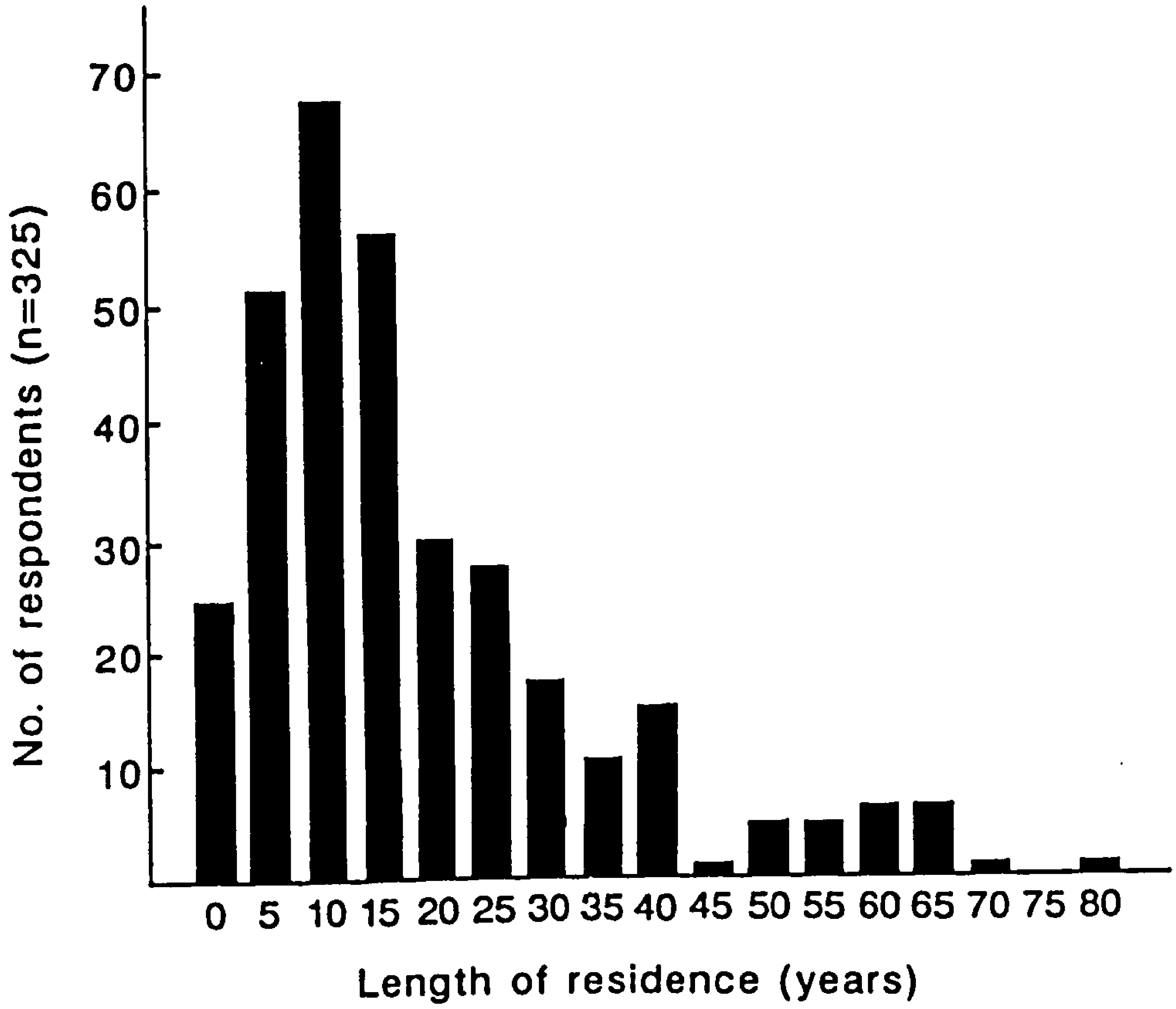
## A2.3.3: HOUSEHOLD SURVEY: RESULTS

### A2.3.1.1: Household Characteristics

Questions regarding length of residence revealed that less than 5% of the sample had lived in Wantage for one year or less. The mean age of residence was 18.5 years. This distribution was somewhat skewed with a 5% trimmed mean of 17 years and median residency of 14 years. The overall picture indicated a high degree of familiarity with the local environment. Figure A2.2 illustrates the distribution of responses to this question.

Respondents were invited to list up to four recreation sites which they had visited over the past year and state average annual frequency of visits to stated sites. Results for this question are given as table A2.21.

Figure A2.2: Household length of residence in Wantage




The information given in answer to the questions regarding current recreation destinations was used to allocate existing visits between three categories of recreation attraction: urban; park (i.e. non-urban attractions with entrance fees); and rural (open access). Responses indicate a significantly higher frequency of visit to rural sites (a mean of over 8 visits/household p.a.) than either urban or park sites (means of 2.0 and 2.6 visits respectively). Table A2.22 details results from these questions. These indicate a strong preference for the recreational attributes of the woodland site discussed in the questionnaire scenario. This trend was borne out by a direct question asking households whether, given the choice, they would prefer to visit a rural (outdoor) or an urban (indoor) recreation site. 298 of the 325 households surveyed (92%) stated that they would prefer to visit a rural/outdoor site leaving just 27 households (8%) stating a preference for an urban/indoor site.

Following the WTP questions (discussed subsequently and detailed in the questionnaire reproduced at end of this commentary and discussed subsequently), respondents were asked to predict how often they would visit the proposed wood annually. Only 11 households (3.4%) stated that they would not visit the wood. Mean predicted visitation frequency was just under 15. Summary statistics are given in table A2.23.

Comparison of tables A2.22 and A2.23 reveals that predicted demand for the proposed wood is relatively very high compared to that for existing sites. Whilst some of this difference may be due to over-enthusiasm in favour of provision[7], and there is clearly a

[7]Analogous to the subsequently discussed phenomena of strategic overbidding in responses to WTP questions.

rounding effect[8], this does demonstrate a very significant demand for the proposed wood. This is perhaps not surprising given the notable absence of open access public space in the locality, particularly of quality rural land.

Table A2.21: Frequency of visits to household-specified recreation sites

| Rank | Site name | Site category[1] | Distance from town (miles) | Number using site |
|---|---|---|---|---|
| 1 | Ridgeway | Rural | 3 | 110 |
| 2 | Oxford | Urban | 15 | 66 |
| 3 | Burford Wildlife Park | Park | 25 | 59 |
| 4 | Snellsmore Common | Rural | 15 | 57 |
| 5 | Lydiard Park | Park | 17 | 47 |
| 6 | Child Beale Trust Park | Park | 35 | 33 |
| 7 | Thorpe Park | Park | 55 | 32 |
| 8 | White Horse Hill | Rural | 6 | 31 |
| 9 | London | Urban | 100 | 31 |
| 10 | Swindon | Urban | 15 | 28 |
| 11 | Abingdon River | Rural | 8 | 25 |
| 12 | Wittenam Clumps | Park | 18 | 23 |
| 13 | Windsor Safari Park | Park | 57 | 20 |
| 14 | Local Villages | Rural | 2 | 19 |
| 15 | Reading | Urban | 40 | 19 |
| 16 | Newbury | Urban | 14 | 17 |
| 17 | Hungerford | Urban | 15 | 16 |
| 18 | Abingdon Town | Urban | 8 | 15 |
| 19 | Manor Road Park | Rural | 1 | 15 |
| 20 | Copewater Park | Park | 15 | 14 |
| 21 | Bowood House | Park | 40 | 12 |
| 22 | Oxford Colleges | Park | 15 | 11 |
| 23 | Blenheim Palace | Park | 25 | 11 |
| 24 | Lynch Hill Reservoir | Park | 12 | 11 |
| 25 | Wallingford | Urban | 13 | 10 |

Notes: 1. Site category definitions are as follows:
Rural = Open access site situated in rural area
Urban = Open access site situated in urban area
Park = Site for which a fee is charged

2. In total, 85 separate recreation sites were mentioned by respondents, but only those occurring over ten times have been included in the above table.

[8] Comparison of tables A2.23 and A2.24 shows that the latter has the relatively smoother distribution typical of real world observations whilst the former exhibits the rounding effects typical of respondents' generalised forecasting.

Table A2.22: Household visit frequency to different types of recreational site (visits p.a.)

| Household Visits pa | Urban Sites | | | Park Sites | | | Rural Sites | | |
|---|---|---|---|---|---|---|---|---|---|
| | n | % | Cumulative % | n | % | Cumulative % | n | % | Cumulative % |
| 0 | 175 | 53.85 | 53.85 | 152 | 46.77 | 46.77 | 127 | 39.08 | 39.08 |
| 1-4 | 109 | 33.53 | 87.38 | 134 | 41.23 | 80.00 | 80 | 24.61 | 63.69 |
| 5-9 | 23 | 7.08 | 94.46 | 26 | 16.00 | 96.00 | 36 | 11.08 | 74.77 |
| 10-14 | 13 | 4.00 | 98.46 | 5 | 1.54 | 97.54 | 21 | 6.46 | 81.23 |
| 15-19 | 2 | 0.62 | 99.08 | 2 | 0.61 | 98.15 | 7 | 2.15 | 83.38 |
| 20-29 | 2 | 0.62 | 99.68 | 4 | 1.23 | 99.38 | 24 | 7.39 | 90.77 |
| 30-39 | 1 | 0.31 | 100.00 | 0 | 0.00 | 99.38 | 13 | 4.00 | 94.77 |
| 40-49 | 0 | 0.00 | 100.00 | 0 | 0.00 | 99.38 | 6 | 1.85 | 96.62 |
| 50+ | 0 | 0.00 | 100.00 | 2 | 0.61 | 100.00 | 11 | 3.38 | 100.00 |
| mean | 2.028 | | | 2.618 | | | 8.040 | | |
| median | 0 | | | 1 | | | 2 | | |
| st.dev | 3.876 | | | 9.922 | | | 14.012 | | |
| tr/mean[1] | 1.403 | | | 1.440 | | | 5.973 | | |

Note: 1. The truncated mean is calculated by removing the upper and lower 2.5% of observations. Total sample size = 325

Table A2.23: Household predicted visit frequency to the wood (visits p.a.)

| Household visits p.a. | n | % | Cumulative % |
|---|---|---|---|
| 0 | 11 | 3.38 | 3.38 |
| 1-4 | 67 | 20.62 | 24.00 |
| 5-9 | 75 | 23.08 | 47.08 |
| 10-14 | 76 | 23.38 | 70.46 |
| 15-19 | 9 | 2.77 | 73.23 |
| 20-29 | 44 | 13.54 | 86.77 |
| 30-39 | 16 | 4.92 | 91.69 |
| 40-49 | 9 | 2.77 | 94.46 |
| 50+ | 18 | 5.54 | 100.00 |
| mean | 14.98 | | |
| median | 10 | | |
| st.dev | 23.03 | | |
| tr.mean | 11.73 | | |

Data detailing household composition by age was also collected and is presented in table A2.24. Observations were categorised into groups roughly corresponding to economic dependency criteria (i.e. pre-school, school, young/mid/older income-earners, pensionable). These categories proved useful in the subsequent bid curve analysis. If adjustment is made to recombine these categories into constant width age bands we observe the expected roughly domed distribution typical of a stratified sample.

Table A4.24: Household age composition: economic age categories

| Age group | Number in household | Frequency (n) | % by age group | Overall mean per household |
|---|---|---|---|---|
| age 0-4 | 0 | 239 | 73.54 | 0.3477 |
| | 1 | 63 | 19.38 | |
| | 2 | 19 | 5.85 | |
| | 3 | 4 | 1.23 | |
| age 5-11 | 0 | 209 | 64.31 | 0.5108 |
| | 1 | 70 | 21.54 | |
| | 2 | 42 | 12.92 | |
| | 3 | 4 | 1.23 | |
| age 12-16 | 0 | 251 | 77.23 | 0.2738 |
| | 1 | 59 | 18.15 | |
| | 2 | 15 | 4.62 | |
| | 3 | 0 | 0.00 | |
| age 17-25 | 0 | 224 | 68.92 | 0.4769 |
| | 1 | 53 | 16.31 | |
| | 2 | 42 | 12.92 | |
| | 3 | 6 | 1.85 | |
| age 26-45 | 0 | 127 | 39.08 | 1.0923 |
| | 1 | 61 | 18.77 | |
| | 2 | 136 | 41.85 | |
| | 3 | 1 | 0.31 | |
| age 46-65 | 0 | 219 | 67.38 | 0.5446 |
| | 1 | 35 | 10.77 | |
| | 2 | 71 | 21.85 | |
| | 3 | 0 | 0.00 | |
| age 65+ | 0 | 276 | 84.92 | 0.2123 |
| | 1 | 30 | 9.23 | |
| | 2 | 18 | 5.54 | |
| | 3 | 1 | 0.31 | |

Finally data was gathered regarding the economic characteristics of households. Principle amongst these variables was household income[9]. Assurances of confidentiality and the use of information cards employing alphabetical income categories, appear to have allayed any resistance to providing such information and a 100% response rate was achieved on this

[9]Data was also gathered regarding professional and employment status. However, a logical categorisation of this data was not satisfactorily achieved and the information was not used in bid curve analysis.

question[10]. Figure A2.3 shows sample income to be normally distributed about the median £15,000-£19,999 category. Table A2.25 provides further information regarding income distribution.

Figure A2.3: Histogram: Distribution of sample household income

Each * represents 2 obs. n = 325

| Category[1] | Count | Histogram |
|---|---|---|
| 1 | 34 | ***************** |
| 2 | 38 | ******************* |
| 3 | 48 | ************************ |
| 4 | 81 | ***************************************** |
| 5 | 57 | ***************************** |
| 6 | 38 | ******************* |
| 7 | 18 | ********* |
| 8 | 11 | ****** |

[1] Note: Category boundaries are given in table A2.25.

Table A2.25: Household income by category

| Income category (£pa) | n | % | Cumulative % |
|---|---|---|---|
| 0-4,999 | 34 | 10.46 | 10.46 |
| 5,000-9,999 | 38 | 11.69 | 22.15 |
| 10,000-14,999 | 48 | 14.77 | 36.92 |
| 15,000-19,999 | 81 | 24.92 | 61.85 |
| 20,000-24,999 | 57 | 17.54 | 79.38 |
| 25,000-29,999 | 38 | 11.69 | 91.08 |
| 30,000-39,999 | 18 | 5.54 | 96.62 |
| 40,000+ | 11 | 3.38 | 100.00 |

### A2.3.3.2 Refusals to pay

Prior to both the annual and per-visit format WTP questions, respondents were asked whether they were, in principle, WTP some amount for the proposed woodland. This question was included primarily to validate a zero bid as it was felt that, in the absence of

[10] We view this as a good test of questionnaire design. Similarly, Bateman et al. (1992) record only a 6% refusal rate for a similar question in a face to face interview situation.

such a question, asking respondents for their WTP might inhibit such bids and upwardly bias mean WTP. Such an approach accords with the emphasis upon 'conservative design' which underpins the NOAA 'blue ribbon' survey design protocol (Arrow et al., 1993). All those who responded negatively regarding the principle of payment were asked to specify their motivations for such a response. Details of these reasons and overall refusal rates are given in table A2.26.

Table A2.26: Refusal reasons and refusal rates for annual and per-visit WTP formats

| Reason for refusal | Annual WTP No. | % | Per-Visit WTP No. | % |
|---|---|---|---|---|
| Insufficient income or other economic constraint | 70 | 21.5 | 37 | 11.4 |
| Access to woodland should be free | 5 | 1.5 | 11 | 3.4 |
| The Government should pay | 3 | 0.9 | 0 | 0.0 |
| The land should remain in agriculture | 1 | 0.3 | 0 | 0.0 |
| Total refusal numbers/rate | 79 | 24.3 | 48 | 14.8 |

Note: Percentages are based upon the entire sample of 325 households (all respondents presented with both WTP formats).

Table A2.26 indicates a relatively high refusal rate regarding the annual WTP question (24.3%). However, as an economic constraint (insufficient income, etc) was by far the prime motivation for refusal, such zero WTP sums do not pose a theoretical problem. The residual refusals for this format include three respondents who indicated an 'extreme free-riding' incentive as their underlying motivation. Such a strategy was expected to occur to some extent. The indicated level is not excessive and is indeed considerably lower than that observed in large scale user studies (Bateman et al., 1992). Those respondents who refuse to bid upon the grounds that the woodland should be open access could arguably be interpreted as articulating a fundamental argument against the entire principle of the economic appraisal of projects (not just monetary evaluation of environmental preferences), arguing instead for a policy-led approach to decision making. If such responses were widespread they might provide a serious criticism of the basis of this study. However, the observed scarcity of such responses can be interpreted as a counter-argument that individuals recognise the need to allocate finite resources in an economically efficient manner.

The lower refusal rate for the per-visit format might be interpreted as reflecting a wider acceptance of use-related entrance fees over the more general annual payment vehicle. Whilst we suspect that the difference between refusal rates for the two formats is likely to be statistically insignificant, it could simply be argued that respondents are expressing a preference for use-related entrance fees rather than annual donations which, amongst other attributes, are likely to be less sensitive to usage. A second, less favourable, interpretation could be that, as our sample will include households who do not enjoy woodland recreation and would not visit the site, the entrance fee vehicle allows such households to state a per-visit WTP sum (where they are unwilling to pay an annual fee) in the knowledge that, as non-visitors they will also ultimately be non-payers. If such logic does describe a significant proportion of the sample then we should have less faith in positive responses to the per-visit entrance fee question. It is notable that not one household stated that its reason for refusing to pay was that it had no intention of visiting. Given that it is likely that some such households were interviewed, this heightens concerns regarding the per-visit measure. Such a conclusion needs to be tempered by the observation that, within stated reasons for refusal, the majority centred upon economic constraints which themselves pose no theoretical problems.

### A2.3.3.3 WTP responses and mean WTP

The Wantage CV study used open-ended (OE) elicitation methods. In the light of our research into the effects of switching elicitation technique (see our Norfolk Broads study detailed at the start of chapter 4) this seems a valid approach although our findings indicate that OE questions may elicit lower bound estimates of WTP. Given a general desire for conservative design in CV studies (Arrow et al., 1993) this seems a potentially desirable feature of this study.

Figures A2.4 and A2.5 illustrate the distribution of responses to (respectively) the annual and per-visit format WTP questions. All refusals are included as zeros.

Figure A2.4: Histogram of responses to annual format WTP question.

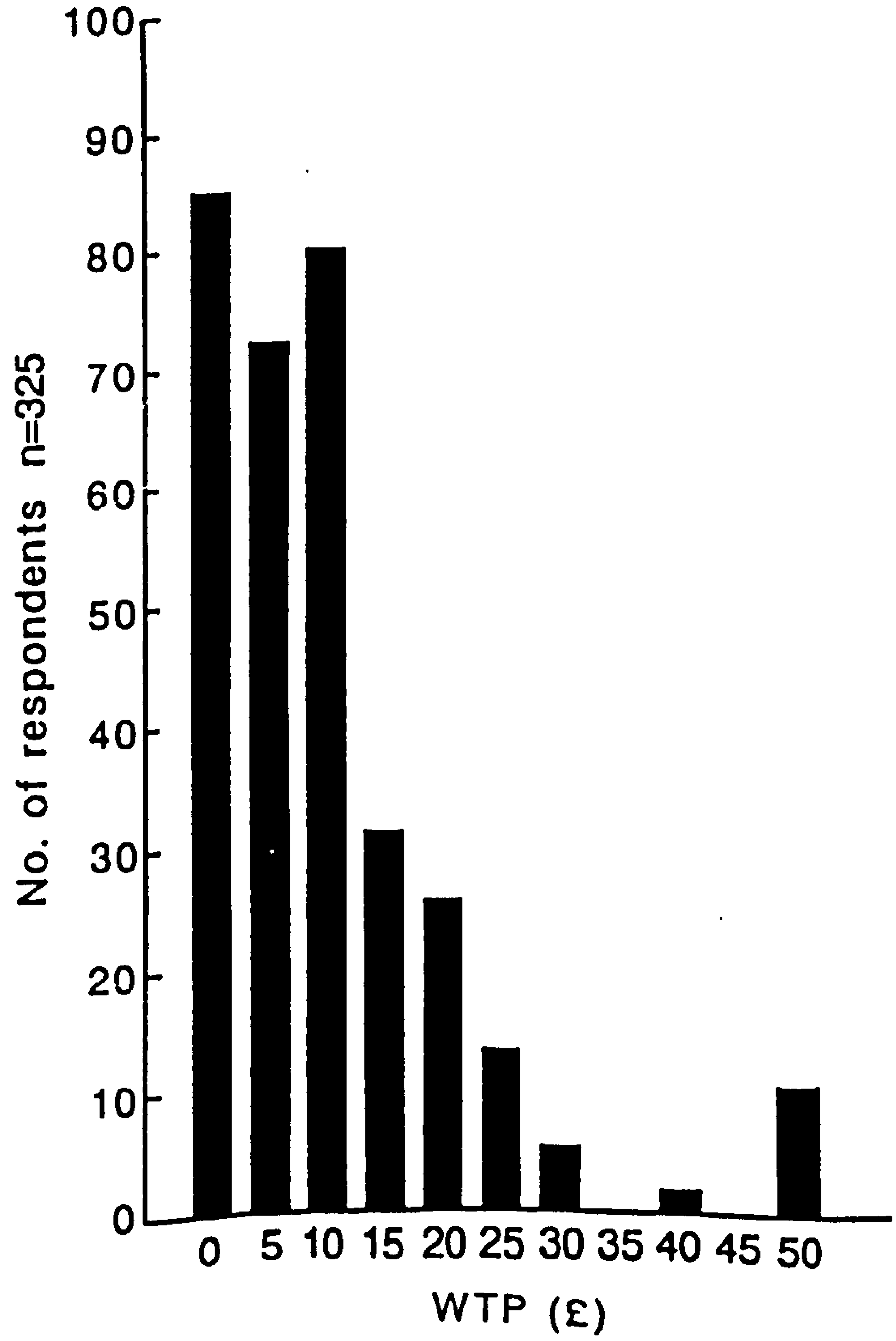
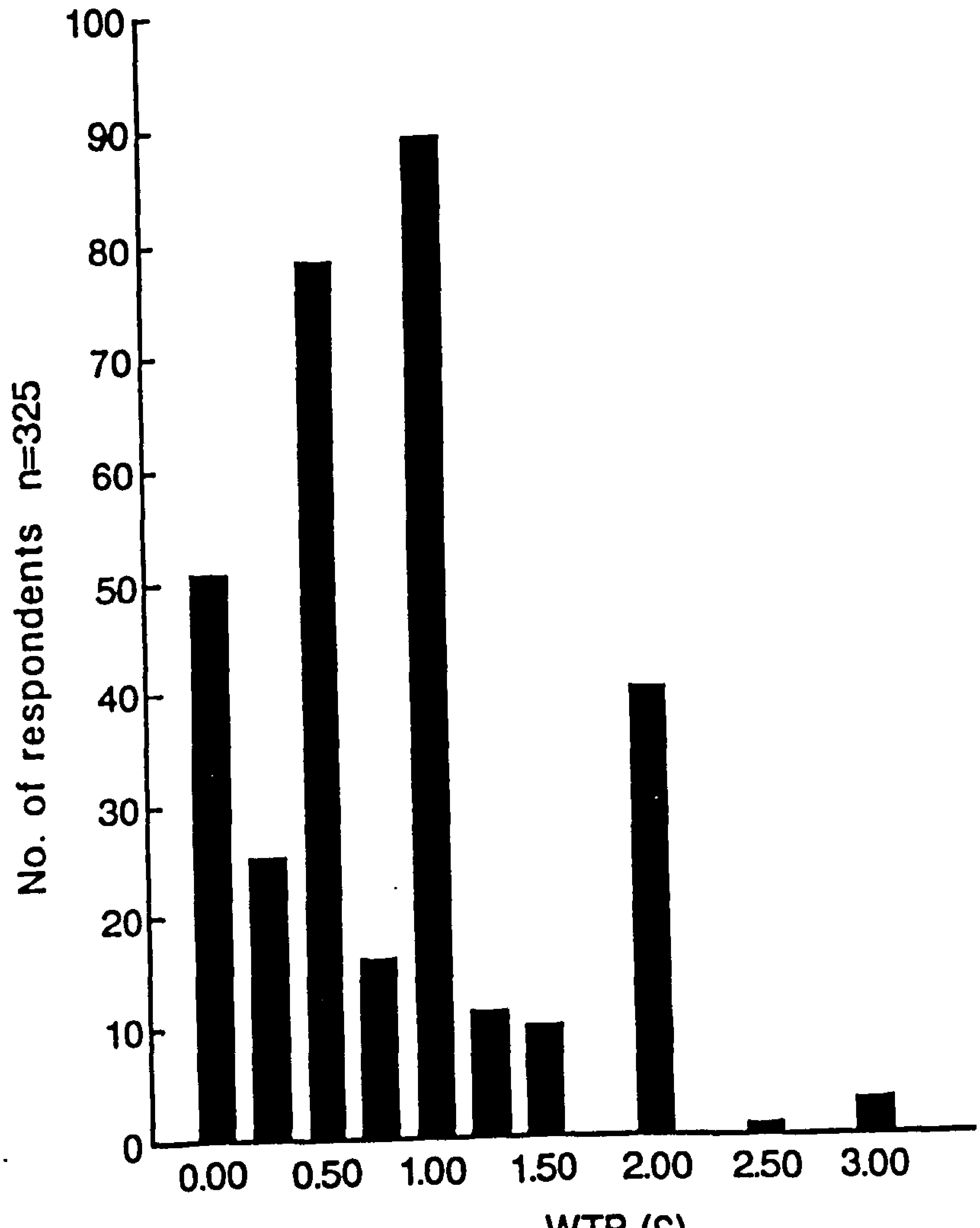


Figure A2.5: Histogram of responses to per-visit format WTP question.




Comparison of the distributions illustrated in figures A2.4 and A2.5 raises some interesting issues which we consider in further detail below.

i. Response rounding

At first glance there may appear to be certain fundamental differences between the distributions illustrated in figures A2.4 and A2.5, with the annual responses seemingly more skewed than the per-visit values. Furthermore, whilst the per-annum distribution appears smoothly declining as values increase the per-visit distribution appears to be clumped upon certain round figures (50p, £1, £2, etc). However, upon closer inspection these distributions exhibit some similarities. The characteristic of respondents giving round number answers in the per-visit scenario is, to some extent, repeated in the annual sum experiment where responses were typically £5, £10, etc. although examination of the overall distributions shows that this rounding effect is more pronounced in the per-visit format question.

ii. 'Warm-glow' altruism

Further examination of the two distributions shows that, examining non-zero bids, both exhibit an initial increase in 'positive' responses as the WTP level increases from zero to some relatively low amount after which the distributions tail off. This trend has been observed elsewhere (Bateman et al., 1992) and may indicate an effect similar to the 'warm-glow giving' phenomena proposed by Andreoni (1990) or the 'purchase of moral satisfaction' idea put forward by Kahneman and Knetsch (1992).

Andreoni (1990) discusses the concept of 'impure altruism' whereby individuals donate to charitable good-causes so that they can enjoy a 'warm-glow' of giving. Therefore, in answering our questionnaire, certain respondents may state some (probably small) bid for warm-glow reasons. This poses no problem provided that such respondents are genuinely prepared to pay the amounts stated. However, it may be that some respondents see the CV hypothetical scenario as an opportunity to endow themselves with a warm-glow satisfaction at no cost. Such respondents will be unwilling to state a true WTP of zero and will prefer to state some (again probably small) bid[11]. A related issue here is that some respondents may have an aversion to stating a zero response. Motivations for such a response are many and complex but centre upon the interactive interview process. Orne (1962) discusses the 'good respondent' who attempts to please the interviewer by stating what they perceive as a 'correct' answer. A zero bid is unlikely to be thought to conform to such specifications. Similarly the respondent may hold the interviewer in high esteem and again 'try to please'. A further motivation may be the desire (either conscious or subconscious) to conform to a 'social norm' WTP as discussed in chapter 3.

All the above motivations are liable to lead respondents who would not actually pay away from a zero stated bid and towards one which arises from the interview mechanism. Such a response cannot necessarily be attached to the specific good in question i.e. we could change the good for any similar scale 'good cause' and those individuals concerned (note, not all respondents) would still give the same response[12].

Whilst it was not possible, without adopting extended psychological testing, to identify such 'warm-glow' bidders, a simple analysis was undertaken to examine the implication of such strategies. Here we assumed that all bids below a certain level fell into the 'warm-glow' category. This is clearly a crude approach but one which was dictated by limited resources.

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[11]This problem will be compounded by rounding effects which, as Bateman et al. (1995a) argue, are likely to operate in a generally upward direction.

[12]In short, such respondents would state such a bid for any similar good cause, i.e. woodlands, the dogs'-home, the donkey-sanctuary, etc.

The distribution of bids under both formats were examined for evidence of any appropriate cut-off point. Table A2.27 details observed responses to the annual format WTP question whilst table A2.28 repeats this analysis for the per-visit (entrance fee) question.

Table A2.27: Bid distribution for the annual format WTP question

| WTP £/household pa | Frequency | % | Cumulative % |
|---|---|---|---|
| 0 | 79 | 24.31 | 24.31 |
| 1-4 | 15 | 4.61 | 28.92 |
| 5 | 63 | 19.39 | 48.31 |
| 6-10 | 76 | 23.38 | 71.69 |
| 11-20 | 61 | 18.77 | 90.46 |
| 21-49 | 21 | 6.46 | 96.92 |
| 50 | 10 | 3.08 | 100.00 |

n = 325

Table A2.28: Bid distribution for the per-visit format WTP question

| WTP £/adult/visit | Frequency | % | Cumulative % |
|---|---|---|---|
| 0 | 48 | 14.77 | 14.77 |
| 0.01-0.49 | 32 | 9.85 | 24.62 |
| 0.50 | 75 | 23.07 | 47.69 |
| 0.51-0.99 | 16 | 4.93 | 52.62 |
| 1.00 | 89 | 27.38 | 80.00 |
| 1.01-1.50 | 21 | 6.46 | 86.46 |
| 1.51-2.00 | 40 | 12.31 | 98.77 |
| 2.01-3.00 | 4 | 1.23 | 100.00 |

n = 325

Both tables A2.27 and A2.28 show that respondents give answers in round numbers (although we do not know the extent to which rounding affects means)[13]. This rounding gives some indication of the amounts which respondents might choose to give under 'warm-

[13]Bateman *et al.* (1995a) argue that rounding effects will inflate dichotomous choice means but have a less predictable (and possibly less pronounced) effect upon OE means.

glow' bidding. For the annual format let us assume that the relevant bid threshold is £5 p.a. whilst for the per-visit question we can assume a threshold of £0.50. We can now recalculate mean WTP by setting all bids up to and including these thresholds to zero. Table A2.29 details the results of such an analysis.

Table A2.29: Impact upon estimated means of truncating potential 'warm-glow' bids

| WTP format | truncation option[1] | mean WTP (£) | median WTP (£) | st. dev. |
|---|---|---|---|---|
| Annual | untruncated | 9.94 | 10.00 | 10.66 |
| | truncated | 8.85 | 10.00 | 11.36 |
| Per Visit | untruncated | 0.82 | 0.75 | 0.64 |
| | truncated | 0.68 | 0.75 | 0.63 |

Note: 1. Untruncated = all bids included as received. Truncated = all per annum bids up to £5 (inclusive) set to zero; all per visit bids up to £0.50 (inclusive) set to zero. All refusals to pay are included as zero's (n=325 throughout).

Table A2.29 indicates that, for both formats, even if we adopt the very strong assumption that all bids up to and including the chosen threshold are 'warm-glow' responses and (again, a strong assumption) should really be zeros, then this makes relatively little difference to the estimated mean, which declines 11% for the annual format and 17% for the per-visit format. We would suggest that such assumptions are, in fact, too strong as they omit bids which are significantly non-zero.

We conclude then that although 'warm-glow' bidding may be a feature of this and other CV surveys, with regard to this study the impact of any such tendency is not severe.

iii. Free riding

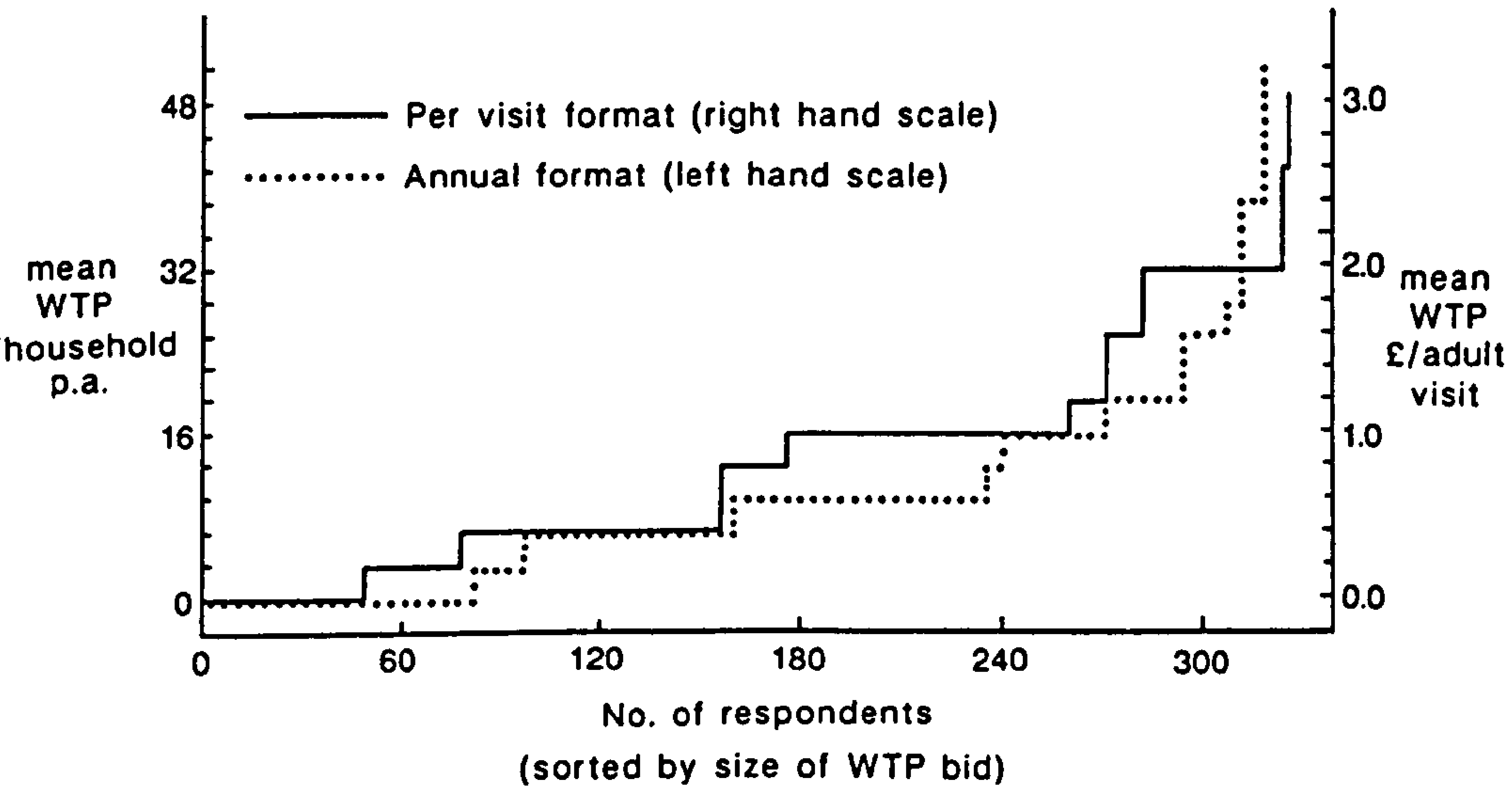
The non-woodland research discussed at the start of chapter 4 suggests that free rider incentives may somewhat reduce WTP responses to open-ended questions. We have stated in our analysis of refusals to pay that extreme free-riding does not appear to be particularly evident in this study. However, less extreme free-riding, in the form of a downward revision of bids may operate within non-zero bids so as to reduce mean WTP. If both a 'warm glow' and 'free-riding' effect are in operation then these would act in opposite directions. However, to suggest that such effects might be self-cancelling would, on the basis of the paucity of evidence to hand, be seriously premature. All we can conclude is that either or both effects may be in operation to uncertain degrees.

iv. Strategic overbidding

Chapter 2 raises the possibility that certain respondents may overstate their true WTP for strategic reasons. Extreme strategic overbidding will be evidenced by upper tail outliers and a consequent high responsiveness in WTP to their omission.

Tables A2.30 and A2.31 analyse, for both WTP formats, the impact of removing successively larger percentages of the very highest bids recorded. Inspecting tables A2.30 and A2.31 we can see that for both payment vehicles a few relatively very high bids appear to have a significant effect upon mean WTP. The relative impact of these bids is illustrated in figure A2.6. Here WTP responses have been sorted from lowest to highest along the horizontal axis showing that for both payment vehicles, a few relatively high responses were recorded.

Figure A2.6: Potential strategic overbidding responses




Consideration of figure A2.6 suggests that, if strategic overbidding is present, then it is confined to a relatively small number of respondents. In both the per-annum and per-visit formats, omission of the very highest few bids does cause the mean to fall rapidly, suggesting these are the extreme outliers indicative of strategic overbidding. However, the rate of decline slows rapidly once these most extreme bids have been removed. Clearly at some point we move from bids which are high because of (possibly) strategic behaviour, to bids which are high because of the interaction of preferences and ability to pay. If we assume that strategic overbidding can be identified by very disproportionately high bids, then figure A2.6 suggests that there are relatively few of these. We therefore conclude that strategic overbidding may occur in a small minority of cases. The impact of such bids will be relatively high and, on the basis of tables A2.30 and A2.31, may be responsible for inflating per-visit mean WTP by perhaps 10% and per-annum mean WTP by anything up to 20% although, without carefully designed, specific experimentation, such estimates are merely ballpark figures.

The result that per-visit values seem less responses to upper bid truncation could be taken as indicating that answers to this format are more resistant to strategic behaviour. However, an alternative explanation follows our 'social norms' hypothesis discussed in chapter 3. If responses to per-visit questions relate more to a notion of a 'reasonable' entrance fee amount than to true WTP then this would account for the apparent relative lack of strategic behaviour but in turn question the validity of such an approach.

Table A2.30: WTP measures for various truncation options: Annual format question

| Upper tail truncation | nN | mean | median | st dev | se mean | min | max | Q1 | Q3 |
|---|---|---|---|---|---|---|---|---|---|
| 0% | 325 | 9.938 | 10.00 | 10.661 | 0.591 | 0.00 | 50.00 | 2.00 | 15.00 |
| 5% | 309 | 8.188 | 5.00 | 7.299 | 0.415 | 0.00 | 30.00 | 0.00 | 10.00 |
| 10% | 293 | 7.253 | 5.00 | 6.245 | 0.365 | 0.00 | 20.00 | 0.00 | 10.00 |
| 15% | 276 | 6.467 | 5.00 | 5.545 | 0.334 | 0.00 | 20.00 | 0.00 | 10.00 |
| 20% | 260 | 5.788 | 5.00 | 4.927 | 0.306 | 0.00 | 15.00 | 0.00 | 10.00 |
| 25% | 244 | 5.184 | 5.00 | 4.463 | 0.286 | 0.00 | 15.00 | 0.00 | 10.00 |
| 30% | 228 | 4.658 | 5.00 | 4.092 | 0.271 | 0.00 | 10.00 | 0.00 | 10.00 |

Table A2.31: WTP measures for various truncation options: Per-visit format question

| Upper tail truncation | n | mean | median | st dev | se mean | min | max | Q1 | Q3 |
|---|---|---|---|---|---|---|---|---|---|
| 0% | 325 | 0.8203 | 0.750 | 0.6409 | 0.0356 | 0.00 | 3.00 | 0.50 | 1.00 |
| 5% | 309 | 0.7479 | 0.500 | 0.5632 | 0.0320 | 0.00 | 2.00 | 0.35 | 1.00 |
| 10% | 293 | 0.6795 | 0.500 | 0.4939 | 0.0289 | 0.00 | 2.00 | 0.25 | 1.00 |
| 15% | 276 | 0.6072 | 0.500 | 0.4068 | 0.0245 | 0.00 | 1.50 | 0.25 | 1.00 |
| 20% | 260 | 0.5631 | 0.500 | 0.3755 | 0.0233 | 0.00 | 1.00 | 0.25 | 1.00 |
| 25% | 244 | 0.5344 | 0.500 | 0.3700 | 0.0237 | 0.00 | 1.00 | 0.25 | 1.00 |
| 30% | 228 | 0.5018 | 0.500 | 0.3609 | 0.0239 | 0.00 | 1.00 | 0.21 | 0.95 |

v. Bid curve analysis

Validity testing was undertaken in part through bid curve analysis. The socioeconomic and preference data collected in the survey was related to both linear and log-linear specifications of the per-annum and per-visit WTP response. Table A2.32 provides details on the available data-set and reports zero order correlation coefficients with these alternative dependent variables.

*The per-annum responses (WTPpa)*

Table A2.32 suggests that there is relatively little difference between using a linear or log-linear specification of WTPpa. However, subsequent multiple regression analysis showed that log-linear specifications performed significantly better. Table A2.33 reports results from a forward-entry stepwise regression analysis relating the log-linear dependent variable lnWTPpa to many of the explanatory variables detailed in table A2.32.

The final equation reported in table A2.33 contains explanatory variables which we might expect to be collinear. However, inspection of coefficient values across steps does not immediately reveal any obvious severe problems as they remain fairly stable. As a further test of multicollinearity a zero order correlation matrix of all these explanatory variables was prepared as detailed in table A2.34.

The lack of multicollinearity between explanatory variables in table A2.34 is surprising, indeed only the correlation between lnRURVIS and lnVISWOOD gives any real cause for concern. Accordingly the latter variable was dropped from our best-fit model which is given as table A2.35.

The bid curve model given in table A2.35 fits the data well in comparison to most CV studies employing OE elicitation methods and satisfies the more stringent guidelines on theoretical validity testing (Mitchell and Carson, 1989; Bateman and Turner, 1993). More importantly the relationships suggested by individual explanatory variables are highly significant and in accord with a-priori expectations. It appears that household income is the most dominant consideration affecting responses to the per-annum WTP question. Responses are also positively linked to visits to rural or town park recreation sites while those who prefer town-based leisure pursuits exhibit significantly lower levels of WTP. A final interesting factor is the positive influence upon WTP exerted by the presence of household members between the ages of 17 and 25. This may be due either to higher recreation demand or to an enhanced environmental awareness amongst this group.

In summary the per-annum study appears to have been a success resulting in theoretically consistent WTP responses.

*The per-visit responses (WTP fee)*

The correlation coefficients of table A2.32 indicate that responses to the per-visit WTP question were much less firmly linked to standard explanatory variables than were the WTPpa bids. Regression analysis of the bid curve for per-visit responses confirmed this observation. While a log-linear dependent variable outperformed a linear specification, the resulting bid curve model, detailed in table A2.36, exhibits a very low degree of overall explanatory power.

Table A2.32: Explanatory variable definitions and zero order correlation matrix

| Explanatory variable | | Dependant Variable | | | |
|---|---|---|---|---|---|
| Label | Definition | WTPpa | lnWTPpa | WTPfee | lnWTPfee |
| YEARS | No. of years resident in Wantage | -0.228 | -0.272 | -0.106 | -0.105 |
| URBVISNO | visits to urban sites pa. | 0.005 | -0.011 | -0.005 | -0.005 |
| PKVISNO | visits to parks pa. | 0.018 | -0.002 | -0.020 | -0.031 |
| RURVISNO | visits to rural sites pa. | 0.151 | 0.163 | -0.037 | -0.051 |
| PREFTOWN | = 1 if prefers town visits; 0 otherwise | -0.153 | -0.194 | -0.016 | -0.014 |
| VISWOOD | predicted visits to proposed wood pa. | 0.166 | 0.140 | -0.087 | -0.108 |
| AGE0-4 | No. in household aged 0-4 years | 0.042 | 0.050 | 0.059 | 0.071 |
| AGE5-11 | No. in household aged 5-11 years | 0.062 | 0.097 | 0.068 | 0.073 |
| AGE12-16 | No. in household aged 12-16 years | 0.072 | 0.092 | 0.061 | 0.062 |
| AGE17-25 | No. in household aged 17-25 years | 0.213 | 0.161 | 0.111 | 0.104 |
| AGE26-45 | No. in household aged 26-45 years | 0.109 | 0.125 | 0.063 | 0.070 |
| AGE46-65 | No. in household aged 46-65 years | 0.051 | 0.038 | 0.069 | 0.060 |
| AGE65+ | No. in household aged over 65 years | -0.184 | -0.181 | -0.197 | -0.209 |
| PROFESS | profession (category: 1-8) | -0.300 | -0.324 | -0.123 | -0.106 |
| EMPLOYED | = 1 if employed; 0 otherwise | 0.160 | 0.135 | -0.011 | -0.044 |
| INCCAT | household income pa. (category: 1-8) | 0.417 | 0.445 | 0.161 | 0.136 |
| INCOME | household income pa. (continuous) | 0.428 | 0.425 | 0.157 | 0.130 |
| lnYEARS | natural log of YEARS | -0.156 | -0.172 | -0.073 | -0.072 |
| lnURBVIS | natural log of URBVISNO | 0.033 | 0.019 | 0.028 | 0.025 |
| lnPKVIS | natural log of PKVISNO | 0.207 | 0.252 | 0.060 | 0.058 |
| lnRURVIS | natural log of RURVISNO | 0.200 | 0.228 | -0.065 | -0.082 |
| lnVISWOOD | natural log of VISWOOD | 0.218 | 0.219 | 0.043 | 0.028 |
| lnAGE4 | natural log of AGE0-4 | 0.031 | 0.045 | 0.070 | 0.083 |
| lnAGE11 | natural log of AGE5-11 | 0.057 | 0.086 | 0.065 | 0.072 |
| lnAGE16 | natural log of AGE12-16 | 0.077 | 0.091 | 0.062 | 0.062 |
| lnAGE25 | natural log of AGE17-25 | 0.211 | 0.156 | 0.103 | 0.095 |
| lnAGE45 | natural log of AGE26-45 | 0.119 | 0.135 | 0.082 | 0.083 |
| lnAGE65 | natural log of AGE46-65 | 0.053 | 0.036 | 0.064 | 0.055 |
| lnAGE65+ | natural log of AGE65+ | -0.191 | -0.186 | -0.194 | -0.205 |
| lnINCCAT | natural log of INCCAT | 0.416 | 0.476 | 0.163 | 0.140 |
| lnINCOME | natural log of INCOME | 0.414 | 0.478 | 0.162 | 0.140 |

Notes: 1. Dependent variables defined as follows:
WTPpa = household stated WTP per annum
lnWTPpa = natural log of WTPpa
WTPfee = household stated WTP per visit
lnWTPfee = natural log of WTPfee

Table A2.33: Stepwise regression of lnWTPpa on 34 predictors

| Step | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Constant | -5.397 | -5.335 | -5.096 | -4.418 | -4.214 | -4.374 |
| lnINCOME<br>t-ratio | 0.755<br>9.79 | 0.726<br>9.56 | 0.683<br>9.06 | 0.683<br>9.16 | 0.647<br>8.54 | 0.630<br>8.33 |
| lnRURVIS<br>t-ratio | | 0.165<br>3.78 | 0.160<br>3.74 | 0.140<br>3.25 | 0.156<br>3.61 | 0.131<br>2.98 |
| lnPKVIS<br>t-ratio | | | 0.246<br>3.69 | 0.227<br>3.43 | 0.239<br>3.62 | 0.235<br>3.59 |
| PREFTOWN<br>t-ratio | | | | -0.59<br>-2.90 | -0.56<br>-2.75 | -0.52<br>-2.58 |
| AGE 17-25<br>t-ratio | | | | | 0.167<br>2.32 | 0.173<br>2.42 |
| lnVISWOOD<br>t-ratio | | | | | | 0.140<br>2.34 |
| S | 1.04 | 1.02 | 1.00 | 0.992 | 0.985 | 0.978 |
| $R^2$ | 22.87 | 26.14 | 29.15 | 30.96 | 32.11 | 33.26 |

n = 325

Table A2.34: Correlation matrix of all variables in stepwise model

| | lnWTPpa | lnINCOME | lnRURVIS | lnPKVIS | PREFTOWN | AGE 17-25 |
|---|---|---|---|---|---|---|
| lnINCOME | 0.478 | | | | | |
| lnRURVIS | 0.228 | 0.100 | | | | |
| lnPKVIS | 0.252 | 0.158 | 0.044 | | | |
| PREFTOWN | -0.194 | -0.032 | -0.170 | -0.104 | | |
| AGE 17-25 | 0.161 | 0.182 | -0.133 | -0.143 | -0.041 | |
| lnVISWOOD | 0.219 | 0.122 | 0.268 | 0.060 | -0.119 | -0.047 |

Table A2.35: Best fitting model of per-annum WTP responses
Dependent variable = lnWTPpa

| Predictor | coeff | st. dev | t-ratio | p |
|---|---|---|---|---|
| Constant | -4.7704 | 0.7115 | -6.70 | 0.000 |
| lnINCOME | 0.64702 | 0.7572 | 8.54 | 0.000 |
| lnRURVIS | 0.15594 | 0.04323 | 3.61 | 0.000 |
| lnPKVIS | 0.23881 | 0.06592 | 3.62 | 0.000 |
| PREFTOWN | -0.5562 | 0.2023 | -2.75 | 0.006 |
| AGE 17-25 | 0.16689 | 0.07185 | 2.32 | 0.021 |

S = 0.9849 R-sq = 32.1% R-sq(adj) = 31.0%

Analysis of variance

| Source | df | SS | MS | F | p |
|---|---|---|---|---|---|
| Regression | 5 | 146.348 | 29.270 | 30.17 | 0.000 |
| Error | 319 | 309.446 | 0.970 | | |
| Total | 324 | 455.793 | | | |

| Source | df | seq SS |
|---|---|---|
| lnINCOME | 1 | 104.252 |
| lnRURVIS | 1 | 14.899 |
| lnPKVIS | 1 | 13.694 |
| PREFTOWN | 1 | 8.269 |
| AGE 17-25 | 1 | 5.234 |

Table A2.36: Best filling model of per visit WTP responses
Dependant variable = ln $WTP_{fee}$

| Predictor | coef | st.dev | t-ratio | p |
|---|---|---|---|---|
| Constant | 0.59457 | 0.02348 | 25.33 | 0.000 |
| AGE65+ | -0.13452 | 0.03412 | -3.94 | 0.000 |
| VISWOOD | -0.0017451 | 0.0008081 | -2.16 | 0.032 |

s = 0.3347 $R^2$ = 5.7% $R^2$(adj) = 5.1% n = 325

Analysis of variance

| Source | df | SS | MS | F | p |
|---|---|---|---|---|---|
| Regression | 2 | 2.1856 | 1.0928 | 9.76 | 0.000 |
| Error | 322 | 36.0628 | 0.1120 | | |
| Total | 324 | 38.2484 | | | |

The equation given in table A2.36 takes a semi-log (dependent) functional form. Explanatory variable relationships are as expected. The negative sign on AGE65+ accords with the expected lower visitation rate and ability to pay of this age group. The negative sign on VISWOOD reinforces the relationship, observed in our Thetford 1 per-visit survey, of responses indicating that regular visitors are more resistant to the per-visit payment vehicle than are occasional visitors. These factors provide the strongest support for the validity of our per-visit results. However, contrary evidence is suggested both by the poor overall fit of this model and the very strong nature of the constant. We believe that this latter factor provides further evidence for our contention that per-visit WTP responses are affected by social norm factors.

### A2.3.3.4: Summary results: household WTP studies

It seems that responses to the per-annum WTP questions were strongly linked to expected explanatory variables and therefore pass a simple test of theoretical validity[14]. Responses to per-visit format questions were less strongly linked to such factors and, while they may still have some justification as magnitude estimates, these results seem to support our social norm hypothesis. Table A2.37 gives univariate WTP statistics for responses to the two formats.

Table A2.37: Summary WTP results: per-annum (WTPpa) and per-visit (WTPfee) formats

| Format | n | mean | median | tr.mean | st.dev | se.mean | max | Q1 | Q3 |
|---|---|---|---|---|---|---|---|---|---|
| WTPpa | 325 | 9.94 | 10.00 | 8.64 | 10.66 | 0.591 | 50.00 | 2.00 | 15.00 |
| WTPfee | 325 | 0.82 | 0.75 | 0.79 | 0.64 | 0.036 | 3.00 | 0.50 | 1.00 |

Note: All values in 1991 prices. Minimum bid = zero for both formats.

Convergent validity testing (see chapter 2) was not feasible for our per-annum format as no directly comparable (remote survey) woodland studies exist within the UK literature. However, a within-format comparison across several different types of outdoor recreation resources showed that the above WTPpa mean was logically related to the substitutability, uniqueness and provision change factors which seemed to determine WTP results for a sample of over thirty studies (Bateman et al., 1994).

Cross-study comparison of our WTPfee result was easier given the relatively high numbers of comparable studies in the literature. Our WTPfee mean falls above but well within one standard deviation of the mean of all other comparable UK studies[15].

## A2.3.4: SURVEY OF FARMERS: RESULTS

Responses were elicited from nineteen farmers using face to face interview techniques. Whilst we have already recognised problems associated with inferring from small sample sizes, eliciting even this sample proved difficult given the necessary steps to secure each interview during the harvest season. We have no reason to suppose that those interviewed form a biased sample and therefore report percentage responses (as well as numbers) as an approximate guide to expected farmer attitudes in similar areas[16].

### A2.3.4.1: Farm characteristics

The interview opened with questions regarding the general characteristics of the farm. Specifically farmers were asked to state the agricultural land use; farm tenure; and average profit per acre (or hectare). Table A2.38 details individual farm responses to these questions.

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[14] In effect, responses were in logical accordance with economic theory. Wider questions regarding the overall validity of CV responses (as reviewed in chapter 2) may still apply.

[15] Mean of other per-visit OE use value studies = £0.63; st.dev = £0.25. Full details of cross-study analysis are given in chapter 3.

[16] We would expect participation rates to rise as per-acre agricultural incomes fall. Such conditions would apply to our subsequent studies of Welsh hill farms.

Table A2.38: Farm characteristics and farmers' willingness to accept compensation for transferring from present output to woodland

| Farm | Land use | Tenure | Profit/acre (hectare) | WTA/acre (hectare) | Allocation acres (ha) | Reason for non-allocation |
|---|---|---|---|---|---|---|
| 1 | Arable/ Sheep | Owned | £100 (£247) | £250 (£618) | 0 | Land should be used to produce food |
| 2 | Arable/ Beef | Owned | ——— | £20,000 (£49,440) | 0 | Does not like government policy |
| 3 | Arable/ Dairy | Owned | £125 (£309) | £300 (£741) | 0 | Does not want public access to the farm |
| 4 | Arable | Owned | £30 (£74) | £200 (£494) | 5 (2) | ——— |
| 5 | Arable | Owned | £105 (£260) | £250 (£618) | 30 (12) | ——— |
| 6 | Arable | Owned | £45 (£74) | £150 (£370) | 2 (0.8) | ——— |
| 7 | Arable/ Beef/Lamb | Owned | £130 (£321) | ——— | 0 | Does not want public access to the farm |
| 8 | Arable | Owned | ——— | ——— | 0 | Land not suitable to grow trees upon |
| 9 | Dairy | Rented | £85 (£210) | ——— | 0 | Does not want public access to the farm |
| 10 | Arable | Owned | £116 (£287) | £300 (£741) | 0 | Farm too small for the scheme |
| 11 | Arable/ Setaside | Owned | £100 (£247) | ——— | 0 | Does not want public access to the farm |
| 12 | Arable/ Beef | Owned | £186 (£459) | £100 (£247) | 125 (50) | ——— |
| 13 | Arable/ Dairy | Owned | £186 (459) | £200 (£494) | 100 (40) | ——— |
| 14 | Arable/ Pigs | Owned | £163 (£402) | £250 (£618) | 20 (8) | ——— |
| 15 | Arable/ Beef | Rented | £150 (£370) | £250 (£618) | 0 | Does not want public access to the farm |
| 16 | Arable | Owned | £280 (£692) | £600 (£1,483) | 3 (1.2) | ——— |
| 17 | Arable | Owned | £145 (358) | £150 (£370) | 0 | Farm too small for scheme |
| 18 | Arable/ Dairy | Owned | £140 (£346) | ——— | 0 | Farmer too old to undertake long-term project |
| 19 | Setaside | Owned | ——— | £250 (£617) | 0 | Unwilling to undertake another scheme to Setaside |
| Total | | | £130 (£321) | £250 (£617) | | |
| Mean | | | £57 (£141) | £121 (£300) | 15 (6) | |

Most farms (10 farms, equivalent to 53% of the total sample) were mixed agricultural producers combining arable with a variety of other standard activities. The remainder of the sample consisted mainly of purely arable producers (7 farms; 37%), one purely dairy farm and one farm entirely in setaside (5% each) completed the sample. Nearly all those interviewed owned their farms (17 farms; 90%). This may limit the applicability of results to rented tenure farms.

Farmers were asked to state their average profit[17] per acre under existing production. This was asked so as to encourage farmers to sensibly consider the immediately following question regarding acceptable levels of financial compensation and to allow a comparison between these two amounts. Mean stated profit was £125/acre (£309/ha). Individual stated profit varied considerably between farms[18]. This may be due in some measure to an unwillingness to reveal profits to the interviewer (three farmers (16%) refused to answer this question) translating into an understatement of true profit. However, it was felt that the majority of this variation was due to changes in economic efficiency and consequent productivity across farms.

### A2.3.4.2: Willingness to allocate land to the woodland project

Individual responses to selected questions are reported in table A2.38. Twelve farmers (63%) initially stated that they were unwilling to allocate land for public access recreational woodland. Of these the most commonly stated reason for refusal was that the farmer did not want to allow public access to the farm (5 farms or 42% of those refusing to enter the scheme). Concerns regarding a loss of rights following entrance to such a scheme may be well founded. Repeated public use of footpaths within a wood may lead to their classification as public rights of way. Furthermore, interviews with senior Forestry Commission staff revealed that current policy will not allow farmers to be granted felling licences unless equivalent areas of replanting are agreed. In other words the decision to allocate a certain area from agriculture into recreational forestry may well be irreversible. Such irreversibility may perversely prove to be a considerable block to the extension of agro-forestry. Other reasons for refusing to participation can be broadly classified as 3 (25%) which were farm specific (farm size or land type); 2 (17%) which disliked the particular policy; and 2 (17%) which reflected the farmers particular preferences. These categorisations might have classified the outcome of these interviews somewhat differently. However, as a rough indication we feel that this is acceptable. It is notable that both of the rented tenure farms declined to allocate land to the scheme[19]. This may be because farmers felt that permission would have to be sought from the owners (which is a legal requirement) or a greater disinclination towards delayed return schemes. However, the sample size precludes any firm conclusion being drawn.

Seven farmers (37%) were initially willing to allocate land to the recreational woodland scheme. Given concerns regarding public access this was felt to be an encouragingly high percentage rate. Mean allocation was just over 40 acres (just over 15 hectares) per participating farm. This mean falls to approximately 15 acres (about 6 hectares) if non-participating farms are also taken into consideration. Uptake amongst participating farms appears to be bimodally distributed with two farms willing to allocate 100 acres or more into

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[17]The simple term 'profit' was preferred to any more technical definition.
[18]Although only one farm lies (just) outside the 95% confidence internal around the mean.
[19]Subsequent analysis (see table A2.39) confirms this as a statistically significant relationship.

woodland and the remainder only willing to undertake small scale afforestation projects. Whilst grant aid is available for small scale schemes, if the objective is to provide a viable, discrete recreational area then such small pockets (unless they can be combined) may not be suitable. Nevertheless the agreement to large scale planting by two farmers is encouraging particularly where the objective (as under the Forestry Commission Community Woodland Scheme)[20] is simply to ensure that the local community has access to a woodland recreation site within five miles of the community centre.

**A2.3.4.3: Willingness to accept compensation**

The majority of interviewees (14 farms; 74%) stated a sum which they would be willing to accept in annual compensation for allocating land out of agriculture and into public access woodland (WTApa). This included 7 of those farms who initially rejected the principle of such allocation (58%). This latter result seems to indicate that, if the price was right, such farms would consider a move out of conventional agriculture. However, there is one very noticeable 'protest bid'[21] amongst this subsample which at £20,000/acre is not only more than 150 standard deviations above the mean and more than 30 times larger than the next highest bid, but is also likely to be of equal magnitude to the entire annual net farm income. It is feasible that this respondent had in mind a discounted total net present value sum for the entirety of the project, in which case such a response would be reasonable. However, given that no other respondents gave answers within even the same magnitude, we feel that such an explanation is unlikely and a protest strategy seems much more likely.

Excluding this one outlier, the mean stated WTApa is £250/acre (£617/ha). Restricting the sample to those who initially stated an area which they were willing to allocate into the scheme has no effect upon this result, adding support to the validity of non-allocators responses (and thereby the entire sample)[22] as being valid bids.

Modelling WTApa

Farmers stated WTApa compensation bids were analysed for any relationship with other collected data. Table A2.39 details a simple zero order correlation matrix. This shows clear correlations between WTApa and profit per acre and the number of acres allocated to the scheme.

A one-way analysis of variance showed that a further variable based upon the type of production currently undertaken at farms had no significant impact upon WTApa.

Regression analysis showed that only the variables PROFIT and ACRES were significant predictors of the dependent variable WTApa. A variety of functional forms were tested for this relationship, the best fitting model being the linear function given in table A2.40.

The model presented in table A2.40 seems to fit the data well (easily satisfying a 1% F-test) and reports logical relationships between the dependent and explanatory variables. Farms with higher profit levels from existing activities demand higher levels of compensation for entering the woodland scheme. Furthermore those who are only willing to consider small scale planting require higher per-acre payments. This implies, logically, that large scale

[20]See discussion of grant schemes in chapter 6.

[21]The author dislikes the general application of this term to anyone who does not give an expected answer to a bidding (WTP or WTA) question. However, this particular respondent must satisfy all relevant requirements of an archetypal 'protester'.

[22]Excluding the single 'protest' bid.

plantations, which presumably will benefit from economies of scale, are considered viable alternatives at a relatively lower per-acre subsidy rate than small scale woodlands.

Table A2.39: Zero order correlation matrix

| VARIABLE | WTApa | TENURE | PROFIT |
|---|---|---|---|
| TENURE | 0.000 | | |
| PROFIT | 0.565 | 0.085 | |
| ACRES | -0.384 | 0.149 | 0.359 |
| AGREE | 0.000 | 0.262 | 0.181 |

where:
WTApa = Compensation required for undertaking woodland scheme (£/acre/annum)
TENURE = 1 if farm is farmer owned; 0 if rented
PROFIT = Stated current profit (£/acre)
ACRES = The number of acres which farmers are prepared to allocate into the woodland project
AGREE = 1 if ACRES>0; otherwise 0

Table A2.40: WTA regression equation and analysis of variance

$$\text{WTApa} = \underset{(1.81)}{94.04} + \underset{(4.04)}{1.48}\ \text{PROFIT} - \underset{(-3.37)}{1.93}\ \text{ACRES}$$

$R^2 = 69.9\%$ $R^2(adj) = 63.2\%$

Analysis of variance

| Source | df | SS | MS | F | p |
|---|---|---|---|---|---|
| Regression | 2 | 122262 | 61131 | 10.43 | 0.005 |
| Error | 9 | 52738 | 5860 | | |
| Total | 11 | 175000 | | | |

The zero order correlation matrix (table A2.39) indicates some multicollinearity between the dependent variables. This is not surprising given that larger farms are likely not only to have higher present profit rates but also to have a greater absolute area of land for allocation into the scheme. A stepwise (forward entry) regression analysis was undertaken to investigate the extent of any problems arising from this correlation. Table A2.41 details results from this analysis.

Table A2.41: Investigating multicollinearity: stepwise regression analysis on dependent variable WTApa

| Step | 1 | 2 |
|---|---|---|
| Constant | 104.90 | 94.04 |
| PROFIT<br>t-ratio | 1.07<br>2.17 | 1.48<br>4.04 |
| ACRES<br>t-ratio | | -1.93<br>-3.37 |
| $R^2$ | 31.94% | 69.86% |

Table A2.41 shows that the inclusion of the ACRES variable causes a significant increase in the size of the coefficient upon the PROFIT variable and also (possibly spuriously) inflates its t-value. This evidence, together with that from the zero order correlation matrix (table A2.39), leads us to conclude that we should not place too much emphasis upon the precise coefficient estimates of the regression equation given in table A2.40. However, the same evidence indicates that observed multicollinearity is not at such a level as to make such estimates invalid, rather they should be treated as having fairly wide confidence intervals. The degree of explanation of the WTA bid curve is not affected by collinearity between explanatory variables. Even allowing for the small sample size, the degree of fit is exceptionally high for an OE CV study, particularly as this survey employed a WTA question. We can conclude that farmers' responses were highly logically consistent and accord with economic theory. This funding runs contrary to most WTA studies and we consider reasons why this may be so subsequently.

## A2.3.5: WANTAGE CV WTP/WTA STUDY: DISCUSSION AND CONCLUSIONS

### A2.3.5.1: Theoretical welfare measures

This study has asked two separate questions. Firstly, householders were interviewed regarding their WTP to ensure the provision of a welfare gain. Both per-annum and per-visit payment formats were tested here. Values from such an exercise should, in theory, estimate the compensating surplus measure of welfare gain[23]. Secondly, farmers were asked to state the amount they were WTA (per annum) in compensation for forgoing existing agricultural production in favour of open-access recreational woodland. This latter exercise provides, in theory, measures of the compensating surplus measure of welfare loss[24]. Before discussion of the relative validity of these various analyses, we present a simple comparison based upon the aggregate WTP and WTA sums implied by these results.

[23] A 'type 1' $CpS_{WTP}$ gain following the typology of Bateman and Turner (1993).
[24] A 'type 4' $CpS_{WTA}$ loss as defined by Bateman and Turner (1993).

### A2.3.5.2: Aggregate values

Aggregation of the household WTP measures

Householders were asked to state WTP for a 100 acre block of recreational woodland. The annual format question elicited a simple mean WTP (including those who refused to pay as zeros) of £9.94 per household. The town of Wantage has an adult population of 11,495, so, even if we take an extreme upper bound estimate on household size (so as to derive a lower bound estimate on household WTP) of 2.57 (CSO,1991)[25] this would imply some 4,473 households in Wantage which would in turn imply an aggregate WTP of £44,450 per annum for the woodland.

Turning to consider our per-visit measure of WTP, we elicited a WTP of £0.82 per adult visit (again including those who refused to pay as zeros). The mean estimated number of visits (including those who would not visit) was just under 15 per annum implying a total annual entrance fee expenditure of £12.29 per adult. Grossing up across all adults[26] implies a total annual WTP entrance fees of £141,252.

Aggregation of the farmers WTA compensation measure

The farm survey estimated a mean WTA compensation of £250/acre p.a. Given that our household survey scenario elicited WTP for a 100 acre site, our estimated WTA for such a site is £25,000 per annum.

Comparison of WTP and WTA measures

Either measure of WTP exceeds our estimate of WTA to a considerable degree. In the case of our annual format we have a simple[27] benefit/cost ratio of 1.78 whilst the entrance fee format yields a ratio of 5.65.

Such results point strongly in favour of the setting-up of such schemes. However, we prefer to retain a cautious approach to the WTP sums. Another way of examining these is to consider the minimum number of payments needed to meet the required aggregate compensation level. Using the per-annum format and our above estimate of household size implies that some 2,515 households (i.e. 56% of all those in Wantage) would need to pay the £9.94 mean WTP for the scheme to break even. Alternatively all households in Wantage would have to pay £5.59 pa for the scheme to again break even. Using the per-visit mean implies that 30,487 individual visits per annum would be required to pay for the forest, i.e. each individual in Wantage would need to make 2.65 paying visits per annum for the site to break even.

### A2.3.5.3: Discussion

At first glance this study appears to have been a success and seems to hold out the possibility of the wider application of CV studies to relatively small-scale decision making problems. However, the discrepancy and particularly the relationship between household

[25]This figure refers to average UK household size rather than the average number of adults per household. If the latter were used this would increase our estimate of household WTP, i.e. we have chosen a conservative, lower bound assumption.

[26]Note that we have already accounted for non-visitors in the annual per-adult visit rate.

[27]The term 'simple' refers here to the fact that this study represents only a partial cost-benefit analysis of such a scheme.

annual and per-visit WTP is somewhat disturbing. Our discussion of bid curves for these measures suggested that answers to the per-visit format questions represented not true WTP valuations, but rather a "price" influenced by social norm expectations of what respondents felt was reasonable to pay for a forest visit. Conversely we argued that answers to the annual format question were, at least in some way, related to respondents true valuations. How then can "aggregate price" exceed "aggregate value"?

One explanation of this discrepancy arises from noting that we have reason to believe both that our annual format WTP measure may be downwardly biased by elicitation effects and that our per-visit measure may be upwardly biased by a number of factors. Regarding the annual format measure, our Norfolk Broads studies (Bateman et al, 1993) regarding elicitation effects in the CV, notes that an open-ended (OE) WTP question format (as used in all the Wantage experiments) will produce an estimated mean WTP significantly below that elicited from a dichotomous choice approach[28]. Whilst we stress that the dichotomous choice format need not, *per se*, be producing an estimate of 'true' WTP[29], the conclusion of this work was that OE formats produce, at best, lower bound estimates of WTP. We have compounded this in our calculation of 'aggregate value' by adopting further lower bound assumptions regarding household size. In short 'true' WTP could lie some way above our per-annum estimate.

Turning to the 'aggregate price' derived from our per-visit measure, a number of points should be noted. Firstly, our aggregation assumptions regarding household composition are not as aggressively lower-bound as for our 'aggregate value' estimate. Secondly, we have some reservations regarding estimated visit rate and note that the adoption of the 5% trimmed mean for this variable would result in a 22% fall in 'aggregate price'. More severe reductions in mean visit rate (which averages across the entire study population) are quite feasible resulting in corresponding further reductions in our "aggregate price" estimate. Thirdly, as we have discussed elsewhere (see chapter 3), it is highly probable that in answering this question respondents are searching for a social norm response regarding a socially appropriate entrance fee. Considerations in forming such a response are likely to include experience of other entrance fees which, as responses to questions regarding other recreation destinations show, includes many with significant fees. Fourthly, and perhaps most importantly, the rounding effect commented upon earlier has a far greater relative impact upon answers to the per-visit question than the annual payment question. Thus, for example, many respondents said that they would pay "one pound" per visit. Multiplying through by predicted visits this rounding often leads to an estimated of annual entrance fee payments being above that given in response to the annual WTP question. Finally, as an extension to this, it may be that the spreading of payments via an entrance fee is relatively attractive when compared to the lump sum payment inherent in the annual format question.

In conclusion, the disparity between 'aggregate value' and 'aggregate price' may not be a problem although the above discussion does highlight the need to consider these measures as point estimates within a wide confidence interval.

Turning to consider farmers' WTA responses, the most striking feature of this analysis is the comparatively very high explanatory power of the WTA bid function. This result

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[28]Bateman et al. (1993) record open-ended mean WTP being approximately half that elicited from a dichotomous choice experiment.

[29]Such a strong conclusion is implied by Arrow et al. (1993) in their preference for dichotomous choice over open-ended approaches.

contradicts findings from many previous WTA studies[30], where respondents have exhibited great difficulty in answering such questions. We believe that our result reflects the fact that UK farmers are well accustomed to making decisions regarding schemes and products which entail differing levels of compensation. These decisions are made with respect to the opportunity cost of forgone alternatives, a factor very well reflected in our bid function.

Finally, even taking into consideration the various actual and potential problems with this study, the clear excess of households' aggregate WTP (by whatever measure) over the WTA compensation amounts stated by farmers does indicate that the implementation of such a scheme as that hypothesised in the questionnaire scenario may well result in the generation of a significant net social benefit[31].

### A2.3.6: Wantage study: household WTP survey questionnaire

<u>Questionnaire</u>

READ OUT THE FOLLOWING:
I am (STATE NAME) from the University of East Anglia. We are conducting a survey examining the demand for countryside recreation around Wantage. I would like to ask you a few questions, any information which you supply will be kept strictly confidential and anonymous, and will be used only for statistical purposes.

1. For what length of time have you been living in the town?

2. What places have you visited for a day out during the last year? Please state for each:
   i. Site name
   ii. Description of site (categorise as rural, urban or park[32])
   iii. How many times did you go?
   iv. How far away is that?
   v. How did you get there?

| | Site A | Site B | Site C | Site D |
|---|---|---|---|---|
| Name | | | | |
| Description | | | | |
| No. of visits | | | | |
| Distance | | | | |
| Transport | | | | |

[30]See review in Mitchell and Carson (1989).

[31]A more certain statement concerning the total net benefits of such a scheme can be made if we assume that farmers have incorporated direct afforestation costs into their WTA compensation statements. This is feasible and, given the fact that grants in respect of many of these costs are available, such an assumption does not appear too strong.

[32]See discussion for definition of these terms.

3. Given the choice, would you prefer to spend time at recreation facilities in the town/city, or in the countryside?

4. The purpose of this survey is to assess interest in a possible community woodland park within the area. It would be within three miles of the town and approximately one hundred acres in size. It would be made up of mixed broadleaved trees and would be for recreational use. Although much of it would be made up of young trees, it would incorporate existing mature woodland. In addition there would be paths laid out and a small car park.
The organisers, while able to get some government funding, would also be reliant on contributions from local townspeople. These contributions would be mainly for planting and maintenance costs.

   a) Given all the above, would you be willing to contribute an annual subscription to a charitable fund set up for such a scheme?

   If no, please state reason.

   If yes, please state amount.

(For half of respondents: read out the following)
It has been estimated that running costs for the wood will be approximately £20,000 per annum. Would this affect your WTP into the fund?

   b) In place of an annual subscription, would you be prepared to pay per adult as a car parking entrance fee?

   If no, please state reasons.

   If yes, please state amount.

   c) If such a woodland were set up, how often would you use it?

5. Please could you give me some information about the members of your household?

a) What is the composition of the household?

| Age Group (years) | No. of People |
|---|---|
| 0-4 | |
| 5-11 | |
| 12-16 | |
| 17-25 | |
| 26-45 | |
| 46-65 | |
| 65+ | |

b) What are the professions of the adults in your household?

c) Could you indicate into which of the following categories your annual household income falls?

| Category | Income (£ pa) |
|---|---|
| 1 | 0-4999 |
| 2 | 5,000-9,999 |
| 3 | 10,000-14,999 |
| 4 | 15,000-19,999 |
| 5 | 20,000-24,999 |
| 6 | 25,000-29,999 |
| 7 | 30,000-39,999 |
| 8 | 40,000+ |

**THANK YOU FOR PARTICIPATING IN THIS SURVEY**

## A2.4: Thetford 2 CV/TC study: Detailed analysis

Between 26th March and 25th April, 1993, 351 visitors to Lynford Stag, Thetford Forest, were interviewed in an on-site survey. Data was collected for both a CV and ITC study with the latter eliciting sufficient data to employ GIS route analysis of travel distance and travel time. This data was also used to estimate an 'arrivals function' which combines information from the survey with details regarding population distribution and road network availability and quality to predict the number of visitors to other specified sites (see details in chapter 5).

The questionnaire used for this survey is reproduced at the end of this discussion. Many of the findings from our earlier studies influenced the design of this instrument and we feel that it allows for a significantly improved and more sophisticated degree of analysis than did its predecessors.

The Lynford Stag site was chosen primarily for the transferability of its recreational attributes. While there are a few other minor attractions[33], the main activity of the site is open-access, recreational walking. This means that many of the attribute related measures of our analysis may be transferable to other sites.

### A2.4.1: THETFORD 2: THE CV STUDY

#### A2.4.1.1: The central question

In designing this study we felt that our previous work, together with our benefit transfer analysis of reviewed studies, had provided us with a good grasp of the range of valuations being derived from a typical CV study of UK woodland recreation. What we wished to investigate in this study was the extent to which theoretically reasonable re-specifications of CV questionnaire design impacted upon WTP response. In particular we wished to address three issues:

i) The mental accounts question: In chapter 2 we discussed the extent to which individuals do, or do not, consider other demands upon disposable income when answering WTP questions.

ii) Payment scenario effects: In the Thetford 1 study separate groups were presented with either per annum or per visit payment scenarios. The Wantage experiment presented first the per annum and then the per visit scenario to all respondents. In the Thetford 2 CV study we set out to see whether answers to these questions were to some extent endogenous to the instrument design and dependent upon the following:

iii) Ordering effects: Does the answer to one question depend upon prior responses? If so can the inclusion, exclusion or re-ordering of questions affect responses? If so to what extent?

These three effects were investigated through a split-sample study design in which respondents were divided into two groups each of which was further divided into two subgroups as follows:

[33]The site also has a car park, an information board giving details of walks at the site, a few picnic benches and barbecue sites, a child's swing and wooden climbing frame, and some toilets. However, our survey confirms that by far the major activity is recreational walking.

Group B: Prior to any WTP question respondents were asked to calculate and state their annual recreational budget.
Group NB: No budget question asked prior to any WTP response.
Subgroup 1: WTP per annum (tax) asked prior to WTP per visit (fee) question.
Subgroup 2: WTP per visit (fee) asked prior to WTP per annum (tax) question.

We therefore have four subgroups each of which provides both a tax (per annum) and a fee (per visit) WTP response. Because of the consequent number of results obtained from such a design, a set of acronyms was set up to identify each result. Table A2.42 details these identifiers (per visit measures given in italics to further clarify differences).

Following the findings of our previous research, an open-ended elicitation method was used throughout as a conservative approach to deriving WTP responses. In addition to the WTP questions the survey also elicited information regarding all relevant visit, socioeconomic and interview condition variables necessary for subsequent validity analysis.

**A2.4.1.2: The payment principle question**

Prior to certain of the WTP (and budget) questions, respondents were asked whether or not they were willing to pay anything at all. This 'payment principle' question was included because we felt that interviewees who did not wish to pay might otherwise feel inhibited from stating such a response if they were directly asked how much they were willing to pay. In such a case we felt that many of these respondents may say some non-zero sum because they felt embarrassed, or otherwise unable, to admit their true, zero, willingness to pay.

Table A2.42: Acronyms for WTP subgroup response sets

| Budget question | Payment ordering scenario<br>t = tax vehicle (per annum payment)<br>*f = fee vehicle (per visit payment)* | |
|---|---|---|
| | Subgroup 1:<br>tax question asked<br>prior to *fee* question | Subgroup 2:<br>*fee* question asked<br>prior to tax question |
| Group NB:<br>annual recreation budget not elicited prior to WTP question | t1NB<br>*f1NB* | t2NB<br>*f2NB* |
| Group B:<br>annual recreation budget was elicited prior to WTP question | t1B<br>*f1B* | t2B<br>*f2B* |

73% of respondents stated that they were prepared to pay at least some amount for the recreational facilities provided at Thetford Forest. This is somewhat lower than for our study of the Norfolk Broads (85% acceptance) and may reflect the increased number of sites which might substitute for Thetford compared to the almost unique nature of Broadland.

The determinants of the decision to respond positively to the payment principle question were investigated through chi-square analysis. This indicated weak (statistically just insignificant) positive relationships with income, travel distance and visit duration[34], and a similarly weak negative relation with interest in wargaming and other structured recreational pursuits. Significant and positive relationships were found for three activity groups: those who often take short walks of less than two miles at the site ($\alpha = 5\%$); those who often use the site for relaxation/enjoying scenery ($\alpha = 1\%$); and those who sometimes or often enjoy nature watching at the site ($\alpha = 1\%$). Tables A2.43, A2.44 and A2.45 detail chi-squared analyses for each of these factors in turn.

Table A2.43: Chi-squared analysis of payment principle response on whether respondent often takes short walks at the site

| Does respondent often take short walks (<2 miles) at the site? | Is respondent WTP anything at all? | | Row totals |
|---|---|---|---|
| | No | Yes | |
| NO | 37.9% (33) | 62.1% (54) | 100% (87) |
| YES | 23.9% (63) | 76.1% (201) | 100% (264) |
| Column totals | 27.3% (96) | 72.7% (255) | 100% (351) |

$\chi^2 = 6.52$

Notes: $\chi^2$ critical values with 1df = 3.84 ($\alpha = 5\%$)
= 6.64 ($\alpha = 1\%$)
Upper numbers in each cell refer to row percentages. Lower figures (in brackets) refer to the actual number of respondents in that cell.

Table A2.44: Chi-squared analysis of payment principle response on whether respondent often relaxes/enjoys scenery at the site

| Does respondent often relax/enjoy scenery at the site? | Is respondent WTP anything at all? | | Row totals |
|---|---|---|---|
| | NO | YES | |
| NO | 39.1% (45) | 60.9% (70) | 100% (115) |
| YES | 21.6% (51) | 78.4% (185) | 100% (236) |
| Column totals | 27.3% (96) | 72.7% (255) | 100% (351) |

$\chi^2 = 11.95$

Notes: $\chi^2$ critical values with 1df = 3.84 ($\alpha = 5\%$)
= 6.64 ($\alpha = 1\%$)
Upper numbers in each cell refer to row percentages. Lower figures (in brackets) refer to the actual number of respondents in that cell.

[34]All factors which support the findings of our Thetford 1 study.

Table A2.45: Chi-squared analysis of payment principle response on whether individual sometimes or often enjoys nature watching at the site

| Does respondent sometimes or often enjoy nature watching at the site | Is respondent WTP anything at all? | | Row totals |
|---|---|---|---|
| | NO | YES | |
| NO | 36.6% (45) | 63.4% (78) | 100% (123) |
| YES | 22.4% (51) | 77.6% (177) | 100% (228) |
| Column totals | 27.3% (96) | 72.7% (255) | 100% (351) |

$\chi^2 = 8.127$

Notes: $\chi^2$ critical values with 1df = 3.84 ($\alpha$ = 5%)
= 6.64 ($\alpha$ - 1%)
Upper numbers in each cell refer to row percentages. Lower figures (in brackets) refer to the actual number of respondents in that cell.

The factors considered in tables A2.43 to A2.45 are clearly related and further $\chi^2$ analysis confirmed that the majority of those who stated that they often relaxed and enjoyed the scenery at the site also stated that they sometimes or often enjoyed nature watching and went for short walks. Clearly then such factors could not be entered separately within a logit model of payment principle responses (as used in Bateman *et al.*, 1992). Consequently an amalgam variable was created whose significance was maximised by grouping together all those who exhibited at least two of the three factors analysed in tables A2.43 to A2.45. The resultant variable (which we label as VISITOR A) proved to be highly significant in explaining responses to the payment principle question. Results from this analysis are given in table A2.46.

Interpretation of table A2.46 is perhaps easiest if we consider which respondents do not fall into our VISITOR A category. These are individuals who are relatively less likely to indulge in nature watching, short walks or just relaxing and enjoying scenery. It seems likely that such respondents may prefer more formal organised recreation[35]. Unfortunately we had not anticipated the potential usefulness of including non-woodland activities in our list of recreational pursuits and so cannot adequately test such a hypothesis. Such questions will be incorporated into future research. However, reasons for both positive and negative responses to the payment principle question were explicitly investigated via direct questioning of respondents. Those who refused to pay anything at all were presented with a show-card detailing various set responses regarding reasons for refusal[36] and asked to state which category response best described their reason for refusal. Table A2.47 details results from this analysis.

[35]This interpretation somewhat supported by the disinclination of those interested in wargames to assent to the payment principle question.

[36]Show cards reproduced with questionnaire at the end of the discussion of this study.

Table A2.46: Chi-squared analysis of payment principle response on VISITOR A variable

| Respondent in VISITOR A category? | Is respondent WTP anything at all? | | Row totals |
|---|---|---|---|
| | NO | YES | |
| NO | 42.6% (43) | 57.4% (58) | 100% (101) |
| YES | 21.2% (53) | 78.8% (197) | 100% (250) |
| Column totals | 27.3% (96) | 72.7% (255) | 100% (351) |

$\chi^2 = 16.540$

Notes: $\chi^2$ critical values with 1df = 3.84 ($\alpha$ = 5%)
= 6.64 ($\alpha$ = 1%)
Upper numbers in each cell refer to row percentages. Lower figures (in brackets) refer to the actual number of respondents in that cell. VISITOR A variable defined in text.

Table A2.47: Respondents stated reason for refusing the principle of payment

| No. | Reason for refusal[1] | No. of respondents | % of all refusals | % of total sample[2] |
|---|---|---|---|---|
| 1 | Cannot afford to pay | 2 | 2.1 | 0.6 |
| 2 | Does not like site | 0 | 0.0 | 0.0 |
| 3 | Prefers natural state | 10 | 10.4 | 2.8 |
| 4 | Refuses to value site | 11 | 11.5 | 3.1 |
| 5 | Someone else should pay | 6 | 6.3 | 1.7 |
| 6 | Pays too much tax already | 24 | 25.0 | 6.8 |
| 7 | Rejects entrance fees | 7 | 7.3 | 2.0 |
| 8 | Other | 12 | 12.5 | 3.4 |
| 9 | Not stated | 24 | 25.0 | 6.8 |
| | Totals | 96 | 100.0 | 27.3 |

Notes: 1. Full details in show cards reproduced with questionnaire
2. Total sample size = 351
Numbers rounded to one decimal place.

Considering the reasons given for refusing to pay for the site we can see that the major specified issue is one of economic constraint (inability to pay, reasons 1; and current expenditure demands, reason 6) although in some ways this might reflect a rejection of the tax and fee vehicles (reasons 6 and 7). Reason 5 (someone else, such as the government, should pay) is the extreme free-rider response. The small number of individuals in this category is encouraging but may nevertheless point to a larger group of respondents who, while prepared to pay something, still understate their total WTP. Our Norfolk Broads study (Bateman et al., 1993) indicated that OE elicitation methods may suffer from a certain degree of understatement. This may apply here although the relatively low numbers in refusal category 5 suggest that this may not be too much of a problem in this instance and will in any case result in conservative predictions of total WTP.

The one category which would suggest that our study is fundamentally invalid is that for individuals who refuse to value the site (response 4). Reasons for such a response may be diverse. However, even if we assumed that all such respondents fundamentally rejected the principle of monetary evaluation, the small number of individuals in this category suggests that we do not have a problem here.

Respondents who accepted the principle of paying at least some amount were similarly asked their reasons for so doing. Table A2.48 details results from this analysis.

Table A2.48: Respondents stated reason for accepting the principle of payment

| No. | Reason for acceptance[1] | No. of respondents | % of all acceptances | % of total sample[2] |
|---|---|---|---|---|
| 1 | Reasonable amount to pay | 28 | 11.0 | 8.0 |
| 2 | Similar price to equivalent sites | 8 | 3.1 | 2.3 |
| 3 | Lives close to site | 8 | 3.1 | 2.3 |
| 4 | Visits site often | 5 | 2.0 | 1.4 |
| 5 | Keen on countryside | 28 | 11.0 | 8.0 |
| 6 | Keen on forests | 3 | 1.2 | 0.9 |
| 7 | Keen on wildlife/environment | 25 | 9.8 | 7.1 |
| 8 | Preserve for future | 92 | 36.1 | 26.2 |
| 9 | Other | 3 | 1.2 | 0.9 |
| 10 | Not stated | 55 | 21.6 | 15.7 |
| | Totals | 255 | 100.0 | 72.7 |

Notes: 1. Full details in show cards reproduced with questionnaire
2. Total sample size = 351
Numbers rounded to one decimal place.

Interpretation of some of the responses in table A2.48 must be somewhat loose as several categories are overlapping (e.g. 5, 6 and 7). However, the lack of respondents in category 2 is encouraging[37]. Perhaps the most interesting observation is the large number of respondents stating that their prime motivation in agreeing to pay something was to preserve such areas for future generations. The wording of this category was phrased so as to separate this from option value, although it is always possible that some respondents may have been influenced by such considerations. Nevertheless the prime rationale behind such a response would appear to be bequest value. In other papers we have been somewhat suspicious of such statements of altruism in CV studies (Bateman, 1992). However, the strength of such apparent feeling within this sample is remarkable and raises an interesting question regarding how the respondent views his or her own WTP bid. While it seems probable that per visit WTP entrance fee bids would relate to the pure use value of a visit, the results of table A2.48 suggest that for many people, responses to per annum WTP questions are quite likely to be a mixture of use plus non-use (bequest and existence) value. In a fully informed, rational expectations model of respondent behaviour we would therefore be able to use the difference between the annual equivalent of per visit response and stated per annum WTP as equal to non-use value. Unfortunately we suspect that problems regarding

[37]Particularly as this appears so near the top of the show card list of options, i.e. it might be inflated by any list-bias effect (see chapter 2).

the discounting of future expectations, measurement error within the individual and (probably most important) payment vehicle effects, may confound such a calculation. Nevertheless the strength of opinion expressed in table A2.48 (and the desirability of successful estimation of non-use values) suggests that this is a worthwhile avenue for future research.

### A2.4.1.3: Calculation of mean WTP and confidence intervals

At the start of each interview, respondents (unbeknown to themselves) were randomly allocated to one of the four subgroups described in table A2.42 such that roughly one-quarter of the total sample was in each subgroup. However, these numbers were then randomly disturbed by those respondents who stated that they were not willing to pay anything at all. As the payment principle question preceded any WTP question, the consequent reduction in subsample sizes is random and does not invalidate or in any way contaminate WTP responses. However, it does mean that we need to subsequently adjust for the differing subsample sizes when calculating mean WTP. Table A2.49 details the number of individuals facing WTP questions (i.e. having previously agreed to the payment principle) in each subgroup.

Table A2.49: Subgroup sample size for WTP questions

| Budget question | Payment ordering scenario | | Row totals |
|---|---|---|---|
| | 1<br>(tax then fee) | 2<br>(fee then tax) | |
| NB<br>(not asked) | 66<br>64.1%<br>44.3% | 37<br>35.9%<br>34.9% | 103<br>100.0%<br>40.4% |
| B<br>(asked) | 83<br>54.6%<br>55.7% | 69<br>45.4%<br>65.1% | 152<br>100.0%<br>59.6% |
| Column totals | 149<br>58.4%<br>100.0% | 106<br>41.6%<br>100.0% | 255<br>100.0%<br>100.0% |

Notes: Cell contents arranged vertically as follows:
1. Number of respondents in cell
2. Row percentage
3. Column percentage.

Table A2.49 shows that, by random chance, certain subgroups contain more payment principle refusals than others. As this was a random allocation we need to redistribute these zero bids equally amongst all subgroups. To do this we first summed the WTP bids in each subgroup and then divided by one-quarter of the total sample size (i.e. distributing zero bids equally) to obtain mean WTP (including reallocated refusals as zero bids). In the following subsections we present results from the analysis of, firstly, per annum and, secondly, per visit WTP responses.

i. Per annum (tax) WTP responses

Table A.2.50 gives total, per annum (tax) WTP for each subgroup.

Table A2.50: Recorded total WTP per annum (£) for each subgroup (omitting payment principle refusals)

| Budget question | Payment ordering scenario 1 (tax then fee) | Payment ordering scenario 2 (fee then tax) |
|---|---|---|
| NB (not asked) | 1101.14 | 668.74 |
| B (asked) | 2860.51 | 1436.51 |

To allow for an even distribution of payment principle refusals and thence calculate mean WTP we simply divide each subgroup total WTP by the sample size divided by number of subgroups, i.e. we divide subgroup total WTP by 351/4 = 87.75. Table A2.51 details results for this calculation along with (in brackets) 95% confidence intervals which were similarly calculated.

Table A2.51: Mean WTP (tax) per annum (£) and 95% confidence intervals (in brackets) for each subgroup (including payment principle refusals as zeros)

| Budget question | Payment ordering scenario 1 (tax then fee) | Payment ordering scenario 2 (fee then tax) |
|---|---|---|
| NB (not asked) | 12.55 (8.11 - 16.99) | 7.62 (2.87 - 12.37) |
| B (asked) | 32.60 (21.76 - 43.43) | 16.37 (11.19 - 21.55) |

Some commentators have also reported means excluding those who refuse to pay. Table A2.52 reports such figures (calculated by reducing sample size from 351 to 255 in the previous analysis) although we prefer to concentrate upon those of table A2.51 as we see these as more representative of all visitors.

Table A2.52: Mean WTP (tax) per annum (£) and 95% confidence intervals (in brackets) for each subgroup (excluding payment principle refusals)

| Budget question | Payment ordering scenario 1 (tax then fee) | Payment ordering scenario 2 (fee then tax) |
|---|---|---|
| NB (not asked) | 17.28 (11.16 - 23.39) | 10.49 (3.95 - 17.02 |
| B (asked) | 44.88 (29.96 - 59.79) | 22.54 (15.40 - 29.67) |

Consideration of the results of table A2.51 indicates that the inclusion or exclusion of the recreational budget question, and/or changes in the ordering of payment vehicle presentation, results in consistent and major impacts upon stated WTP[38]. The inclusion of the budget question raised mean annual WTP by a factor of 2.60 for vehicle ordering scenario 1 (tax then fee) and by a factor of 2.15 for vehicle ordering scenario 2 (fee then tax). Given the magnitude of change this clearly raises major questions for CV research. The direction of change is also interesting. Most commentators (Mitchell and Carson, 1989; Willis and Garrod, 1992) discuss cases in which, *a priori*, we would expect that respondents' consideration of annual expenditure upon recreation and consequent budget constraints would lead to a reduction in stated WTP compared to statements made without such consideration. However, here we observe a very strong opposite effect whereby respondents who are asked to calculate their present annual expenditure state significantly higher WTP sums than those not asked the prior budget question.

Why has this effect occurred? It seems to us that two interpretations are possible, one deriving from economic theory and the other influenced by psychological literature. An economic argument might be that respondents forced to overtly consider their annual recreational budget find that, on average, this accounts for a significant portion of their total annual expenditure, perhaps more than they realised without such consideration. Certainly stated recreational budgets were not insignificant. The mean budget (£227.30) was considerably affected by the skewed nature of this distribution as described (with income) in table A2.53. Nevertheless, the median value of £120 shows that most respondents had considerable recreational budgets. Following this line of argument, upon consideration of the apparent importance of recreation in individuals' preference sets, such respondents gave higher WTP sums than would otherwise have been stated.

If we accept the economic argument then a supplementary question arises as to which WTP measure (with, or without, the prior budget question) is correct. This line of reasoning would seem to suggest that answers formulated following the consideration of available budgets will be less susceptible to mental accounting problems and therefore preferable[39]. However, this conclusion runs counter to that provided by psychological interpretations of our results. Here the calculation of the annual budget (which is relatively high compared to WTP for the forest) acts as an anchor for subsequent WTP statements. Kahneman et al. (1982) suggest that such an effect is most likely to occur where individuals are inexperienced and face considerable uncertainty in forming their response. Certainly individuals do not have much experience of setting prices as opposed to reacting to them[40].

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[38]Note that there is some overlap of confidence intervals for changes between certain subgroups (although not for others). Nevertheless strong impacts do appear to have been detected here. In every case the mean from one subgroup falls outside the confidence interval of its vertical or horizontal neighbour (i.e. where we vary just one factor; as the factors have contrary effects, varying both tends to cancel each other out).

[39]Such a conclusion would imply that the bulk of the CV literature, which has not incorporated mental account questions, is flawed.

[40]Our own work (Bateman *et al.*, 1993) suggests that respondents exhibit greater uncertainty in answering OE (as per this experiment) than DC WTP questions. Use of an OE format may therefore exacerbate this problem although the extent of this exacerbation will be constant across respondents ie. elicitation effects do not explain these findings. In future work we would aim to repeat this experiment within a DC format to reduce the level of uncertainty which OE formats may induce.

Table A2.53: Descriptive statistics for respondents' annual recreational budget and gross household income (£ pa)

| Variable | No. asked question | No answering question | mean | median | trimmed mean | st. dev. | Q1 | Q3 | max. | 95% CI | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | lower | upper |
| Budget | 167 | 152 | 227.30 | 120.00 | 169.40 | 345.50 | 70.00 | 250.00 | 2500.00 | 171.90 | 282.60 |
| Income | 351 | 348 | 18,247 | 17,500 | 17,524 | 10,823 | 12,500 | 25,000 | 55,000 | 17,106 | 19.388 |

Clearly this finding gives us pause for thought regarding the degree to which WTP responses may be manipulated by small and apparently defensible changes in questionnaire design. The responsiveness of stated WTP to the inclusion of the budget question is remarkable and a matter of significant concern for future CV studies.

Turning to consider the impact of changing the order of payment questions upon per annum responses: for those subgroups not given the prior budget question, placing a per visit question before the per annum question lowered the latter to just 60.7% of stated annual WTP when not preceded by a per visit question[41]. For those subgroups who were given a prior budget question, this disparity increased so that WTPpa preceded by a per visit question is just 50.2% of WTPpa not so preceded. Here an economic justification might be that such respondents were taking prior per-visit payments and extrapolating them to produce a per-annum sum. However, this would imply that per annum bids made prior to per-visit bids were in error. Here then the psychological argument that the relatively small per-visit WTP sums have anchored subsequent per annum statements, seems the most logical explanation of these results[42].

Consideration of the rates of impact of the mental account (budget) and ordering (payment vehicle) effects suggests some interaction. It appears that the use of a per visit question prior to the WTP per annum response diminishes the impact upon WTPpa of inserting the budget question. This is as expected as inclusion of the per-visit question restricts the range of per annum responses. Furthermore inclusion of a prior budget question increases the disparity between an otherwise unpreceded WTPpa bid and the response to the same question when preceded by a per visit question. Here the inclusion of the budget question opens up the range of subsequent per annum WTP responses.

ii. Per visit (fee) WTP responses

The mental account and payment vehicle ordering effects upon per visit WTP bids were also analysed. Mean WTP and confidence intervals were calculated as per the annual WTP experiments. Table A2.54 gives total WTP for each subgroup.

[41] Based on results of table A2.51.

[42] Which in turn can only enhance the anchoring interpretation of the budget effect.

Table A2.54: Recorded total WTP (£) via per visit fees by each subgroup (excluding payment principle refusals)

| Budget question | Payment ordering scenario 1 (tax then fee) | Payment ordering scenario 2 (fee then tax) |
|---|---|---|
| NB (not asked) | 39.55 | 17.25 |
| B (asked) | 68.50 | 40.15 |

Table A2.55 details mean WTP via per visit fees for each subgroup and 95% confidence intervals. Here all payment principle refusals are included as zeros allocated equally between subgroups.

Table A2.55: Mean per visit (fee) WTP (£) and 95% confidence intervals (in brackets) for each subgroup (including payment principle refusals as zeros)

| Budget question | Payment ordering scenario 1 (tax then fee) | Payment ordering scenario 2 (fee then tax) |
|---|---|---|
| NB (not asked) | 0.45 (0.35 - 0.55) | 0.20 (0.11 - 0.29) |
| B (asked) | 0.78 (0.53 - 1.03) | 0.46 (0.30 - 0.62) |

For comparison table A2.56 repeats this analysis omitting payment principle refusals. For reasons stated previously we prefer the results given in table A2.55.

Table A2.56: Mean per visit (fee) WTP (£) and 95% confidence intervals (in brackets) for each subgroup (excluding payment principle refusals)

| Budget question | Payment ordering scenario 1 (tax then fee) | Payment ordering scenario 2 (fee then tax) |
|---|---|---|
| NB (not asked) | 0.62 (0.48 - 0.76) | 0.27 (0.15 - 0.39) |
| B (asked) | 1.07 (0.73 - 1.42) | 0.63 (0.41 - 0.85) |

Considering table A2.55 we can see that the design effects detected in the per annum experiments have been repeated in the per-visit studies, although because fee responses were smaller than per annum bids, the line of ordering is reversed. Here the prefixing of per visit WTP questions by per annum questions increases per-visit WTP bids. Similarly, and as before, the inclusion of a prior question regarding recreation budgets leads to significant increases in subsequent per visit WTP responses. The economic and psychological arguments surrounding these effects are as before although we feel that the influence of 'social norm' pressures upon per visit responses (see chapter 3) may have diminished the intensity of these effects compared to those observed in the per-annum experiments. This additional factor is most clearly demonstrated when we contrast the per-visit means in table A2.55 with their per annum equivalents in table A2.51. In both cases the lower left hand cell (subgroups t1B and f1B) represents WTP when both positive (budget and ordering) effects are in operation resulting in the most extreme WTP responses. For this cell in the per-annum experiments the budget effect (vertical) raises mean WTP by a factor of 2.6 while the ordering effect (horizontal) increases mean WTP by a factor of 2.0. In the per visit experiments the equivalent factor increases are in both cases roughly 1.7. We would argue that this relative diminishment of extreme effects by the per-visit vehicle are due to the 'social norm' pressures exserted upon respondents who take into account notions of a socially 'fair' entrance price and experience of fees elsewhere when formulating their per-visit WTP response.

### A2.4.1.4: Validation: bid function analysis

Validation of our results was carried out as for previous studies with the main emphasis being upon statistical investigation of the factors determining WTP responses.

i. Per-annum WTP responses

Examination of the most appropriate functional form was conducted as before and again concluded that a natural log specification of the dependent variable fitted the data best. Following this, consideration switched to identification of significant explanatory variables via one-way analyses of variance and stepwise linear regression. The one-way analyses highlighted a number of interesting relationships. Weakly significant ($\alpha > 0.05$) factors included a negative relation with being a first time visitor or member of a sports/WI or other club and a positive relation with the number of day visits to the site annually[43]. Strongly significant ($\alpha < 0.05$) variables were as follows (figures in brackets are ρ values from oneway analyses of variance):

| | | |
|---|---|---|
| $ORDER_{tax}$ | = | 1 if respondent had been asked a per-visit (fee) question prior to per annum (tax) WTP; = 0 otherwise (p = 0.000) |
| BUDGET | = | 1 if respondent had been asked to state annual recreational budget prior to per annum (tax) WTP; = 0 otherwise (p = 0.000) |
| NOTCAR | = | 1 if visitor did not arrive by car; = 0 otherwise (p = 0.003) |
| SUPERB | = | 1 if respondent rated scenery at the site as superb; = 0 otherwise (p = 0.028) |
| RSPB | = | 1 if respondent was a member of the Royal Society for the Protection of Birds; = 0 otherwise (p = 0.021) |
| TRUST | = | 1 if respondent was a member of a wildlife trust; = 0 otherwise |

[43]Other even weaker but correctly signed factors include: income(+ve); sunniness(+ve); temperature(+ve); multi-site trips(-ve); enjoyment of the journey(-ve); length of time on site(+ve); and whether respondent was a tax-payer(+ve).

(p = 0.040)

LOWINCOME = 1 if respondent's household income was below £5,000 per annum; = 0 otherwise (p = 0.048)

All these explanatory variables had significantly positive effects upon per-annum WTP with the exception of the $ORDER_{tax}$ and LOWINCOME variables which were negatively related. Table A2.57 details the best fitting regression model of per annum WTP.

Table A2.57: Best fitting bid function for per annum WTP.
Dependent variable = natural log of per annum WTP (ln WTPpa)

| variable | coeff. | st. dev. | t-ratio | ρ |
|---|---|---|---|---|
| Constant | 1.2573 | 0.1157 | 10.86 | 0.000 |
| $ORDER_{tax}$ | -0.6024 | 0.1359 | -4.43 | 0.000 |
| BUDGET | 1.4668 | 0.1370 | 10.71 | 0.000 |
| NOTCAR | 1.1772 | 0.3259 | 3.61 | 0.000 |
| SUPERB | 0.6226 | 0.2033 | 3.06 | 0.002 |

s = 1.267 $R^2$ = 31.8% $R^2$(adj) = 31.0%
Regression F = 40.18 ρ = 0.000
Variables as defined in text.

A GLM analysis was used to test an interaction term between the $ORDER_{tax}$ and BUDGET variables. However, this was found not to be significant (p = 0.375).

Table A2.58 reports zero-order correlation coefficients for the variables incorporated in table A2.57 providing simple confirmation of the lack of multicollinearity within this equation. Omitted variable tests confirmed the stability of estimates.

Table A2.58: Correlation matrix for dependent and explanatory variables

| variable | ln WTPpa | $ORDER_{tax}$ | BUDGET | NOTCAR |
|---|---|---|---|---|
| $QORDER_{tax}$ | -0.200 | | | |
| BUDGET | 0.482 | -0.048 | | |
| NOTCAR | 0.157 | 0.035 | 0.030 | |
| SUPERB | 0.117 | 0.038 | 0.011 | -0.084 |

The overall predictive power of our best fit model is, by CV standards, quite good for an OE study. What is of concern is the confirmation of the strength of the vehicle ordering and mental accounting effects upon individuals' responses. The inclusion of a prior budget question very significantly increases subsequent per-annum WTP responses whereas a prior per-visit WTP question acts to reduce subsequent per-annum responses. Of the two the budget effect is the greater both in terms of absolute magnitude and statistical significance, but both factors are very clearly at work here.

ii. Per visit WTP responses

As before validity testing focussed upon estimation of a bid function for WTP responses. Initial investigations showed that, due to a relative lack of variation in per-visit WTP responses, a linear dependent variable fitted the data better than a log-linear specification. We interpret this as a sign that responses to per-visit questions are dominated by our 'social-norm' factors rather than by standard socioeconomic and visit characteristics.

Simple data analysis techniques were used to identify potential explanatory variables[44]. A number of interesting but statistically weak quadratic relationships with WTP were noted. Per visit WTP was found to initially rise with distance (particularly noticeable at about 15 miles). The reason for this would appear to be linked to the purposefulness of the visit. Visitors who travel some considerable way specifically to visit the site clearly have a strong preference for its attractions. However, as distance becomes particularly long, purposefulness falls and visits become more by chance than design, i.e. such very long distance visitors generally happen upon the site by accident and stop just to break the journey, their real destination being elsewhere. This interpretation is supported by the positive relation with visitors' rating of Thetford in terms of their overall day's enjoyment and negative relationships with enjoyment of travel and visits to other sites that day. These findings underscore the importance of using enjoyment-adjusted travel costs in our subsequent TC study of the site, without which we would overestimate consumers surplus for the site.

A second quadratic relationship was found with the number of day visits per annum. Here WTP is initially relatively small at low numbers of annual visits. This is a function both of the meanderers and passers-by referred to above and because those who make few trips may do so because they have many available alternatives. As the number of trips increases so, initially, does per-visit WTP. Here we have respondents who like the site but do not make very high numbers of visits because of trip distance and substitute availability (which will be collinear). However, at very high numbers of visits, WTP per-visit falls back again. Such respondents probably live close and may have few available substitutes. For them a per-visit fee would translate to a considerable annual cost to which they are understandably resistant.

A third quadratic, identified to some degree in all our empirical studies, is with age. Both the young and old tend to give lower WTP bids (both per-annum and per-visit) than the middle-aged, a result most likely to be reflecting disposable income distributions.

A number of simple but statistically weak linear relationships were also identified. WTP per visit was found to be negatively related to having started the day's journey at home rather than from a holiday address, and to the principle activities of wargaming and dogwalking (for reasons given above; dogwalkers live locally and visit often). Weak positive relations were found with picnicking and relaxing/enjoying scenery as principle visit objectives and with income.

A number of statistically significant ($\alpha < 0.05$) variables were identified as follows (numbers in brackets are $\rho$ values from one-way analyses of variance):

| | | |
|---|---|---|
| $ORDER_{fee}$ | = | 1 if respondent had been asked a per-annum (tax) question prior to per-visit (fee) WTP; =0 otherwise (p = 0.033) |
| BUDGET | = | 1 if respondent had been asked to state annual recreational budget prior to per-visit (fee) WTP; =0 otherwise (p = 0.024) |
| CAMPOFT | = | 1 if respondent often camps in the area; = 0 otherwise (p = 0.007) |
| SUPERB | = | 1 if respondent rated scenery at the site as superb; = 0 otherwise (p = 0.014) |

[44]Techniques include histograms and plots, calculation of correlation coefficients and one-way analyses of variance.

| | | |
|---|---|---|
| STAY4 | = | 1 if respondent spends at least 4 hours on site per visit (p = 0.035) |
| BUSINESS | = | 1 if respondent stated that the prime reason for visiting the site was connected to a business meeting[45]; = 0 otherwise (p = 0.000) |
| GREEN | = | 1 if respondent is a member of at least one of the following: any wildlife trust, the National Trust, the Broads Society, Friends of the Earth, Greenpeace; = 0 otherwise (p = 0.004) |

Unlike the per-annum experiment, the ordering variable ($ORDER_{fee}$) is now positively related to stated (per-visit) WTP indicating that the asking of a prior per-annum question raised respondents subsequent per-visit WTP bid. The relationship of WTP with BUDGET is (as before) positive, as is that with CAMPOFT, SUPERB, STAY4 and BUSINESS. This is all as expected. However, against our first expectations, the variable GREEN proved to be strongly negatively related to per-visit (fee) WTP although membership of such groups was positively related to annual WTP[46]. It seems that the members of such groups strongly object to the ending of the open-access nature of the site implicit in the fee vehicle. It is interesting to note that the survey took place in the middle of a well publicised, year-long review of the Forestry Commission which had raised fears of the wholesale privatisation of the estate and consequent loss of current open-access rights. This strong objection to fees by such respondents (who were the most likely to be aware of this review[47]) may well reflect a deeper protest against the prospect of privatisation[48].

All the variables listed above are simple, two-level, dummies. The number of respondents at any level was 45 or above in all cases except for the variable BUSINESS which had the value 1 for just two interviewees but proved to be highly significant.

Table A2.59 reports the best fitting bid function which included both of our focus variables ($ORDER_{fee}$ and BUDGET) and any other significant explanatory variables[49].

Table A2.59: Whole-sample bid function for per-visit WTP responses

| Explanatory variable | coeff. | st. dev. | t-ratio | p |
|---|---|---|---|---|
| Constant | 0.4812 | 0.0695 | 6.92 | 0.000 |
| BUDGET | 0.1464 | 0.0769 | 1.90 | 0.058 |
| $ORDER_{fee}$ | 0.1143 | 0.0763 | 1.50 | 0.135 |
| GREEN | -0.2566 | 0.0864 | -2.97 | 0.003 |
| CAMPOFT | 0.2958 | 0.1109 | 2.67 | 0.008 |
| BUSINESS | 5.1102 | 0.5081 | 10.06 | 0.000 |

s = 0.7085 $R^2$ = 28.5% $R^2$(adj) = 27.4%
Regression F = 27.44 (p = 0.000)

[45]This information was elicited from interviewees' comments when specifying the 'other' category in answer to a question regarding the main reason for coming to the forest.

[46]Interestingly membership of non-environmental groups such as sports clubs was (weakly) positively related to per-visit WTP and negatively related to per-annum WTP. This makes sense as such respondents visit forest sites less and therefore would minimise expenditure on such recreation by paying per use rather than a flat rate.

[47]Most of these groups, including even the normally sedate National Trust, had lobbied hard against the possibility of privatisation (see Stirling, 1994).

[48]Such protests do, arguably, cause problems for the validity of our per-visit valuations. However, this is to some extent examined in our consideration of answers to the payment principle question. Furthermore, the problems raised by ordering and mental accounting effects are of a far greater magnitude.

[49]The variable SUPERB was omitted at ρ = 0.052, ie. it is stronger than our focus variables.

Analysis of unusual observations revealed two highly anomalous respondents both of whom had standard residual values exceeding +6. No logical explanatory factors were apparent and we conclude that either these respondents were behaving strategically by overbidding or they had misunderstood the question. If the latter is true it may be that they gave a per-party answer to what was a per-person question. No further extreme unusual observations were detected and it was decided to re-estimate the bid function omitting these two respondents. Results for this analysis are given in table A2.60.

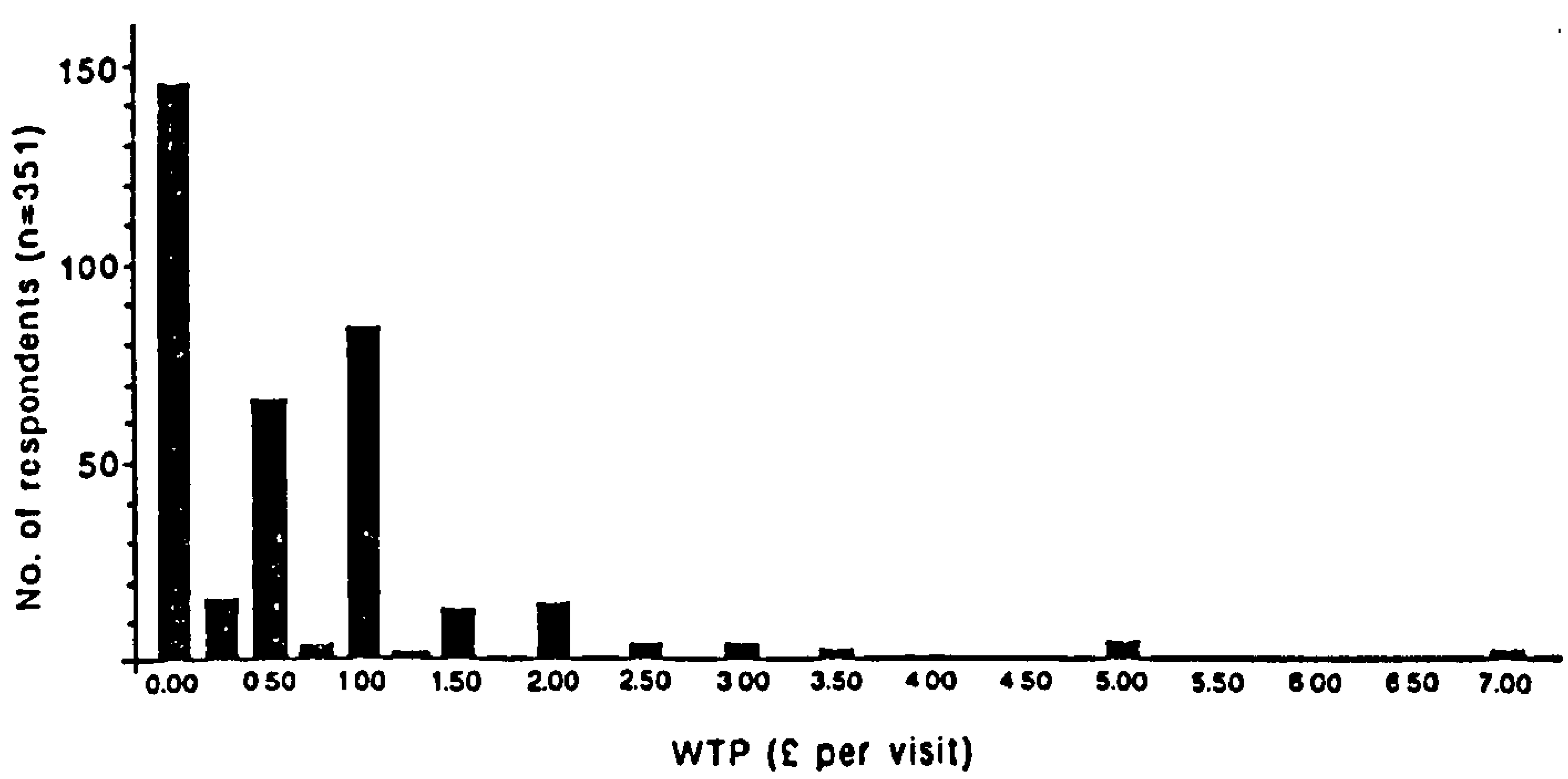
Table A2.60: Bid function for per-visit WTP responses: omitting two observations

| Explanatory variable | coeff. | st. dev. | t-ratio | p |
|---|---|---|---|---|
| Constant | 0.4647 | 0.0617 | 7.53 | 0.000 |
| BUDGET | 0.0865 | 0.0685 | 1.26 | 0.207 |
| $ORDER_{fee}$ | 0.1224 | 0.0677 | 1.80 | 0.072 |
| GREEN | -0.2198 | 0.0767 | -2.87 | 0.004 |
| CAMPOFT | 0.3175 | 0.0984 | 3.23 | 0.001 |
| BUSINESS | 5.1676 | 0.4505 | 11.47 | 0.000 |

s = 0.6281 $R^2$ = 33.4% $R^2$ (adj) = 32.4% Regression F = 34.42 (p = 0.000)

Tables A2.59 and A2.60 reveal several interesting characteristics of the per-visit WTP responses. The focus variables $ORDER_{fee}$ and BUDGET, while exerting pressure upon bids, are not the highly significant determinants exhibited in per-annum responses. Indeed neither satisfy a 5% confidence test[50]. Other explanatory variables are as expected (given our previous discussions). With the exception of the BUSINESS variable (which only applies to two responses), by far the strongest determining factor is the constant. This, combined with the overall good degree of fit (for a CV bid function), gives, we believe, strong support to our argument that per-visit responses are highly determined by individuals' common conception of a 'social-norm' level of acceptable charging for entry to such a site. This is vividly demonstrated by figure A2.7 which details the distribution of per-visit bids. These are in the main clumped upon either zero, £0.50 or £1.00 amounts[51]. Respondents are, we argue, tempering their own true valuations with both their own experience of fee paying (e.g. through car-parking fees at comparable sites) and their conceptions of a socially just level of payment for what is, traditionally, an open-access good.

Figure A2.7: Distribution of per-visit WTP bids




[50]Interestingly the relative strength of these variables changes between tables A2.59 and A2.60 indicating that these are much weaker factors than in the per-annum experiment.

[51]Strictly this will cause problems for OLS techniques, but not to any degree which would invalidate our findings.

### A2.4.1.5: The Thetford 2 CV study: conclusions

This study has raised as many questions as it has provided answers. By analysing the extent to which WTP bids can be manipulated by design variations we have raised questions as to which design permutation is preferable. The variations in design we have tested are, we feel, all justifiable. The introduction of a prior budget question can be justified on the grounds that this addresses the possibility of mental accounting error and indeed studies have adopted such an approach (Willis and Garrod, 1991; 1993). Furthermore, as several studies have adopted both per-visit and per-annum measures (Bishop, 1992; Whiteman and Sinclair, 1994), the possibility of these interacting in a way controlled by their ordering is worrying. In effect our study shows that mean per annum WTP can be almost halved by the inclusion of a prior per-visit question or more than doubled by a prior budget question (with the budget effect somewhat outriding the payment ordering effect if both priors are included). The fact that both these effects are less pronounced upon per-visit WTP bids is hardly comforting if this is as a result of (and evidence for) a social-norm conditioning of such answers.

The implications of these findings for our research (and for the wider use of CV) may depend upon the perspective of the individual researcher. We have experienced very differing reactions from colleagues to these findings. Dr Colin Price (Bangor) has taken them as further evidence of the 'sheer subjectivity' of CV results. Conversely Professor Kerry Turner (UEA) has pointed out that, while results could be doubled or halved they could not be increased or decreased by a larger factor, i.e. the possibility of creating a confidence interval of valuation arises.

We have some sympathy for both interpretations of these findings. Certainly when we take into account the effect upon WTP of varying the elicitation method (Bateman *et al.*, 1993), then the design effects observed in the present study are certain to widen any resultant 'valuation envelope'[52]. In effect, by adopting an OE format for this study, we have ensured a conservative, lower-bound design with respect to elicitation effects. To adopt a further lower-bound assumption with regards to the design effects studied here might be somewhat dangerous, certainly the lowest means of £7.62 per annum and £0.20 per visit are, to say the least, highly conservative. This is a thorny problem, beset with uncertainties to which we return later.

## A2.4.2: THETFORD 2: THE ITC STUDY

Alongside the CV experiments, the Thetford 2 study undertook a travel cost analysis of visitors recreation use-value for Lynford Stag. Following the discussions of chapter 2 we again used an individual rather than zonal (Clawson-Knetsch) approach to the TC.

Three research objectives were defined for this study:

1. To examine the application of geographical information systems (GIS) to travel cost studies. It was felt that the spatial analysis capabilities of GIS were of considerable potential value to such studies.
2. To conduct a full sensitivity analysis across a range of time cost and travel cost assumptions. The valuation of such costs clearly has considerable impact upon subsequent consumer surplus estimates but, as discussed in chapter 2, there is some debate regarding both the absolute value and methodological approach towards valuation of these cost elements.
3. To assess the impact and validity of using ordinary least squares (OLS) or truncated

[52] Bateman *et al.* (1992).

maximum likelihood (ML) estimation techniques. Chapter 2 showed that OLS approaches are technically invalid in that they fail to recognise the truncation of non-visitors. Nevertheless many TC studies have used OLS techniques (see appendix 1 and our own Thetford 1 ITC study) and a comparative investigation appeared timely.

**A2.4.2.1: The survey**

All 351 parties interviewed in the Thetford 2 CV study were also asked travel cost questions. Therefore sampling details are as before and the common CV/TC questionnaire is reproduced at the end of this discussion.

Several survey questions focused upon the trip itself. Respondents were asked to state:

(i) Home address, and trip origin if different to this (e.g. if on holiday away from home);
(ii) How they travelled to the site;
(iii) The perceived travel time and cost;
(iv) The number of other sites visited during the days trip;
(v) The proportion of the whole days enjoyment attributable to time spent travelling; time spent at the survey site; time spent at other sites.

**A2.4.2.2: Perceived and GIS calculated travel distance and duration**

As stated a prime objective of this study was to examine the potential application of GIS spatial analysis techniques to the TC. It was decided that a simple test of effectiveness would be to compare respondents' perceptions of travel distance and duration with those calculated through use of the GIS. A-priori it is not immediately clear which of these approaches is superior. If we use visitors' statements then these should reflect individual routing decisions and travel speeds. In particular they will highlight visitors who take routes which are not shortest distance/duration so as to increase enjoyment of the journey. However, a problem with reliance upon interviewees' description of the journey is that both distance and duration estimates are liable to suffer from rounding effect. This is likely to be proportionately worse for shorter journeys where the rounding error may well be relatively large. The GIS approach addresses the rounding problem directly by producing accurate estimates of distance and duration. However, the drawback of this approach is that, unless highly detailed trip itineraries are elicited, assumptions have to be made regarding logical trip routing which may not capture deviations due to those who take unusual routes to a site. Comparison of ITC results based upon perceived costs with those based upon GIS calculations therefore seemed an interesting exercise.

Calculations of GIS trip costs first required accurate information regarding trip origin. Using the data collected from question (i) above the national grid reference of trip origin was located by consulting the Ordnance Survey Gazetteer of Great Britain (Ordnance Survey, 1987)[53]. Figure A2.8 illustrates trip origins for the entire sample in relation to the survey site. This shows clearly the importance of spatial factors in the determination of visits. Trip origins were concentrated around Thetford, with over 90% of visitors having set out from within 100 miles of the site. However, straight line distance is clearly a rather crude determinant of visits and one of the principle advantages of adopting a GIS approach was that it allowed us to account for both the distribution and quality of the available road network.

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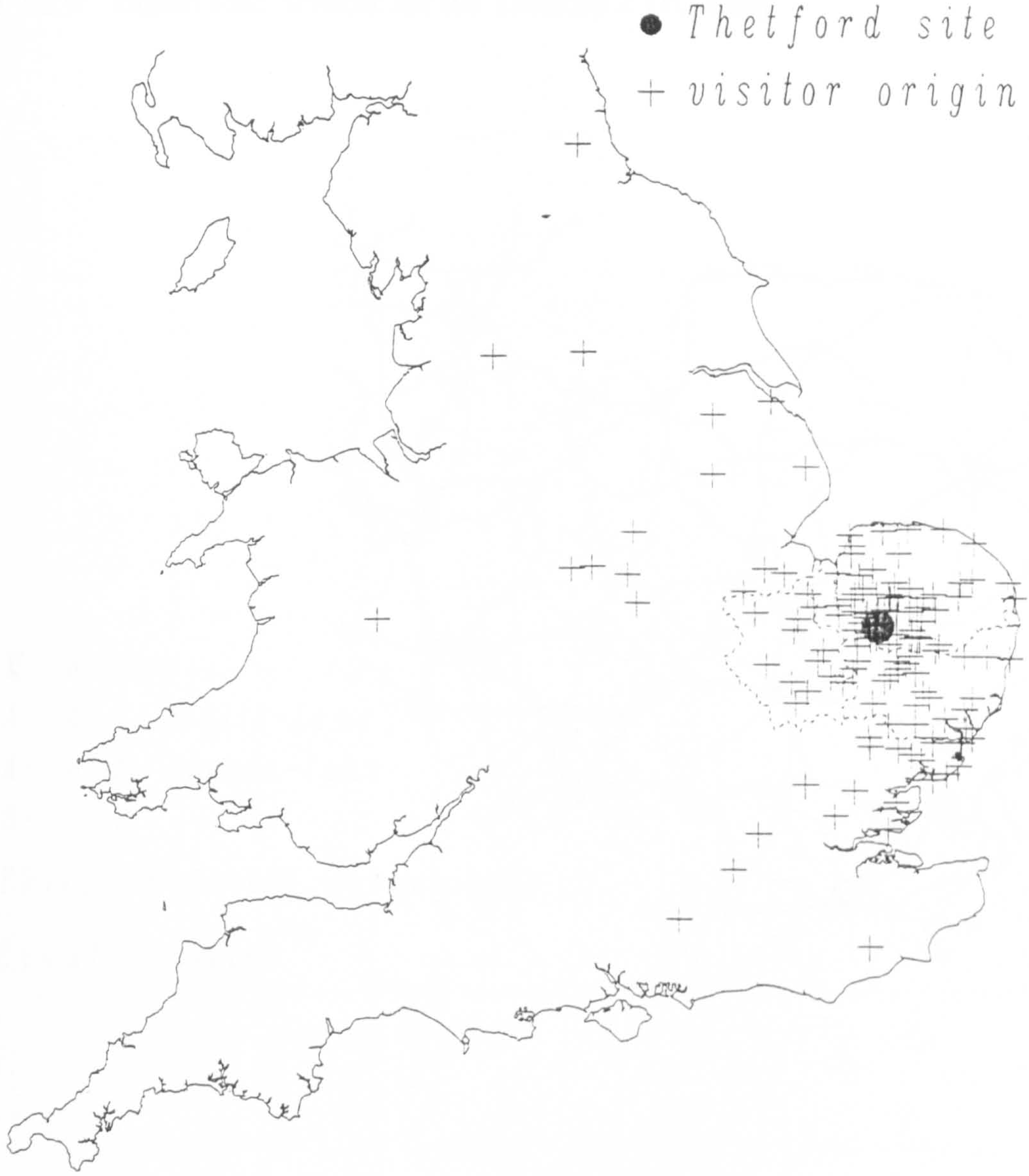
[53]Like all our data from all surveys, the recording accuracy of this data was checked by double-punching all completed questionnaires and comparing resultant datasets.

Figure A2.8: Trip origin for visitor sample: Lynford Stag, Thetford Forest




Digital road network details were extracted from the Bartholomew 1:250,000 scale database for the UK. This source provides information on the quality and width of roads, distinguishing 15 road categories ranging from minor, single-track country lanes to six-lane motorways. Computing time and space limitations made it impractical to assemble a road network for the entire area covering origins of Thetford visitors (this ranged from Edinburgh in the north to Hampshire in the south). We therefore defined a study area to include the counties of Norfolk, Suffolk and Cambridgeshire, together with adjoining districts in Lincolnshire and Essex[54]. This encompassed over 92% of the visitor origins. Figure A2.9 illustrates the resulting digital road network[55].

Figure A2.9: Digital road network for the Thetford 2 ITC study


[54]The Bartholomew's road coverage is stored in map tiles (100 km squares) on the national grid. The relevant map tiles were appended and subsequently clipped using the study area boundary as defined above. Undershoots (common in the Bartholomew's data) were located and corrected whenever possible.

[55]Supplemental data for visitors from outside this region was obtained by use of the Automobile Association's 'Auto Route' package.

The classification and quality of individual roads is defined in the Bartholomew's database. By applying differential road speeds to these details, travel times can be calculated for discrete sections of road. From these, travel times can be calculated for the whole of the available road network. Data detailing average travel speeds for differing categories of road were obtained from a variety of sources. This exercise revealed both the paucity of such data and some significant differences in estimates. An initial investigation was undertaken using road speeds given in Department of Transport sources as detailed in table A2.61.

Table A2.61: Initial road speed estimates

| Road Type | Average Road Speed (mph) | |
|---|---|---|
| | Rural | Urban |
| Minor Road | 20 | 15 |
| A-Road Primary Single Carriageway | 50 | 35 |
| A-Road Single Carriageway | 40 | 25 |
| B-Road (with passing places) | 30 | 17 |
| B-Road Single Carriageway | 30 | 17 |
| A-Road Dual Carriageway | 55 | 35 |
| B-Road Dual Carriageway | 40 | 25 |
| A-Road Primary Dual Carriageway | 60 | 40 |
| Motorway | 70 | 50 |
| A-Road Single Carriageway (under construction) | 40 | 25 |
| B-Road Single Carriageway (under construction) | 30 | 17 |
| A-Road Dual Carriageway (under construction) | 55 | 35 |

Sources: Department of Transport (1992, 1993)

Travel times from each road segment in the network were calculated via equation A2.1:

$$\text{travel time} = \frac{\text{length of road segment (in miles)}}{\text{speed (miles per hour)}} \qquad \text{(A2.1)}$$

In their study of recreation in the Forest of Dean, Colenutt and Sidaway (1973) show that minimum travel time provides an extremely strong explanatory variable in predicting visits. This can be calculated by specifying the time from equation (A2.1) as the impedance associated with a particular road segment in the digital network. An algorithm is then used to identify the route between the trip origin and forest site which minimises the cumulative impedance, thereby also isolating the minimum travel time. Utilising the road speeds in table A2.61, a series of travel times were calculated for a variety of routes between a sample of towns and villages in the area. These were then compared with those generated by using the alternative road speeds given in Gatrell and Naumann (1992) and the Automobile Associations 'Autoroute' route planning software package. Further calibration was achieved by calculation of travel times for a number of routes well known to the author and colleagues. These assessments consistently pointed to the conclusion that the road speeds given in table A2.61 were overestimates of those realistically attainable. This contrast was particularly striking with respect to rural roads[56]. Such a finding reflects the fact that official road speed estimates, such as those given in table A2.61, suffer from limited information regarding the impact of road junctions and other sources of traffic congestion. Although it was feasible to consult Ordnance Survey maps regarding the topology of motorway junctions it was not practical to conduct a systematic assessment of all junctions (or other traffic constraints) throughout the road network[57]. Accordingly, a sensitivity analysis was undertaken to obtain appropriate adjustment factors, the multipliers eventually identified from comparing calculated travel times with those regarded as more realistic being given in table A2.62. Applying these multipliers produced a set of adjusted road speeds as detailed in table A2.63.

Table A2.62: Multipliers used to produce adjusted road speeds

| Road Type | Adjustment Factor |
|---|---|
| Rural primary, dual-carriageways or motorways | 0.9 |
| Rural non primary, A & B roads | 0.8 |
| All others, including minor rural roads and all urban roads | 0.7 |

The GIS calculation of individuals' travel times and distances can be broken down into three steps. First, the site was identified on the road network and an AllocateIn operation in the Arcplot module of the Arc/Info GIS. This command minimises the impedance (here travel time) between a specified point (the site) and each unique segment[58] of the road network[59]. The calculated impedance value is assigned to each individual road link[60], expressed in this case,as the time (in minutes) that it took to travel from one end to the other of that section of road. These times are then stored in an Arc/Info 'Lookup' (output) table.

[56] To illustrate, the journey from Norwich to Thetford would be expected to take 35-40 minutes. Our initial model using speeds from table A2.61 suggested a travel time of 31 minutes, whereas using our adjusted road speeds produced an estimate of 38 minutes.

[57] Further details are given in Bateman et al. (1995b).

[58] The road network is held as vector features (see Environmental Systems Research Institute (1992a) for further details).

[59] AllocateIn works by finding the sum impedance (time) for travelling between two points (the site and the nearest end of the road segment) along possible routes between them. The algorithm (which is generally credited to Dijkstra (1959)) works recursively though the entire road network, keeping information about the minimum-impedance route found so far, until all possible route permutations are exhausted. For further information about the algorithm used see Environmental Systems Research Institute (1991a, 1992a).

[60] The point at which two digitised road segments meet.

Table A2.63: Adjusted road speed estimates

| Road Type | Average Road Speed (mph) | |
|---|---|---|
| | Rural | Urban |
| Minor Road | 14 | 11 |
| A-Road Primary Single Carriageway | 45 | 25 |
| A-Road Single Carriageway | 32 | 18 |
| B-Road (with passing places) | 24 | 12 |
| B-Road Single Carriageway | 24 | 12 |
| A-Road Dual Carriageway | 50 | 25 |
| B-Road Dual Carriageway | 36 | 18 |
| A-Road Primary Dual Carriageway | 54 | 28 |
| Motorway | 63 | 35 |
| A-Road Single Carriageway (under construction) | 32 | 18 |
| B-Road Single Carriageway (under construction) | 24 | 12 |
| A-Road Dual Carriageway (under construction) | 50 | 25 |
| Motorway (under construction) | 63 | 35 |

The second step involved finding the nearest point on the road network to each individual visit origin. Travel times from this point to the site were then extracted by use of both the lookup table and by interpolation between the two endpoints of each road segment[61]. This step was performed by means of the Arc/Info command Addroutemeasure[62].

The third step, to determine the distance travelled by each visitor along these minimal-impedance routes (using our adjusted, quality sensitive road speeds) proved more difficult. after running for three days the relevant Arc/Info command (Measureroute) had finished less than half the necessary calculations. Reasons for this slow operation are likely to be related to the size and complexity of the East Anglian digital road network and the large number of journey origins under consideration[63]. Whatever the precise problem, it was clear than an

[61]This procedure is known as 'dynamic segmentation'. For further details see Environmental Systems Research Institute (1991a, 1992a).

[62]See Environmental Systems Research Institute (1991b, 1992b) for details.

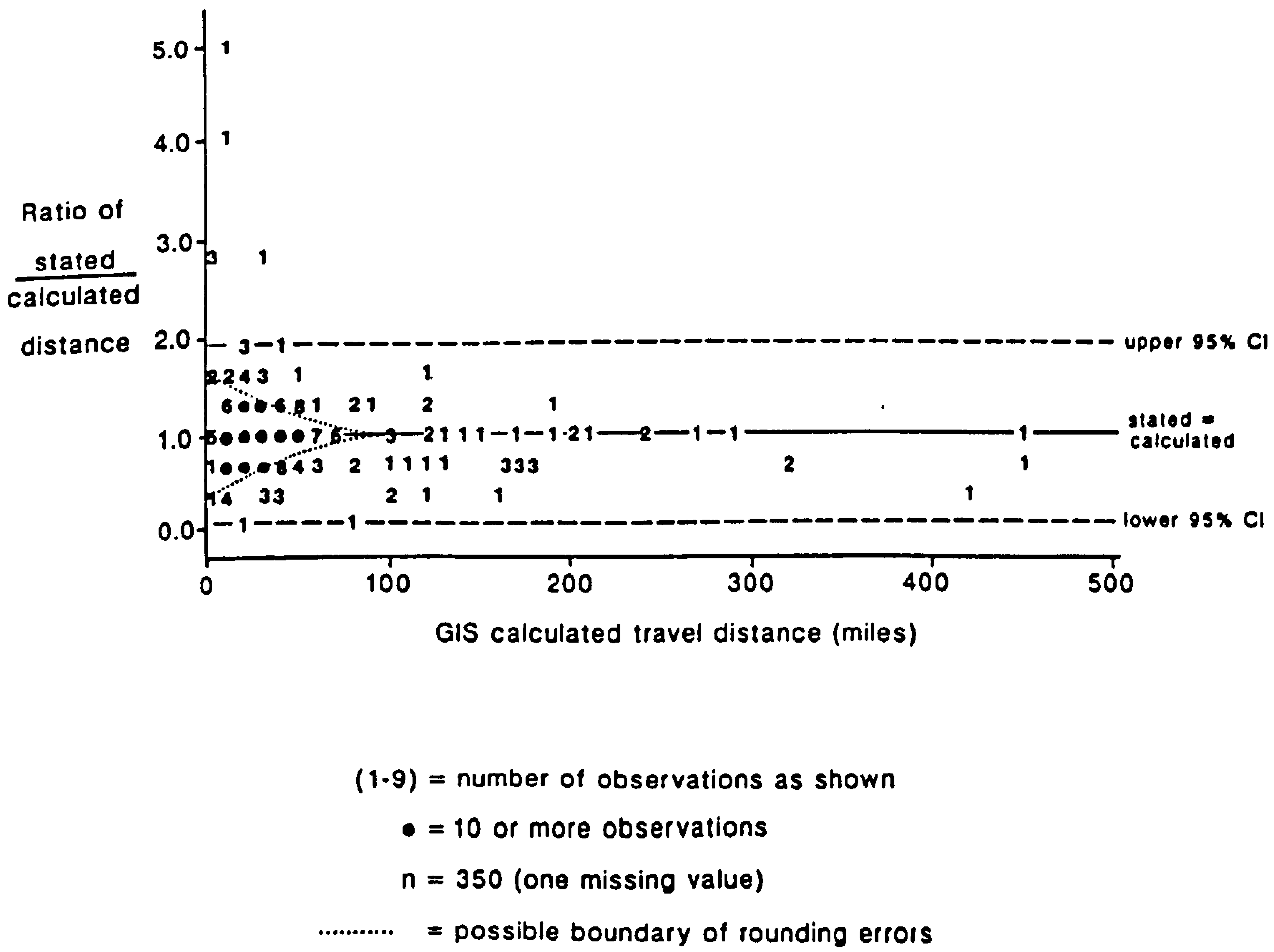
[63]The road network consisted of 19,255 individual links onto which 326 visitor origins were attached. 95% of all the visitor parties sampled were on the digital road network. The remainder had travel distances estimated via the Automobile Associations 'Auto Route' software from which journey durations were estimated. This is a cruder approach than our GIS analysis but acceptable given that few of these distant visitors will use anything other than major roads.

alternative approach was required. This was provided in the form of a customised programme written in Arc Macro Language (AML) by Julii Brainard[64]. This performed the necessary distance calculations in a total running time of about 18 hours.

As noted at the start of this section, visit cost estimates based upon GIS calculated distance and duration have both advantages and disadvantages over those based on visitors perception. Figure A2.10 plots the ratio of stated to GIS calculated distance against the absolute value of the latter.

Examining figure A2.10 shows that, on average, both distance measures coincide reasonably well. The comparatively larger deviation between the measures at low distance is as expected and derives, we argue, mainly from rounding error in statements regarding short journeys. We have drawn in (dotted lines) a cone of observations which may fit into this category. Support for such a line of reasoning is given by noting that, for these 'rounding-error' observations, roughly as many respondents state travel distances below the GIS calculation as above. As the GIS distance is based on a minimum impedance algorithm (minimum time), those respondent estimates below the equality line must be subject to some form of error, an error which we argue is due to rounding. For observations within this category, the GIS calculated distance may provide a better basis for cost estimates than does stated distance.

Figure A2.10: Graph of the ratio of stated to GIS calculated distance against calculated distance




[64]School of Environmental Science, University of East Anglia. Without Julii's assistance this work could not have been successfully completed.

As the majority of respondents fall into this category this is an encouraging finding. However, figure A2.10 also shows us that for a few respondents calculated distance is likely to be a poor estimate of true distance. Six extreme cases are identified all lying above the upper 95% confidence interval around the mean. All of these are for stated distances of less than 100 miles and it seems most likely that these respondents are 'meanderers'; those whose main objective is enjoyment of the journey rather than time spent on-site. For these individuals the advantages of removing rounding problems are more than outweighed by the error induced by the logical routing assumption underlying the GIS calculated distance.

While the majority of observations fall within our rounding error cone the few observations for which the ratio of stated to calculated distance is large, do cause a problem. Overall it is difficult to decide, prior to our subsequent analysis, which distance measure is superior. In hindsight we feel that our survey should have elicited more information upon route itinerary for meanderers. Integration of such information into our GIS distance and duration calculations should produce a superior measure.

### A2.4.2.3: Definition of trip generating functions

ITC tgf's were estimated by regressing the number of visits which parties made to the site per annum on a variety of explanatory variables. Examination of raw data plots indicated that a natural log dependent variable would fit the data best[65]. Subsequent tests confirmed this and the variable lnVISIT was accordingly defined as follows:

lnVISIT = ln(Q+1) where Q is the number of visits (whether day trip or as part of a wider holiday) made by the party to the site per annum.

Travel cost was initially defined as the sum of time and journey cost, both of which were subjected to sensitivity analysis. Time costs were calculated upon a wage rate basis. Income was elicited as a nine category variable in the survey and was then converted to a per minute wage rate by taking the mid-point of the respondents income category and dividing by (52*35*60), i.e. assuming a 35 hour week. The return trip journey time (whether based upon GIS calculations or respondent statements[66]) was then monetised by multiplying by the calculated income per minute. Following the discussions of chapter 2 several wage rate/leisure time conversion factors where then applied to produce our various estimates of time cost. The conversion factors applied are as follows:

1. 100% (assuming that leisure time is valued at the full wage rate);
2. 43% (the Department of Transport appraisal rate[67]);
3. 0% (assuming that their is no opportunity cost of non-work time).
4. Best fit (data determined).

[65]Descriptive statistics for the dependent variable are as follows:

| Mean | Std.Dev. | Skew. | Kurt. | Min. | Max. | Cases |
|---|---|---|---|---|---|---|
| 14.650 | 43.494 | 5.540 | 37.473 | 1 | 365 | 351 |

[66]The GIS calculation of journey time was not thought appropriate for walkers and cyclists. Therefore, in all analyses, stated journey times (question 15) were used for this group.

[67]As used in Benson and Willis (1992).

Journey cost was also based upon return trips[68]. Three valuation assumptions were tested as follows[69]:

1. 8p per mile (Automobile Association estimate of average petrol costs[70]).
2. 23p per mile (Automobile Association estimate of average total running costs[71]).
3. Perceived (unlike the previous two, this assumption was not related to distance travelled but instead set journey cost at that level stated by respondents in answer to a direct question).

The sum of time and journey cost was then divided through by a factor relating to the proportion of the days enjoyment which was attributed by respondents to their time on-site at Thetford Forest[72]. This made allowance for the fact that not all of the trip costs could be attributed to this particular site. Such allowance is especially important when, as here, we have evidence of meanderer's and multi-site visitors amongst the sample.

This adjusted travel cost estimate formed the first of a considerable list of variables which were considered within our tgf analysis. To ensure comparability a consistent (semi-log dependent) functional form and list of explanatory variables was used for all analyses, explanatory variables being as follows[73]:

| | | |
|---|---|---|
| TC | = | Travel cost (as defined in text) |
| HSIZE | = | Household size |
| HOLS | = | Respondent on holiday (0-1) |
| WORK | = | Respondent working (0-1) |
| LIVE | = | Respondent lives near site (0-1) |
| RATING | = | Scenery rating (1-4) |
| TAX | = | Respondent is a taxpayer (0-1) |
| NT | = | Respondent in the National Trust |
| MDOG | = | Main reason for visit is dog walking |

An income variable was omitted from the above because of intercorrelation with the time cost element of travel costs. Such a variable was tested within a separate set of tgf's where zero time costs were used, but here the income variable proved insignificant[74].

Four different approaches to tgf definition were investigated as follows:
1. ML and OLS analysis of tgf's based upon GIS calculated distance and duration;
2. ML analysis of tgf's based upon respondents estimate of total journey cost

[68]The GIS calculates distance from the Bartholomew digital road network which is based upon the OS national grid. This gives a distance in km which was converted to miles using a factor of 1.609.

[69]Bus, coach and other non-car travellers incur time costs as for car drivers but have journey costs valued as per their stated perceptions (question 16).

[70]Quoted in Benson and Willis (1992).

[71]ibid.

[72]Question 18.

[73]Other variables considered but rejected from the comparative models include: party size; age<25; age>65; membership of any environmental organisation; membership of separate organisations; other main activity dummies. Income was omitted because of collinearity with time cost (in a zero wage rate model an income variable proved insignificant).

[74]t-values of the order of 0.7.

(perceived cost) and GIS calculated duration;

3. ML analysis of tgf's based on respondents estimate of journey duration from which journey cost is also calculated.

4. ML analysis of tgf's based on respondents estimates of journey duration and journey cost.

Sensitivity analyses concerning the per unit value of journey cost and travel time were also carried out on all appropriate options.

**A2.4.2.4: Analysis of tgf's based upon GIS calculated distance and duration**

Here journey distances and duration are as calculated in our GIS analysis with the full sensitivity range of unit journey and time costs being applied as discussed. The main advantage of such an approach is that it counters the rounding errors inherent in respondents' estimates of journey distance and duration, while the main disadvantage is the inability to detect meanderers.

OLS analysis was carried out as discussed previously. Truncated ML analysis was based upon the approach of Willis and Garrod (1991)[75]. Here we can rewrite our tgf as:

$$\ln VISIT_i = \beta X_i + e_i$$

where: i indexes individuals; $X_i$ is our vector of independent explanatory variables (as defined previously) with coefficient vector $\beta$; and $e_i$ are disturbances assumed to be independent, identically distributed $N(0,\sigma^2)$. Given this model, the ML estimator is based on the density function of $\ln VISIT_i$ which is truncated normal as follows:

$$f(\ln VISIT_i) = \begin{cases} \dfrac{(1/\sigma)\varnothing[(\ln VISIT_i - \beta X_i)/\sigma]}{(1-\Phi[-\beta X_i/\sigma])} & \text{if } VISIT_i > 0 \\ 0 & \text{otherwise} \end{cases}$$

Goodness of fit measures were given by $R^2$ statistics for OLS regressions and log likelihood values for ML analyses. Consumer surplus estimates were given by:

$$CS = \frac{[\ln(Q+1)-Q]}{b}$$

where Q = number of visits made per annum

b = travel cost coefficient

i) ML results

Sensitivity analysis showed that a marginal journey cost assumption (8p/mile) fitted the data better than an estimate based on full running costs (23p/mile). Furthermore, a zero time cost assumption fitted better than either the DOT (43%) or full wage rate assumptions. Iteration revealed that a small wage rate ($2^1/_2$%) time cost assumption provided a superior fit to the data. Table A2.64 reports our best fitting ML model based on GIS calculated journey distance and duration.

The model given in table A2.64 fits the data reasonably well and has expected signs and significance on all explanatory variables. The travel cost variable is highly significant, easily passing a 1% test, and indicating that visits are inversely related to the sum of journey and time costs.

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[75]Which in turn is based on Maddala (1984). We are very grateful to Guy Garrod (University of Newcastle upon Tyne) for copious and excellent assistance with this analysis.

Table A2.65 gives travel cost coefficient, log-likelihood value and three consumer surplus measures for the entire range of sensitivity analyses for ML models based upon GIS calculated distance and duration. Consumer surplus is given as: (i) per household per annum; (ii) per household per visit; and (iii) per person per visit. Upper figures in these cells relate to value in the study year (1993) while lower figures (in brackets) are deflated to 1990 values to allow comparison with our other studies and with those reviewed in chapter 3.

Examining table A2.65 we can see that our best fitting model (journey cost @ 8p/mile; time cost @ 2.5% wage rate) gives a per household per visit consumer surplus of £3.95 (1993 prices; £3.59 at 1990 prices), and a per person per visit consumer surplus of £1.32 (1993 prices; £1.20 at 1990 prices). These values seem far more defensible than previous published ITC estimates for UK woodland recreation as given in Willis and Garrod (1991). We feel this may well be due to the more satisfactory functional form permitted by the larger sample size of our study. Such results also accord reasonably well with our earlier Thetford 1 ITC experiment although we feel that the present study is superior[76].

The most worrying finding from table A2.65 is the comparatively minor difference in fit between our best fit model and ones using differing journey and time cost assumptions. It is arguable that the deletion of just a very few observations might well reverse the ordering of the goodness-of-fit statistics such that another model appeared optimal. Given that such changes would imply very substantial revisions of our consumer surplus estimates this appears worrying. However, a counter argument can be found. Our sensitivity analysis amounts to simply altering multipliers within the TC variable. Although the differing coefficient values this engenders results in considerably differing consumer surplus estimates, such changes cannot (by their nature) have particularly significant impacts upon model fit. Therefore the differences between such models will of necessity be small. Nevertheless, even if we accept such an argument this may still imply problems for the travel cost method as it means that substantial changes in consumer surplus estimates may be engineered by switching between models of quite similar explanatory power. This is a serious issue for practical evaluation studies as the implications for CBA assessments involving such evaluations are clearly major.

ii) OLS results

Given the findings of our ML analyses, only zero and 43% wage rate time costs were used in the OLS sensitivity analysis. The best fitting model used a unit journey cost value of 8p/mile and a zero time cost. Table A2.66 details this model.

All the explanatory variables in table A2.66 are correctly signed and generally of high statistical significance. Table A2.67 gives our sensitivity analysis range of consumer surplus measures. Here we report results for models with identical explanatory variables to those used in the ML analyses of tables A2.64 and A2.65. This results in a slight difference in certain of the statistics reported for the model given in table A2.66 and its counterpart in table A2.67 but means that the t-values and consumer surplus estimates of table A2.67 are directly comparable with those for our ML analyses given in table A2.65.

The results given in table A2.67 confirm our prior ML findings that models using marginal journey costs (8p/mile) and very low (here zero) time costs fit the data best. Also, and for the same reasons as before, there is comparatively little difference in overall degrees of explanation across these models[77].

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[76] In particular the Thetford 1 study relied upon OLS estimation procedures (see subsequent discussion).

[77] This is of course comparing refinements within a common functional form. As noted in our Thetford 1 ITC study, differences between functional forms can be much more pronounced.

**Table A2.64: Best fitting ML model based on GIS estimates of journey distance and duration (journey cost @ 8p/mile; time cost @ 2.5% of wage rate).**

| Maximum likelihood estimates converged after 4 iterations | | | | | | |
|---|---|---|---|---|---|---|
| Log-likelihood .......... -454.59 | | | | | | |
| Variable[1] | Coefficient | Std. Error | T-ratio | Prob:t:>x | Mean of X | Std.D. of X |
| Constant | -0.485323 | 0.592317 | -0.819 | 0.41258 | 1.0000 | 0.0000 |
| TC | -0.0776564 | 0.024008 | -3.235 | 0.00122 | 3.8367 | 4.3731 |
| HSIZE | 0.0718489 | 0.054196 | 1.326 | 0.18493 | 3.3704 | 1.4480 |
| HOLS | -1.47287 | 0.533289 | -2.762 | 0.00575 | 0.0427 | 0.2026 |
| WORK | 1.74084 | 0.453372 | 3.840 | 0.00012 | 0.0228 | 0.1495 |
| LIVE | 2.27700 | 0.394588 | 5.771 | 0.00000 | 0.0285 | 0.1666 |
| RATING | 0.505034 | 0.157927 | 3.198 | 0.00138 | 3.0000 | 0.5127 |
| NT | -0.462887 | 0.241705 | -1.915 | 0.05548 | 0.1339 | 0.3410 |
| TAX | 0.441578 | 0.237004 | 1.863 | 0.06244 | 0.8604 | 0.3471 |
| MDOG | 0.606602 | 0.246530 | 2.461 | 0.01387 | 0.0997 | 0.3001 |
| Sigma | 1.17890 | 0.070205 | 16.792 | 0.00000 | 0.0000 | 0.0000 |

Note: 1. Variables as defined previously in text.

**Table A2.65: Sensitivity analysis: ML models based on GIS calculated distance and duration**

| Travel cost (pence/mile) | Travel time (% of income) | Travel cost coefficient (t-value) | Log likelihood value | CS/household per annum (£)[1] | CS/household per visit (£)[1,2] | CS/person per visit (£)[1,3] |
|---|---|---|---|---|---|---|
| 8p | 0% | -0.084758 (-3.32) | -455.46 | 140.39 (127.55) | 3.62 (3.29) | 1.21 (1.10) |
| 8p | 43% | -0.031808 (-2.92) | -455.59 | 374.10 (339.87) | 9.65 (8.77) | 3.22 (2.92) |
| 8p | 100% | -0.016002 (-2.72) | -456.28 | 743.61 (675.57) | 19.18 (17.42) | 6.39 (5.81) |
| 8p | 2.5% | -0.077656 (-3.24) | -454.59 | 153.23 (139.21) | 3.95 (3.59) | 1.32 (1.20) |
| 23p | 0% | -0.031207 (-3.32) | -455.36 | 381.31 (346.42) | 9.83 (8.93) | 3.28 (2.98) |
| 23p | 43% | -0.020856 (-3.02) | -455.72 | 570.56 (518.36) | 14.71 (13.36) | 4.90 (4.45) |
| 23p | 100% | -0.013251 (-3.00) | -455.35 | 898.02 (815.85) | 23.16 (21.04) | 7.72 (7.01) |
| 23p | 6%[4] | -0.029540 (-3.32) | -455.34 | 402.83 (365.97) | 10.39 (9.44) | 3.46 (3.15) |

Notes: [1] Upper values in each cell are at 1993 prices, lower values (in brackets) are at 1990 prices. Deflator from CSO (1993).
[2] On average households visited Thetford 14.65 times per annum.
[3] Calculated using median party composition figures of 3 persons (2 of which were >16 years). Mean party size was considerably skewed by a few large parties and was not thought to provide an appropriate measure. Note that this assumption treats adults and children equally.
[4] Best fitting wage rate with a 23p/mile journey cost.

For the following TML models all explanatory variables entered at a 15% significance level: 8p/43%; 8p/100%; 8p/2.5%. For all remaining TML models, all explanatory variables with the exception of HSIZE, entered at a 15% significance level.

**Table A2.66: Best fitting OLS model based on GIS estimates of journey distance and duration. (journey cost @8p/mile; zero time cost)**

| | | | |
|---|---|---|---|
| Dependent variable | LnVISIT | No. of observations | 351 |
| Mean of dependent variable | 1.71926 | Standard deviation of dependent variable | 1.10743 |
| Standard error of regression | 0.984964 | Sum of Squared residuals | 331.793 |
| $R^2$ | 22.70% | $R^2$ (adj) | 20.89% |

| Variable | Coefficient | Std. Error | T-ratio | Prob:t:>x | Mean of X | Std.D. of X |
|---|---|---|---|---|---|---|
| Constant | 0.574852 | 0.352221 | 1.637 | 0.10168 | 1.0000 | 0.0000 |
| TC | -0.0432747 | 0.013387 | -3.226 | 0.00126 | 9.9258 | 11.106 |
| HOLS | -0.798169 | 0.264766 | -2.984 | 0.00284 | 0.042735 | 0.20255 |
| WORK | 1.40939 | 0.359360 | 3.923 | 0.00009 | 0.022792 | 0.14945 |
| LIVE | 2.00810 | 0.319801 | 6.282 | 0.00000 | 0.028490 | 0.16661 |
| RATING | 0.334414 | 0.105753 | 3.169 | 0.00153 | 3.0000 | 0.51270 |
| NT | -0.305482 | 0.156728 | -1.916 | 0.05543 | 0.13390 | 0.34103 |
| TAX | 0.277334 | 0.153215 | 1.773 | 0.07615 | 0.86040 | 0.34707 |
| MDOG | 0.425503 | 0.179052 | 2.396 | 0.01658 | 0.099715 | 0.30005 |

**Table A2.67: Sensitivity analysis: OLS models based on GIS calculated distance and duration**

| Travel cost (pence/mile) | Travel time (% of income) | Travel cost coefficient (t-value) | $R^2$ | CS/household per annum (£)[1] | CS/household per visit (£)[1,2] | CS/person per visit (£)[1,3] |
|---|---|---|---|---|---|---|
| 8p | 0% | -0.046776 (-2.93) | 21.72% | 313.19 (284.53) | 21.38 (19.42) | 7.13 (6.47) |
| 8p | 43% | -0.011519 (-2.12) | 20.79% | 1271.82 (1155.45) | 86.81 (78.87) | 28.94 (26.29) |
| 23p | 0% | -0.016801 (-2.90) | 21.69% | 871.97 (792.19) | 59.52 (54.07) | 19.84 (18.02) |
| 23p | 43% | -0.008904 (-2.51) | 21.21% | 1645.33 (1494.78) | 112.13 (101.87) | 37.38 (33.96) |

Notes: [1] Upper values in each cell are at 1993 prices, lower values (in brackets) are at 1990 prices. Deflator from CSO (1993).
[2] On average households visited Thetford 14.65 times per annum.
[3] Calculated using median party composition figures of 3 persons (2 of which were >16 years). Mean party size was considerably skewed by a few large parties and was not thought to provide an appropriate measure. Note that this assumption treats adults and children equally.
For all OLS models all explanatory variables entered at a 15% significance level.

Comparison of our ML and OLS estimates can be conducted on three levels: statistical; cross-study; and theoretical. On statistical grounds the ML models appear to have explained the data somewhat better than their OLS counterparts. Although comparison of overall degrees of explanation statistics (log likelihood values versus $R^2$) is problematic, explanatory variable t-values in directly comparable models were generally higher in ML than OLS models, and invariably so with regard to the travel cost variable.

Cross-study comparisons also suggest that the ML models have performed better, producing best-fit consumer surplus estimates which are much more in line with both other studies and prior expectations than those produced by our OLS models. However, such tests of validity are weak unless backed by theoretical justification.

The theoretical case for preferring ML over OLS estimates is strong. Several authors (see chapter 2) have argued that OLS methods are inappropriate for analysing on-site recreation data as such surveys do not elicit any information on individuals who choose not to visit the site. OLS methods neglect the truncation of the visits variable at zero. Balkan and Kahn (1988) show that in such circumstances OLS methods result in an over-estimate of consumer surplus. Conversely truncated ML techniques can explicitly allow for the absence of non-visitors. Comparison of tables A2.65 with A2.67 suggests that the findings of Balkan and Kahn (1988) are confirmed by our study[78]. Consequently we adopt ML estimation techniques in our subsequent analyses.

### A2.4.2.5: Analysis of tgf's based on perceived journey cost and GIS calculated duration

Here journey duration is calculated as before but journey cost (petrol, etc) is taken from responses to a direct survey question[79]. Such an approach goes part way towards addressing the problem of meanderers. However, in relying upon respondents statements some rounding errors may be reintroduced to the dataset.

Given our prior findings regarding likely time costs, two wage rates were investigated, zero and 43%, with the former providing the better fitting model which is detailed in table A2.68. Consumer surplus estimates for both perceived cost models are given in table A2.69.

Our best fitting model based on perceived costs performs only marginally worse than that based upon GIS calculations and produces very similar consumer surplus estimates. This would appear to give some additional validity to both approaches. As before, and for the same reasons, the overall degree of fit between perceived cost models is similar.

### A2.4.2.6: Analysis of tgf's based upon respondents estimate of journey duration

In these analyses both journey cost and time cost are derived from respondents statements regarding journey duration. A specific question asked respondents to state how long it had taken them to travel to the site. These responses were then doubled to give round trip journey times to which wage rate proportions could be applied to derive time costs. Implicit journey distance was calculated by assuming an average speed of 40 mph[80], a figure based upon our earlier GIS research. Applying our various per-unit rates gave us our perceived journey cost. Such an approach provides an arguably more complete approach to meanderers than does the previous section, however it is more liable to the rounding errors induced by moving away from our GIS calculated measures.

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[78]In their meta-analysis of 77 TC studies, Smith and Kaoru (1990) find that adjusting for truncation could reduce OLS estimates by over $50.

[79]Question 16.

[80]Multiplying return journey time (in minutes) by $^2/_3$ gives implicit travel distance (in miles) at 40mph.

**Table A2.68: Best fitting ML model based on perceived journey cost and zero time costs**

| Maximum likelihood estimates converged after 4 iterations | | | | | | |
|---|---|---|---|---|---|---|
| Log-likelihood .......... -455.95 | | | | | | |
| Variable | Coefficient | Std. Error | T-ratio | Prob:t:>x | Mean of X | Std.D. of X |
| Constant | -0.0917968 | 0.554329 | -0.166 | 0.86847 | 1.0000 | 0.0000 |
| TC | 0.0836772 | 0.026318 | -3.179 | 0.00148 | 3.3437 | 3.9130 |
| HOLS | -1.53383 | 0.536695 | -2.858 | 0.00426 | 0.0427 | 0.2026 |
| WORK | 1.74738 | 0.453857 | 3.850 | 0.00012 | 0.0228 | 0.1495 |
| LIVE | 2.17069 | 0.397130 | 5.466 | 0.00000 | 0.0285 | 0.1666 |
| RATING | 0.461651 | 0.156705 | 2.946 | 0.00322 | 3.0000 | 0.5127 |
| NT | -0.518101 | 0.242304 | -2.012 | 0.03250 | 0.1339 | 0.3410 |
| TAX | 0.409297 | 0.238369 | 2.154 | 0.08597 | 0.8604 | 0.3471 |
| MDOG | 0.601554 | 0.245362 | 2.500 | 0.01422 | 0.0997 | 0.3001 |
| Sigma | 1.18499 | 0.070902 | 16.689 | 0.00000 | 0.0000 | 0.0000 |

**Table A2.69: Sensitivity analysis: ML models based on perceived journey cost and GIS calculated duration**

| Travel cost (pence/mile) | Travel time (% of income) | Travel cost coefficient t-value) | Log likelihood value | CS/household per annum (£)[1] | CS/household per visit (£)[1,2] | CS/person per visit (£)[1,3] |
|---|---|---|---|---|---|---|
| Perceived | 0% | -0.083677 (-3.18) | -455.95 | 142.21 (129.20) | 3.66 (3.33) | 1.22 (1.11) |
| Perceived | 43% | -0.034485 (-3.03) | -456.60 | 345.06 (313.49) | 8.90 (8.08) | 2.97 (2.69) |

Notes: 1 Upper values in each cell are at 1993 prices, lower values (in brackets) are at 1990 prices. Deflator from CSO (1993).
2 On average households visited Thetford 14.65 times per annum.
3 Calculated using median party composition figures of 3 persons (2 of which were >16 years). Mean party size was considerably skewed by a few large parties and was not thought to provide an appropriate measure. Note that this assumption treats adults and children equally.

All explanatory variables entered at a 15% significance level.

Sensitivity analysis showed that a zero time cost assumption fitted the data best, outperforming any positive wage rate[81]. This causes a slight problem with regard to the journey cost assumption as, with no time cost element, both 8p/mile and 23p/mile journey costs will give identical degrees of overall model fit (i.e. they act as simple multipliers to an otherwise identical travel cost term). Given than an 8p/mile assumption has performed better in our previous analyses we chose this as our preferred best model, detailed in table A2.70.

Table A2.71 details travel cost coefficients, overall fit and consumer surplus estimates for all the models estimated in this analysis. The best fit per household per visit estimate of consumer surplus is a little over £1 higher than for the models based on our GIS calculations and has a very marginally superior log-likelihood value.

#### A2.4.2.7: Analysis of tgf's based on respondents estimates of journey duration and cost

In this analysis both journey duration (and hence time costs) and journey cost are taken directly from visitors responses to separate questions eliciting this information as part of the on-site survey. As before such an approach should capture the behaviour of meanderers better than our GIS calculations but is susceptible to response-rounding errors. By comparing results from this approach to those from the previous analysis based solely upon perceived duration, we can also assess the relative accuracy of respondents estimates of journey duration and journey cost.

As previously we only estimated models for zero and 43% wage rate time costs, a 100% rate seeming unfeasible given prior results. Of those the zero time cost model performed marginally better and is reported in full in table A2.72.

Table A2.73 details travel cost coefficients, overall fit and consumer surplus estimates for both of the models estimated in this analysis. Best fit consumer surplus estimates are similar to those based solely upon perceived journey duration but model fit is somewhat worse (see table A2.71 for comparison). This indicates that respondents perceived journey distance more accurately than they do journey cost.

#### A2.4.2.8: Thetford 2 ITC study: Conclusions

This study has examined three separate and very fundamental issues regarding the application of the ITC. Firstly, we have examined both OLS and ML estimation methods and found convincing evidence supporting the use of the latter. Secondly, regarding the valuation of journey costs and travel time we have applied a full sensitivity analysis across a range of tgf definitions consistently finding that petrol only journey costs and very low or zero time costs gave us best fitting models[82]. Travel cost functions based upon respondents estimates of journey cost performed worse than these flat rate approaches and subsequent analysis suggested that visitors are relatively unsure of journey costs compared to their perception of journey duration. Thirdly, the issue of journey distance and duration has been addressed both through more conventional analysis of respondents estimates and through a novel application of GIS software. We have argued that, while the former approach is better suited to the identification of respondents who take circuitous routes to the site, the GIS approach reduces the rounding errors which are endemic amongst the majority of visitors. Comparison of the statistical power of tgf's derived from these two approaches is interesting.

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[81] Variable wage rate assumptions were tested here.

[82] This result gives further support for our questioning of the assumptions used by Benson and Willis (1992) and thereby for our revised estimate of their results (see chapter 3).

**Table A2.70: Best fitting ML model based on perceived journey duration from which journey costs are derived (journey costs @ 8p/mile; zero time costs)**

| Log-likelihood ................. -453.93 | | | | | | |
|---|---|---|---|---|---|---|
| Variable | Coefficient | Std. Error | T-ratio | Prob:t:>x | Mean of X | Std.D.of X |
| Constant | -0.247513 | 0.589563 | -0.420 | 0.67461 | 1.0000 | 0.0000 |
| TC | -0.106951 | 0.031096 | -3.439 | 0.00058 | 3.2268 | 3.1712 |
| HSIZE | 0.0631174 | 0.054057 | 1.168 | 0.24297 | 3.3704 | 1.4480 |
| HOLS | -1.40119 | 0.530947 | -2.639 | 0.00831 | 0.0427 | 0.2026 |
| WORK | 1.73693 | 0.452641 | 3.837 | 0.00012 | 0.0228 | 0.1495 |
| LIVE | 2.14083 | 0.396713 | 5.396 | 0.00000 | 0.0285 | 0.1666 |
| RATING | 0.466641 | 0.155442 | 3.002 | 0.00268 | 3.0000 | 0.5127 |
| NT | -0.455569 | 0.240327 | -1.896 | 0.05801 | 0.1339 | 0.3410 |
| TAX | 0.389710 | 0.235351 | 1.656 | 0.09775 | 0.8604 | 0.3471 |
| MDOG | 0.625690 | 0.245218 | 2.552 | 0.01072 | 0.0998 | 0.3001 |
| Sigma | 1.17540 | 0.069881 | 16.820 | 0.00000 | 0.0000 | 0.0000 |

## Table A2.71: Sensitivity analysis: ML models based on perceived duration and derived distance

| Travel cost (pence/mile) | Travel time (% of income) | Travel cost coefficient (t-value) | Log likelihood value | CS/household per annum (£)[1] | CS/household per visit (£)[1,2] | CS/person per visit (£)[1,3] |
|---|---|---|---|---|---|---|
| 8p | 0% | -0.031096<br>(-3.439) | -453.93 | 188.53<br>(171.28) | 4.86<br>(4.42) | 1.62<br>(1.47) |
| 8p | 43% | -0.011713<br>(-2.765) | -456.09 | 367.43<br>(333.82) | 9.47<br>(8.60) | 3.16<br>(2.87) |
| 8p | 100% | -0.006123<br>(-2.499) | -456.90 | 777.72<br>(706.57) | 20.06<br>(18.22) | 6.70<br>(6.09) |
| 23p | 0% | -0.010816<br>(-3.439) | -453.93 | 319.88<br>(290.62) | 8.25<br>(7.50) | 2.75<br>(2.50) |
| 23p | 43% | -0.007083<br>(-3.118) | -454.92 | 538.81<br>(489.52) | 13.89<br>(12.62) | 4.64<br>(4.22) |
| 23p | 100% | -0.046728<br>(-2.840) | -455.84 | 896.72<br>(814.68) | 23.12<br>(21.00) | 7.72<br>(7.01) |

Notes:
1 Upper values in each cell are at 1993 prices, lower values (in brackets) are at 1990 prices. Deflator from CSO (1993).
2 On average households visited Thetford 14.65 times per annum.
3 Calculated using median party composition figures of 3 persons (2 of which were >16 years). Mean party size was considerably skewed by a few large parties and was not thought to provide an appropriate measure. Note that this assumption treats adults and children equally.

For the following truncated ML models all explanatory variables entered at a 15% significance level: 8p/43%; 8p/100%; 8p/2.5%.
For all remaining truncated ML models, all explanatory variables with the exception of HSIZE, entered at a 15% significance level.

**Table A2.72: Best fitting ML model based on perceived journey duration and cost (journey costs as stated by respondent; zero time cost)**

Log-likelihood ................ -455.47

| Variable | Coefficient | Std. Error | T-ratio | Prob:t:>x | Mean of X | Std.D.of X |
|---|---|---|---|---|---|---|
| Constant | -0.489717 | 0.593045 | -0.826 | 0.40894 | 1.0000 | 0.0000 |
| TC | -0.0676986 | 0.023003 | -2.943 | 0.00325 | 3.5135 | 4.5566 |
| HSIZE | 0.0969824 | 0.054356 | 1.784 | 0.07439 | 3.3704 | 1.4480 |
| HOLS | -1.47050 | 0.536713 | -2.740 | 0.00615 | 0.0427 | 0.2026 |
| WORK | 1.82321 | 0.454354 | 4.013 | 0.00006 | 0.0228 | 0.1495 |
| LIVE | 2.25116 | 0.397103 | 5.669 | 0.00000 | 0.0285 | 0.1666 |
| RATING | 0.469444 | 0.156934 | 2.991 | 0.00278 | 3.0000 | 0.5127 |
| NT | -0.484902 | 0.242462 | -2.000 | 0.04551 | 0.1339 | 0.3410 |
| TAX | 0.399381 | 0.238005 | 1.678 | 0.09334 | 0.8604 | 0.3471 |
| MDOG | 0.649186 | 0.246816 | 2.630 | 0.00853 | 0.0997 | 0.3001 |
| Sigma | 1.18268 | 0.070644 | 16.741 | 0.00000 | 0.0000 | 0.0000 |

**Table A2.73: Sensitivity analysis: ML models based on perceived journey duration and journey cost**

| Travel cost (pence/mile) | Travel time (% of income) | Travel cost coefficient (t-value) | Log likelihood value | CS/household per annum (£)[1] | **CS/household per visit (£)[1,2]** | CS/person per visit (£)[1,3] |
|---|---|---|---|---|---|---|
| Perceived | 0% | -0.023003 (-2.943) | -455.47 | 175.77 (159.69) | 4.53 (4.12) | 1.51 (1.04) |
| Perceived | 43% | -0.011113 (-2.831) | -455.80 | 378.26 (343.65) | 9.75 (8.86) | 3.25 (2.95) |

Notes: 1 Upper values in each cell are at 1993 prices, lower values (in brackets) are at 1990 prices. Deflator from CSO (1993).
2 On average households visited Thetford 14.65 times per annum.
3 Calculated using median party composition figures of 3 persons (2 of which were >16 years). Mean party size was considerably skewed by a few large parties and was not thought to provide an appropriate measure. Note that this assumption treats adults and children equally.

For the following truncated ML models all explanatory variables entered at a 15% significance level: 8p/43%; 8p/100%; 8p/2.5%. For all remaining truncated ML models, all explanatory variables with the exception of HSIZE, entered at a 15% significance level.

As figure A2.10 showed there are a very few meanderers compared to the numbers whose distance estimates may suffer from rounding error. However, the omission of these few meanderers in the GIS-based tgf's is likely to lead to a relatively large fall in overall fit compared to the impact of rounding errors upon tgf's based on visitors responses. In the event our best fit GIS-based tgf has a log-likelihood value only slightly lower than the best fit response-based tgf.[83] These give per household per visit consumer surplus estimates of £3.95 (1993 prices; £3.59 at 1990 prices) and £4.86 (£4.42) respectively, amounts that could defensibly be used to mark out an envelope of valuation. We strongly suspect that a measurement approach which combines the accuracy of our GIS approach with route itinerary information elicited from respondents would provide a significantly superior basis for ITC studies.

[83]Best fit GIS-based tgf (8p/mile journey cost and 2.5% time cost; see table A2.65) has log-likelihood value -454.59 while best fit response-based tgf (8p/mile journey cost and zero time cost; see table A2.71) has log-likelihood value -453.93.

## A2.4.3: THETFORD 2: JOINT CV/ITC SURVEY QUESTIONNAIRE

**UNIVERSITY OF EAST ANGLIA** **SERIAL NUMBER** [ ][ ][ ][ ]

**THETFORD FOREST RECREATION SURVEY 1993**

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**CONFIDENTIAL**

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LOCATION ..........................................

LOCATION NUMBER [ ][ ]

INTERVIEW NUMBER [ ][ ] [ ][ ][ ]

DATE .../.../1993

DAY Mon = 1 Tue = 2 Wed = 3 Thu = 4
Fri = 5 Sat = 6 Sun = 7

TIME INTERVIEW STARTED (24 hour clock) [ ][ ][ ][ ]

TIME INTERVIEW ENDED (24 hour clock) [ ][ ][ ][ ]

WEATHER CONDITIONS

(a) Sunny........... = 1
Broken Cloud.... = 2
Overcast........ = 3

(b) Hot............. = 1
Warm............ = 2
Cool............ = 3

(c) Dry.............. = 1
Drizzle/Showers.. = 2
Persistent rain.. = 3

(d) Calm............. = 1
Breezy........... = 2
Windy............ = 3

---

Final bid (Tax) [ ][ ][ ][ ] • [ ][ ]

Final bid (Fee) [ ][ ][ ][ ] • [ ][ ]

Type: Tax/Fee = 1

Fee/Tax = 2

Budget question asked? Yes = 1

No = 0

INTERVIEWER INSTRUCTIONS

1. You should not normally interview those under 18
2. If interviewing a family group you should aim to interview the head of household
3. Read out the following:

**Hello, I am (name, show identification) from the University of East Anglia. We are carrying out a survey of people visiting Thetford Forest and I would be grateful if you would answer a few questions. Any information which you provide will be strictly confidential and only used for statistical analysis. I shall not be asking your name.**

If A = Yes, then proceed
If A = No, then withdraw politely

**First, I would like to get some basic information regarding your visit.**

1. **Are you on holiday for more than one day or is this just a day trip from home, or are you working here?** (circle answer below)

Holiday = 1

Day trip = 0

Working = 2 (go to Q.6)

Live here = 3 (go to Q.6)

2. **Is this your first visit to Thetford forest**

Yes = 1 (go to Q.3)

No = 0 (go to Q.6)

3. **Will you visit again?**

Yes = 1 (go to Q.4)

No = (go to Q.5)

Not sure = 2 (go to Q.4)

4. **How often do you think you will visit in the next 12 months? (include todays visit as one)**

| | | |
|---|---|---|
| | | |

(now go to Q.7)

5. **Why will you not be visiting again?**

..............................................................

..............................................................

(now go to Q.7)

6. a. **How many day trips have you taken to Thetford forest in the past 12 months?** (include todays trip as one) [ ][ ][ ]

b. **How many holidays (more than one night) have you taken at Thetford forest during the last 12 months?** [ ][ ][ ]

c. **On average how long are these holidays (in days)?** (zero if no holidays at Thetford) [ ][ ][ ]

7. **How many of the people in your party today are (including yourself):**

a. 16 or over? [ ][ ]

b. Under 16? [ ][ ]

8. **How many people in your individual family household including yourself and any who are not with you today are**

a. 16 or over? [ ][ ]

b. Under 16? [ ][ ]

9. **Approximately where do you live?** (City/Town/village and county only, not house address)

[ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ]

[ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ]

10. **How far away is that** (miles)? [ ][ ][ ]

11. **Is this** (location above) **where you began your journey from today?**

Yes = 1 (go to Q.14)
No = 0 (go to Q.12)

12. **Where did you set out from today**

[ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ]

[ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ]

13. **How far away is that** (miles)?

[ ][ ][ ]

14. **How did you travel here today?**

Car = 0
Local Bus = 1
Coach = 2
Walk = 3
Cycle = 4
Other = 5 (please specify)

..........................................................

15. **How long did your journey take?**

[ ][ ] hours [ ][ ] mins

16. **How much did your journey cost?**
(If a passenger in a car please give cost of car journey irrespective of who paid)

(£) [ ][ ][ ][ ] . [ ][ ]
pounds pence

17. **How many other sites will you visit during today?**

None = 0

One = 1

Two = 2

More = 3

18. **Please apportion your enjoyment of the day amongst the following.**

a) Time spent travelling [ ][ ][ ]

b) Time at **Thetford forest** [ ][ ][ ]

c) Time at other sites [ ][ ][ ]

----------
100

19. **How long in total do you expect to stay at Thetford forest today?**

[ ][ ] hours     [ ][ ] mins

**I would now like to ask you some more specific questions about what you value at Thetford forest.**

20. **From the list below please select your main reason for coming here today.** Choose one only.

| | (show card 1) |
|---|---|
| Walking less than 2 miles | 01 |
| Walking more than 2 miles | 02 |
| Walking the dog (any distance) | 03 |
| Relaxing/enjoying scenery | 04 |
| Picnicking | 05 |
| Adventure playground | 06 |
| Birdwatching | 07 |
| Nature watching | 08 |
| Cycling | 09 |
| Horse riding | 10 |
| Camping | 11 |
| War games | 12 |
| Other (please specify) | 14 |

21. **Now for each of the activities shown on this card** (show card 2) **in turn please state whether you participate in them "often" or "sometimes" (at least once but not often) or "never" either at Thetford forest or elsewhere**

| | OFTEN | SOMETIMES | NEVER |
|---|---|---|---|
| Walking less than 2 miles | 2 | 1 | 0 |
| Walking more than 2 miles | 2 | 1 | 0 |
| Walking the dog (any distance) | 2 | 1 | 0 |
| Relaxing/enjoying scenery | 2 | 1 | 0 |
| Picnicking | 2 | 1 | 0 |
| Adventure playground | 2 | 1 | 0 |
| Birdwatching | 2 | 1 | 0 |
| Nature watching | 2 | 1 | 0 |
| Cycling | 2 | 1 | 0 |
| Horse riding | 2 | 1 | 0 |
| Camping | 2 | 1 | 0 |
| War games | 2 | 1 | 0 |

22. **Which of the following would you say describes the scenery at Thetford Forest?**

1. Unattractive
2. Average scenic value
3. Attractive
4. Superb

## TAXES/FEES

For half the sample use this page, otherwise use p.8
Before reading the following please circle this number: 1

**The recreational facilities provided at Thetford are currently paid for by the public via taxes. The government are considering whether or not it is worth investing additional taxpayers money in forest recreation. One important consideration therefore is to find out how much the recreational activities, landscape and other characteristics of forests such as Thetford are worth to the people who visit. To get some idea of this we are asking people a few questions about the amount of money they might be willing to pay to ensure the conservation of this particular site.**

23. **Would you be in favour of some increased government spending and thereby an increase in your taxes in order to ensure conservation of this site?**

    Yes = 1 (go to Q.24)

    No = 2 (go to Q.26)

    d/k = 3 (go to Q.24)

24. Note: you should omit the following for half of those asked the questions on this page (if question omitted code = XXXXX in box below then go to Q.25)

    **Before asking how much more in taxes you might be prepared to pay I should like you to consider how much you already spend upon recreation and the countryside per year. Please consider day trip costs (petrol, admission fees, etc), donations to countryside causes, membership fees, etc.**
    (help this calculation by estimating monthly costs and grossing up)

    Annual Budget = £ | | | | | |

    (if no answer when asked: code = NNNNN)

25. **Now, remembering that any money you spend on Thetford forest you cannot spend elsewhere please state how much extra in taxes you would be prepare to spend each year to conserve Thetford forest**

    £ | | | | | . | | |

26. **There is no entrance fee here. In place of any taxes, what is the most which you would be prepared to pay per adult as an entrance fee with children charged half the adult fee?**
    (children being anyone under 16)

    £ | | | . | | |

    (if refused to pay go to Q.27, otherwise go to Q.28)

**FEES/TAXES**

Before reading the following please circle this number: 2

23. **There is no entrance fee here. What is the most which you would be prepared to pay per adult as an entrance fee with children charged half the adult fee**
(children being anyone under 16)

£ [ | ] • [ | ]

**In order to help you answer the next questions I should like to give you some background information.**

**The recreational facilities provided at Thetford are currently paid for by the public via taxes. The government are considering whether or not it is worth investing additional taxpayers money in forest recreation. One important consideration therefore is to find out how much the recreational activities, landscape and other characteristics of forests such as Thetford are worth to the people who visit. To get some idea of this we are asking people a few questions about the amount of money they might be willing to pay to ensure the conservation of this particular site.**

24. **Instead of an entrance fee, would you be in favour of some increased government spending and thereby an increase in your taxes to ensure conservation of this site?**

Yes = 1 (go to Q.25)
No = 2 (go to Q.27)
d/k = 3 (go to Q.25)

25. Note: you should omit the following for half of those asked the questions on this page (if question omitted code = XXXXX in box below then go to Q.26)

**Before asking how much more in taxes you might be prepared to pay I should like you to consider how much you already spend upon recreation and the countryside per year. Please consider day trip costs (petrol, admission fees, etc), donations to countryside causes, membership fees, etc.**
(help this calculation by estimating monthly costs and grossing up)

Annual Budget = £ [ | | | | ]

(if no answer when asked: code = NNNNN)

26. **Now, remembering that any money you spend on Thetford forest you cannot spend elsewhere please state how much extra in taxes you would be prepare to spend each year**

£ [ | | | ] • [ | ]

(now go to Q.28)

27. (if refused to pay) **What is your main reason for your reply?** (show card 3)

1 = I cannot afford to pay but would do so otherwise

2 = I do not like the site

3 = I prefer the natural state of the site

4 = I refuse to value the site (why?).....................

5 = I feel that this is someone else's responsibility (government, etc)

6 = I pay too much tax already

7 = I do not agree with entrance fees at forests

(now go to Q.29)

28. (if agreed to pay) **What is your main reason for your reply?** (show card 4)

1 = Feels that this is a reasonable amount to pay

2 = Similar amount as paid at other sites of equal value

3 = Live close to this site

4 = Visit this site often

5 = Very keen on countryside in general

6 = Very keen on forests in particular

7 = Very keen on wildlife/the environment

8 = Feel we should preserve areas for future generations

9 = Other (please state)

..............................................

..............................................

**Finally, I need to ask some details so that we can characterise your household. This is to ensure at the end of our survey that we have interviewed a cross section of the population.**

29. **Could you please tell me which of these letters, a to i, best describes your total household income (pre-tax including state benefits, pensions, interest on investments, etc)** (show card 5)

[Please stress: a. All answers are completely anonymous and confidential.
b. The importance of getting an accurate reply to this question - we need to account for the fact that ability to pay clearly influences responses to tax and entrance fee questions]

30. **Are you currently a tax payer?**

Yes = 1

No = 0

31. **Could you tell me into which of these broad groups, a to h, your age falls?** (show card 6)

32. **Lastly, are you a member of any of the following?** (circle all relevant numbers) (show card 7)

**01 RSPB**
**02 National Trust**
**03 The Broads Society (or Broads Authority)**
**04 Norfolk Naturalist Trust**
**05 Suffolk Wildlife Trust**
**06 Any other Local or County Nature Trust/Volunteers etc**
**07 Any sports club**
**08 Any church/religious/charity group**
**09 Lions/Rotary etc**
**10 Greenpeace/Friends of the Earth etc**
**11 World Wide Fund for Nature**
**12 Womens Institute**
**13 Other not covered above (please specify)**

.......................................

**THANK YOU VERY MUCH FOR YOUR HELP**

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# Appendix 3: Arrivals Function Analysis

## A3.1: ESTIMATING THE ARRIVALS FUNCTION

Travel time zones were defined and zonal populations extracted as detailed in chapter 5. In total 351 parties were interviewed during the survey, of which 326 (92.8%) started their journey from a location within the area covered by our GIS road network. Allocating these observations into their origin time-zones gives us our base data for estimating an arrivals function. Table A3.1 details this data.

Table A3.1: Base data for arrivals function analysis

| Timezone (TZ) | Popn. | Visits (parties) | Visit rate (VR) |
|---|---|---|---|
| 5 | 954 | 13 | 0.0138004 |
| 10 | 21596 | 31 | 0.0014355 |
| 15 | 13326 | 8 | 0.0006003 |
| 20 | 14377 | 10 | 0.0006956 |
| 25 | 26811 | 26 | 0.0009698 |
| 30 | 58416 | 38 | 0.0006505 |
| 40 | 191009 | 46 | 0.0002408 |
| 50 | 405831 | 65 | 0.0001602 |
| 60 | 375134 | 17 | 0.0000453 |
| 75 | 776817 | 48 | 0.0000618 |
| 90 | 562508 | 15 | 0.0000267 |
| 105 | 253762 | 7 | 0.0000276 |
| 120 | 23604 | 2 | 0.0000847 |

where:

TZ = Timezone defined in minutes of travel time from the visit origin to the survey site, eg. 5 = the 0 to 5 minute timezone
Popn = Population of the timezone
Visits = Visits (parties) from timezone
VR = Visits/Population ie. party visit rate

Our arrivals function relates party visit rate (VR) to travel time (the origin timezone, TZ). Initial analysis investigated the appropriate functional form of such a relationship across all time-zones (5 to 120 minutes inclusive). Linear, semi-log (dependent and independent), and double log specifications were tested with results being given in tables A3.2 to A3.5 respectively.

Table A3.2: Linear arrivals function (all time zones)

| Predictor | Coef. | Stdev | t-ratio | p |
|---|---|---|---|---|
| Constant | 0.003597 | 0.001649 | 2.18 | 0.052 |
| TZ | -0.00004335 | 0.00002682 | -1.62 | 0.134 |

s = 0.003509 R-sq = 19.2% R-sq(adj) = 11.8%

Analysis of variance

| SOURCE | DF | SS | MS | F | p |
|---|---|---|---|---|---|
| Regression | 1 | 0.00003217 | 0.00003217 | 2.61 | 0.134 |
| Error | 11 | 0.00013546 | 0.00001231 | | |
| Total | 12 | 0.00016763 | | | |

One observation with a large standard residual (closest zone).

Table A3.3: Semi-log (dependent) arrivals function (all time zones)

| Predictor | Coef | Stdev | t-ratio | p |
|---|---|---|---|---|
| Constant | -6.1923 | 0.4683 | -13.22 | 0.000 |
| TZ | -0.041032 | 0.007618 | -5.39 | 0.000 |

s = 0.9969 R-sq = 72.5% R-sq(adj) = 70.0%

Analysis of variance

| SOURCE | DF | SS | MS | F | p |
|---|---|---|---|---|---|
| Regression | 1 | 28.828 | 28.828 | 29.01 | 0.000 |
| Error | 11 | 10.932 | 0.994 | | |
| Total | 12 | 39.761 | | | |

2 observations with large standard residuals (closest and furthest zones).

Table A3.4: Semi-log (independent) arrivals function (all time zones)

| Predictor | Coef | Stdev | t-ratio | p |
|---|---|---|---|---|
| Constant | 0.010876 | 0.003127 | 3.48 | 0.005 |
| lnTZ | -0.0026541 | 0.0008517 | -3.12 | 0.010 |

s = 0.002845 R-sq = 46.9% R-sq(adj) = 42.1%

Analysis of variance

| SOURCE | DF | SS | MS | F | p |
|---|---|---|---|---|---|
| Regression | 1 | 0.000078598 | 0.000078598 | 9.71 | 0.010 |
| Error | 11 | 0.000089035 | 0.000008094 | | |
| Total | 12 | 0.000167633 | | | |

One observation with a large standard residual (closest zone).

Table A3.4: Double-log arrivals function (all time zones)

| Predictor | Coef | Stdev | t-ratio | p |
|---|---|---|---|---|
| Constant | -1.8818 | 0.6764 | -2.78 | 0.018 |
| lnTZ | -1.7862 | 0.1842 | -9.70 | 0.000 |

s = 0.6153 R-sq = 89.5% R-sq(adj) = 88.6%

Analysis of variance

| SOURCE | DF | SS | MS | F | p |
|---|---|---|---|---|---|
| Regression | 1 | 35.596 | 35.596 | 94.03 | 0.000 |
| Error | 11 | 4.164 | 0.379 | | |
| Total | 12 | 39.761 | | | |

No statistically unusual observations

Examining tables A3.2 to A3.5 we can see the clear superiority of a double-log specification. However, upon analysis it was noted that the furthest zone (120 minutes) was only partially included in the study area (as defined by the available road network immage). It therefore had a very small population relative to the size implied by the zone and consequently produced a less reliable observation on visit rate than do other zones. Our 'best-fit' arrivals function therefore adopts a double-log functional form but omits the furthest (120 minute) time zone observation from the regression. Table A3.6 reports this best-fit arrivals function which is illustrated in figure A3.1.

Table A3.6: Best-fit arrivals function

| Predictor | Coef | Stdev | t-ratio | p |
|---|---|---|---|---|
| Constant | -1.4569 | 0.6054 | 02.41 | 0.037 |
| lnTZ | -1.9348 | 0.1699 | -11.39 | 0.000 |

s = 0.5238 R-sq = 92.8% R-sq(adj) = 92.1%

Analysis of variance

| SOURCE | DF | SS | MS | F | p |
|---|---|---|---|---|---|
| Regression | 1 | 35.589 | 35.589 | 129.70 | 0.000 |
| Error | 10 | 2.744 | 0.274 | | |
| Total | 11 | 38.333 | | | |

No statistically unusual observations.

Figure A3.1: The arrivals function

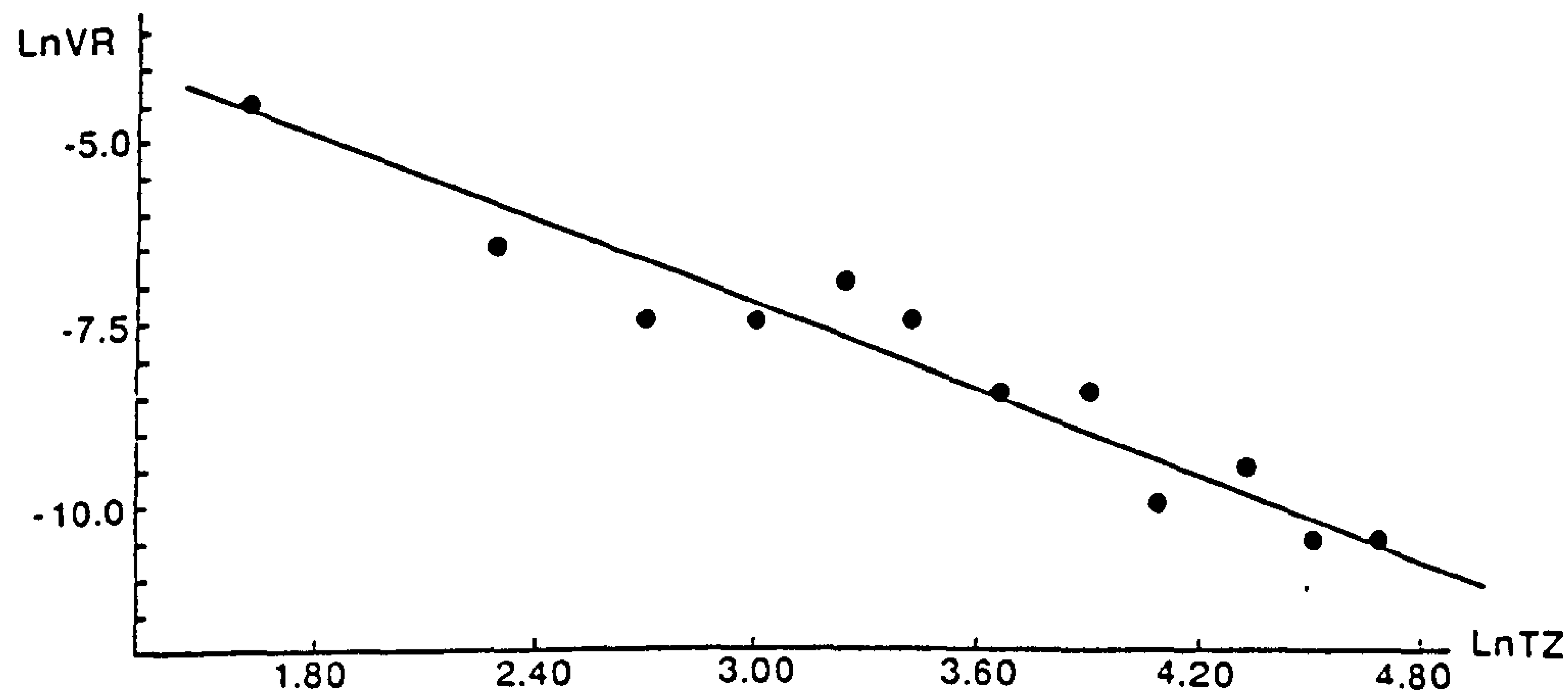


Figure A3.1 seems to suggest the possibility of some correlation between residuals. A Durbin-Watson (DW) statistic of 1.41 was calculated. For df = 15 (DW is not tabulated for lower values) and one explanatory variable the relevant bounds of significance are $d_L$ = 1.08 and $d_u$ = 1.36. This confirmed that there was not any significant serial correlation problem[1].

A number of possible redefinitions of our model were tested. Table A3.7 omits the outer two time zones. However, this fails to perform as well as the model given in table A3.6.

Table A3.7: Double-log arrivals function omitting outer two time zones

| Predictor | Coef | Stdev | t-ratio | p |
|---|---|---|---|---|
| Constant | -1.4739 | 0.6758 | -2.18 | 0.057 |
| lnTZ-2 | -1.9287 | 0.1961 | -9.84 | 0.000 |

s = 0.5520 R-sq = 91.5% R-sq(adj) = 90.5%

[1]However, ongoing work from a subsequent survey of bathing water sites is investigating the possibility that a discontinuous function may be more appropriate, i.e. local visitors may have different trip generation functions to those coming from more distant origins.

Analysis of variance

| SOURCE | DF | SS | MS | F | p |
|---|---|---|---|---|---|
| Regression | 1 | 29.485 | 29.485 | 96.77 | 0.000 |
| Error | 9 | 2.742 | 0.305 | | |
| Total | 10 | 32.227 | | | |

No unusual observations.

In a further sensitivity analysis time zones were redefined as their mid points (eg. the 5 minute zone becomes the 2.5 minute zone). Here the best model for the entire dataset (all zones) is given by table A3.8. Various respecifications of this model were analysed including the omission of the outer one and outer two time zones (given as tables A3.9 and A3.10 respectively. However, none of these models outperformed that of table A3.6 which was adopted for all our subsequent analyses of visitor recreation demand.

Table A3.8: Arrivals function defining zones by their mid-point values (all time zones).

| Predictor | Coef | Stdev | t-ratio | p |
|---|---|---|---|---|
| Constant | -2.9385 | 0.5695 | -5.16 | 0.000 |
| lnTZ.5 | -1.5613 | 0.1604 | -9.73 | 0.000 |

s = 0.6132 R-sq = 89.6% R-sq(adj) = 88.7%

Analysis of variance

| SOURCE | DF | SS | MS | F | p |
|---|---|---|---|---|---|
| Regression | 1 | 35.624 | 35.624 | 94.74 | 0.000 |
| Error | 11 | 4.136 | 4.136 | | |
| Total | 12 | 39.761 | 39.761 | | |

One unusual observation; the closest time zone had a statistically large influence.

Table A3.9: Arrivals function defining zones by mid-point values (omits furthest timezone).

| Predictor | Coef | Stdev | t-ratio | p |
|---|---|---|---|---|
| Constant | -2.6667 | 0.5319 | -5.01 | 0.000 |
| lnTZ.5-1 | -1.6680 | 0.1549 | -10.77 | 0.000 |

s = 0.5516 R-sq = 92.1% R-sq(adj) = 91.3%

Analysis of variance

| SOURCE | DF | SS | MS | F | p |
|---|---|---|---|---|---|
| Regression | 1 | 35.291 | 35.291 | 116.01 | 0.000 |
| Error | 10 | 3.042 | 0.304 | | |
| Total | 11 | 38.333 | | | |

One unusual observation: the closest zone had a statistically large influence.

Table A3.10: Arrivals function defining zones by mid-point values (omits 2 furthest time zones).

| Predictor | Coef | Stdev | t-ratio | p |
|---|---|---|---|---|
| Constant | -2.7289 | 0.5803 | -4.70 | 0.000 |
| lnTZ.5-2 | -1.6428 | 0.1753 | -9.37 | 0.000 |

s = 0.5769 R-sq = 90.7% R-sq(adj) = 89.7%

Analysis of variance

| SOURCE | DF | SS | MS | F | p |
|---|---|---|---|---|---|
| Regression | 1 | 29.232 | 29.232 | 87.84 | 0.000 |
| Error | 9 | 2.995 | 0.333 | | |
| Total | 10 | 32.227 | | | |

One unusual observation: the closest zone had a statistically large influence.

Our best-fit arrivals function is therefore the double log model relating visit rate to time zone for all data observations except the furthest zone with time zones defined as their outer time boundary. This model was then extrapolated to predict visit rate (predVR) for all time zones up to 500 minutes. Results of this analysis are given in table A3.11 which compares predVR with actual observations (actVR) for the 13 time zones of the Thetford Forest study.

Table A3.11: Predicted and actual visitor rates in the Thetford Forest study

| TZ | predVR | actVR | predVR/actVR |
|---|---|---|---|
| 5 | 0.0103972 | 0.0138004 | 0.75340 |
| 10 | 0.0027285 | 0.0014355 | 1.90082 |
| 15 | 0.0012476 | 0.0006003 | 2.07818 |
| 20 | 0.0007160 | 0.0006956 | 1.02946 |
| 25 | 0.0004655 | 0.0009698 | 0.48000 |
| 30 | 0.0003274 | 0.0006505 | 0.50331 |
| 40 | 0.0001879 | 0.0002408 | 0.78028 |
| 50 | 0.0001222 | 0.0001602 | 0.76269 |
| 60 | 0.0000859 | 0.0000453 | 1.89599 |
| 75 | 0.0000559 | 0.0000618 | 0.90394 |
| 90 | 0.0000393 | 0.0000267 | 1.47326 |
| 105 | 0.0000292 | 0.0000276 | 1.05770 |
| 120 | 0.0000225 | 0.0000847 | 0.26611 |
| 150 | 0.0000147 | | |
| 180 | 0.0000103 | | |
| 210 | 0.0000077 | | |
| 240 | 0.0000059 | | |
| 300 | 0.0000038 | | |
| 360 | 0.0000027 | | |
| 500 | 0.0000014 | | |

where:
TZ = time zone (upper boundary in minutes of travel time)
predVR = predicted visitor rate
actVR = actual visitor rate
pr/ac VR = predicted/actual visitor rate

Analysis of table A3.11 indicates that while the arrivals function predicts overall visits well, it is less apparently reliable in predicting arrivals for any one time zone. This is mainly a consequence of the limited survey period and sample size and we feel that additional resources would both improve the arrivals function and reinforce it's validity. However, we did feel that this issue deserved further investigation and so our arrivals function was used to predict zonal and total arrivals for the duration of the survey period. Results from this analysis are given in table A3.12.

Table A3.12: Comparison of actual with predicted visits for the survey period.

| TZ | actVR | predVR |
|---|---|---|
| 5 | 13 | 9.7942 |
| 10 | 31 | 58.9255 |
| 15 | 8 | 16.6255 |
| 20 | 10 | 10.2946 |
| 25 | 26 | 12.4801 |
| 30 | 38 | 19.1257 |
| 40 | 46 | 35.8929 |
| 50 | 65 | 49.5751 |
| 60 | 17 | 32.2318 |
| 75 | 48 | 43.3891 |
| 90 | 15 | 22.0989 |
| 105 | 7 | 7.4039 |

Analysis of table A3.12 shows that actual and predicted visitor rates are well correlated ($r = 0.719$). Regression analysis showed that predVR satisfied a 1% significance test as a predictor of actVR, while only one zone (10 minute zone) was significantly poorly predicted (standard residual = -2.01). Total actual visits from the first 12 travel time zones was 324, compared with 317.84 total predicted visits. Therefore the number of visits which our arrivals function predicts for the survey period is within 2% of the number which actually occurred[2].

## A3.2: MODELLING ANNUAL VISITS

Our estimated arrivals function only relates to those visitors who were interviewed during those days which were sampled during the survey period. If we wish to extrapolate our arrivals function to estimate annual arrivals we need to take account of the following:

i. Visits which occur while interviewers were occupied with other visitors or which occur outside interview hours;
ii. Visits which occur on non-sampled days during the survey period;
iii. Visits which occur outside the survey period.

In the following sections we make all of the adjustments outlined above and in so doing develop a model of annual visitation pattern at the Thetford site. This allows us to extrapolate our arrivals function onto an annual basis. This *adjusted annual arrivals function* is subsequently used to predict per annum visit totals for five sites in Wales for which information on actual arrivals is available, thus permitting an actual versus predicted validation test of the applicability of our adjusted annual arrivals function to other sites.

[2]Here, we are referring only to the number of visitors which were actually interviewed versus the predicted number interviewed, i.e. both actual and predicted numbers ignore those who would not have been interviewed because they arrived out of survey hours, etc. An adjustment for non-surveyed visitors is made in appendix A3.2.

## A3.2.1: ALLOWING FOR NON-INTERVIEWED VISITORS DURING SURVEY DAYS

The 1993 Thetford Forest survey interviewed 351 parties over 17 survey days (one of which was curtailed due to poor weather) spread across the period 26.3.93 to 25.4.93. From 1.4.93 an electronic induction loop car counter operated at the site giving accurate information regarding the number of party visits per week. Table A3.13 details visit and survey data for the overlapping period of 12 days[3].

Table A3.13: Overlap of interview days and electronic counter operation days

| Overlap period | Counter days (1) | Interview days (2) | Interviews (No. of parties) (3) | Cars (4) | (4)* [(2)/(1)] =(5) | Interview rate [(3)/(5)] (%) |
|---|---|---|---|---|---|---|
| 1.4.93-4.4.93 | 4 | 2 | 45 | 658 | 329 | 13.6778 |
| 5.4.93-11.4.93 | 7 | 6 | 103 | 844 | 723 | 14.2378 |
| 12.4.93-19.4.93 | 7 | 2 | 59 | 1436 | 410 | 14.3802 |
| 19.4.93-26.4.93 | 7 | 2 | 50 | 1099 | 314 | 15.9236 |
| Totals | 25 | 12 | 257 | 4037 | 1776 | 14.4707 |

Table A3.13 shows that we achieved just over a 14% interview rate on the 12 days for which data is available. Assuming that this rate also applies for the full 16 effective days which were sampled then multiplying our total sample size by a factor of 1/0.144707 gives our best estimate of the total number of visitors during those days of the survey on which interviewing took place. Therefore the estimated number of arrivals during those 16 days is as follows:

$$\text{Estimated arrivals (parties)} = 351 * \frac{1}{0.144707}$$

$$= 351 * 6.9105$$

$$= 2426$$

However, the sample period was not evenly distributed throughout the days of the week. In order to increase sample size, 7 of the sample days were on weekends (3 Saturdays and 4 Sundays). We therefore need to examine whether arrival rates are significantly larger on weekend days than weekdays as, if they are, then our arrivals function will overestimate visitors.

Table A3.14 shows on which days the survey was conducted and the number of interviews on each day. Average interview numbers are calculated in the final column. The average number of interviews/day over all days was 20.16 ($\sigma = 5.68$). Weekend days did record a higher interview rate of 22.55 interviews/day ($\sigma = 2.75$) compared to a mean for weekdays of 19.20 interviews/day ($\sigma = 6.24$). However, upon testing, this difference was found to be highly insignificant ($t = 0.62$).

Table A3.14: Interview rates across survey days

[3]A potential problem would arise at sites with a large number of pedestrian visitors not arriving by car. As confirmed by our survey this is not a significant problem at Lynford Stag which can only be reached on foot by a lengthy walk.

| Day | Interviews (No. of parties) | Cumulative interview count | % of total sample | Cumulative % of total sample | Survey (No. of days) | Average interviews/day |
|---|---|---|---|---|---|---|
| Mon | 29 | 29 | 8.26 | 8.26 | 1 | 29.0 |
| Tues | 32 | 61 | 9.12 | 17.38 | 2 | 16.0 |
| Wed | 20 | 81 | 5.70 | 23.08 | 1 | 20.0 |
| Thurs Fri | 10 | 91 | 2.85 | 25.93 | 1 | 10.0 |
| Sat | 105 | 196 | 29.91 | 55.84 | 5 | 21.0 |
| Sun | 76 | 272 | 21.65 | 77.49 | 3 | 25.3 |
| | 79 | 351 | 22.51 | 100.00 | 4 | 19.8 |
| N = 351 | | | | | | mean=20.16 $\sigma = 5.68$ |

One possible complicating factor was very adverse weather conditions on one of the weekend sample days. Removing this from the dataset raised the weekend day mean to 25.65 (s = 0.35). However, whilst this increased the overall apparent contrast between weekend and weekday distributions this difference remained statistically insignificant (t = 1.26) and, as Britain is no stranger to adverse weather we feel that our initial findings are more defensible.

In summary we can conclude that our inflation factor of 6.9105 is unbiased in relating survey day interviews to the total number of parties visiting per survey day.

## A3.2.2: ALLOWING FOR NON-SURVEYED DAYS DURING THE SURVEY PERIOD

Ultimately we need to relate arrivals during our sample period to annual arrivals. As arrivals data is recorded upon a weekly rather than daily basis it will be convenient to convert our 16 day estimate to one which relates to the entire encompassing five week (35 day) period. Given the above investigation, a justifiable and simple conversion is to multiply by a factor of 35/16. Therefore our party arrivals estimate for a five week period from late March to the end of April 1993 is as follows:

= 351 * 6.9105 * 2.1875

= 351 * 15.1167

= 5306

## A3.2.3: RELATING SAMPLE PERIOD TO ANNUAL VISITS

We now need to consider evaluation of a factor to relate estimates for the sample period to annual arrivals. To do this we first require an accurate estimate of annual visits.

### A3.2.3.1: Adjusting for systematic errors in pneumatic visit counters

Table A3.15 details weekly visitor data collected via pneumatic counter from March 1990 up to the installation of an electronic loop counter on 1 April 1993. Table A3.16 details weekly visitor data from the latter electronic counter from it's installation to the end of July 1993.

A major problem facing UK forest recreation research has been the acknowledged deficiencies of pneumatic visit counters[4]. Pneumatic counters tend to suffer from systematic errors, that is they record the overall pattern of visits reasonably well but tend to be systematically inaccurate in recording absolute numbers. For example, a particular pneumatic counter may, on average, fail to register one car in ten whilst another pneumatic counter may double count on average one car in fifteen. Each pneumatic counter seems to have its own idiosyncrasies. This means that we have to calculate adjustment factors for any individual pneumatic counter whose data we wish to use.

This situation has been considerably improved by the recent introduction of electronic loop counters which are considered to be far more accurate. However, such counters have only been installed at a few sites and since early 1993. One of the major reasons determining our choice of survey site was the installation of an electronic loop counter at Lynford Stag. Because errors in the pneumatic counters tend to be systematic, comparison of the data obtained from a particular pneumatic counter with that derived for the same period from electronic loop counters allows estimation of a pneumatic/electronic loop conversion factor. Such a factor can then be applied to the pneumatically derived annual visitor estimates to adjust these for error in such counters. While we did not have a period over which both pneumatic and electronic loop counters were in operation, we can compare counts made by the electronic loop device with those made by the pneumatic counter for the same period in the previous year. While this is perhaps less than ideal such a comparison can be improved by ensuring that factors such as the number of bank holidays and wet weather days is the same during compared periods. Such checks were made and appropriate comparable periods defined. Table A3.17 compares data from the electronic loop counter in 1993 with data from the relevant pneumatic counter[5] for identical periods in 1992 and 1991. The weighted mean adjustment factor implied from table A3.17 was 0.7427, ie. the annual visitor totals recorded by the pneumatic counter should be adjusted by this factor.

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[4]Pers. comm., Roger Oakes, Forestry Commission Statistics Branch, Edinburgh, August 1993.

[5]It is very important to note that each individual pneumatic counter is liable to exhibit its own idiosyncratic systematic error. The counter in table A3.17 systematically overestimated arrivals whereas analysis of an earlier counter used in 1990 showed that it underestimated arrivals (electronic loop/pneumatic = 1.3483). It is therefore important individual adjustment factors are calculated for each pneumatic counter.

Table A3.15: Lynford Stag traffic count 1990-93: pneumatic counter

Note: some pneumatic counters are designed to record the number of vehicle axles while others record the number of tyres. Weekly readings have to be divided by either 2 or 4 accordingly. Counter types are recorded in the remarks column.

| Date of Reading | | | Traffic Counter Reading | | | | | Difference from previous reading | | | | Remarks (eg. about counter type, weather, public holidays, closures, special events) | Cars: (party visits) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Month | Year | | | | | | | | | | | |
| | | | 4 | 1 | 8 | 2 | 0 | | | | | DIVIDE BY 2 UNTIL 31.5.90 | |
| 1 | 3 | 90 | 4 | 2 | 8 | 5 | 0 | 1 | 0 | 3 | 0 | Wet & windy | 515 |
| 8 | 3 | 90 | 4 | 3 | 5 | 6 | 9 | | 7 | 1 | 9 | Wet & windy-generally cloudy | 359 |
| 15 | 3 | 90 | 4 | 4 | 5 | 7 | 6 | 1 | 0 | 0 | 7 | Windy at weekend-fine & warm week | 503 |
| 22 | 3 | 90 | 4 | 5 | 9 | 6 | 3 | 1 | 3 | 8 | 7 | Warm & windy | 639 |
| 29 | 3 | 90 | 4 | 6 | 9 | 0 | 5 | | 9 | 4 | 2 | Cold & windy weekend | 471 |
| 5 | 4 | 90 | 4 | 8 | 4 | 1 | 3 | 1 | 5 | 0 | 8 | Warm weekend otherwise variable | 754 |
| 12 | 4 | 90 | 4 | 9 | 7 | 4 | 3 | 1 | 3 | 3 | 0 | Sunny but cold wind | 665 |
| 19 | 4 | 90 | 5 | 1 | 7 | 7 | 3 | 2 | 0 | 3 | 0 | Windy, cold & showery | 1015 |
| 26 | 4 | 90 | 5 | 3 | 1 | 7 | 2 | 1 | 3 | 9 | 9 | Improvement from weekend | 699 |
| 3 | 5 | 90 | 5 | 4 | 9 | 5 | 4 | 1 | 7 | 8 | 2 | Warm & dry becoming hot | 891 |
| 10 | 5 | 90 | 5 | 7 | 9 | 2 | 8 | 2 | 9 | 7 | 4 | Hot & dry w/e, cooler BH Monday | 1487 |
| 17 | 5 | 90 | | | | | | | | | | COUNTER DEFECTIVE - REMOVED | |
| 13 | 8 | 90 | | | 9 | 1 | 4 | | | | | NEW COUNTER INSTALLED, DIVIDE BY 4 | |
| 16 | 8 | 90 | | 3 | 5 | 1 | 7 | 2 | 5 | 9 | 3 | Hot & Sunny becoming cooler | 648 |
| 23 | 8 | 90 | 1 | 2 | 6 | 2 | 9 | 10 | 0 | 3 | 6 | Rain at w/e becoming hot | 2509 |
| 30 | 8 | 90 | 2 | 9 | 0 | 5 | 2 | 16 | 4 | 2 | 3 | Hot Bank Holiday | 4106 |
| 6 | 9 | 90 | 3 | 9 | 6 | 8 | 1 | 10 | 6 | 2 | 9 | Becoming changeable & cooler | 2657 |
| 13 | 9 | 90 | 3 | 8 | 0 | 0 | 8 | 8 | 3 | 2 | 7 | Warm | 2082 |
| 20 | 9 | 90 | 5 | 5 | 3 | 3 | 9 | 7 | 3 | 2 | 1 | Pleasant w/e | 1830 |
| 27 | 9 | 90 | 6 | 1 | 2 | 2 | 4 | 5 | 9 | 3 | 5 | Showery & cool | 1484 |
| 4 | 10 | 90 | 6 | 3 | 5 | 5 | 0 | 2 | 2 | 6 | 6 | " " " | 566 |
| 11 | 10 | 90 | 6 | 4 | 8 | 8 | 9 | 1 | 3 | 2 | 9 | Warmer | 332 |
| 18 | 10 | 90 | | 6 | 4 | 4 | 1 | 1 | 5 | 6 | 2 | Sunny w/e & generally warm | 390 |

Table A3.15 (cont.)

| Date of Reading | | | Traffic Counter Reading | | | | | Difference from previous reading | | | | Remarks (eg. about weather, public holidays, closures, special events) | Cars: (party visits) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Month | Year | | | | | | | | | | | |
| | | | 6 | 6 | 4 | 2 | 1 | | | | | | |
| 25 | 10 | 90 | 6 | 7 | 8 | 5 | 3 | 1 | 4 | 3 | 2 | Variable sunshine | 358 |
| 1 | 11 | 90 | 6 | 9 | 2 | 7 | 3 | 1 | 4 | 2 | 0 | " " | 355 |
| 8 | 11 | 90 | 7 | 0 | 1 | 1 | 9 | | 8 | 4 | 6 | " " + rain | 211 |
| 15 | 11 | 90 | 7 | 1 | 1 | 2 | 2 | 1 | 0 | 0 | 3 | " " " " | 251 |
| 22 | 11 | 90 | 7 | 2 | 0 | 1 | 8 | | 8 | 9 | 6 | Dull wet & cool | 224 |
| 29 | 12 | 90 | 7 | 2 | 7 | 8 | 5 | | 7 | 6 | 7 | " " " " | 192 |
| 6 | 12 | 90 | 7 | 3 | 4 | 1 | 5 | | 6 | 3 | 0 | Variable | 157 |
| 10 | 12 | 90 | | | 5 | 3 | 0 | | | | | DEFECTIVE COUNTER-NEW ONE INSTALLED Variable, cold | - |
| 13 | 12 | 90 | | 1 | 1 | 3 | 1 | | 6 | 0 | 1 | & snow | 150 |
| 20 | 12 | 90 | | 3 | 0 | 0 | 1 | 1 | 8 | 7 | 0 | " " " " | 467 |
| 27 | 12 | 90 | | | | | | | | | | Not read: 1/2 of following week total | 660 |
| 3 | 1 | 91 | | 8 | 2 | 8 | 2 | 5 | 2 | 8 | 1 | Variable but windy | 660 |
| 10 | 1 | 91 | 1 | 0 | 7 | 0 | 6 | 2 | 4 | 2 | 4 | " " " | 606 |
| 17 | 1 | 91 | 1 | 3 | 1 | 3 | 3 | 2 | 4 | 2 | 7 | Variable | 607 |
| 24 | 1 | 91 | 1 | 5 | 3 | 7 | 3 | 2 | 2 | 4 | 0 | " | 560 |
| 31 | 1 | 91 | 1 | 7 | 5 | 0 | 9 | 2 | 1 | 3 | 6 | Cloudy & cold | 534 |
| 7 | 2 | 91 | 1 | 9 | 6 | 0 | 9 | 2 | 1 | 0 | 0 | " " cold | 525 |
| 14 | 2 | 91 | 1 | 9 | 8 | 5 | 1 | | 2 | 4 | 2 | Snow & very cold | 60 |
| 21 | 2 | 91 | 2 | 1 | 9 | 8 | 8 | 2 | 1 | 3 | 7 | Milder | 534 |
| 28 | 2 | 91 | 2 | 4 | 7 | 7 | 6 | 2 | 8 | 8 | 8 | " | 722 |
| 7 | 3 | 91 | 2 | 8 | 2 | 6 | 1 | 3 | 4 | 8 | 5 | " | 871 |
| 14 | 3 | 91 | 3 | 1 | 4 | 1 | 6 | 3 | 1 | 5 | 5 | Cool | 789 |
| 21 | 3 | 91 | 3 | 5 | 5 | 3 | 9 | 4 | 1 | 2 | 3 | Variable | 1031 |
| 28 | 3 | 91 | 3 | 9 | 9 | 1 | 4 | 4 | 3 | 7 | 5 | | 1094 |
| 4 | 4 | 91 | 5 | 0 | 8 | 1 | 9 | 10 | 9 | 9 | 5 | Bank holiday weekend BH | 2749 |
| 11 | 4 | 91 | 5 | 6 | 0 | 9 | 4 | 5 | 2 | 7 | 5 | | 1319 |
| 18 | 4 | 91 | 6 | 1 | 6 | 0 | 2 | 5 | 5 | 0 | 8 | Cool | 1377 |
| 25 | 4 | 91 | 6 | 5 | 2 | 9 | 9 | 3 | 6 | 9 | 7 | Cool, showery | 924 |

Table A3.15 (cont.)

| Date of Reading | | | Traffic Counter Reading | | | | | Difference from previous reading | | | | Remarks (eg. about weather, public holidays, closures, special events) | Adjusted cars: |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Month | Year | | | | | | | | | | | |
| | | | 6 | 5 | 2 | 9 | 9 | | | | | | |
| 2 | 5 | 91 | 7 | 1 | 7 | 1 | 3 | 6 | 4 | 1 | 4 | Cool | 1603 |
| 9 | 5 | 91 | 8 | 0 | 2 | 3 | 4 | 8 | 5 | 2 | 1 | BH Monday - cool | 2130 |
| 16 | 5 | 91 | 8 | 7 | 3 | 0 | 0 | 7 | 0 | 6 | 6 | Cool, sunny intervals | 1766 |
| 23 | 5 | 91 | 9 | 3 | 9 | 8 | 8 | 6 | 6 | 8 | 8 | " " " | 1672 |
| 30 | 5 | 91 | | 5 | 6 | 6 | 4 | 12 | 6 | 7 | 6 | " " " BH | 3169 |
| 6 | 6 | 91 | 1 | 3 | 6 | 4 | 2 | 6 | 9 | 7 | 8 | " " " | 1744 |
| 13 | 6 | 91 | 1 | 9 | 4 | 4 | 9 | 5 | 8 | 0 | 7 | Cool, showery & windy | 1452 |
| 20 | 6 | 91 | 2 | 5 | 4 | 3 | 1 | 5 | 9 | 8 | 2 | " " " " | 1495 |
| 27 | 6 | 91 | 3 | 2 | 0 | 1 | 7 | 6 | 6 | 8 | 6 | " " " " | 1671 |
| 4 | 7 | 91 | 3 | 9 | 6 | 1 | 5 | 7 | 5 | 9 | 8 | " " " " | 1899 |
| 11 | 7 | 91 | 4 | 8 | 4 | 1 | 4 | 8 | 7 | 9 | 9 | Hot & sunny | 2200 |
| 18 | 7 | 91 | 5 | 6 | 7 | 9 | 1 | 8 | 3 | 7 | 7 | " " " | 2094 |
| 25 | 7 | 91 | 6 | 6 | 2 | 0 | 2 | 9 | 4 | 1 | 1 | " " " | 2353 |
| 2 | 8 | 91 | 7 | 8 | 0 | 5 | 3 | 11 | 8 | 5 | 1 | Mainly hot & sunny, some showers | 2963 |
| 8 | 8 | 91 | 9 | 0 | 1 | 3 | 0 | 12 | 0 | 7 | 7 | " " " " " " | 3019 |
| 15 | 8 | 91 | 0 | 1 | 5 | 7 | 6 | 11 | 4 | 4 | 6 | " " " " cool on Sunday | 2861 |
| 22 | 8 | 91 | 1 | 3 | 6 | 7 | 6 | 12 | 1 | 0 | 0 | Warm & dry | 3025 |
| 29 | 8 | 91 | 3 | 1 | 4 | 0 | 3 | 17 | 7 | 2 | 7 | Warm & dry except Friday BH | 4432 |
| 5 | 9 | 91 | 4 | 3 | 4 | 7 | 4 | 12 | 0 | 7 | 1 | " " " | 3018 |
| 12 | 9 | 91 | 5 | 1 | 9 | 7 | 6 | 8 | 5 | 0 | 2 | " " " | 2125 |
| 19 | 9 | 91 | 5 | 8 | 5 | 9 | 4 | 6 | 6 | 1 | 8 | Variable but mainly sunny | 1654 |
| 26 | 9 | 91 | 6 | 4 | 3 | 7 | 3 | 5 | 7 | 7 | 9 | Showery | 1445 |
| 3 | 10 | 91 | 6 | 8 | 8 | 5 | 0 | 4 | 4 | 7 | 7 | " | 1119 |
| 10 | 10 | 91 | 7 | 4 | 2 | 2 | 7 | 5 | 3 | 7 | 7 | Dry & sunny | 1344 |
| 17 | 10 | 91 | 7 | 9 | 3 | 5 | 7 | 5 | 1 | 3 | 0 | Windy, cool & showery | 1282 |
| 24 | 10 | 91 | 8 | 3 | 6 | 8 | 0 | 4 | 3 | 3 | 7 | Cloudy & cool | 1084 |
| 31 | 10 | 91 | 8 | 8 | 0 | 0 | 1 | 4 | 3 | 2 | 1 | " " " | 1080 |
| 7 | 11 | 91 | 9 | 1 | 5 | 7 | 0 | 3 | 4 | 6 | 9 | | 867 |

Table A3.15 (cont.)

| Date of Reading | | | Traffic Counter Reading | | | | | Difference from previous reading | | | | Remarks (eg. about weather, public holidays, closures, special events) | Adjusted cars: |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Month | Year | | | | | | | | | | | |
| | | | 9 | 1 | 5 | 7 | 0 | | | | | . | |
| 14 | 11 | 91 | 9 | 4 | 8 | 5 | 0 | 3 | 2 | 8 | 0 | Cloudy & cool | 820 |
| 21 | 11 | 91 | 9 | 7 | 4 | 8 | 6 | 2 | 6 | 3 | 6 | " " " | 659 |
| 28 | 11 | 91 | 0 | 0 | 3 | 3 | 0 | 2 | 8 | 4 | 4 | " but milder | 711 |
| 5 | 12 | 91 | 0 | 2 | 9 | 4 | 0 | 2 | 5 | 9 | 0 | " " " | 647 |
| 12 | 12 | 91 | 0 | 4 | 6 | 3 | 0 | 1 | 6 | 9 | 0 | Cold & frosty | 422 |
| 19 | 12 | 91 | 0 | 6 | 6 | 9 | 0 | 2 | 0 | 6 | 0 | Milder | 515 |
| 26 | 12 | 91 | 0 | 8 | 7 | 7 | 3 | 2 | 0 | 8 | 3 | Windy & mild | 521 |
| 2 | 1 | 92 | 1 | 2 | 4 | 3 | 2 | 3 | 6 | 5 | 9 | Mild | 915 |
| 9 | 1 | 92 | 1 | 5 | 2 | 6 | 8 | 2 | 8 | 2 | 6 | " | 706 |
| 16 | 1 | 92 | 1 | 7 | 3 | 1 | 7 | 2 | 0 | 4 | 9 | " & cloudy | 512 |
| 23 | 1 | 92 | 1 | 9 | 8 | 4 | 5 | 2 | 5 | 2 | 8 | Sunny spells - cold | 632 |
| 30 | 1 | 92 | 2 | 2 | 0 | 3 | 4 | 2 | 1 | 8 | 9 | Variable but mainly cloudy | 547 |
| 6 | 2 | 92 | 2 | 4 | 0 | 9 | 0 | 2 | 0 | 6 | 4 | Cold variable cloud | 516 |
| 13 | 2 | 92 | 2 | 6 | 7 | 0 | 3 | 2 | 6 | 1 | 3 | Changeable | 653 |
| 20 | 2 | 92 | 2 | 9 | 3 | 7 | 2 | 2 | 6 | 6 | 9 | " | 667 |
| 27 | 2 | 92 | 3 | 3 | 4 | 3 | 0 | 4 | 0 | 5 | 8 | Half term - variable | 1014 |
| 5 | 3 | 92 | 3 | 7 | 3 | 1 | 9 | 3 | 8 | 8 | 9 | Variable | 972 |
| 12 | 3 | 92 | 4 | 0 | 8 | 9 | 4 | 3 | 5 | 7 | 5 | " | 894 |
| 19 | 3 | 92 | 4 | 3 | 8 | 4 | 3 | 2 | 9 | 4 | 9 | " & wet | 737 |
| 26 | 3 | 92 | 4 | 7 | 0 | 7 | 2 | 3 | 2 | 2 | 9 | " " " | 807 |
| 2 | 4 | 92 | 4 | 9 | 9 | 4 | 9 | 2 | 8 | 7 | 7 | " " " | 719 |
| 9 | 4 | 92 | 5 | 3 | 9 | 4 | 1 | 3 | 9 | 9 | 2 | " " " | 998 |
| 16 | 4 | 92 | 5 | 8 | 9 | 0 | 7 | 5 | 9 | 6 | 6 | " " " | 1491 |
| 23 | 4 | 92 | 7 | 0 | 0 | 3 | 3 | 11 | 1 | 2 | 6 | Variable Easter BH | 2781 |
| 30 | 4 | 92 | 7 | 6 | 3 | 2 | 3 | 6 | 2 | 9 | 0 | " & cool | 1572 |
| 7 | 5 | 92 | 8 | 6 | 4 | 1 | 6 | 10 | 0 | 9 | 3 | May BH Mainly cold became warmer | 2523 |
| 14 | 5 | 92 | 9 | 1 | 3 | 3 | 0 | 4 | 9 | 2 | 4 | Variable - wet w/e | 1231 |
| 21 | 5 | 92 | 9 | 9 | 4 | 0 | 3 | 8 | 0 | 7 | 3 | Mainly hot & dry | 2018 |

Table A3.16: Lynford Stag traffic count 1993: electronic loop counter

| Week no. | Week commencing | Start of week reading | End of week reading | Change | Cars (party visits) | Remarks |
|---|---|---|---|---|---|---|
| 1 | 1.4.93 | 46230 | 47546 | 1316 | 658 | Dry/cool |
| 2 | 5.4.93 | 47546 | 49234 | 1688 | 844 | Overcast/drizzle BH |
| 3 | 12.4.93 | 49234 | 52106 | 2872 | 1436 | Warm/sunny BH |
| 4 | 19.4.93 | 52106 | 54304 | 2198 | 1099 | Cool/sunny |
| 5 | 26.4.93 | 54304 | 56471 | 2167 | 1083 | Cold/windy |
| 6 | 3.5.93 | 56471 | 59700 | 3229 | 1615 | Warm/sunny BH |
| 7 | 10.5.93 | 59700 | 61816 | 2116 | 1058 | Hot/dry |
| 8 | 17.5.93 | 61816 | 63735 | 1919 | 959 | Hot/dry |
| 9 | 24.5.93 | 63735 | 66514 | 2779 | 1389 | Hot/dry |
| 10 | 31.5.93 | 66514 | 70384 | 3870 | 1935 | Warm/sunny BH |
| 11 | 7.6.93 | 70384 | 73863 | 3479 | 1739 | Warm/sunny |
| 12 | 14.6.93 | 73863 | 76436 | 2573 | 1287 | Warm/overcast |
| 13 | 21.6.93 | 76436 | 79072 | 2636 | 1318 | Dull/drizzle |
| 14 | 28.6.93 | 79072 | 82460 | 3388 | 1694 | Warm/sunny |
| 15 | 5.7.93 | 82460 | 85624 | 3164 | 1582 | Cool/damp |
| 16 | 12.7.93 | 85624 | 88329 | 2705 | 1352 | Warm/damp |
| 17 | 19.7.93 | 88329 | 91193 | 2864 | 1432 | Wet/warm |
| 18 | 26.7.93 | 91193 | 94845 | 3652 | 1826 | Cool/windy |

Notes: The 'Change' column refers to the difference between the start and end of week readings. This tells us the number of cars both entering and leaving the car park. Dividing this number by 2 gives the number of cars visiting the site during the week (shown in the 'Cars' column). Total cars for the entire period shown = 24307.
BH = Bank holiday

Table A3.17: Comparison of visitor counts by pneumatic and electronic loop counters Lynford Stag (1991-93)

| Period | Counter | Cars | Electronic Loop / Pneumatic |
|---|---|---|---|
| 1.4.93-10.6.93 | Electronic loop | 13,071 | 0.7233 |
| 1.4.92-10.6.92[1] | Pneumatic | 18,071 | |
| 4.4.93-1.8.93 | Electronic loop | 23,850 | 0.7543 |
| 4.4.91-1.8.91 | Pneumatic | 31,617 | |

Note: 1. Counter removed due to failure 11.6.92
2. Ratios are 0.7233136 and 0.754341 respectively. Weighted mean = 0.7427264.

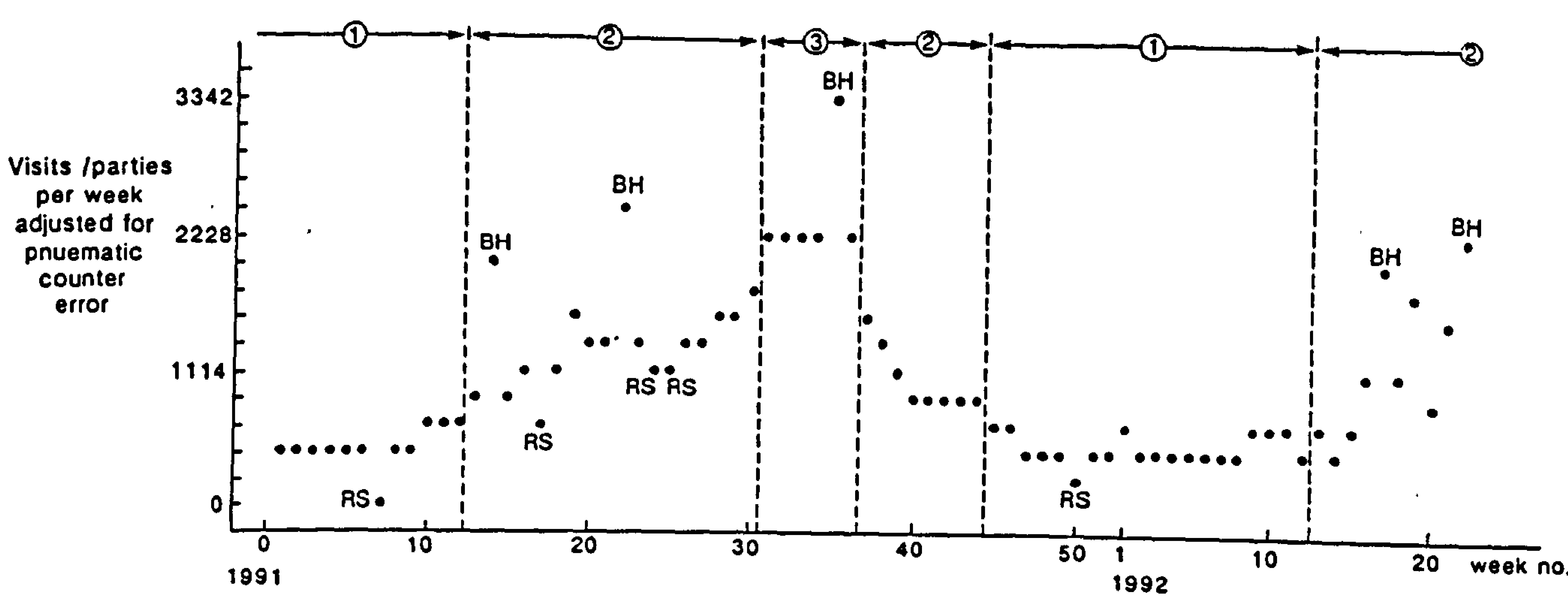
### A3.2.3.2: Modelling Annual Visit Trends

In section A3.1 we estimate an arrivals function which can predict the number of visitors which will arrive during the survey period[6]. We now need to convert this to an estimate of annual arrivals. This is achieved by examining the relationship between arrivals in our sample study period and annual arrivals. But for a derived factor to be reliable this relationship needs to be stable.

Data from the same pneumatic counter analysed in table A3.17 was held for the period w/c 13.12.90 to w/c 4.6.92. An initial analysis investigated two 12-month periods within this dataset: 3.1.91 to 1.1.92 and 6.6.91 to 4.6.92 (both consist of 364 days). Adjusting for pneumatic counter error, annual arrivals were 56316 and 56843 parties respectively, a difference of less than 1% between the two annual sums. Figure A3.2 shows the frequency of visits per week for virtually the entire operation of this single pneumatic counter. Note that the seasonal periods are defined to reflect the interaction of both seasonal and holiday period dates. These two factors are highly collinear and may not be entered separately into the model.

[6]Which we have previously adjusted for those who were not interviewed during the survey period.

Figure A3.2: Visits to Lynford Stag (parties per week): w/c 3.1.91 to w/c 4.6.92




Key: BH = Bank holiday (excluding Christmas)
RS = Raining or snowing/frosty
1 = Winter period
2 = Spring/Autumn period
3 = Summer period

Considering our two 12 month periods (3.1.91 to 1.7.92) and (6.6.91 to 4.6.92), there is clearly a considerable area of overlap. However, the non-overlapping weeks of the first period show a striking similarity to corresponding weeks in the second. In both cases relevant variables determining visits appear to be seasonal factors, bank holidays (BH) and rain or snow (RS).

In order to test the stability of the relationship between our survey period and annual visits, a simple statistical model of the latter was constructed. Using this, a hypothesis as to the stability of the sample/annual relationship could be tested. All visitor data was adjusted for pneumatic counter error prior to modelling.

As figure A3.2 indicates, there is clearly a strong seasonal pattern to arrivals[7]. This reflects a mixture of annual weather patterns heightened by the distribution of holidays. Visits are roughly constant at a low level for approximately the first 12 weeks of the year after which visit frequency grows at a fairly steady rate until a plateau is reached at about week 31. Visit frequency falls relatively sharply from week 37 to return to winter levels by about week 45. Oneway analysis of variance tests showed that the pre and post New Year winter visitation rates were insignificantly different as were the spring and autumn periods. Figure A3.3 details this analysis. Three highly distinct seasonal periods could then be defined: Winter; Spring/Autumn; and Summer. Figure A3.4 details statistical analysis of such a three level seasonality variable[8].

[7]Both monthly and weekly variables were examined with the latter, as expected, providing a better fit to the data.

[8]Initial analyses (such as those detailed in figures A3.3 and A3.4) examined the dataset for 3.1.91 to 1.1.92. The full regression model, detailed subsequently, examines data for the full period from 13.12.90 to 4.6.92.

Further investigation revealed two further important explanatory variables affecting weekly visit totals. Firstly, weeks which contained a bank holiday[9]: recorded significantly higher visit numbers than comparable weeks within the same season but without bank holidays. Secondly, weeks characterised by unusually high levels of rain for the season or which experienced snow[10] recorded significantly lower visit rates than comparable weeks in the same season without such adverse weather conditions.

Figure A3.3: Oneway analysis of variance of weekly visits (parties) on 5 seasonal periods during the year 3.1.91 to 1.1.92. Visits adjusted for pneumatic counter error.

```
Individual 95% CI's for mean visitor
       numbers in each period                    Period
     (based on pooled st. dev.)
--------+---------+---------+--------
  (--*-)                              1. Post New Year
             (-*-)                    2. Spring
                         (---*---)    3. Summer
        (---*--)                      4. Autumn
  (--*--)                             5. Pre New Year
-------+---------+---------+---------
     700       1400       2100
  Mean visitor numbers per period
```

Analysis of variance on weekly visits (pooled st. dev = 322.5)

| Source | df | SS | MS | F | p |
|---|---|---|---|---|---|
| Period | 4 | 19082608 | 4770652 | 45.88 | 0.000 |
| Error | 47 | 4887401 | 103987 | | |
| Total | 51 | 23970008 | | | |

| Period | n | mean | st.dev |
|---|---|---|---|
| 1. Post new year | 12 | 464.1 | 175.4 |
| 2. Spring | 18 | 1349.7 | 418.9 |
| 3. Summer | 6 | 2391.3 | 443.5 |
| 4. Autumn | 8 | 1033.6 | 264.8 |
| 5. Pre new year | 8 | 479.2 | 114.5 |

[9] Tests were run to examine the effect of the double bank holidays of the Easter period. These proved to be insignificantly different from single day bank holidays. We conclude that a bank holiday significantly raises the probability that a household will visit but a double bank holiday does not lead to two visits being made.

[10] Data from Forestry Commission records. Various permutations of weather were investigated with rain/snow being the only factor not collinear with the seasonality variable ie. rain/snow depresses visitor rate irrespective of the season.

Figure A3.4: Oneway analysis of variance of weekly visits (parties) on 3 seasonal periods for the year 3.1.91 to 1.1.92. Visits adjusted for pneumatic counter error.

```
Individual 95% CI's for mean visitor
     numbers in each period                    Period
    (based on pooled st. dev.)
--------+---------+---------+---------+
  (-*-)                                  1. Winter
            (-*-)                      2. Spring/
                                                    Autumn
                             (---*---)   3. Summer
--------+---------+---------+---------+
       700      1400      2100      2800
    Mean visitor numbers per period
```

Analysis of variance on weekly visits (pooled st. dev = 333.3)

| SOURCE | DF | SS | MS | F | p |
|---|---|---|---|---|---|
| Period(3) | 2 | 18527962 | 9263981 | 83.41 | 0.000 |
| ERROR | 49 | 5442047 | 111062 | | |
| TOTAL | 51 | 23970008 | | | |

| LEVEL | N | MEAN | STDEV |
|---|---|---|---|
| 1.Winter | 20 | 470.2 | 150.7 |
| 2.Spring/Autumn | 26 | 1252.5 | 401.3 |
| 3.Summer | 6 | 2391.3 | 443.5 |

With our three explanatory variables defined, regression models of weekly visitor rate could be estimated. A linear specification provided a best fit to the data, the model being reported as table A3.18[11].

Table A3.18: Generalised linear model of weekly visitation pattern at Lynford Stag, Thetford Forest.
Dependent variable = visits per week (adjusted for pneumatic counter error)
Data period: 13.12.90 to 4.6.92

| Term | Coeff | Stdev | t-value | p |
|---|---|---|---|---|
| Constant | 1623.58 | 56.01 | 28.99 | 0.000 |
| Season: | | | | |
| Winter | -803.40 | 40.48 | -19.85 | 0.000 |
| Spring/Autumn | -120.85 | 40.84 | -2.96 | 0.004 |
| Rain/Snow | -131.93 | 30.92 | -4.27 | 0.000 |
| Bank Holiday | 432.65 | 44.97 | 9.62 | 0.000 |

[11]The model is fitted using a generalised linear modelling (GLM) package where the upper level of each categorical variable is taken as the reference point from which category coefficients for that variable are calculated. Thus the upper level of the season variable (3; summer) is not explicitly shown as it is the default when season is neither winter or spring/autumn. Standard output from the GLM package would refer to the absence of rain/snow or of bank holidays, however as this is counter to the conventional approach in specifying dummy variables, the variables in table A3.18 have been respecified to give standard outputs ie visit rate is lowered by rain/snow and raised by bank holidays.

Analysis of variance

| Source | df | Seq SS | Adj SS | Adj MS | F | p |
|---|---|---|---|---|---|---|
| Season | 2 | 23452372 | 17710412 | 8855206 | 197.09 | 0.000 |
| RainSnow | 1 | 1980331 | 817955 | 817955 | 18.21 | 0.000 |
| BankHol | 1 | 4159146 | 4159146 | 4159146 | 92.57 | 0.000 |
| Error | 73 | 3279836 | 3279836 | 44929 | | |
| Total | 77 | 32871684 | | | | |

where:

VISITS = Dependent variable: Number of parties (cars) visiting Lynford Stag per week
SEASON = 1 for a winter week; 2 for a spring/autumn week; 3 for a summer week
RAINSNOW = 1 if significant rain or snow during the week; 0 otherwise
BANKHOL = 1 if week contains a bank holiday; 0 otherwise

The model given in table A3.18 describes the data well ($R^2$ = 90.0%) with expected relationships on all explanatory variables, the latter all being significant at the 1% level.

The model was then used to examine those periods which are relevant to the relationship between our survey observations and annual visits. Our survey spanned the five week period from 26.3.93 to 25.4.93 and so we wish to see how robust the relationship between such a period and annual arrivals might be. The model given in table A3.18 uses data for similar periods both in 1991 and 1992 and period/annual relationships can be calculated for both. However, the model gives us reason to believe that this relationship will not be completely stable for these two years. Whilst the 5 week period 28.3.91 to 1.5.91 contains just one rainy week, the 5 week period 26.3.92 to 29.4.92 contains three (bank holidays being constant between the periods). The model therefore predicts that the latter period will have less visitors than the former but that the annual totals for 1991 and 1992 are likely to be similar(from our previous observations and because annual weather patterns are similar). Examining actual arrivals for these periods we find that the predictions of our model are borne out. Table A3.19 details visits for the survey periods in previous years (1991, 1992), along with respective annual totals and resultant ratios.

Table A3.19: Survey period/annual arrivals conversion factors

| Year | Party visits during 'survey period' | Annual visits | Ratio |
|---|---|---|---|
| 1991 | 5543 | 56316 | 10.1598 |
| 1992 | 5048 | 56843 | 11.2605 |

Although the two periods appear dissimilar a oneway analysis of variance rejected such a hypothesis (p = 0.796). In effect the relationship between visits in the sample period and annual visits varies logically with the explanatory variables in table A3.18 but does not appear to be vastly unstable. Given that the 1991 period appears to be one of relatively good weather, and that for 1992 seems relatively poor, a reasonable assumption would be to adopt a midway point between the two resulting values, this being 10.7102. Applying such a factor to our survey sample (after allowing for those not surveyed on survey days and for those days not sampled during the survey period) gives a predicted arrival total for the 1993 survey period of 5306 party visits, an estimate which accords well with actual visits in 1993 and lies midway between actual visits in 1991 and 1992 further justifying our choice of a mean period/annual conversion ratio.

### A3.2.3.3: Summary: relating survey period to annual visits

A number of conversion factors have now been calculated such that we can now relate our observed sample of 351 party visits to an estimated annual visit total as follows:

i. Allowing for those who were not interviewed on survey days:

= 351 * 6.9105

= 2426 parties

ii. Allowing for days not surveyed during the survey period:

= 351 * 6.9105 * 2.1875

= 351 * 15.1167

= 5306 parties

iii. Relating the survey period to annual totals (after first allowing for pneumatic counter error in the latter):

= 351 * 6.9105 * 2.1875 * 10.7102

= 351 * 161.9031

= 56828 parties

Our estimated total party visits based upon our survey observations accords well with both the 1991 and 1992 totals detailed in table A3.19 being within 1% of the former and almost identical to the latter.

The arrivals function detailed in chapter 5 operates in terms of parties for which the above conversion factors are appropriate. However, we could further convert this to estimate the number of person visits per annum. Table A3.20 provides descriptive statistics regarding party and household size and composition gathered from our survey at Lynford Stag.

Table A3.20: Party and household size and composition: Thetford 2 survey

| Variable | n[1] | mean | median | tr. mean[2] | st. dev | s.e. mean | min | max | Q1 | Q3 |
|---|---|---|---|---|---|---|---|---|---|---|
| Party16+ | 350 | 2.374 | 2 | 2.067 | 2.174 | 0.116 | 0 | 25 | 2 | 2 |
| Party<16 | 350 | 1.480 | 1 | 1.229 | 2.230 | 0.119 | 0 | 28 | 0 | 2 |
| House16+ | 351 | 2.234 | 2 | 2.152 | 0.924 | 1.049 | 1 | 11 | 2 | 2 |
| House<16 | 351 | 1.137 | 1 | 1.044 | 1.204 | 0.064 | 0 | 6 | 0 | 2 |

Notes: 1. 1 missing observation with regard to party age
2. 5% trimmed mean

Table A3.20 shows that the average party consisted of 2.37 adults and 1.48 children. These means are somewhat inflated by a very few large parties and it may therefore be more valid to consider the median party which consists of 2 adults and 1 child[12]. Using such an estimate implies that nearly 170,000 person visits are made to Lynford Stag every year[13].

## A3.3: TESTING THE VALIDITY OF APPLYING THE ARRIVALS FUNCTION TO SITES IN WALES

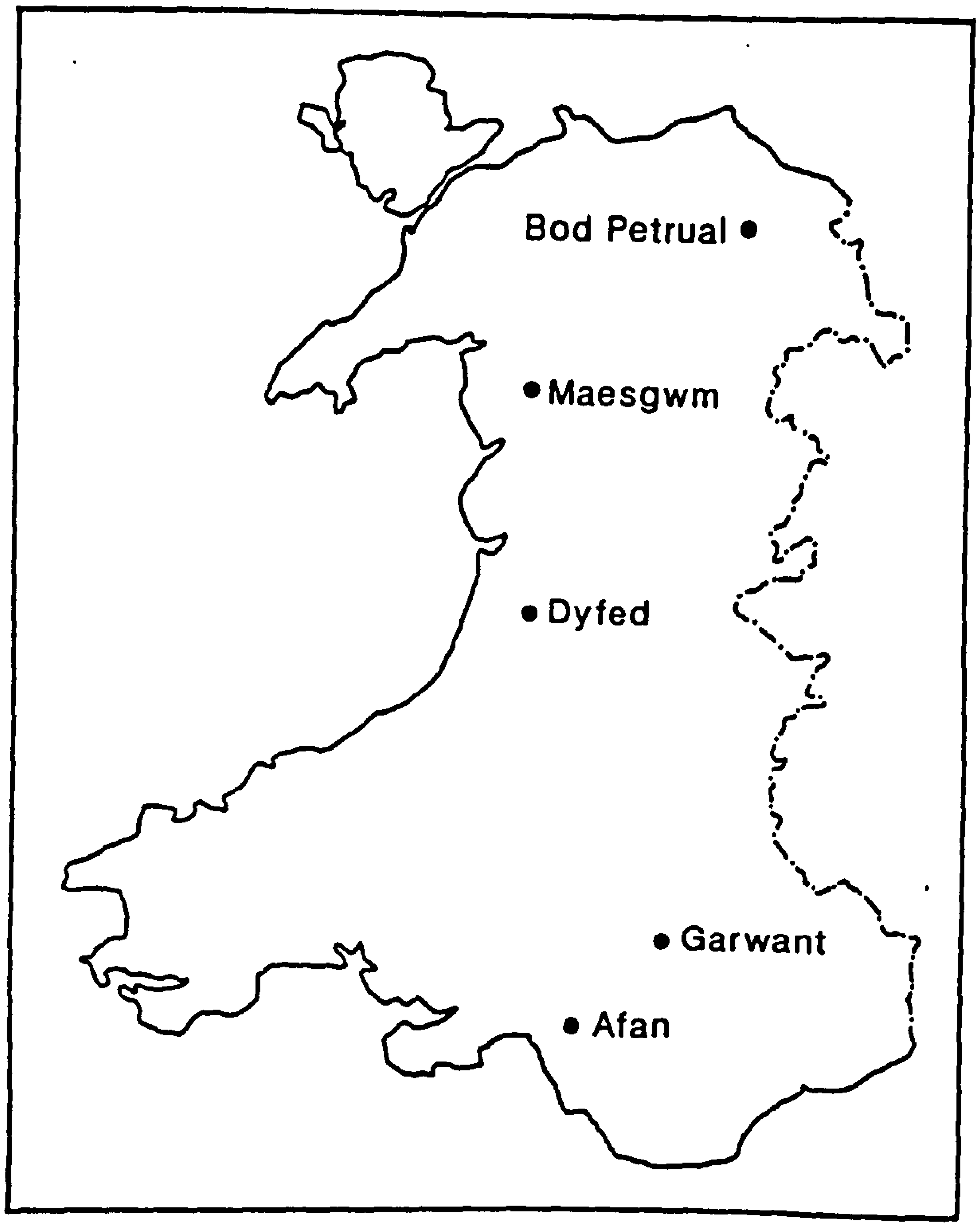
In order to test the applicability of the arrivals function to sites in Wales, it was decided to compare predicted with actual visit frequencies for a sample of sites. Unfortunately high quality visitor data does not exist for Welsh woodland sites. Extensive enquiries to the Welsh Tourist Board (NTB), the Countryside Council for Wales (CCW), the Woodland Trust and the Countryside Commission failed to locate any firm statistical information regarding visits to specific woodland sites. The only reasonable data was provided by the Forestry Commission[14]. This consisted of counts of visitors taken at five visitor centres (VC) at various locations across Wales as illustrated in figure A3.3.

[12]Interestingly this coincides with the Forestry Commission's own working estimate of party size being 3 persons (Anna Chylak, Forestry Commission, Thetford Forest, pers comm, August 1993).

[13]Precis estimate is 169,739 person visits, the majority of which are repeat visits. On average each visitor visits 14.65 times per year, implying that some 11,586 individual people visit Lynford Stag p.a.

[14]Data provided by Simon Gillam, Head of Statistics Branch, Forestry Commission, Edinburgh.

Figure A3.3: Location of five site in Wales used for actual versus predicted test of arrivals function.




A major problem in comparing our prediction of arrivals with those actually counted in VC's is that not all visitors to a site will enter the VC either because they choose not to or because they arrive out of opening hours. If we are to relate our prediction of arrivals with some measure of actual arrivals we clearly require an estimate of the proportion of site visitors who enter VC's. Unfortunately the Forestry Commission only have one site for which they have reliable counts both of site visitors and VC admissions, that being at Grizedale, Cumbria. Here during 1991 some 243,000[15] visitors arrived at the site of which 75,000[16] entered the VC i.e. approximately 30.8%. Using this factor the Welsh VC admissions data can be used to provide an estimate of the total number of visitors to each relevant site. Table A3.21 gives details of the location of our five sample sites, visitor numbers recorded at VC's and corresponding estimates of actual annual visit.

[15]Derived from a counter at the entrance to the car park and information that average car occupancy was roughly 3 people.
[16]Data from an electronic eye recorder.

Table A3.21: Five Welsh woodland sites used in actual versus predicted validity test of arrival function.

| Site No. (1) | Site Name (2) | Forest District (3) | Map OS Ref (4) | VC admissions (people pa)[1] (5) | 'actual' site visitors[2] (pa) (6) | Predicted visits pa[3] (7) | Comments (Bob Farmer, FC Aberystwyth, 25.8.93) |
|---|---|---|---|---|---|---|---|
| 1 | Maesgwm VC | Dolgellau | SH 715278 | 37000 | 120130 | 86606 | Major FC sale point for Christmas trees (sold at VC) |
| 2 | Dyfed VC, Bwlch Nant Yr Arian | Ceredigion | SN 718813 | 10000 | 32468 | 89125 | VC closed most of year |
| 3 | Garwant VC | Morgannwg | SO 004132 | 60000 | 194805 | 202588 | |
| 4 | Afan Forest Park & Countryside Centre | SE Wales | SS 820950 | 80000 | 259740 | 159026 | Site has several special attractions not normally found at FC sites |
| 5 | Bod Petrual VC, Moel Famau | Clwyd | SJ 171611 | 45000 | 146104 | 251128 | Very erratic VC opening hours. Generally VC found to be closed even during scheduled hours |

VC = Visitor Centre
1. From VC counts
2. Assumes that 30.8% of site visitors enter the VC (ie. VC count $*(^1/_{0.308})$ = 'actual' site visitors)
3. Prediction obtained by applying our arrivals function to a time zone population map calculated for each site

Columns (1) to (4) in table A3.21 give identifier and locational information for the five sites used in our actual versus predicted test of the arrivals function. Column (5) details VC visitor counts while column (6) gives corresponding estimates of annual visits based upon the Grisedale adjustment factor. An immediate point to note therefore is that this 'actual' arrivals data is a best estimate rather than an observation. The opinion of relevant Forestry Commission and Forestry Enterprise personnel was sought regarding the validity of such a procedure.[17] It was felt that in general the proportion of visitors entering VC's was likely to be similar between the Grizedale and Welsh sites. However, certain site specific factors were highlighted as liable to disturb the relationship between VC counts and actual visits to the site. VC's at sites 2 (Dyfed) and 5 (Bod Petrual) were recognised as being closed for significantly longer periods than Grizedale or the other Welsh sites. Furthermore, whilst not necessarily disturbing the VC/total arrivals relationship, it was pointed out that site 4 (Afan) contained many attractions not normally found at a forest site and that this was liable to increase VC and actual arrivals above the level which would be expected (and predicted by our arrivals function) for a conventional forest.[18] Similarly Site 1 was pointed out to be a major FC Christmas tree sale point which may, to a lesser degree, increase arrivals.

Time zones and relevant population distributions were calculated for the OS grid references of each of the five sites. Applying our arrivals function to these time zone maps allowed us to predict the number of visitors to each site as given in column (7) of table A3.21.

Comparing our 'actual' arrivals figure with that predicted makes apparent the importance of the individual site characteristics emphasised by FC personnel. Whereas there is a good correspondence for site 3 where no special features apply (ie. a 'standard' woodland site), there is somewhat of an underprediction at site 1, due in part to its use as an FC Christmas tree sales point, and a considerable underprediction at site 4 due to the extended range of attractions already discussed. Conversely, sites where VC's were closed for unusually long periods (sites 2 and 5) suffered from an apparent overprediction of visitors. In all these cases the direction of apparent error is as expected given the features of that site. Our arrivals function only relates to standard woodland sites and will therefore underpredict for sites with additional attractions. The apparent overprediction at sites 2 and 5 is, indeed, likely not to show an error in our arrivals function but to reflect the distorted relationship between VC admissions and total visits at those sites. In short the observed 'errors' may not be because of weakness in our arrivals function but are to be expected given the nature of the sites concerned. What this does show is that our arrivals function is valid for predicting visits to an average woodland site in Wales but that it is not valid for predicting visits to any particular site given the impact which unique site characteristics are liable to have. This is true for any statistical relationship.

The strength of the relation between our 'actual' and predicted measures was investigated using a simple regression between the two. Ignoring the special factors emphasised by FC officials this relationship was given by equation (1).

---

[17]Simon Gillam, Head of Statistics Branch, Forestry Commission Headquarters, Edinburgh; Bob Farmer, Head of Forest Management, Forestry Enterprise (Wales), Aberystwyth.

[18]Site 4, the Afan Argoed Country Park, is not only well advertised in FC, CCW, West Glamorgan County Council and Neath Borough Council literature (four separate leaflets are distributed by these organisations) but also contains a very wide variety of attributes not normally available at most forest sites. These include a museum of mining; cafeterias; organised activities (orienteering, classroom lectures, Land Rover tours, etc); good wheelchair facilities; camping and caravan facilities, etc. These additional assets are thought to be a major factor explaining our underestimate of visitors to this site, which is based upon the standard woodland features of the site alone.

$$\text{ACTUAL} = \underset{\substack{(0.204)\\ [4.42]}}{0.903}\ \text{PREDICTED} \qquad (1)$$

$R^2$ = 82.99% (st. dev) [t-value]

where:

ACTUAL = VC arrivals *(1/0.308)
PREDICTED = arrivals predicted by applying our arrivals function to a time zone population map for each site.

The simple model given in equation (1) fits the data well. Encouragingly the coefficient upon PREDICTED is statistically insignificantly different from 1, such that we have no reason to reject a hypothesis that ACTUAL = PREDICTED. The PREDICTED variable is highly significant, easily satisfying a 5% confidence test ($\rho = 0.012$).

We can now incorporate the site specific information given by FC personnel by defining two dummy variables as follows;

CLOSED = 1 for sites which are closed for unusually extended periods (sites 2 and 5); 0 otherwise
SPECIAL = 1 for sites which have exceptional additional attractions (taken as site 4 only); 0 otherwise

The resulting model is given as equation (2):

$$\text{ACTUAL} = \underset{\substack{(0.135)\\ [7.10]}}{0.958}\ \text{PREDICTED} - \underset{\substack{(32988)\\ [-2.23]}}{73692}\ \text{CLOSED} + \underset{\substack{(39787)\\ [2.70]}}{107397}\ \text{SPECIAL} \qquad (2)$$

$R^2$ = 98.42% (st. dev) [t-values]

The model given in equation (2) fits exceedingly well although this is hardly surprising given the small number of data points and relatively high number of dummy variables. More important is that, after controlling for site-specific factors, the coefficient on PREDICTED is now indistinguishable from a value of 1 and highly significant.

In summary, the lack of available observations upon actual arrivals at Welsh sites makes our predicted versus actual test less than ideal. However, given the paucity of data, the available information does encourage us to believe that our arrivals function does provide reasonable estimates of potential visitors to sites in Wales and can be adopted for further use.

## A3.4: VALUING WOODLAND RECREATION: SUMMARY

In preparing our recreation demand valuation maps we wanted to examine defensible estimates of per party per visit values obtained from both CVM and TCM studies. Our Thetford 1 and 2 ITCM experiments had directly estimated such values but this was not the case with other studies. This left us with two routes for obtaining such values:

1. grossing up from per individual per visit values as per table A3.22;
2. converting from per household per annum values as per table A3.23.

Table A3.22: Calculating per party from per person values (1990 prices)

| Study | Method | £/person /visit[1] | £/party/visit[2] | | |
|---|---|---|---|---|---|
| | | | mean | upper 95% CI | lower 95% CI |
| Benson and Willis (1992): adjusted | ZTCM | 1.48 | 4.52 | 4.85 | 4.22 |
| Cross-study (meta analysis) | CVM | 0.60 | 1.82 | 1.95 | 1.69 |
| Thetford 1 (low range payment card) | CVM | 1.21 (0.99-1.43) | 3.69 | 3.96 | 3.44 |
| Thetford 1 (high range payment card) | CVM | 1.55 (1.19-1.92) | 4.73 | 5.07 | 4.41 |
| Thetford 1 (OLS) | ITCM | 1.07 | 3.37 | 3.61 | 3.14 |
| Wantage (WTP/visit study) | CVM | 0.82 | 2.50 | 2.68 | 2.33 |
| Thetford 2 (WTP/visit, no preceding questions) | CVM | 0.20 (0.11-0.29) | 0.61 | 0.65 | 0.57 |
| Thetford 2 (WTP/visit, after mental a/c question only) | CVM | 0.46 (0.30-0.62) | 1.40 | 1.51 | 1.31 |
| Thetford 2 (WTP/visit, after WTP pa. question only) | CVM | 0.45 (0.35-0.55) | 1.37 | 1.47 | 1.28 |
| Thetford 2 (WTP/visit after mental a/c and WTP pa questions) | CVM | 0.78 (0.53-1.03) | 2.38 | 2.55 | 2.55 |
| Thetford 2 (ML model: GIS based time and journey costs) | ITCM | 1.20 | 3.59 | 3.85 | 3.35 |
| Thetford 2 (ML model: based on perceived duration) | ITCM | 1.47 | 4.42 | 4.74 | 4.12 |

Notes: 1. Figures are best estimate means. Figures in brackets represent 95% CI's (where calculated).

2. Per party per visit measures were not explicitly reported in the following studies: Benson and Willis (1992); cross study CVM meta-analysis; Thetford 1, Wantage and Thetford 2 CVM studies. In the above table per party per visit estimates have been calculated from reported per person per visit measures using party composition statistics (adults and children being treated equally in this analysis). Such statistics were taken from the Thetford 2 survey as detailed in table A3.22A as follows.

Table A3.22A: Descriptive statistics for party size: Thetford 2 survey

| Measure | Party size (no. of persons) |
|---|---|
| mean<br>upper 95% CI<br>lower 95% CI | 3.0523<br>3.2726<br>2.8468 |

Note: All measures adjusted for skew by taking logarithms, calculating mean and t-intervals and then finding exponentials.

3. Farmers WTA compensation for committing land into recreational forestry = £ 300/ha pa. (£ 121/acre pa.)

## Table A3.23: Calculating per party from per annum values (1990 prices)

| Study | Method | £/household pa.[1] | £/party/visit[2] | | |
|---|---|---|---|---|---|
| | | | mean | upper 95% CI | lower 95% CI |
| Thetford 1 (users WTP pa) | CVM | 5.14 (1.48-8.81) | 0.95 | 1.10 | 0.83 |
| Wantage (WTP pa study) | CVM | 9.94[3] | 1.84 | 2.13 | 1.60 |
| Thetford 2 (WTP pa, no preceding questions) | CVM | 12.55 (8.11-16.99) | 2.33 | 2.69 | 2.01 |
| Thetford 2 (WTP pa, after mental a/c question only) | CVM | 32.60 (21.76-43.43) | 6.05 | 7.00 | 5.23 |
| Thetford 2 (WTP pa, after WTP/visit question only) | CVM | 7.62 (2.87-12.37) | 1.41 | 1.64 | 1.22 |
| Thetford 2 (WTP pa, after mental a/c and WTP/visit questions) | CVM | 16.37 (11.19-21.55) | 3.04 | 3.51 | 2.63 |

Notes: 1. Figures are best estimate means. Figures in brackets represent 95% CI's (where calculated).

2. Per party per visit measures were not explicitly reported in the following studies: Benson and Willis (1992); cross study CVM meta-analysis; Thetford 1, Wantage and Thetford 2 CVM studies. In the above table per party per visit estimates have been calculated from per annum visit rates. Such statistics were taken from the Thetford 2 survey as detailed in table A3.23A as follows.

Table A3.23A: Descriptive statistics for annual visit rate: Thetford 2 survey

| Measure | Annual visit rate |
|---|---|
| mean<br>upper 95% CI<br>lower 95% CI | 5.3876<br>6.2283<br>4.6604 |

Note: All measures adjusted for skew by taking logarithms, calculating mean and t-intervals and the finding exponentials.

3. Farmers WTA compensation for committing land into recreational forestry = £ 300/ha pa. (£ 121/acre pa.)

In chapter 5 we concentrate upon per party per visit values derived from per person rather than per annum estimates. This is primarily because of reservations regarding the relationship between annual and per visit CVM WTP responses. In an early study of WTP for preserving the Norfolk Broads (Bateman et. al., 1992) we asked respondents to state both per annum and once-and-for-all capitalised WTP sums. Comparison of the two showed the latter to be not much more than twice the former. This implies either a very high discount rate, an inability to fully understand the question or (as we suspect) elements of both.[19] Such potential problems were compounded by evidence in our work on discounting that social discounting may be hyperbolic rather than exponential in nature (Cropper et al, 1992; Henderson and Bateman, 1993, 1995).[20] These factors conspired to make us wary regarding the relationship between annual and per visit values which we feel may be far more complex and uncertain than the simple relation implied in table A3.23. Accordingly we have concentrated upon the less controversial analysis given in table A3.22 although we note with some interest that the range of per party per visit values given in both tables is similar.

[19]An additional problem here is that, as this study dealt with major impacts to a very important and unique resource which was highly valued be respondents (all users), income constraints would soon bind upon respondents in moving from annual to once and for all payments.

[20]While such an assertion may seem radical to economists, hyperbolic discounting is the accepted and frequently observed norm in behaviouralist research (see Rachlin, 1991; and discussion in chapter 6)

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Henderson, N. and Bateman, I.J. (1995), Empirical and public choice evidence for hyperbolic social discount rates and the implications for intergenerational discounting, *Environmental and Resource Economics*, 5:413-324.

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# Appendix 4: Details Of Timber Valuation Analyses

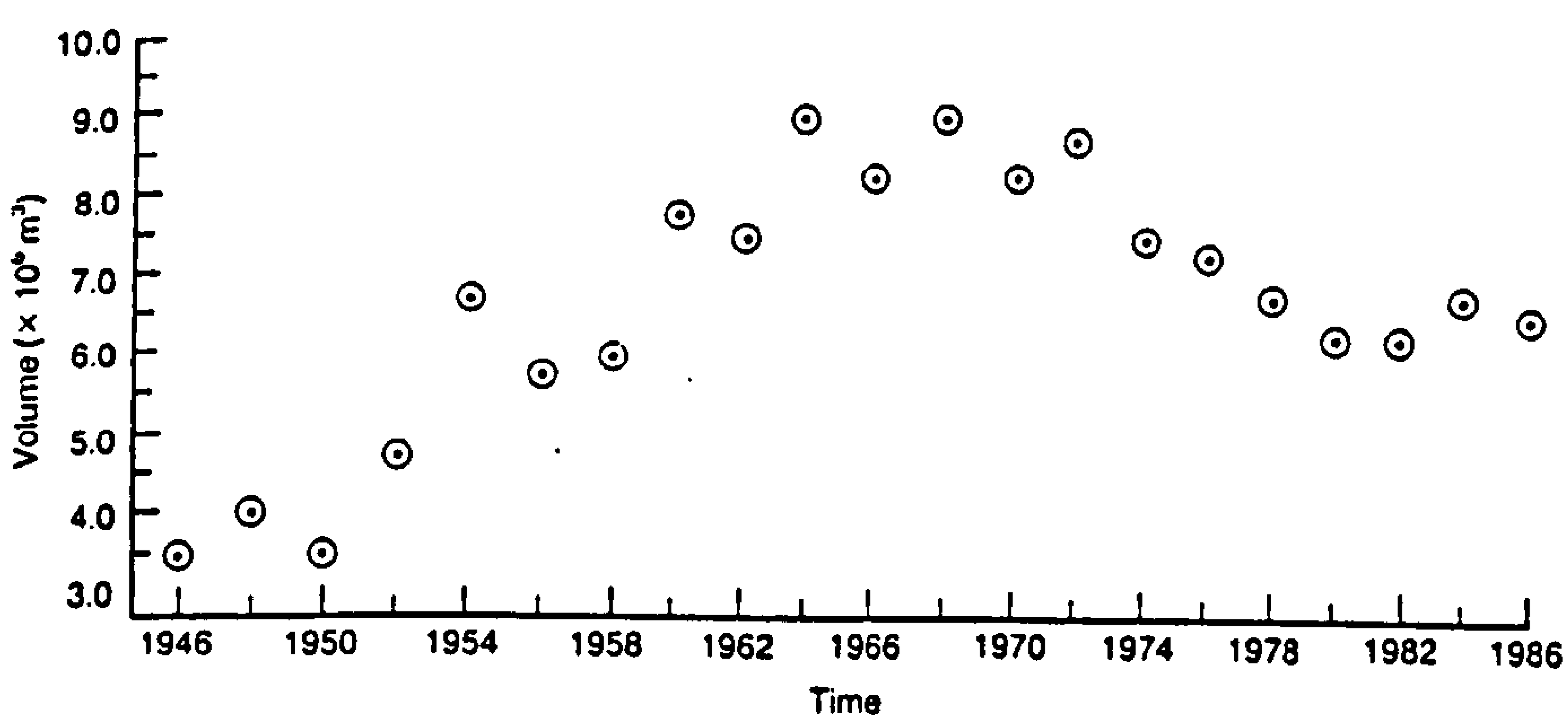
## APPENDIX 4.1: AN ECONOMETRIC MODEL OF THE UK SOFTWOOD MARKET: DETAILED ANALYSIS

### A4.1.1: INTRODUCTION

For UK farmers the introduction in 1987 of the Farm Woodlands Scheme and the subsequent Woodlands Grant Scheme was heralded as a new phase in agricultural diversification. However, for the UK timber market these grants and subsidies represented simply a new facet in a long history of positive supply-side intervention by the government to promote the cause of home-produced timber.

Although the theoretical arguments for import substitution are weak, the UK's high consumption of timber and timber-related produce, at £6.3bn in 1991 (FICGB, 1992) the fourth highest value import item (see figure A4.1), is based upon a domestic timber resource proportionately lower than almost all of its European partners. At the same time the physical and biological conditions of the UK are ideal for the production of high demand, lower grade commercial softwood (UK requirements have for nearly two decades been approximately 80% for softwoods: Leigh & Randall, 1981; FICGB, 1992) with gestation periods almost half those of Scandinavian producers (Kula, 1986).

Figure A4.1: Imports of sawn softwoods: 1946-86 (million $m^3$)[1]




Note: 1. Later statistics do not separate out sawn from round wood (FICGB, 1992; FC, 1994)
Source: adapted from Forest Industry Commission of Great Britain (1987)

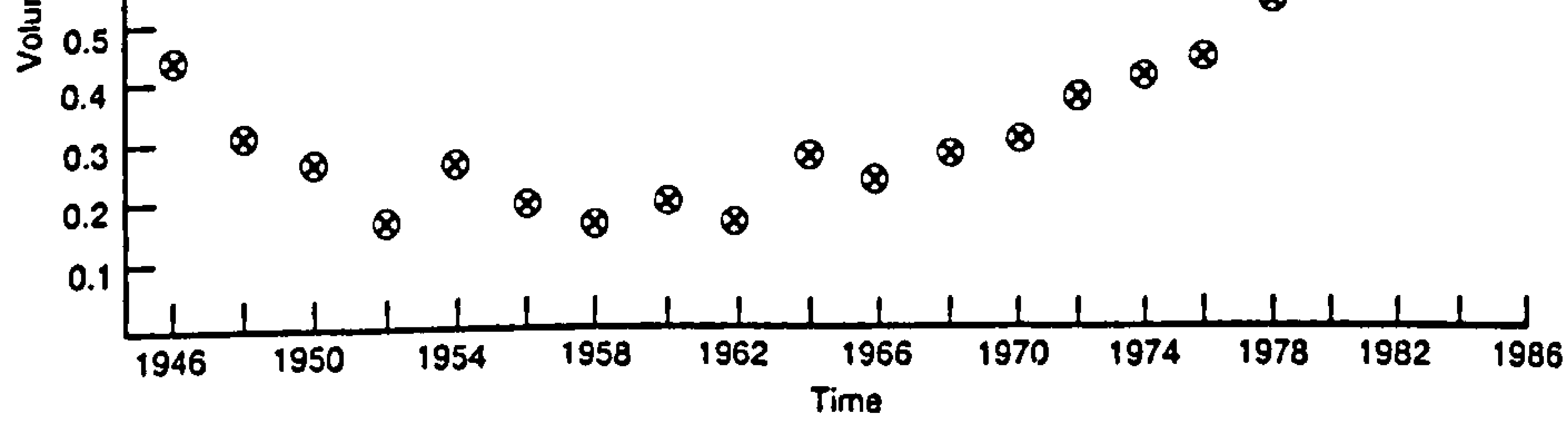
We can therefore justify consideration of the UK timber market as the study of a large, economically important, well-developed market in which the UK may exhibit some technical production advantages over competitors. Furthermore, because of the importance of output lags to production decisions, modelling is vital if we are to provide the best forecast for investment returns.

This is particularly important in the face of the considerable and ongoing debate concerning future real prices in the industry (Johnston et al., 1967; Doran, 1979; Hart, 1987; Whiteman, 1995).

Government intervention in the supply-side production of domestic timber has a long history dating from the creation of the Forestry Commission in 1919. While initial objectives concerned strategic demands, subsequent goals have included timber production, rural employment, environmental and recreational aims and, more recently, concerns over agricultural overproduction. Furthermore, accelerating awareness of individuals' tax relief possibilities (arising from the rise of specialized timber-oriented investment consultancies) has, from insignificant post-war beginnings, led to a consistently rapid growth in the private production of UK timber (with the necessary output lag), such that by 1994 private woodlands in Great Britain amounted to some 1,506,000ha (of which 1,344,000ha was classed as productive) compared to a GB Forestry Commission estate of 871,000ha (of which 827,000ha was classed as productive) (Forestry Commission, 1994). That we can attribute the growth of the private forestry sector to the introduction of tax-relief and grant incentives has been shown both by direct studies of this relationship (Phillip, 1976; Kula & McKillop, 1988) and by analysis of the poor financial returns to forestry, compared with traditional agricultural activities (HM Treasury, 1972).

Analysing softwood production, the cumulative effect of these planting decisions has been a lagged increase in domestic output of sawn softwood (see figure A4.2) from 440,000m$^3$ in 1946 to 1,235,000m$^3$ in 1985 (Timber Trade Federation, 1973, 1987) and 2,600,000m$^3$ in 1991 (FICGB, 1992)[1]. Such a relatively rapid rate of output growth represents a marked increase in self-sufficiency from an initial 11% of total (home and imported) production figure to 16%[2], achieved during a period when market size has virtually doubled from 3,890,000m$^3$ in 1946 to 7,767,000m$^3$ annually in 1985 (Timber Trade Federation, 1973, 1987).

Figure A4.2: UK domestic production of sawn softwood (million m$^3$)




Source: Timber Trade Federation (1987)

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[1] Forecast to peak at 11,500,000m$^3$ in 2026 after which domestic production is set to decline due to the present cutback in FC planting (FICGB, 1992).

[2] Because of changes in reporting procedures, present sawn softwood self-sufficiency is difficult to calculate. However, self-sufficiency for the entire wood product market including recycled fibres (1991 total consumption = 53,123,200m$^3$ wood raw material equivalent) was about 28% in 1991 (FICGB, 1991).

## A4.12: MODELLING THE UK TIMBER MARKET

### A4.2.1: Some definitions

In our attempt to model the timber market in the UK we adopt the following notation and definitions:

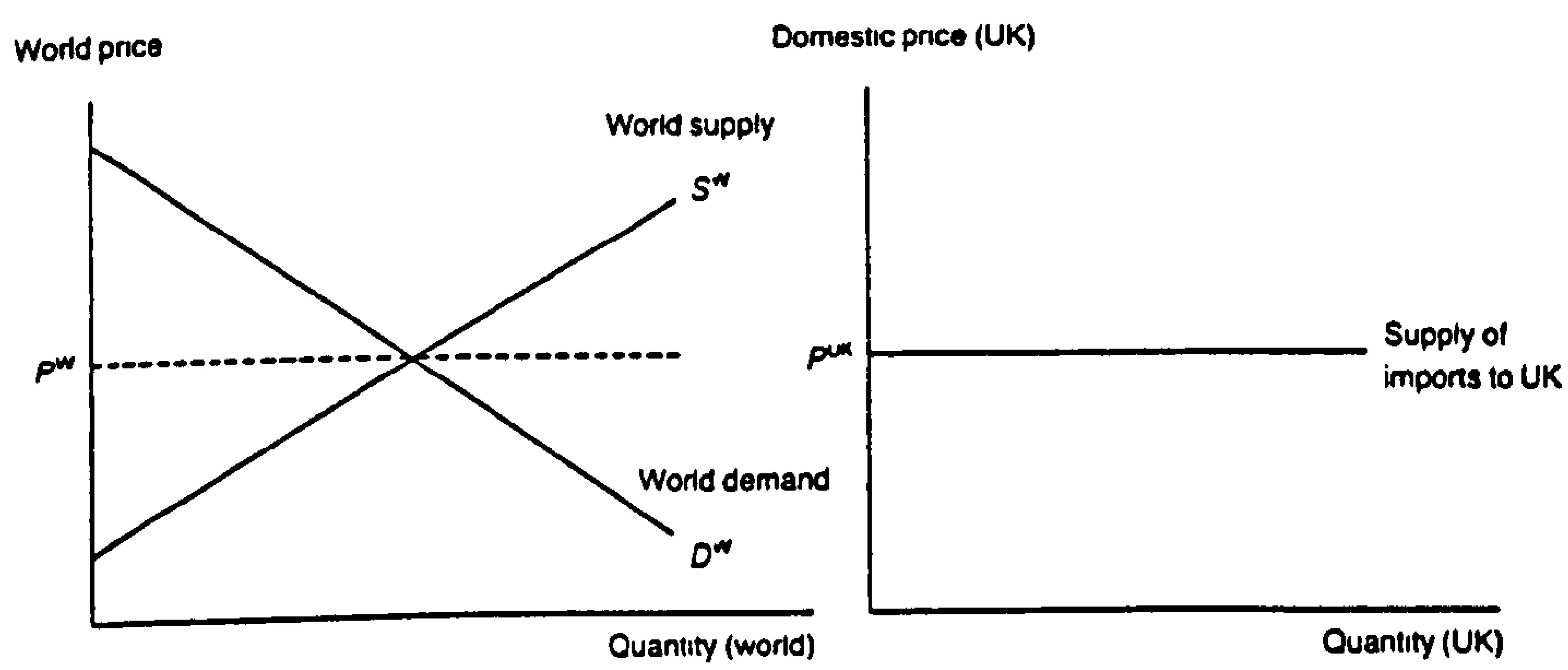
(i) By timber we mean sawn softwood. Home production ($H_t$) plus imports ($I_t$) plus net stock flows ($\Delta S_t$) defines our supply of timber variable ($Q_t$) which, on the assumption of market clearing in each period, equals the market demand (figures from Timber Trade Federation, 1987).

(ii) We define the appropriate price variable as the deflated real price reflected in the real import price ($P_t = P_t^W = P_t^{UK}$). This would appear appropriate. The UK may be viewed as a price-taker, since imports account for 84-89% of total sawn softwood consumption during the data period (Leigh & Randell, 1981). Thus, the supply of imports is perfectly elastic at the world price (see figure A4.3). Following this the appropriate price series (see figure A4.4) is taken as the Imported Sawn Softwood Real Price Index (Forestry Commission, 1982).

(iii) Income ($Y_t$) is real GNP at market prices in the UK (Central Statistical Office, 1989).

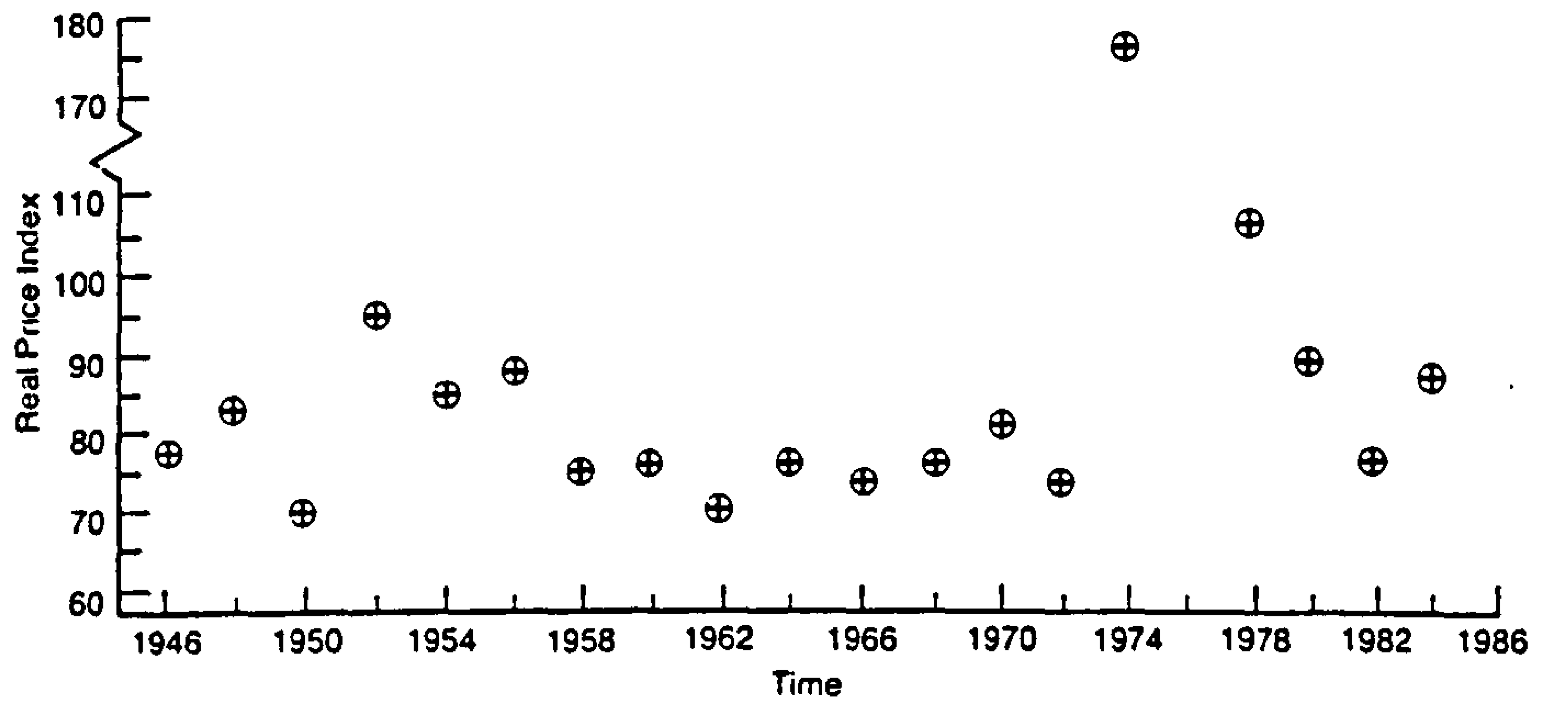
(iv) A time trend ($t$) to proxy output response to the uptake of grants and tax incentives discussed previously. We select our data period of 1958-85 inclusive to reflect this lagged output response. Pre-war plantation data are sparse and incomplete, but those available (Forestry Commission, 1923, 1933) support the contention that afforestation rose throughout the decades following the introduction of tax incentives. This increased plantation shows itself in domestic sawn softwood production in the selected data period (figure A4.2).

Figure A4.3: UK domestic softwood price determination




Source: Bateman and Mellor (1990)

Figure A4.4: Imported sawn softwood real price index 1946-1986 (1975=100)




Note: A longer time series is reported in chapter 6

Source: Forestry Commission (1982, 1988)

### A4.1.2.2: The model

Traditional econometric model-building is via either single equation models where variables can be categorized as either dependent or explanatory according to the underlying economic theory, or simultaneous equation models where variables are classed as endogenous or exogenous. Simple models of market behaviour incorporating demand and supply schedules are typically simultaneous in nature (see Kmenta, 1986, for example), since both price and quantity are determined together and require equations to be identified prior to their consistent estimation via techniques such as two-stage least squares, or maximum likelihood methods. In this particular market the exogeneity of price (i.e. the fact that the UK faces the world price of timber) makes such an approach unnecessary and so instead we model the market via single equation methods.[3]

### A4.1.2.3: Demand

In examining UK timber demand, a simple relationship is proposed such that $D_t = f(P_t, Y_t, t)$. Estimating such a model gives us equation (A4.1):

$$\ln D_t = \underset{(-3.912)}{-19.801} - \underset{(-7.417)}{0.491} \ln P_t + \underset{(5.884)}{3.116} \ln Y_t - \underset{(-4.631)}{1.492} \ln t \qquad \text{(A4.1)}$$

$$\hat{\rho} = \underset{(8.826)}{0.858} \qquad R^2 = 0.81$$

$$DW = 2.00 \qquad n = 28 \qquad df = 24$$

[3] To confirm our assumption of price exogeneity, Bateman and Mellor (1990) also estimate a simultaneous equation model. This failed to outperform our single equation approach, a result which would appear to justify our view on price exogeneity.

The sample applied is 1958-85 (inclusive). A double log specification was selected in preference to alternative functional forms which yielded poor results. The further advantage of using this specification is that the coefficients are estimates of the (constant) price and income elasticities of demand.

Equation (A4.1) is well specified as is evidenced by the elasticities with respect to price and income having the theoretically 'correct' signs and being individually significantly different from zero at the 1% level. First-order serially correlated errors are handled by the Cochrane-Orcutt iterative estimation procedure, giving $\hat{\rho} = 0.858$ and a Durbin-Watson statistic of 2.00. The coefficient on $\ln t$ is significantly negative suggesting that, *ceteris paribus*, a reduction in demand (probably due to the substitution of alternative products for timber) is occurring over time. The fact that real income is increasing over the period more than offsets this downward trend, such that the net demand for sawn softwood has been increasing throughout our data period.

Finally, our equation when estimated over different subsets of the 1958-85 period demonstrated a commendable degree of parameter stability and appeared robust to the choice of data period (Chow tests confirmed this).

### A4.1.2.4: Home production

Initial expectations of a home production function were for some positive relationship with price. However, upon testing, neither simple nor lagged functions gave any significant relationship (all estimations yielded insignificant results, some giving a negative coefficient on price). This led us to conclude that home production is not price sensitive but instead driven by other factors.

If we denote $H_t^*$ as the desired level of home production in year $t$, then it is plausible to assume a multiplicative partial adjustment process of the form (see, for example, Johnston, 1984, p.350; Gujarati, 1979, p.271):

$$\left[\frac{H_t}{H_{t-1}}\right] = \left[\frac{H_t^*}{H_{t-1}}\right]^{\alpha} \quad 0<\alpha<1$$

This equation simply states that a constant percentage of the discrepancy between the actual and desired level of $H$ is eliminated within a single year.

Substituting this relationship into our home production function results in an equation which includes lagged $\ln H$ as an explanatory variable. This gives rise to the following estimated function:

$$\ln H_t = \underset{(-1.679)}{-0.063} + \underset{(12.737)}{0.890} \ln H_{t-1} + \underset{(2.475)}{0.302} \ln t \qquad \text{(A4.2)}$$

$R^2 = 0.98$

Durbin $h = 0.55$ $\quad n = 28$ df $= 24$

The sample applied was 1958-85 (inclusive). The inclusion of a lagged dependent variable as a regressor biases the Durbin-Watson statistic towards 2 and so we report here the Durbin $h$ statistic, which is asymptotically standard normal. A value of 0.55 gives no cause to suspect first-order serial correlation.

Examining equation (A4.2) we can see that last periods production is the strongest determinant of current production. The coefficient of 0.89 indicates a sluggish adjustment process[4] as one might expect with habits and inertia playing an important role in current cropping decisions. The positive coefficient on ln $t$ is consistent with the argument advanced previously concerning $t$ proxying the uptake of grants which has increased over the years.

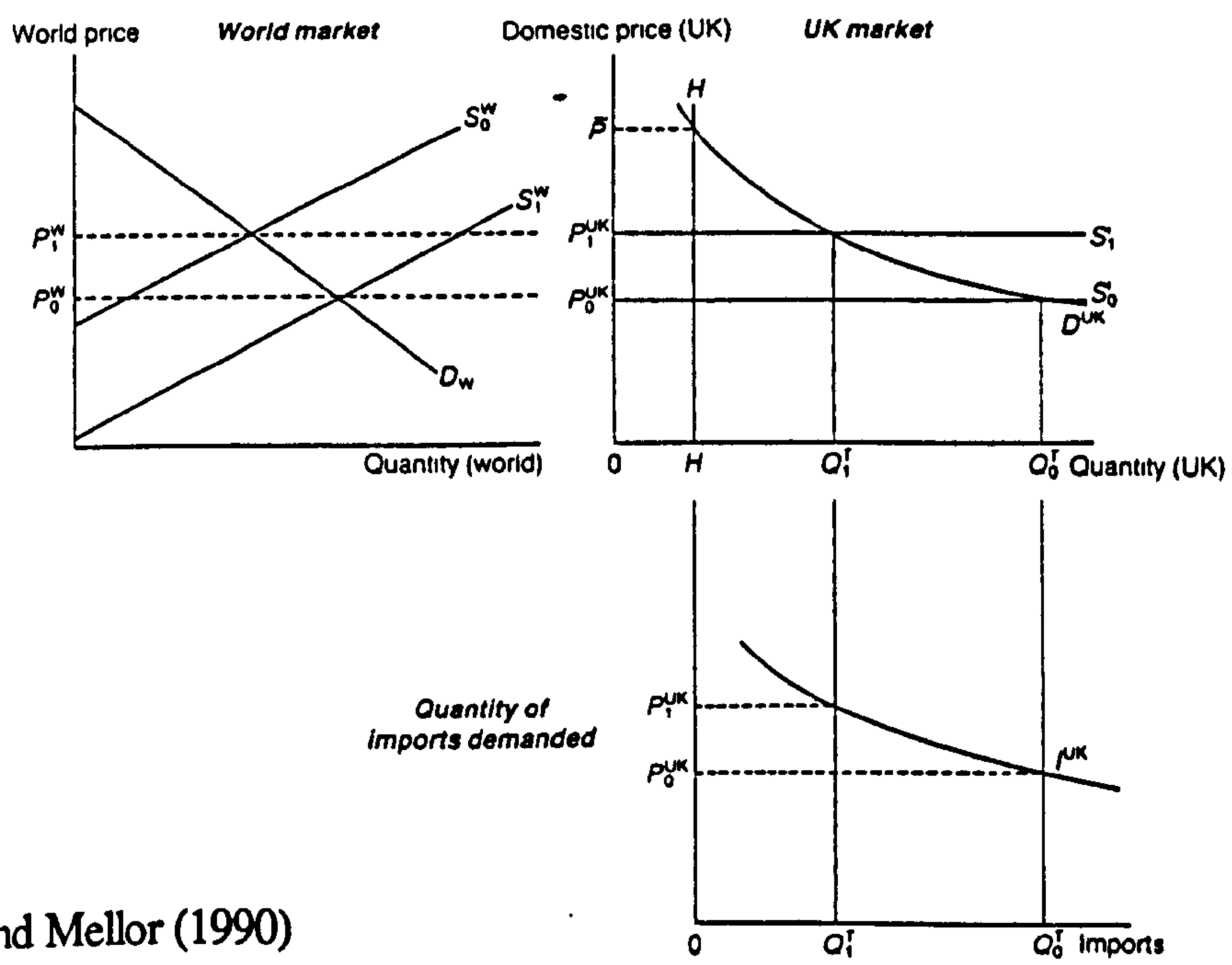
This analysis of demand and home production in the UK leads us to consider an appropriate import function, to which we now turn.

### A4.1.2.5: Imports

Consider figure A4.5, which reproduces the world demand and supply schedules and the corresponding UK import supply offer curve ($S$). We have also sketched in the price inelastic home production curve and the demand curve for the UK.

We can see that a decrease in world supply has the effect of raising the world and hence the UK price from $P_0^W$ to $P_1^W$. An initial total consumption of $OQ_0^T$ (comprising $OH$ of home production and $HQ_0^T$ of imported wood) falls to $OQ_1^T$ (which now comprises $OH$ of home production and $HQ_1^T$ of imports). Clearly, home production is unaffected until price rises to $\overline{P}$, until which time imports alone are choked off by price increases. The response of imports to price changes is shown in the lower part of figure A4.5. The UK demand function defines the demand for imported wood curve as the identity $I_t \equiv D_t - H_t$. This identity implies that imports will have a negative coefficient relationship with ln $t$ (as confirmed in our estimated demand function, equation A4.1). Thus, we see the uptake of tax-relief grants (proxied by time) leading to expansion of home production (see equation A4.2) which, through the import identity, leads to a contraction of imports.

Figure A4.5: Price elasticity relationships

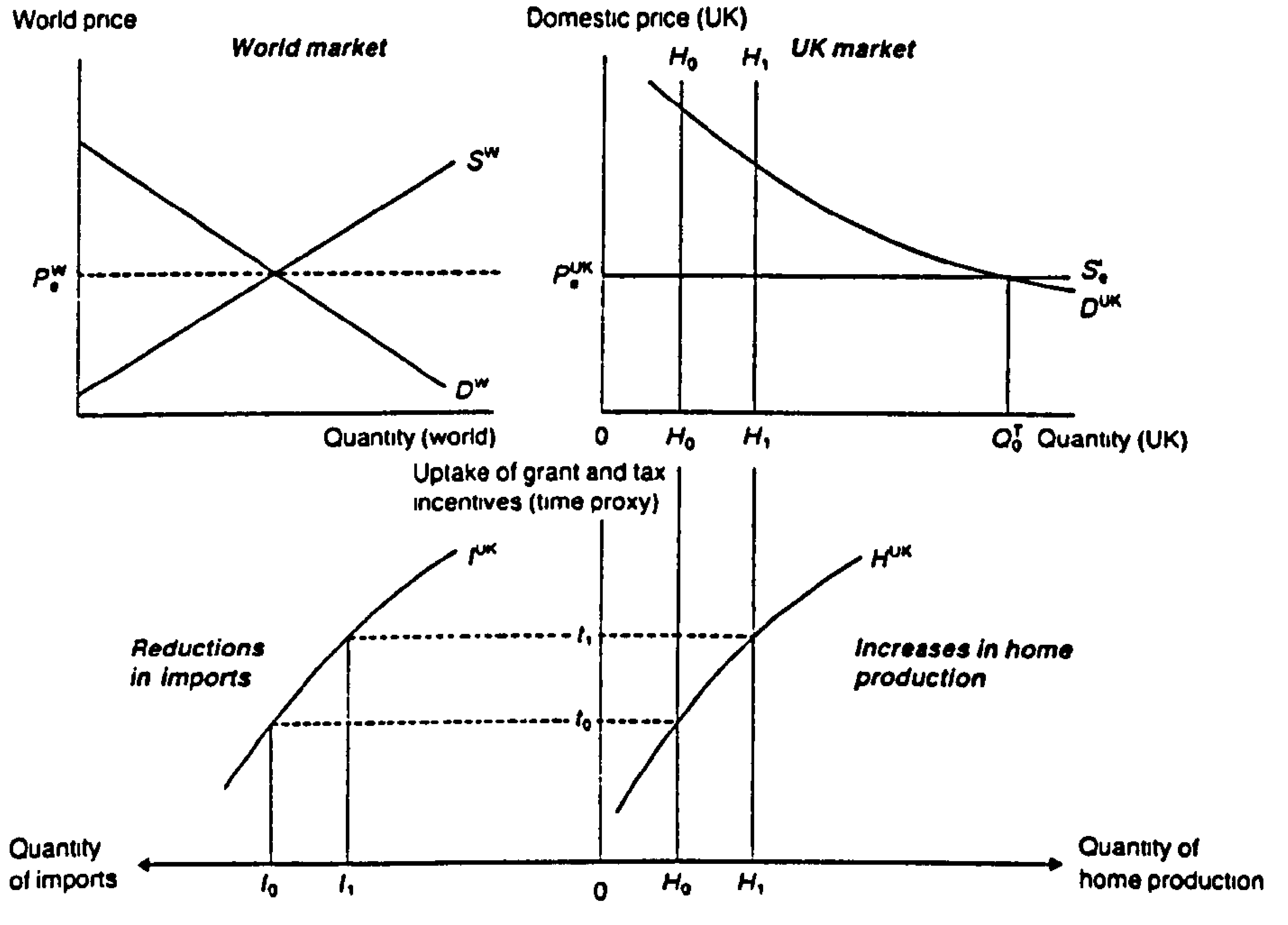



Source: Bateman and Mellor (1990)

[4] A coefficient of 1.0 suggests a perfect inertia situation (cf. the Cobweb model, common in studies of agricultural supply), whereas a coefficient of 0.0 indicates a perfect adjustment.

Figure A4.6 examines this relationship. Assuming, for simplicity, a stable world market, uptake of grant/tax incentives over time is represented by an expanding home production schedule ($H_0$ to $H_1$). This leads to a contraction of imports from $H_0Q_0^T$ to $H_1Q_0^T$. This prediction of the theory, backed up by our empirical evidence, appears wholly consistent with the UK experience in recent years.

Figure A4.6: Long term impact of expanding domestic (UK) supply




Source: Bateman and Mellor (1990)

The lower panels of figure A4.6 illustrate the effects of uptake of grant and domestic tax-relief incentives upon home production and imports of wood. Here, the vertical axis shows the time proxy for uptake of these incentives, and illustrates the relevant temporal relationships with home production rising from $H_0$ to $H_1$ and imports contracting from $I_0$ to $I_1$.

### A4.1.3: Conclusions

We have presented and estimated a simple econometric model of the UK timber market. Our results demonstrate our *a priori* beliefs concerning the relative magnitudes of elasticities, and tie in with a simple economic model of the market. We have captured the effects of price, income and the grant schemes which collectively provide a statistically sound explanation for the behaviour of economic agents in this market. The model helps us to understand and quantify relationships and (for example) enables us to consider future changes under different policy scenarios should we wish.

Remembering that the model is by nature autoregressive, any forecasts derived from it assume implicitly the producer/consumer response can validly be said to extend consistently out of the base time series into the future. Because of this, the model and its forecasts should not be used as a measuring rod to gauge the impact upon production of such comparatively recent market changes as the Farm Woodland Scheme, the Farm Woodland Premium Scheme, the Woodland Grant Scheme and the removal of major tax incentives to afforestation. However, whilst these schemes do entail a substantial shift in the nature of the UK domestic timber market, long production lags are likely to sustain the validity of the model for some time to come.

Accepting the need for caution when extrapolating forward, what do such models imply for our wider research? The most important conclusion is that, given the clearly established link between domestic and world prices and the equally well defined capacity for home production to substitute for imports without a consequent impact upon demand, our models suggest that there is little grounds for expecting real increases in UK softwood prices into the foreseeable future. Given this our best assumption for the softwood timber valuation models presented in chapter 6 is for constant real prices.

# APPENDIX 4.2: TIME-SERIES ANALYSIS OF SAWN SOFTWOOD REAL PRICES

We wished to test the following hypotheses:

Ho: Increasing Annual Real Timber Prices

Ha: Constant Annual Real Timber Prices

Figures for imported sawn softwood were employed as a general proxy for UK timber prices. Data for the inclusive period 1940-80 was obtained from Forestry Commission price indices (reported in Whiteman, 1995), adjusted for inflation (1975 = 100). A number of time-series analyses were performed and the results for the three most appropriate models are presented below.

## A4.2.1: AUTOREGRESSIVE MODEL: AR(1)

Model

$$ISSRPI_t = 29.3 + 0.64\ ISSRPI_{t-1} + e_t \qquad (A4.3)$$

where:

$ISSRPI_t$ = Imported sawn softwood real price index in year t

$e_t$ = Prediction error in year t

Final Estimates of Parameters

| Type | Estimate | S.D. | t |
|---|---|---|---|
| AR 1 | 0.640 | 0.124 | 5.15 |
| Constant | 29.285 | 1.672 | 17.52 |
| Mean | 81.411 | 4.647 | |

No. of obs.: 40

Residuals: SS = 4244.51 (back forecasts excluded)

MS = 111.70 df = 38

The model given in equation (A4.3) shows real price in any period as a function of previous price, some constant and an error term. However, as this is not a difference equation and the coefficient on previous price is less than one, this model does not support the null hypothesis of increasing real prices and it must be rejected in favour of the alternative hypothesis; constant real price.

## A4.2.2: MOVING AVERAGE MODEL: MA(1)

The results shown in equation (A4.4) show a lower mean squared result for this model (MS = 109.10) compared to that from equation (A4.3) (MS = 111.70), indicating a slightly higher degree of explanation. Furthermore this model does exhibit improved t-ratio statistics for both parameter coefficients although both these models have good results here.

Model

$$ISSRPI_t = 82 + e_t + 0.702\,e_t \qquad (A4.4)$$

Final Estimates of Parameters

| Type | Estimate | S.D. | t |
|---|---|---|---|
| MA 1 | -0.702 | 0.116 | -6.06 |
| Constant | 81.889 | 2.790 | 29.36 |
| Mean | 81.899 | 2.790 | |

No. of obs.: 40
Residuals: SS = 4145.97 (back forecasts excluded)
MS = 109.10 df = 38

Here we have a model where the present real price level in any period is determined by a constant, a less than unitary coefficient of previous period prediction error plus this periods error. Again there is no support for Ho.

### A4.2.3: AUTOREGRESSIVE/MOVING AVERAGE MODEL: ARIMA (1,0,1)

This model (equation A4.5) gave the highest degree of explanation (MS = 107.64) and superior $\chi^2$ results (although all reported models passed 5% confidence tests). However t-ratios were severely eroded and the coefficient upon previous period real price has thus become somewhat suspect.

Model

$$ISSRPI_t = 56.49 + 0.309\ ISSRPI_{t-1} + 0.523\, e_{t-1} + e_t \qquad (A4.5)$$

Final Estimates of Parameters

| Type | Estimate | S.D. | t |
|---|---|---|---|
| AR 1 | 0.309 | 0.215 | 1.44 |
| MA 1 | -0.523 | 0.192 | 02.72 |
| Constant | 56.491 | 2.498 | 22.61 |
| Mean | 81.747 | 3.615 | |

No. of obs.: 40
Residuals: SS = 3982.86 (back forecasts excluded)
MS = 107.64 df = 38

As before, coefficients from our ARIMA model do not support Ho.

### A4.2.4: CONCLUSIONS

None of our estimated time series models support an assumption of increasing real softwood prices for the UK.

## APPENDIX 4.3: FARMERS (PRIVATE) TIMBER VALUES

This appendix details results from our rotation models for farmers' evaluation of the timber value of plantations. These were derived from our programmed private cost-benefit flow models discussed in chapter 6[5]. Financial results include timber values and associated costs and subsidy values which vary according to which scheme the farm is registered under. Subsidy Registration codes (indicating the combination of subsidy types under which a farmer might register) are built up from the following:

| | | |
|---|---|---|
| SI | = | subsidy paid on land which was recently improved grassland or under arable production |
| SU | = | subsidy paid on land which was previously unimproved grassland |
| nda | = | farm is not in a notified agriculturally disadvantaged area |
| da | = | farm is in an agriculturally disadvantaged area |
| sda | = | farm is in an agriculturally specially disadvantaged area |
| -CW | = | community woodland supplement not paid |
| +CW | = | community woodland supplement paid. |

So, for example, the code SInda-CW refers to planting which occurs on land which was recently improved grassland or under arable production (SI), on a farm location which is not classed as a disadvantaged area (nda), and for which Community Woodland Supplement is not being paid (-CW).

Financial results are detailed across all species relevant YC and likely discount rates (including hyperbolic; see chapter 6 for further discussion). Three tables are given for each discount rate:

(i) NPV for a single optimal rotation
(ii) NPV for a perpetual series of optimal rotations
(iii) The annuity equivalent of (ii).

The optimal rotation length varies according to species, YC and discount rate as defined in chapter 6. The determination of discount rates and annuity equivalents is also discussed in chapter 6.

Table A4.3.1 to A4.3.15 give results for Sitka spruce while tables A4.3.B1 to A4.3.B15 give results for beech.

[5] These models were programmed as MINITAB macros (available from author) using the data sources described in chapter 6.

Table A4.3.1: NPV of an optimal rotation of Sitka Spruce: r = 1.5%
Various yield classes and subsidy types
Producer Financial Values (£; 1990 prices)

| Subsidy Type | YC6 | YC8 | YC10 | YC12 | YC14 | YC16 | YC18 | YC20 | YC22 | YC24 |
|---|---|---|---|---|---|---|---|---|---|---|
| SInda-CW | 4376 | 6425 | 8707 | 10611 | 12396 | 14466 | 16491 | 18409 | 20289 | 22557 |
| SIda-CW | 3818 | 5866 | 8148 | 10053 | 11837 | 13907 | 15932 | 17850 | 19731 | 21999 |
| SIsda-CW | 3259 | 5308 | 7590 | 9494 | 11278 | 13349 | 15374 | 17292 | 19172 | 21440 |
| SInda+CW | 6840 | 8864 | 11093 | 12942 | 14711 | 16767 | 18761 | 20680 | 22560 | 24813 |
| SIda+CW | 6282 | 8305 | 10535 | 12383 | 14153 | 16208 | 18203 | 20121 | 22001 | 24254 |
| SIsda+CW | 5723 | 7747 | 9976 | 11825 | 13594 | 15650 | 17644 | 19563 | 21443 | 23695 |
| SUnda-CW | 1649 | 3697 | 5979 | 7884 | 9668 | 11738 | 13763 | 15681 | 17562 | 19830 |
| SUda-CW | 2208 | 4256 | 6538 | 8443 | 10227 | 12297 | 14322 | 16240 | 18120 | 20388 |
| SUsda-CW | 2208 | 4256 | 6538 | 8443 | 10227 | 12297 | 14322 | 16240 | 18120 | 20388 |
| SUnda+CW | 4113 | 6136 | 8366 | 10214 | 11984 | 14039 | 16034 | 17952 | 19832 | 22085 |
| SUda+CW | 4671 | 6695 | 8924 | 10773 | 12542 | 14598 | 16593 | 18511 | 20391 | 22644 |
| SUsda+CW | 4671 | 6695 | 8924 | 10773 | 12542 | 14598 | 16593 | 18511 | 20391 | 22644 |

Table A4.3.2: NPV of a perpetual series of optimal rotations of Sitka Spruce: r = 1.5%
Various yield classes and subsidy types
Producer Financial Values (£; 1990 prices)

| Subsidy Type | YC6 | YC8 | YC10 | YC12 | YC14 | YC16 | YC18 | YC20 | YC22 | YC24 |
|---|---|---|---|---|---|---|---|---|---|---|
| SInda-CW | 6040 | 8979 | 12498 | 15687 | 18468 | 21726 | 25181 | 28110 | 30981 | 34742 |
| SIda-CW | 5269 | 8198 | 11697 | 14862 | 17636 | 20887 | 24328 | 27257 | 30128 | 33882 |
| SIsda-CW | 4498 | 7417 | 10895 | 14036 | 16804 | 20048 | 23475 | 26404 | 29275 | 33022 |
| SInda+CW | 9440 | 12387 | 15924 | 19132 | 21919 | 25182 | 28649 | 31578 | 34449 | 38216 |
| SIda+CW | 8669 | 11606 | 15122 | 18307 | 21086 | 24343 | 27796 | 30725 | 33596 | 37355 |
| SIsda+CW | 7898 | 10825 | 14320 | 17481 | 20254 | 23504 | 26943 | 29872 | 32743 | 36495 |
| SUnda-CW | 2276 | 5167 | 8583 | 11655 | 14404 | 17629 | 21016 | 23945 | 26816 | 30541 |
| SUda-CW | 3046 | 5948 | 9385 | 12481 | 15237 | 18468 | 21869 | 24798 | 27669 | 31402 |
| SUsda-CW | 3046 | 5948 | 9385 | 12481 | 15237 | 18468 | 21869 | 24798 | 27669 | 31402 |
| SUnda+CW | 5676 | 8575 | 12009 | 15100 | 17855 | 21085 | 24484 | 27413 | 30284 | 34015 |
| SUda+CW | 6447 | 9356 | 12811 | 15926 | 18687 | 21924 | 25337 | 28266 | 31137 | 34875 |
| SUsda+CW | 6447 | 9356 | 12811 | 15926 | 18687 | 21924 | 25337 | 28266 | 31137 | 34875 |

Table A4.3.3: **Annualised equivalent of a perpetual series of optimal rotations of Sitka Spruce: r = 1.5%**
**Various yield classes and subsidy types**
**Producer Financial Values (£; 1990 prices)**

| Subsidy Type | YC6 | YC8 | YC10 | YC12 | YC14 | YC16 | YC18 | YC20 | YC22 | YC24 |
|---|---|---|---|---|---|---|---|---|---|---|
| SInda-CW | 98.15 | 145.90 | 203.10 | 254.92 | 300.11 | 353.05 | 409.19 | 456.79 | 503.45 | 564.56 |
| SIda-CW | 85.62 | 133.22 | 190.07 | 241.50 | 286.59 | 339.41 | 395.33 | 442.93 | 489.59 | 550.58 |
| SIsda-CW | 73.10 | 120.53 | 177.04 | 228.08 | 273.06 | 325.78 | 381.47 | 429.07 | 475.72 | 536.60 |
| SInda+CW | 153.40 | 201.28 | 258.76 | 310.90 | 356.18 | 409.20 | 465.54 | 513.14 | 559.79 | 621.00 |
| SIda+CW | 140.87 | 188.60 | 245.73 | 297.48 | 342.65 | 395.57 | 451.68 | 499.28 | 545.93 | 607.02 |
| SIsda+CW | 128.34 | 175.91 | 232.70 | 284.06 | 329.13 | 381.94 | 437.82 | 485.41 | 532.07 | 593.04 |
| SUnda-CW | 36.98 | 83.96 | 139.48 | 189.39 | 234.07 | 286.48 | 341.51 | 389.11 | 435.77 | 496.30 |
| SUda-CW | 49.50 | 96.65 | 152.51 | 202.81 | 247.60 | 300.11 | 355.37 | 402.97 | 449.63 | 510.28 |
| SUsda-CW | 49.50 | 96.65 | 152.51 | 202.81 | 247.60 | 300.11 | 355.37 | 402.97 | 449.63 | 510.28 |
| SUnda+CW | 92.23 | 139.34 | 195.14 | 245.38 | 290.14 | 342.64 | 397.86 | 445.46 | 492.11 | 552.74 |
| SUda+CW | 104.76 | 152.03 | 208.17 | 258.80 | 303.67 | 356.27 | 411.72 | 459.32 | 505.97 | 566.72 |
| SUsda+CW | 104.76 | 152.03 | 208.17 | 258.80 | 303.67 | 356.27 | 411.72 | 459.32 | 505.97 | 566.72 |

**Table A4.3.4:** **NPV of an optimal rotation of Sitka Spruce: r = 3%**
**Various yield classes and subsidy types**
**Producer Financial Values (£; 1990 prices)**

| Subsidy Type | YC6 | YC8 | YC10 | YC12 | YC14 | YC16 | YC18 | YC20 | YC22 | YC24 |
|---|---|---|---|---|---|---|---|---|---|---|
| SInda-CW | 2745 | 3620 | 4752 | 5859 | 6966 | 7930 | 9043 | 10444 | 11656 | 13072 |
| SIda-CW | 2218 | 3093 | 4225 | 5332 | 6438 | 7403 | 8516 | 9917 | 11129 | 12544 |
| SIsda-CW | 1690 | 2566 | 3698 | 4805 | 5911 | 6876 | 7989 | 9389 | 10602 | 12017 |
| SInda+CW | 4573 | 5443 | 6559 | 7628 | 8713 | 9662 | 10766 | 12167 | 13371 | 14787 |
| SIda+CW | 4046 | 4916 | 6032 | 7101 | 8185 | 9135 | 10239 | 11640 | 12844 | 14259 |
| SIsda+CW | 3519 | 4389 | 5504 | 6574 | 7658 | 8608 | 9712 | 11113 | 12317 | 13732 |
| SUnda-CW | 148 | 1023 | 2156 | 3263 | 4369 | 5334 | 6447 | 7847 | 9059 | 10475 |
| SUda-CW | 675 | 1551 | 2683 | 3790 | 4896 | 5861 | 6974 | 8374 | 9587 | 11002 |
| SUsda-CW | 675 | 1551 | 2683 | 3790 | 4896 | 5861 | 6974 | 8374 | 9587 | 11002 |
| SUnda+CW | 1976 | 2846 | 3962 | 5031 | 6116 | 7065 | 8170 | 9571 | 10774 | 12190 |
| SUda+CW | 2504 | 3374 | 4489 | 5559 | 6643 | 7593 | 8697 | 10098 | 11302 | 12717 |
| SUsda+CW | 2504 | 3374 | 4489 | 5559 | 6643 | 7593 | 8697 | 10098 | 11302 | 12717 |

Table A4.3.5: NPV of a perpetual series of optimal rotations of Sitka Spruce: r = 3%
Various yield classes and subsidy types
Producer Financial Values (£; 1990 prices)

| Subsidy Type | YC6 | YC8 | YC10 | YC12 | YC14 | YC16 | YC18 | YC20 | YC22 | YC24 |
|---|---|---|---|---|---|---|---|---|---|---|
| SInda-CW | 3103 | 4109 | 5463 | 6937 | 8390 | 9672 | 11102 | 12822 | 14408 | 16159 |
| SIda-CW | 2507 | 3511 | 4857 | 6313 | 7755 | 9029 | 10455 | 12175 | 13757 | 15507 |
| SIsda-CW | 1911 | 2912 | 4251 | 5689 | 7120 | 8386 | 9808 | 11527 | 13105 | 14855 |
| SInda+CW | 5171 | 6178 | 7539 | 9031 | 10494 | 11784 | 13218 | 14938 | 16528 | 18279 |
| SIda+CW | 4574 | 5580 | 6933 | 8407 | 9859 | 11141 | 12571 | 14290 | 15877 | 17627 |
| SIsda+CW | 3978 | 4982 | 6327 | 7782 | 9224 | 10498 | 11924 | 13643 | 15225 | 16975 |
| SUnda-CW | 168 | 1162 | 2478 | 3863 | 5262 | 6505 | 7915 | 9634 | 11199 | 12949 |
| SUda-CW | 764 | 1760 | 3084 | 4487 | 5897 | 714 | 8562 | 10281 | 11850 | 13600 |
| SUsda-CW | 764 | 1760 | 3084 | 4487 | 5897 | 7148 | 8562 | 10281 | 11850 | 13600 |
| SUnda+CW | 2235 | 3231 | 4555 | 5957 | 7366 | 8617 | 10030 | 11750 | 13319 | 15069 |
| SUda+CW | 2831 | 3829 | 5161 | 6581 | 8001 | 9260 | 10678 | 12397 | 13970 | 15720 |
| SUsda+CW | 2831 | 3829 | 5161 | 6581 | 8001 | 9260 | 10678 | 12397 | 13970 | 15720 |

Table A4.3.6: Annualised equivalent of a perpetual series of optimal rotations of Sitka Spruce: r = 3%
Various yield classes and subsidy types
Producer Financial Values (£; 1990 prices)

| Subsidy Type | YC6 | YC8 | YC10 | YC12 | YC14 | YC16 | YC18 | YC20 | YC22 | YC24 |
|---|---|---|---|---|---|---|---|---|---|---|
| SInda-CW | 93.10 | 123.27 | 163.89 | 208.11 | 251.69 | 290.16 | 333.07 | 384.65 | 432.25 | 484.75 |
| SIda-CW | 75.22 | 105.32 | 145.71 | 189.38 | 232.64 | 270.87 | 313.65 | 365.24 | 412.70 | 465.20 |
| SIsda-CW | 57.34 | 87.37 | 127.53 | 170.66 | 213.59 | 251.59 | 294.24 | 345.82 | 393.15 | 445.66 |
| SInda+CW | 155.12 | 185.35 | 226.18 | 270.92 | 314.81 | 353.51 | 396.54 | 448.13 | 495.85 | 548.35 |
| SIda+CW | 137.24 | 167.40 | 208.00 | 252.20 | 295.76 | 334.23 | 377.13 | 428.71 | 476.30 | 528.80 |
| SIsda+CW | 119.35 | 149.45 | 189.82 | 233.47 | 276.71 | 314.94 | 357.71 | 409.29 | 456.75 | 509.26 |
| SUnda-CW | 5.03 | 34.85 | 74.34 | 115.89 | 157.87 | 195.16 | 237.44 | 289.02 | 335.96 | 388.46 |
| SUda-CW | 22.91 | 52.80 | 92.52 | 134.61 | 176.92 | 214.45 | 256.85 | 308.44 | 355.51 | 408.01 |
| SUsda-CW | 22.91 | 52.80 | 92.52 | 134.61 | 176.92 | 214.45 | 256.85 | 308.44 | 355.51 | 408.01 |
| SUnda+CW | 67.04 | 96.93 | 136.64 | 178.70 | 220.99 | 258.51 | 300.91 | 352.49 | 399.56 | 452.06 |
| SUda+CW | 84.92 | 114.88 | 154.82 | 197.42 | 240.04 | 277.80 | 320.32 | 371.91 | 419.11 | 471.61 |
| SUsda+CW | 84.92 | 114.88 | 154.82 | 197.42 | 240.04 | 277.80 | 320.32 | 371.91 | 419.11 | 471.61 |

Table A4.3.7: NPV of an optimal rotation of Sitka Spruce: r = 6%
Various yield classes and subsidy types
Producer Financial Values (£; 1990 prices)

| Subsidy Type | YC6 | YC8 | YC10 | YC12 | YC14 | YC16 | YC18 | YC20 | YC22 | YC24 |
|---|---|---|---|---|---|---|---|---|---|---|
| SInda-CW | 1903 | 2076 | 2385 | 2686 | 3106 | 3479 | 4016 | 4490 | 4983 | 5651 |
| SIda-CW | 1435 | 1607 | 1917 | 2218 | 2638 | 3011 | 3548 | 4022 | 4515 | 5183 |
| SIsda-CW | 967 | 1139 | 1449 | 1750 | 2170 | 2543 | 3080 | 3554 | 4047 | 4715 |
| SInda+CW | 3209 | 3379 | 3685 | 3983 | 4394 | 4759 | 5284 | 5754 | 6243 | 6907 |
| SIda+CW | 2741 | 2911 | 3217 | 3515 | 3926 | 4291 | 4816 | 5286 | 5774 | 6439 |
| SIsda+CW | 2272 | 2442 | 2749 | 3047 | 3458 | 3823 | 4348 | 4817 | 5306 | 5971 |
| SUnda-CW | -448 | -275 | 35 | 336 | 756 | 1129 | 1666 | 2139 | 2632 | 3301 |
| SUda-CW | 20 | 193 | 503 | 804 | 1224 | 1597 | 2134 | 2608 | 3100 | 3769 |
| SUsda-CW | 20 | 193 | 503 | 804 | 1224 | 1597 | 2134 | 2608 | 3100 | 3769 |
| SUnda+CW | 858 | 1028 | 1334 | 1632 | 2044 | 2409 | 2933 | 3403 | 3892 | 4556 |
| SUda+CW | 1326 | 1496 | 1803 | 2101 | 2512 | 2877 | 3401 | 3871 | 4360 | 5024 |
| SUsda+CW | 1326 | 1496 | 1803 | 2101 | 2512 | 2877 | 3401 | 3871 | 4360 | 5024 |

Table A4.3.8: NPV of a perpetual series of optimal rotations of Sitka Spruce: r = 6%
Various yield classes and subsidy types
Producer Financial Values (£; 1990 prices)

| Subsidy Type | YC6 | YC8 | YC10 | YC12 | YC14 | YC16 | YC18 | YC20 | YC22 | YC24 |
|---|---|---|---|---|---|---|---|---|---|---|
| SInda-CW | 1962 | 2149 | 2480 | 2807 | 3285 | 3719 | 4373 | 4915 | 5486 | 6260 |
| SIda-CW | 1480 | 1664 | 1993 | 2318 | 2790 | 3219 | 3864 | 4403 | 4971 | 5741 |
| SIsda-CW | 997 | 1180 | 1506 | 1829 | 2295 | 2719 | 3354 | 3890 | 4455 | 5223 |
| SInda+CW | 3309 | 3498 | 3831 | 4162 | 4646 | 5088 | 5753 | 6299 | 6873 | 7650 |
| SIda+CW | 2826 | 3013 | 3345 | 3673 | 4152 | 4588 | 5244 | 5786 | 6358 | 7132 |
| SIsda+CW | 2343 | 2528 | 2858 | 3183 | 3657 | 4087 | 4734 | 5274 | 5842 | 6613 |
| SUnda-CW | -462 | -285 | 36 | 351 | 799 | 1207 | 1814 | 2342 | 2898 | 3656 |
| SUda-CW | 21 | 200 | 523 | 840 | 1294 | 1707 | 2324 | 2855 | 3413 | 4175 |
| SUsda-CW | 21 | 200 | 523 | 840 | 1294 | 1707 | 2324 | 2855 | 3413 | 4175 |
| SUnda+CW | 885 | 1064 | 1388 | 1706 | 2161 | 2575 | 3194 | 3725 | 4285 | 5047 |
| SUda+CW | 1368 | 1549 | 1874 | 2195 | 2656 | 3076 | 3704 | 4238 | 4800 | 5565 |
| SUsda+CW | 1368 | 1549 | 1874 | 2195 | 2656 | 3076 | 3704 | 4238 | 4800 | 5565 |

Table A4.3.9: **Annualised equivalent of a perpetual series of optimal rotations of Sitka Spruce: r = 6%**
**Various yield classes and subsidy types**
**Producer Financial Values (£; 1990 prices)**

| Subsidy Type | YC6 | YC8 | YC10 | YC12 | YC14 | YC16 | YC18 | YC20 | YC22 | YC24 |
|---|---|---|---|---|---|---|---|---|---|---|
| SInda-CW | 117.74 | 128.92 | 148.79 | 168.43 | 197.08 | 223.17 | 262.40 | 294.91 | 329.15 | 375.57 |
| SIda-CW | 88.77 | 99.85 | 119.59 | 139.08 | 167.38 | 193.14 | 231.82 | 264.16 | 298.23 | 344.46 |
| SIsda-CW | 59.81 | 70.77 | 90.39 | 109.73 | 137.69 | 163.11 | 201.23 | 233.42 | 267.31 | 313.35 |
| SInda+CW | 198.54 | 209.86 | 229.89 | 249.70 | 278.79 | 305.28 | 345.20 | 377.91 | 412.37 | 459.03 |
| SIda+CW | 169.57 | 180.79 | 200.69 | 220.36 | 249.09 | 275.26 | 314.62 | 347.17 | 381.45 | 427.92 |
| SIsda+CW | 140.61 | 151.71 | 171.48 | 191.01 | 219.39 | 245.23 | 284.03 | 316.42 | 350.53 | 396.81 |
| SUnda-CW | -27.70 | -17.08 | 2.16 | 21.07 | 47.96 | 72.39 | 108.84 | 140.53 | 173.89 | 219.36 |
| SUda-CW | 1.27 | 12.00 | 31.36 | 50.42 | 77.66 | 102.42 | 139.42 | 171.27 | 204.81 | 250.47 |
| SUsda-CW | 1.27 | 12.00 | 31.36 | 50.42 | 77.66 | 102.42 | 139.42 | 171.27 | 204.81 | 250.47 |
| SUnda+CW | 53.10 | 63.86 | 83.25 | 102.34 | 129.67 | 154.51 | 191.64 | 223.53 | 257.11 | 302.82 |
| SUda+CW | 82.07 | 92.94 | 112.46 | 131.69 | 159.37 | 184.54 | 222.22 | 254.28 | 288.03 | 333.93 |
| SUsda+CW | 82.07 | 92.94 | 112.46 | 131.69 | 159.37 | 184.54 | 222.22 | 254.28 | 288.03 | 333.93 |

Table A4.3.10: NPV of an optimal rotation of Sitka Spruce: r = 12%
Various yield classes and subsidy types
Producer Financial Values (£; 1990 prices)

| Subsidy Type | YC6 | YC8 | YC10 | YC12 | YC14 | YC16 | YC18 | YC20 | YC22 | YC24 |
|---|---|---|---|---|---|---|---|---|---|---|
| SInda-CW | 1539 | 1547 | 1566 | 1600 | 1640 | 1704 | 1758 | 1841 | 1951 | 2099 |
| SIda-CW | 1168 | 1175 | 1195 | 1228 | 1268 | 1332 | 1386 | 1469 | 1579 | 1727 |
| SIsda-CW | 796 | 804 | 823 | 856 | 897 | 960 | 1015 | 1098 | 1208 | 1356 |
| SInda+CW | 2581 | 2588 | 2607 | 2640 | 2681 | 2744 | 2797 | 2879 | 2988 | 3135 |
| SIda+CW | 2209 | 2217 | 2236 | 2269 | 2309 | 2372 | 2425 | 2508 | 2616 | 2763 |
| SIsda+CW | 1838 | 1845 | 1864 | 1897 | 1937 | 2001 | 2054 | 2136 | 2244 | 2392 |
| SUnda-CW | -409 | -401 | -382 | -349 | -308 | -245 | -191 | -108 | 2 | 150 |
| SUda-CW | -38 | -30 | -10 | 23 | 63 | 127 | 181 | 264 | 374 | 522 |
| SUsda-CW | -38 | -30 | -10 | 23 | 63 | 127 | 181 | 264 | 374 | 522 |
| SUnda+CW | 632 | 640 | 659 | 692 | 732 | 795 | 849 | 931 | 1039 | 1187 |
| SUda+CW | 1004 | 1011 | 1031 | 1063 | 1104 | 1167 | 1220 | 1302 | 1411 | 1558 |
| SUsda+CW | 1004 | 1011 | 1031 | 1063 | 1104 | 1167 | 1220 | 1302 | 1411 | 1558 |

**Table A4.3.11:** **NPV of a perpetual series of optimal rotations of Sitka Spruce: r = 12%**
**Various yield classes and subsidy types**
**Producer Financial Values (£; 1990 prices)**

| Subsidy Type | YC6 | YC8 | YC10 | YC12 | YC14 | YC16 | YC18 | YC20 | YC22 | YC24 |
|---|---|---|---|---|---|---|---|---|---|---|
| SInda-CW | 1545 | 1555 | 1576 | 1610 | 1652 | 1718 | 1777 | 1866 | 1985 | 2141 |
| SIda-CW | 1172 | 1182 | 1202 | 1236 | 1278 | 1343 | 1401 | 1490 | 1607 | 1762 |
| SIsda-CW | 799 | 808 | 828 | 862 | 904 | 969 | 1025 | 1113 | 1229 | 1383 |
| SInda+CW | 2590 | 2602 | 2623 | 2658 | 2701 | 2767 | 2827 | 2919 | 3040 | 3197 |
| SIda+CW | 2217 | 2228 | 2249 | 2284 | 2326 | 2392 | 2452 | 2542 | 2662 | 2818 |
| SIsda+CW | 1844 | 1855 | 1875 | 1910 | 1952 | 2018 | 2076 | 2165 | 2284 | 2439 |
| SUnda-CW | -411 | -404 | -384 | -351 | -311 | -247 | -193 | -109 | 2 | 153 |
| SUda-CW | -38 | -30 | -11 | 23 | 64 | 128 | 183 | 268 | 381 | 532 |
| SUsda-CW | -38 | -30 | -11 | 23 | 64 | 128 | 183 | 268 | 381 | 532 |
| SUnda+CW | 635 | 643 | 663 | 696 | 738 | 802 | 858 | 944 | 1058 | 1210 |
| SUda+CW | 1008 | 1017 | 1037 | 1071 | 1112 | 1177 | 1233 | 1320 | 1436 | 1589 |
| SUsda+CW | 1008 | 1017 | 1037 | 1071 | 1112 | 1177 | 1233 | 1320 | 1436 | 1589 |

Table A4.3.12: **Annualised equivalent of a perpetual series of optimal rotations of Sitka Spruce: r = 12%**
**Various yield classes and subsidy types**
**Producer Financial Values (£; 1990 prices)**

| Subsidy Type | YC6 | YC8 | YC10 | YC12 | YC14 | YC16 | YC18 | YC20 | YC22 | YC24 |
|---|---|---|---|---|---|---|---|---|---|---|
| SInda-CW | 195.85 | 197.16 | 199.75 | 204.14 | 209.49 | 217.82 | 225.25 | 236.60 | 251.66 | 271.37 |
| SIda-CW | 148.56 | 149.80 | 152.36 | 156.71 | 162.02 | 170.31 | 177.63 | 188.84 | 203.72 | 223.32 |
| SIsda-CW | 101.27 | 102.44 | 104.97 | 109.28 | 114.55 | 122.79 | 130.00 | 141.08 | 155.77 | 175.28 |
| SInda+CW | 328.40 | 329.86 | 332.51 | 336.96 | 342.39 | 350.80 | 358.44 | 370.04 | 385.43 | 405.34 |
| SIda+CW | 281.12 | 282.50 | 285.12 | 289.53 | 294.92 | 303.29 | 310.81 | 322.28 | 337.49 | 357.29 |
| SIsda+CW | 233.83 | 235.13 | 237.72 | 242.11 | 247.45 | 255.78 | 263.19 | 274.52 | 289.55 | 309.25 |
| SUnda-CW | -52.08 | -51.16 | -48.73 | -44.53 | -39.39 | -31.30 | -24.44 | -13.82 | 0.23 | 19.45 |
| SUda-CW | -4.79 | -3.80 | -1.34 | 2.90 | 8.08 | 16.22 | 23.18 | 33.94 | 48.24 | 67.50 |
| SUsda-CW | -4.79 | -3.80 | -1.34 | 2.90 | 8.08 | 16.22 | 23.18 | 33.94 | 48.24 | 67.50 |
| SUnda+CW | 80.48 | 81.54 | 84.03 | 88.29 | 93.51 | 101.68 | 108.74 | 119.62 | 134.07 | 153.42 |
| SUda+CW | 127.77 | 128.90 | 131.42 | 135.72 | 140.98 | 149.20 | 156.37 | 167.38 | 182.01 | 201.47 |
| SUsda+CW | 127.77 | 128.90 | 131.42 | 135.72 | 140.98 | 149.20 | 156.37 | 167.38 | 182.01 | 201.47 |

**Table A4.3.13:** **NPV of an optimal rotation of Sitka Spruce: r = 6% (Hyperbolic discounting)**
**Various yield classes and subsidy types**
**Producer Financial Values (£; 1990 prices)**

| Subsidy Type | YC6 | YC8 | YC10 | YC12 | YC14 | YC16 | YC18 | YC20 | YC22 | YC24 |
|---|---|---|---|---|---|---|---|---|---|---|
| SInda-CW | 3173 | 4378 | 5698 | 6699 | 7728 | 8571 | 9646 | 11089 | 12189 | 13514 |
| SIda-CW | 2691 | 3896 | 5217 | 6218 | 7247 | 8089 | 9165 | 10608 | 11708 | 13032 |
| SIsda-CW | 2210 | 3415 | 4735 | 5736 | 6765 | 7608 | 8683 | 10126 | 11226 | 12551 |
| SInda+CW | 4970 | 6166 | 7461 | 8408 | 9408 | 10231 | 11297 | 12740 | 13830 | 15154 |
| SIda+CW | 4488 | 5685 | 6979 | 7926 | 8927 | 9750 | 10815 | 12258 | 13348 | 14672 |
| SIsda+CW | 4007 | 5203 | 6498 | 7445 | 8446 | 9269 | 10334 | 11777 | 12867 | 14191 |
| SUnda-CW | 767 | 1972 | 3292 | 4293 | 5322 | 6165 | 7240 | 8683 | 9783 | 11108 |
| SUda-CW | 1248 | 2453 | 3773 | 4775 | 5804 | 6646 | 7722 | 9165 | 10265 | 11589 |
| SUsda-CW | 1248 | 2453 | 3773 | 4775 | 5804 | 6646 | 7722 | 9165 | 10265 | 11589 |
| SUnda+CW | 2564 | 3760 | 5055 | 6002 | 7002 | 7825 | 8891 | 10334 | 11424 | 12748 |
| SUda+CW | 3045 | 4242 | 5536 | 6483 | 7484 | 8307 | 9372 | 10815 | 11905 | 13229 |
| SUsda+CW | 3045 | 4242 | 5536 | 6483 | 7484 | 8307 | 9372 | 10815 | 11905 | 13229 |

Table A4.3.14: NPV of a perpetual series of optimal rotations of Sitka Spruce: r = 6% (Hyperbolic discounting)
Various yield classes and subsidy types
Producer Financial Values (£; 1990 prices)

| Subsidy Type | YC6 | YC8 | YC10 | YC12 | YC14 | YC16 | YC18 | YC20 | YC22 | YC24 |
|---|---|---|---|---|---|---|---|---|---|---|
| SInda-CW | 3897 | 5391 | 7074 | 8471 | 9875 | 11034 | 12467 | 14332 | 15817 | 17535 |
| SIda-CW | 3306 | 4798 | 6477 | 7863 | 9260 | 10414 | 11844 | 13710 | 15192 | 16911 |
| SIsda-CW | 2714 | 4205 | 5879 | 7254 | 8645 | 9794 | 11222 | 13087 | 14568 | 16286 |
| SInda+CW | 6104 | 7593 | 9263 | 10632 | 12022 | 13171 | 14600 | 16465 | 17945 | 19664 |
| SIda+CW | 5513 | 7001 | 8665 | 10023 | 11407 | 12552 | 13977 | 15843 | 17321 | 19039 |
| SIsda+CW | 4922 | 6408 | 8068 | 9415 | 10792 | 11932 | 13355 | 15220 | 16696 | 18414 |
| SUnda-CW | 942 | 2428 | 4087 | 5429 | 6801 | 7936 | 9357 | 11222 | 12695 | 14413 |
| SUda-CW | 1533 | 3021 | 4685 | 6038 | 7416 | 8556 | 9979 | 11844 | 13320 | 15038 |
| SUsda-CW | 1533 | 3021 | 4685 | 6038 | 7416 | 8556 | 9979 | 11844 | 13320 | 15038 |
| SUnda+CW | 3149 | 4631 | 6276 | 7590 | 8948 | 10074 | 11490 | 13355 | 14823 | 16542 |
| SUda+CW | 3740 | 5223 | 6874 | 8198 | 9563 | 10694 | 12112 | 13977 | 15448 | 17167 |
| SUsda+CW | 3740 | 5223 | 6874 | 8198 | 9563 | 10694 | 12112 | 13977 | 15448 | 17167 |

Table A4.3.15: Annualised equivalent of a perpetual series of optimal rotations of Sitka Spruce: r = 6% (Hyperbolic discounting)
Various yield classes and subsidy types
Producer Financial Values (£; 1990 prices)

| Subsidy Type | YC6 | YC8 | YC10 | YC12 | YC14 | YC16 | YC18 | YC20 | YC22 | YC24 |
|---|---|---|---|---|---|---|---|---|---|---|
| SInda-CW | 233.82 | 323.45 | 424.46 | 508.28 | 592.50 | 662.03 | 747.10 | 859.90 | 949.02 | 1052.13 |
| SIda-CW | 198.34 | 287.88 | 388.59 | 471.75 | 555.59 | 624.84 | 710.66 | 822.57 | 911.54 | 1014.64 |
| SIsda-CW | 162.86 | 252.31 | 352.73 | 435.22 | 518.68 | 587.66 | 673.33 | 785.24 | 874.05 | 977.16 |
| SInda+CW | 366.25 | 455.61 | 555.78 | 637.93 | 721.31 | 790.29 | 875.98 | 987.88 | 1076.72 | 1179.83 |
| SIda+CW | 330.77 | 420.04 | 519.92 | 601.40 | 684.40 | 753.10 | 838.65 | 950.55 | 1039.24 | 1142.35 |
| SIsda+CW | 295.29 | 384.46 | 484.05 | 564.87 | 647.49 | 715.91 | 801.31 | 913.22 | 1001.76 | 1104.86 |
| SUnda-CW | 56.50 | 145.68 | 245.23 | 325.73 | 408.04 | 476.19 | 561.43 | 673.33 | 761.70 | 864.80 |
| SUda-CW | 91.99 | 181.25 | 281.09 | 362.26 | 444.95 | 513.37 | 598.76 | 710.67 | 799.18 | 902.29 |
| SUsda-CW | 91.99 | 181.25 | 281.09 | 362.26 | 444.95 | 513.37 | 598.76 | 710.67 | 799.18 | 902.29 |
| SUnda+CW | 188.94 | 313.41 | 376.55 | 455.38 | 536.85 | 604.44 | 689.41 | 801.32 | 889.40 | 992.51 |
| SUda+CW | 224.42 | 313.41 | 412.41 | 491.91 | 573.76 | 641.63 | 726.74 | 838.65 | 926.88 | 1029.99 |
| SUsda+CW | 224.42 | 58.91 | 412.41 | 491.91 | 573.76 | 641.63 | 726.74 | 838.65 | 926.88 | 1029.99 |

Table A4.3.B1: NPV of an optimal rotation of Beech: r = 1.5%
Various yield classes and subsidy types
Producer Financial Values (£; 1990 prices)

| Subsidy Type | YC4 | YC6 | YC8 | YC10 |
|---|---|---|---|---|
| SInda-CW | 4773 | 5906 | 7329 | 9297 |
| SIda-CW | 3986 | 5119 | 6543 | 8511 |
| SIsda-CW | 3200 | 4333 | 5757 | 7724 |
| SInda+CW | 6760 | 7873 | 9293 | 11256 |
| SIda+CW | 5974 | 7087 | 8507 | 10470 |
| SIsda+CW | 5187 | 6301 | 7720 | 9684 |
| SUnda-CW | 896 | 2029 | 3453 | 5421 |
| SUda-CW | 1682 | 2815 | 4239 | 6207 |
| SUsda-CW | 1682 | 2815 | 4239 | 6207 |
| SUnda+CW | 2883 | 3997 | 5416 | 7380 |
| SUda+CW | 3670 | 4783 | 6203 | 8166 |
| SUsda+CW | 3670 | 4783 | 6203 | 8166 |

Table A4.3.B2: NPV of a perpetual series of optimal rotations of Beech: r = 1.5%
Various yield classes and subsidy types
Producer Financial Values (£; 1990 prices)

| Subsidy Type | YC4 | YC6 | YC8 | YC10 |
|---|---|---|---|---|
| SInda-CW | 5507 | 6903 | 8591 | 10928 |
| SIda-CW | 4599 | 5984 | 7669 | 10004 |
| SIsda-CW | 3692 | 5065 | 6748 | 9080 |
| SInda+CW | 7800 | 9204 | 10893 | 13231 |
| SIda+CW | 6893 | 8284 | 9971 | 12307 |
| SIsda+CW | 5985 | 7365 | 9049 | 11383 |
| SUnda-CW | 1034 | 2372 | 4047 | 6372 |
| SUda-CW | 1941 | 3291 | 4969 | 7296 |
| SUsda-CW | 1941 | 3291 | 4969 | 7296 |
| SUnda+CW | 3327 | 4672 | 6349 | 8675 |
| SUda+CW | 4234 | 5591 | 7270 | 9599 |
| SUsda+CW | 4234 | 5591 | 7270 | 9599 |

Table A4.3.B3: **Annualised equivalent of a perpetual series of optimal rotations of Beech: r = 1.5%**
**Various yield classes and subsidy types**
**Producer Financial Values (£; 1990 prices)**

| Subsidy Type | YC4 | YC6 | YC8 | YC10 |
|---|---|---|---|---|
| SInda-CW | 89.48 | 112.18 | 139.60 | 177.58 |
| SIda-CW | 74.74 | 97.24 | 124.63 | 162.56 |
| SIsda-CW | 59.99 | 82.30 | 109.65 | 147.54 |
| SInda+CW | 126.75 | 149.56 | 177.01 | 215.01 |
| SIda+CW | 112.00 | 134.62 | 162.03 | 199.99 |
| SIsda+CW | 97.26 | 119.68 | 147.05 | 184.97 |
| SUnda-CW | 16.80 | 38.54 | 65.77 | 103.54 |
| SUda-CW | 31.54 | 53.48 | 80.74 | 118.56 |
| SUsda-CW | 31.54 | 53.48 | 80.74 | 118.56 |
| SUnda+CW | 54.06 | 75.92 | 103.17 | 140.96 |
| SUda+CW | 68.81 | 90.86 | 118.15 | 155.98 |
| SUsda+CW | 68.81 | 90.86 | 118.15 | 155.98 |

Table A4.3.B4: **NPV of an optimal rotation of Beech: r = 3%**
**Various yield classes and subsidy types**
**Producer Financial Values (£; 1990 prices)**

| Subsidy Type | YC4 | YC6 | YC8 | YC10 |
|---|---|---|---|---|
| SInda-CW | 4083 | 4577 | 5240 | 6191 |
| SIda-CW | 3345 | 3839 | 4502 | 5454 |
| SIsda-CW | 2607 | 3102 | 3765 | 4716 |
| SInda+CW | 5589 | 6071 | 6723 | 7669 |
| SIda+CW | 4851 | 5333 | 5986 | 6931 |
| SIsda+CW | 4114 | 4595 | 5248 | 6194 |
| SUnda-CW | 409 | 903 | 1566 | 2517 |
| SUda-CW | 1146 | 1641 | 2304 | 3255 |
| SUsda-CW | 1146 | 1641 | 2304 | 3255 |
| SUnda+CW | 1915 | 2397 | 3049 | 3995 |
| SUda+CW | 2653 | 3134 | 3787 | 4733 |
| SUsda+CW | 2653 | 3134 | 3787 | 4733 |

Table A4.3.B5: NPV of a perpetual series of optimal rotations of Beech: r = 3%
Various yield classes and subsidy types
Producer Financial Values (£; 1990 prices)

| Subsidy Type | YC4 | YC6 | YC8 | YC10 |
|---|---|---|---|---|
| SInda-CW | 4274 | 4836 | 5576 | 6615 |
| SIda-CW | 3502 | 4057 | 4791 | 5826 |
| SIsda-CW | 2730 | 3277 | 4006 | 5038 |
| SInda+CW | 5852 | 6414 | 7155 | 8193 |
| SIda+CW | 5079 | 5635 | 6370 | 7405 |
| SIsda+CW | 4307 | 4855 | 5585 | 6617 |
| SUnda-CW | 428 | 954 | 1667 | 2689 |
| SUda-CW | 1200 | 1734 | 2452 | 3478 |
| SUsda-CW | 1200 | 1734 | 2452 | 3478 |
| SUnda+CW | 2005 | 2532 | 3245 | 4268 |
| SUda+CW | 2777 | 3312 | 4030 | 5056 |
| SUsda+CW | 2777 | 3312 | 4030 | 5056 |

Table A4.3.B6: Annualised equivalent of a perpetual series of optimal rotations of Beech: r = 3%
Various yield classes and subsidy types
Producer Financial Values (£; 1990 prices)

| Subsidy Type | YC4 | YC6 | YC8 | YC10 |
|---|---|---|---|---|
| SInda-CW | 128.23 | 145.09 | 167.29 | 198.44 |
| SIda-CW | 105.06 | 121.70 | 143.74 | 174.79 |
| SIsda-CW | 81.89 | 98.32 | 120.19 | 151.14 |
| SInda+CW | 175.55 | 192.43 | 214.65 | 245.80 |
| SIda+CW | 152.38 | 169.04 | 191.10 | 222.16 |
| SIsda+CW | 129.21 | 145.66 | 167.54 | 198.51 |
| SUnda-CW | 12.83 | 28.63 | 50.00 | 80.68 |
| SUda-CW | 36.00 | 52.01 | 73.55 | 104.33 |
| SUsda-CW | 36.00 | 52.01 | 73.55 | 104.33 |
| SUnda+CW | 60.15 | 75.97 | 97.35 | 128.05 |
| SUda+CW | 83.32 | 99.35 | 120.91 | 151.69 |
| SUsda+CW | 83.32 | 99.35 | 120.91 | 151.69 |

Table A4.3.B7: NPV of an optimal rotation of Beech: r = 6%
Various yield classes and subsidy types
Producer Financial Values (£; 1990 prices)

| Subsidy Type | YC4 | YC6 | YC8 | YC10 |
|---|---|---|---|---|
| SInda-CW | 3296 | 3365 | 3479 | 3680 |
| SIda-CW | 2679 | 2748 | 2861 | 3062 |
| SIsda-CW | 2061 | 2130 | 2244 | 2445 |
| SInda+CW | 4396 | 4461 | 4571 | 4769 |
| SIda+CW | 3778 | 3843 | 3953 | 4151 |
| SIsda+CW | 3160 | 3225 | 3335 | 3533 |
| SUnda-CW | 123 | 192 | 305 | 506 |
| SUda-CW | 740 | 809 | 923 | 1124 |
| SUsda-CW | 740 | 809 | 923 | 1124 |
| SUnda+CW | 1222 | 1287 | 1397 | 1595 |
| SUda+CW | 1840 | 1905 | 2015 | 2212 |
| SUsda+CW | 1840 | 1905 | 2015 | 2212 |

Table A4.3.B8: NPV of a perpetual series of optimal rotations of Beech: r = 6%
Various yield classes and subsidy types
Producer Financial Values (£; 1990 prices)

| Subsidy Type | YC4 | YC6 | YC8 | YC10 |
|---|---|---|---|---|
| SInda-CW | 3338 | 3427 | 3560 | 3782 |
| SIda-CW | 2713 | 2798 | 2928 | 3147 |
| SIsda-CW | 2087 | 2169 | 2296 | 2512 |
| SInda+CW | 4452 | 4542 | 4677 | 4901 |
| SIda+CW | 3826 | 3913 | 4045 | 4266 |
| SIsda+CW | 3201 | 3284 | 3413 | 3631 |
| SUnda-CW | 124 | 195 | 312 | 520 |
| SUda-CW | 750 | 824 | 944 | 1155 |
| SUsda-CW | 750 | 824 | 944 | 1155 |
| SUnda+CW | 1237 | 1310 | 1429 | 1639 |
| SUda+CW | 1863 | 1939 | 2061 | 2274 |
| SUsda+CW | 1863 | 1939 | 2061 | 2274 |

Table A4.3.B9: Annualised equivalent of a perpetual series of optimal rotations of Beech: r = 6%
Various yield classes and subsidy types
Producer Financial Values (£; 1990 prices)

| Subsidy Type | YC4 | YC6 | YC8 | YC10 |
|---|---|---|---|---|
| SInda-CW | 200.31 | 205.61 | 213.57 | 226.92 |
| SIda-CW | 162.77 | 167.87 | 175.65 | 188.83 |
| SIsda-CW | 125.24 | 130.13 | 137.73 | 150.74 |
| SInda+CW | 267.11 | 272.53 | 280.60 | 294.04 |
| SIda+CW | 229.57 | 234.79 | 242.68 | 255.95 |
| SIsda+CW | 192.04 | 197.05 | 204.76 | 217.86 |
| SUnda-CW | 7.44 | 11.71 | 18.73 | 31.21 |
| SUda-CW | 44.98 | 49.44 | 56.66 | 69.30 |
| SUsda-CW | 44.98 | 49.44 | 56.66 | 69.30 |
| SUnda+CW | 74.25 | 78.62 | 85.76 | 98.34 |
| SUda+CW | 111.78 | 116.36 | 123.68 | 136.43 |
| SUsda+CW | 111.78 | 116.36 | 123.68 | 136.43 |

Table A4.3.B10: NPV of an optimal rotation of Beech: r = 12%
Various yield classes and subsidy types
Producer Financial Values (£; 1990 prices)

| Subsidy Type | YC4 | YC6 | YC8 | YC10 |
|---|---|---|---|---|
| SInda-CW | 2551 | 2552 | 2559 | 2582 |
| SIda-CW | 2093 | 2095 | 2101 | 2125 |
| SIsda-CW | 1635 | 1637 | 1643 | 1667 |
| SInda+CW | 3533 | 3534 | 3539 | 3563 |
| SIda+CW | 3076 | 3076 | 3082 | 3105 |
| SIsda+CW | 2618 | 2619 | 2624 | 2647 |
| SUnda-CW | 44 | 45 | 52 | 75 |
| SUda-CW | 501 | 503 | 509 | 533 |
| SUsda-CW | 501 | 503 | 509 | 533 |
| SUnda+CW | 1026 | 1027 | 1032 | 1056 |
| SUda+CW | 1484 | 1485 | 1490 | 1513 |
| SUsda+CW | 1484 | 1485 | 1490 | 1513 |

Table A4.3.B11: NPV of a perpetual series of optimal rotations of Beech: r = 12%
Various yield classes and subsidy types
Producer Financial Values (£; 1990 prices)

| Subsidy Type | YC4 | YC6 | YC8 | YC10 |
|---|---|---|---|---|
| SInda-CW | 2555 | 2562 | 2574 | 2599 |
| SIda-CW | 2097 | 2102 | 2114 | 2139 |
| SIsda-CW | 1638 | 1643 | 1653 | 1678 |
| SInda+CW | 3540 | 3547 | 3560 | 3586 |
| SIda+CW | 3081 | 3088 | 3100 | 3126 |
| SIsda+CW | 2623 | 2628 | 2640 | 2665 |
| SUnda-CW | 44 | 45 | 52 | 76 |
| SUda-CW | 502 | 505 | 512 | 536 |
| SUsda-CW | 502 | 505 | 512 | 536 |
| SUnda+CW | 1028 | 1031 | 1039 | 1063 |
| SUda+CW | 1487 | 1490 | 1499 | 1523 |
| SUsda+CW | 1487 | 1490 | 1499 | 1523 |

Table A4.3.B12: Annualised equivalent of a perpetual series of optimal rotations of Beech: r = 12%
Various yield classes and subsidy types
Producer Financial Values (£; 1990 prices)

| Subsidy Type | YC4 | YC6 | YC8 | YC10 |
|---|---|---|---|---|
| SInda-CW | 323.95 | 324.75 | 326.31 | 329.55 |
| SIda-CW | 265.82 | 266.51 | 267.94 | 271.14 |
| SIsda-CW | 207.69 | 208.27 | 209.58 | 212.73 |
| SInda+CW | 448.75 | 449.67 | 451.38 | 454.67 |
| SIda+CW | 390.62 | 391.43 | 393.01 | 396.26 |
| SIsda+CW | 332.49 | 333.19 | 334.64 | 337.84 |
| SUnda-CW | 5.54 | 5.74 | 6.59 | 9.59 |
| SUda-CW | 63.67 | 63.98 | 64.96 | 68.00 |
| SUsda-CW | 63.67 | 63.98 | 64.96 | 68.00 |
| SUnda+CW | 130.34 | 130.66 | 131.66 | 134.71 |
| SUda+CW | 188.47 | 188.90 | 190.03 | 193.12 |
| SUsda+CW | 188.47 | 188.90 | 190.03 | 193.12 |

Table A4.3.B13: NPV of an optimal rotation of Beech: r = 6%
(Hyperbolic discounting)
Various yield classes and subsidy types
Producer Financial Values (£; 1990 prices)

| Subsidy Type | YC4 | YC6 | YC8 | YC10 |
|---|---|---|---|---|
| SInda-CW | 4303 | 5279 | 6450 | 8079 |
| SIda-CW | 3647 | 4623 | 5793 | 7423 |
| SIsda-CW | 2991 | 3967 | 5137 | 6766 |
| SInda+CW | 5963 | 6902 | 8046 | 9661 |
| SIda+CW | 5307 | 6245 | 7389 | 9005 |
| SIsda+CW | 4651 | 5589 | 6733 | 8349 |
| SUnda-CW | 969 | 1945 | 3115 | 4744 |
| SUda-CW | 1625 | 2601 | 3771 | 5401 |
| SUsda-CW | 1625 | 2601 | 3771 | 5401 |
| SUnda+CW | 2629 | 3567 | 4711 | 6327 |
| SUda+CW | 3285 | 4224 | 5368 | 6983 |
| SUsda+CW | 3285 | 4224 | 5368 | 6983 |

Table A4.3.B14: NPV of a perpetual series of optimal rotations of Beech: r = 6%
(Hyperbolic discounting)
Various yield classes and subsidy types
Producer Financial Values (£; 1990 prices)

| Subsidy Type | YC4 | YC6 | YC8 | YC10 |
|---|---|---|---|---|
| SInda-CW | 4986 | 6168 | 7581 | 9527 |
| SIda-CW | 4226 | 5401 | 6810 | 8753 |
| SIsda-CW | 3465 | 4635 | 6038 | 7979 |
| SInda+CW | 6910 | 8064 | 9457 | 11393 |
| SIda+CW | 6149 | 7297 | 8686 | 10619 |
| SIsda+CW | 5389 | 6530 | 7914 | 9845 |
| SUnda-CW | 1122 | 2272 | 3662 | 5595 |
| SUda-CW | 1883 | 3039 | 4433 | 6369 |
| SUsda-CW | 1883 | 3039 | 4433 | 6369 |
| SUnda+CW | 3046 | 4168 | 5538 | 7461 |
| SUda+CW | 3806 | 4935 | 6309 | 8235 |
| SUsda+CW | 3806 | 4935 | 6309 | 8235 |

**Table A4.3.B15:** **Annualised equivalent of a perpetual series of optimal rotations of Beech: r = 6% (Hyperbolic discounting)**
**Various yield classes and subsidy types**
**Producer Financial Values (£; 1990 prices)**

| Subsidy Type | YC4 | YC6 | YC8 | YC10 |
|---|---|---|---|---|
| SInda-CW | 299.17 | 370.09 | 454.88 | 571.61 |
| SIda-CW | 253.55 | 324.09 | 408.59 | 525.17 |
| SIsda-CW | 207.92 | 278.08 | 362.31 | 478.74 |
| SInda+CW | 414.59 | 483.82 | 567.44 | 683.57 |
| SIda+CW | 368.96 | 437.81 | 521.15 | 637.14 |
| SIsda+CW | 323.34 | 391.81 | 474.87 | 590.71 |
| SUnda-CW | 67.35 | 136.34 | 219.70 | 335.68 |
| SUda-CW | 112.97 | 182.35 | 265.99 | 382.11 |
| SUsda-CW | 112.97 | 182.35 | 265.99 | 382.11 |
| SUnda+CW | 182.76 | 250.07 | 332.27 | 447.65 |
| SUda+CW | 228.39 | 296.07 | 378.55 | 494.08 |
| SUsda+CW | 228.39 | 296.07 | 378.55 | 494.08 |

# APPENDIX 4.4: SOCIAL TIMBER VALUES - BASE FIGURES

In contrast with appendix 4.3, here we remove all subsidy and grant payments to provide base data for our analysis of the social value of timber production (in fact these models were actually calculated first and then adapted to produce the farm financial results reported previously). As explained in chapter 6 this data ignores both transfer payments and externalities. The economic security value of domestic supply is dealt with in appendix 4.5 while the external benefits of recreation and carbon sequestration are dealt with in other chapters.

Again results are detailed across all YC and discount rates although we explain in chapter 6 that the 12% rate is indefensible as a social discount rate while the 6% (exponential) rate can also be criticised. Both are included for comparison with the private values reported previously. Tables A4.4.1 to A4.4.3 detail respectively: optimal NPV; perpetual rotation NPV; and the latter's annual equivalent for Sitka spruce. Tables A4.4.B1 to A4.4.B3 repeat this analysis for beech.

**Table A4.4.1:** **NPV of timber for an optimal rotation of conifer (Sitka spruce): excludes all externalities**
**Various Yield Classes and Discount Rates**
**Social values (£; 1990 prices)**

| Discount rate | YC6 | YC8 | YC10 | YC12 | YC14 | YC16 | YC18 | YC20 | YC22 | YC24 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.5% | 755.64 | 2804.17 | 5086.14 | 6690.70 | 8774.75 | 10845.10 | 12870.00 | 14788.30 | 16668.50 | 18936.60 |
| 3% | -708.55 | 166.55 | 1298.91 | 2406.09 | 3512.30 | 4477.13 | 5589.82 | 6990.40 | 8202.61 | 9618.32 |
| 6% | -1242.46 | -1069.74 | -760.29 | -458.82 | -38.90 | 333.70 | 871.05 | 1344.60 | 1837.44 | 2505.73 |
| 12% | -1119.74 | -1111.86 | -1092.56 | -1059.35 | -1018.83 | -955.23 | -901.17 | -817.99 | -708.14 | -560.01 |
| 6% HYP | -50.57 | 1154.31 | 2474.71 | 3475.82 | 4504.99 | 5347.67 | 6422.87 | 7866.00 | 8966.00 | 10290.30 |

**Table A4.4.2:** **NPV of timber for a perpetual series of optimal rotations for conifer (Sitka spruce): excludes all externalities**
**Various yield classes and discount rates**
**Social values (£; 1990 prices)**

| Discount rate | YC6 | YC8 | YC10 | YC12 | YC14 | YC16 | YC18 | YC20 | YC22 | YC24 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.5% | 1042.83 | 3918.72 | 7300.96 | 10334.60 | 13073.70 | 16287.90 | 19652.30 | 22581.40 | 25452.50 | 29165.70 |
| 3% | -801.14 | 189.06 | 1493.14 | 2848.56 | 4230.33 | 5460.38 | 6862.65 | 8582.15 | 10139.60 | 11889.70 |
| 6% | -1281.31 | -1107.46 | -790.54 | -479.44 | -41.13 | 356.77 | 948.48 | 1471.97 | 2022.99 | 2775.58 |
| 12% | -1123.85 | -1117.71 | -1099.05 | -1066.44 | -1026.52 | -963.36 | -910.94 | -829.28 | -720.59 | -571.13 |
| 6% HYP | -62.12 | 1421.51 | 3072.47 | 4395.35 | 5756.38 | 6884.35 | 8300.90 | 10166.00 | 11634.50 | 13352.90 |

Table A4.4.3: **Annuity value of timber from a perpetual series of rotations for conifer (Sitka spruce): excludes all externalities**
**Various yield classes and discount rates**
**Social values (£; 1990 prices)**

| Discount rate | YC6 | YC8 | YC10 | YC12 | YC14 | YC16 | YC18 | YC20 | YC22 | YC24 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.5% | 16.95 | 63.68 | 118.64 | 167.94 | 212.45 | 264.68 | 319.35 | 366.95 | 413.60 | 473.94 |
| 3% | -24.03 | 5.67 | 44.79 | 85.46 | 126.91 | 163.81 | 205.88 | 257.47 | 304.19 | 356.69 |
| 6% | -76.88 | -66.45 | -47.43 | -28.77 | -2.47 | 21.41 | 56.91 | 88.32 | 121.38 | 166.54 |
| 12% | -142.48 | -141.70 | -139.33 | -135.20 | -130.14 | -122.13 | -115.49 | -105.13 | -91.35 | -72.41 |
| 6% HYP | -3.73 | 85.29 | 184.35 | 263.72 | 345.38 | 413.06 | 498.05 | 609.96 | 698.07 | 801.17 |

**Table A4.4.B1:** NPV of timber for an optimal rotation of broadleaf (beech): excludes all externalities
Various yield classes and discount rates
Social values (£; 1990 prices)

| Discount rate | YC4 | YC6 | YC8 | YC10 |
|---|---|---|---|---|
| 1.5% | -897.94 | 235.22 | 1658.86 | 3626.75 |
| 3% | -1238.60 | -744.06 | -81.11 | 870.08 |
| 6% | -1240.85 | -1171.76 | -1058.17 | -857.17 |
| 12% | -1072.23 | -1070.74 | -1064.20 | -1040.74 |
| 6% HYP | -565.18 | 411.07 | 1581.35 | 3210.55 |

**Table A4.4.B2:** NPV of timber for a perpetual series of optimal rotations for broadleaves (beech): excludes all externalities
Various yield classes and discount rates
Social values (£; 1990 prices)

| Discount rate | YC4 | YC6 | YC8 | YC10 |
|---|---|---|---|---|
| 1.5% | -1036.08 | 274.96 | 1944.44 | 4263.04 |
| 3% | -1296.80 | -786.19 | -86.32 | 929.57 |
| 6% | -1256.74 | -1193.17 | -1082.70 | -880.94 |
| 12% | -1074.15 | -1074.67 | -1070.52 | -1047.71 |
| 6% HYP | -654.89 | 480.27 | 1858.78 | 3785.92 |

**Table A4.4.B3:** Annuity values of timber from a perpetual series of rotations for broadleaves (beech): excludes all externalities
Various yield classes and discount rates
Social values (£; 1990 prices)

| Discount rate | YC4 | YC6 | YC8 | YC10 |
|---|---|---|---|---|
| 2% | -16.84 | 4.47 | 31.60 | 69.27 |
| 3% | -38.91 | -23.59 | -2.59 | 27.89 |
| 6% | -75.41 | -71.59 | -64.96 | -52.86 |
| 12% | -136.18 | -136.24 | -135.72 | -132.83 |
| 6% HYP | -39.29 | 28.82 | 111.53 | 227.16 |

# APPENDIX 4.5: SOCIAL TIMBER VALUES - INCLUDING ECONOMIC SECURITY VALUE

Following our discussions of chapter 6, if we set aside woodland recreation and carbon sequestration values for subsequent analysis, then only the economic security value of domestic supply is sufficiently quantified to augment our social evaluation of timber production. This appendix extends the base data figures detailed in appendix 4.4 to include this economic security value. Layout of tables is as before.

**Table A4.5.1:** NPV of timber and economic security factor for an optimal rotation of conifer (Sitka spruce). Excludes all other externalities. Various yield classes and discount rates.
Social values (£; 1990 prices)

| Discount rate | YC6 | YC8 | YC10 | YC12 | YC14 | YC16 | YC18 | YC20 | YC22 | YC24 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.5% | 786.17 | 2855.10 | 5159.73 | 7083.13 | 8885.01 | 10976.00 | 13021.10 | 14958.60 | 16857.60 | 19148.40 |
| 3% | -697.10 | 186.90 | 1330.62 | 2448.78 | 3566.03 | 4540.49 | 5664.31 | 7078.95 | 8303.29 | 9733.21 |
| 6% | -1240.59 | -1066.01 | -753.37 | -448.82 | -24.64 | 351.69 | 894.41 | 1372.73 | 1870.55 | 2545.56 |
| 12% | -1119.65 | -1111.65 | -1092.12 | -1058.54 | -1017.57 | -953.31 | -898.68 | -814.64 | -703.66 | -553.10 |
| 6% HYP | -33.44 | 1183.55 | 2517.11 | 3528.02 | 4567.41 | 5418.45 | 6504.40 | 7962.00 | 9072.99 | 10410.60 |

**Table A4.5.2:** NPV of timber and economic security factor for a perpetual series of optimal rotations of conifer (Sitka spruce). Excludes all other externalities. Various yield classes and discount rates.
Social values (£; 1990 prices)

| Discount rate | YC6 | YC8 | YC10 | YC12 | YC14 | YC16 | YC18 | YC20 | YC22 | YC24 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.5% | 1084.17 | 3989.90 | 7406.60 | 10471.20 | 13237.90 | 16484.60 | 19883.00 | 22841.50 | 25741.30 | 29491.80 |
| 3% | -788.20 | 212.16 | 1529.60 | 2899.10 | 4295.05 | 5537.65 | 6954.10 | 8690.86 | 10264.10 | 12031.70 |
| 6% | -1279.37 | -1103.60 | -783.35 | -468.99 | -26.06 | 376.00 | 973.91 | 1502.76 | 2059.44 | 2819.70 |
| 12% | -1123.77 | -1117.50 | -1098.60 | -1065.63 | -1025.25 | -961.43 | -908.42 | -825.88 | -716.03 | -565.00 |
| 6% HYP | -41.18 | 1457.52 | 3125.11 | 4461.36 | 5836.14 | 6975.48 | 8406.26 | 10290.10 | 11773.30 | 13509.00 |

**Table A4.5.3:** **Annuity value of timber and economic security factor for a perpetual series of optimal rotations of conifer (Sitka spruce). Excludes all other externalities. Various yield classes and discount rates. Social values (£; 1990 prices)**

| Discount rate | YC6 | YC8 | YC10 | YC12 | YC14 | YC16 | YC18 | YC20 | YC22 | YC24 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.5% | 17.63 | 64.84 | 120.36 | 170.16 | 215.12 | 267.87 | 323.10 | 371.17 | 418.30 | 479.24 |
| 3% | -23.65 | 6.36 | 45.89 | 86.97 | 128.85 | 166.13 | 208.62 | 260.73 | 307.92 | 360.95 |
| 6% | -76.76 | -66.22 | -47.00 | -28.14 | -1.56 | 22.56 | 58.43 | 90.17 | 123.57 | 169.18 |
| 12% | -142.47 | -141.67 | -139.28 | -135.10 | -129.98 | -121.89 | -115.17 | -104.70 | -90.78 | -71.63 |
| 6% HYP | -2.46 | 87.45 | 187.51 | 267.68 | 350.17 | 418.53 | 504.38 | 617.40 | 706.40 | 810.54 |

**Table A4.5.B1:** **NPV of timber and economic security factor for an optimal rotation of broadleaves (beech). Excludes all other externalities. Various yield classes and discount rates**
**Social values (£; 1990 prices)**

| Discount rate | YC4 | YC6 | YC8 | YC10 |
|---|---|---|---|---|
| 1.5% | -886.09 | 258.62 | 1696.66 | 3684.20 |
| 3% | -1233.73 | -733.98 | -64.24 | 896.44 |
| 6% | -1240.19 | -1170.18 | -1055.28 | -852.28 |
| 12% | -1072.18 | -1070.61 | -1063.92 | -1040.23 |
| 6% HYP | -553.56 | 432.47 | 1614.46 | 3259.89 |

**Table A4.5.B2:** **NPV of timber and economic security factor for an optimal rotation of broadleaves (beech). Excludes all other externalities. Various yield classes and discount rates**
**Social values (£; 1990 prices)**

| Discount rate | YC4 | YC6 | YC8 | YC10 |
|---|---|---|---|---|
| 1.5% | -1022.41 | 302.31 | 1988.74 | 4330.56 |
| 3% | -1291.71 | -775.54 | -68.36 | 957.72 |
| 6% | -1256.07 | -1191.56 | -1079.74 | -875.91 |
| 12% | -1074.11 | -1074.54 | -1070.24 | -1047.19 |
| 6% HYP | -641.43 | 505.27 | 1897.70 | 3844.10 |

**Table A4.5.B3:** **NPV of timber and economic security factor for an optimal rotation of broadleaves (beech). Excludes all other externalities. Various yield classes and discount rates**
**Social values (£; 1990 prices)**

| Discount rate | YC4 | YC6 | YC8 | YC10 |
|---|---|---|---|---|
| 1.5% | -16.61 | 4.91 | 32.32 | 70.37 |
| 3% | -38.75 | -23.27 | -2.05 | 28.73 |
| 6% | -75.36 | -71.49 | -64.78 | -52.55 |
| 12% | -136.17 | -136.23 | -135.68 | -132.76 |
| 6% HYP | -38.49 | 30.32 | 113.86 | 230.65 |

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# Appendix 5: Yield Class Models

## A5.1 DESCRIPTION OF VARIABLES IN THE LANDIS DATABASE

This section describes the variables in the LandIS database and their estimation. In each case the variable name used in our analyses is given in brackets at the end of each section heading.

### A5.1.1 ACCUMULATED TEMPERATURE (Acctemp)

Accumulated temperature (AT) is the integrated excess of temperature, above a fixed value, over an extended period such as a month or a year (Shellard, 1959). When calculated over the growing season it is regarded as a reasonable guide to energy input.

An early investigation into AT mapping is reported by Bendelow and Hartnup (1980) who use data for 139 stations in England and Wales for the period 1931-60 (Meteorological Office, 1963). The LandIS database uses the same dataset to calculate AT values for temperatures > 0°C at 5km intervals by relating observed AT to altitude and grid reference using the equation (A5.1):

$$AT = \beta_0 + \beta_1 ALT + \beta_2 LAT + \beta_3 LON \qquad (A5.1)$$

where:

ALT = altitude in m OD
LAT = 4 digit OS National Grid northing
LON = 4 digit OS National Grid easting
AT = degrees above 0°C

The LandIS database uses the following coefficient values:

$\beta_0$ = 1785.03
$\beta_1$ = 1.1217
$\beta_2$ = -0.0494
$\beta_3$ = -0.0310
$R^2$ = 91%

While equation (A5.1) fits the data well, generating spatial data sets by regression leads to smoothing of the data and there are some differences between estimated and measured accumulated temperature at specific sites. On average these are about 2°C.

### A5.1.2 GROWING SEASON (Growseas)

The growing season (GS) is frequently used to assess the potential agricultural productivity of the land. In the past this was done by measuring the period of days in which air temperatures were above 6°C, however, soil temperatures are now thought more appropriate. Variations in growing season depend chiefly on altitude, slope and aspect.

The growing season, as defined by Smith (1976), is the period that the soil temperature, at 30 cm depth, remains above 6°C. The average date of increase above 6°C is assumed to be the start of the growing season while the average date of decrease below 6°C is assumed to be its end. Smith reports growing season for 55 MAFF agroclimatic areas in England and Wales for the period 1941-70. These data figures have been analysed by Jones and Thomasson (1985) to give equations for the growing season and grazing season length dependent upon altitude, latitude and longitude, as detailed in equation (A5.2):

$$GS = \beta_o + \beta_1 ALT + \beta_2 LAT + \beta_3 LON \quad (A5.2)$$

where GS = growing season (in days)

other variables as previously defined

The LandIS database calculates GS using the following coefficients:

$\beta_o$ = 353.17
$\beta_1$ = -0.2260
$\beta_2$ = -0.0098
$\beta_3$ = -0.0119
R = 89%

Again this model fits the data well and is used to generate the 5km data held in LandIS.

### 5.1.3 GRAZING SEASON (Growseas)

The grazing season (GZ) is defined by Smith (1976) as the period for which animals can be put to graze with some expectation of adequate fodder and without risk of damage by treading. It is related to but not coincident with the growing season. In spring, time must elapse after the start of appreciable grass growth before it is feasible to graze stock and experience suggests that this delay increases with altitude. Smith assumed a 5 day delay to the beginning of the season at altitudes up to 50m OD, plus one further day for every 25m increase in altitude up to a maximum of 15 days at 300m OD and above. The date of return to field capacity (see subsequent description) has been adopted as the end of the growing season.

As with growing season, variation depends mainly on altitude, slope and aspect, though rainfall may also be a factor. Jones and Thomasson (1985) estimate grazing season using the same regression model as for growing season as shown in equation (A5.3):

$$GZ = \beta_o + \beta_1 ALT + \beta_2 LAT + \beta_3 LON \quad (A5.3)$$

where GZ = length of grazing season (in days)

other variables as previously defined

The LandIS database calculates GZ using the following coefficients derived from data for the 1941-1970 period:

$\beta_o$ = 238.9
$\beta_1$ = -0.4243
$\beta_2$ = -0.0072
$\beta_3$ = 0.0074
$R^2$ = 85%

### 5.1.4 MOISTURE DEFICIT FOR GRASS (Mdefgra)

Potential evapotranspiration (PT) is defined as the water transpired by a short green crop such as grass which completely covers the ground and is amply supplied with water around the roots. Given these conditions PT varies with meteorological conditions. When combined with rainfall it is used to calculate the potential soil moisture deficit (PSMD) as shown in equation (A5.4):

$$PSMD = \Sigma (R - PT) \quad (A5.4)$$

where:

R = Rainfall (mm)
PT = Potential Evapotranspiration (mm)

Jones and Thomasson (1985) extract monthly rainfall totals (in mm) for 970 stations for 1961-75 from the Meteorological Office Hydranet dataset. Calculated monthly PT values (Penman, 1948) were also obtained from the Meteorological Office for approximately 40 'evaporation' stations in England and Wales which had reliable and complete datasets for the same period. Data from 35 of these were found to fit the national pattern according to Grindley's (1970) isopletus of average PT for 1956-75, and were considered suitable for calculating deficits.

To calculate moisture deficits, PT data were need for each rainfall station. These were estimated using PT data from the nearest evaporation station and the altitude data for each of the rainfall stations. The relationship between PT and altitude is shown in table A5.1.

Table A5.1: Decrease in potential evapotranspiration with altitude

| Month | mm/100m rise |
|---|---|
| Jan | 1.5 |
| Feb | 2.0 |
| Mar | 3.0 |
| Apr | 3.5 |
| May | 3.5 |
| Jun | 3.0 |
| Jul | 3.0 |
| Aug | 2.5 |
| Sep | 2.0 |
| Oct | 1.5 |
| Nov | 1.0 |
| Dec | 1.0 |
| Winter | 10.0 |
| Summer | 17.5 |
| Total | 27.5 |

The data selected for each rainfall station was the estimated average annual PT that fitted most closely to the Grindley isopletus.

The monthly moisture deficits for the years 1961-75 were calculated from monthly moisture balances of R- PT and the values, when negative, accumulated to give month end PSMD. A deficit usually develops in April or May, reaches a maximum in July, August or September and declines during Autumn. The seasonal maximum PSMD was determined for each year from 1961-75 together with the month at the end of which it occurred. The mean of the maximum PSMD values was calculated for the 15 year period for each rainfall station.

### 5.1.5 MOISTURE DEFICIT FOR SUGAR BEET/POTATOES (Mdefsbpt)

Maximum PSMD is mainly relevant to grass and adjustments are needed in calculating moisture deficits for areal and root crops to allow for limited ground cover early in the season. These are fully described by Thomasson (1979) but a brief outline is given below. The adjusted deficits for sugar beet and potatoes, termed MD or Mdefsbpt, are calculated as per equation (A5.5):

Mdefsbpt = (August PSMD) - 1/3 (June PSMD) - 1/3 (mid-May PSMD) (A5.5)

The adjustment is needed for sugar beet and potatoes because the ground is bare until mid-May and full ground cover is achieved about the end of June. Growth then continues throughout the period of maximum deficit, often until the end of August. These crop adjusted MD values are always smaller than the maximum PSMD and this accords with field experience.

In the wetter part of Wales, the period of PSMD is short, often restricted to parts of May, June, or July, and the maximum PSMD is normally less than 50mm on average. Some dry districts can have average PSMD values of over 200mm and in the drier years can be as large as 300mm. Such values are far in excess of the water reserves of most soils and unlikely to be achieved in practice even under grass growing throughout the summer. However, large potential deficits do suggest the amount of irrigation water that would be required to sustain continuous growth of a sensitive crop.

### 5.1.6 MOISTURE DEFICIT FOR CEREALS (Mdefcer)

This is calculated for winter wheat and spring barley in a similar manner to Mdefsbpt using the equations (A5.6) and (A5.7):

MD (winter wheat) = (mid-July PSMD) - 1/3 (April PSMD) (A5.6)

MD (spring barley) = (mid-July PSMD) - 1/3 (mid-May PSMD) (A5.7)

The LandIS variable Mdefcer is a midpoint between these two.

### 5.1.7 PLANT AVAILABLE WATER (Avwatgra, Avwatcer, Avwatpot)

Available water is the amount of water in a soil available for plant growth after excess moisture has drained away under the influence of gravity (Rudeforth et al., 1984). This therefore varies according to both the soil type and the crop in question. LandIS consequently provides three measures of available water for each grid reference, namely that for grass (Avwatgra), cereals (Avwatcer) and sugar-beet/potatoes (Avwatpot).

### 5.1.8 AVERAGE ANNUAL RAINFALL (Rainfall)

Rainfall is the dominant influence on both the duration of field capacity and soil moisture conditions. The LandIS spatial dataset of average annual rainfall (AAR) is interpolated from the 1:625,000 rainfall map for 1941-70 (Meteorological Office, 1977). Values of AAR to the nearest 25mm were chosen for individual 10km squares where the map has isohyets at 50mm intervals (districts receiving less than 1000mm). Values at 50mm intervals were interpolated for rainfall totals up to 1200mm and, for larger AAR's, 100mm intervals were chosen. It is accepted that where a significant rainfall gradient occurs within a single 10km square, the interpolated average will be only an approximation of the AAR for certain part of that square.

### 5.1.9 FIELD CAPACITY DAYS (Fcapdays)

The term field capacity (Fcap) is used in the meteorological sense to mean the condition of zero soil moisture deficit rather than an specific water content or water potential (Webster and Beckett, 1972). The average meteorological field capacity period has been estimated by Smith and Trafford (1976) from rainfall and potential evapotranspiration (PT) data for 1941-70, using a standard soil-water abstraction model for short rooted crops (Smith 1967). The maximum amount of water extractable from the soil during a growing season is assumed to be 125mm. Many soils contain more than 125mm of available water and some have considerably less, so the field capacity data presented here should be regarded as benchmark values which need adjustment before they represent the condition of specific soils.

The duration of field capacity is useful for investigating the degree of soil wetness. Over England and Wales the duration of meteorological Fcap is shortest in East Anglia with factor which reflected these interrelations might therefore prove a strong predictor of tree growth. Norusis (1985) identifies four steps in conducting a PCA:

1. A correlation matrix is prepared so that variables which do not appear to be related to others within the dataset can be identified (suppression-type problems can also be identified at this stage). The appropriateness of PCA can also be assessed at this point;
2. The number of factors necessary to adequately represent the dataset is identified. Clearly unless this is substantially less than the number of variables then the exercise is of little value;
3. The factors may be transformed (rotated) to make them more interpretable;
4. Factor scores are computed to indicate how individual observations perform on each factor. These may then be used as predictors within a regression model.

Inspection of summary statistics (see chapter 7, table 7.5) suggested that environmental explanatory variables may vary significantly between Sitka spruce and beech plantations and so separate PCAs were conducted for each species.

When an initial attempt was made to undertake PCA using the FACTOR command of SPSS-X, a warning message of the form 'ill conditioned data matrix' was encountered (though results were generated). Further investigation suggested that this situation might reflect either:

i. variables with a very small coefficient of variation (e.g. <0.002%)

or ii. high correlations between a number of the input variables.

Subsequent calculations suggested that the former was unlikely to be a problem (see chapter 7, table 7.5) but that the latter might well be. It is almost ironic that while PCA searches out for relationships between variables, if some of these are extremely strong then calculation problems can exist. To investigate this possibility, Pearson correlation matrices were calculated for both Sitka spruce and beech datasets of environmental variables. These are reported as tables A5.2 and A5.3 respectively. These tables cover all the LandIS variables discussed in the previous section and five further variables (Wselvgr2, Dsl2, Wsaspgr2, Topex1km and Wind1km2) which were either specially created for this research or supplied by the Forestry Commission. Further details regarding these variables are given in chapter 7.

Inspection of tables A5.2 and A5.3 indicated no problem with any of the non-LandIS variables. However, the LandIS variables were found to form five internally correlated groups as follows:

<u>Group 1</u>: *Acctemp; Growseas; Grazseas
<u>Group 2</u>: *Rainfall; RetWet; RetMed; RetDry; *FcapDays; EndWet; *EndMed; EndDry
<u>Group 3</u>: *MdefGra; MdefCer; MdefSbpt
<u>Group 4</u>: *AvwatGra; AvwatCer; AvwatPot
<u>Group 5</u>: AutMWD; *SprMWD

Within each of these groups, one or more (depending upon the degree of correlation) variables were chosen to be entered into the PCA (marked * above). Choice of variable depended upon the biological plausibility of a relationship with YC, the degree of correlation with other variables and the consequent requirement that the resultant data matrix should not be ill-conditioned. All these conditions were satisfied.

Table A5.2: Pearson correlation coefficients: Sitka spruce sub-compartments

| | Acc temp | Grow seas | Gras seas | Rainfall | Ret Wet | Ret Med | Ret Dry | End Wet | End Med | End Dry | Fcap Days | Mdef gra | Mde fcer | Mdef sbpt | Avwat Gra | Avwat Cer | Avwat Pot | Work abil | Aut MWD | Spr MWD | Wsel vgr2 | Dsl2 | Wsas pgr2 | Topex 1km2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Growseas | 1.00 | | | | | | | | | | | | | | | | | | | | | | | |
| Grazseas | 0.99 | 0.99 | | | | | | | | | | | | | | | | | | | | | | |
| Rainfall | -0.32 | -0.30 | -0.34 | | | | | | | | | | | | | | | | | | | | | |
| RetWet | 0.33 | 0.31 | 0.37 | -0.90 | | | | | | | | | | | | | | | | | | | | |
| RetMed | 0.35 | 0.33 | 0.37 | -0.96 | 0.97 | | | | | | | | | | | | | | | | | | | |
| RetDry | 0.34 | 0.32 | 0.36 | -0.97 | 0.94 | 0.99 | | | | | | | | | | | | | | | | | | |
| EndWet | -0.35 | -0.33 | 0.39 | 0.81 | -0.94 | -0.89 | -0.85 | | | | | | | | | | | | | | | | | |
| EndMed | -0.37 | -0.35 | 0.37 | 0.95 | -0.88 | -0.96 | -0.97 | 0.81 | | | | | | | | | | | | | | | | |
| EndDry | -0.32 | -0.30 | 0.33 | 0.95 | -0.83 | -0.94 | -0.97 | 0.74 | 0.98 | | | | | | | | | | | | | | | |
| FcapDays | -0.32 | -0.30 | 0.33 | 0.92 | -0.92 | -0.96 | -0.96 | 0.82 | 0.94 | 0.92 | | | | | | | | | | | | | | |
| MdefGra | 0.55 | 0.53 | 0.57 | -0.65 | 0.70 | 0.68 | 0.67 | -0.64 | -0.62 | -0.60 | -0.70 | | | | | | | | | | | | | |
| MdefCer | 0.52 | 0.50 | 0.54 | 0.71 | 0.74 | 0.74 | 0.72 | -0.66 | -0.68 | -0.65 | -0.76 | 0.96 | | | | | | | | | | | | |
| MdefSbpt | 0.46 | 0.44 | 0.47 | -0.49 | 0.55 | 0.52 | 0.51 | -0.53 | -0.47 | -0.44 | -0.54 | 0.82 | 0.80 | | | | | | | | | | | |
| AvwatGra | -0.26 | -0.26 | -0.27 | 0.23 | -0.27 | -0.29 | -0.28 | 0.25 | 0.27 | 0.26 | 0.31 | -0.27 | -0.27 | -0.22 | | | | | | | | | | |
| AvwatCer | -0.27 | -0.27 | -0.28 | 0.25 | -0.29 | -0.31 | -0.30 | 0.27 | 0.29 | 0.27 | 0.32 | -0.28 | -0.28 | -0.24 | 0.99 | | | | | | | | | |
| AvwatPot | -0.27 | -0.27 | -0.29 | 0.27 | -0.32 | -0.33 | -0.32 | 0.28 | 0.31 | 0.29 | 0.36 | -0.32 | -0.32 | -0.25 | 0.98 | 0.97 | | | | | | | | |
| Workabil | -0.31 | -0.31 | -0.32 | 0.28 | -0.29 | -0.31 | -0.30 | 0.30 | 0.29 | 0.27 | 0.29 | -0.25 | -0.24 | -0.22 | 0.75 | 0.76 | 0.69 | | | | | | | |
| AutMWD | 0.18 | 0.16 | 0.18 | -0.29 | 0.34 | 0.32 | 0.31 | -0.35 | -0.30 | -0.26 | -0.36 | 0.39 | 0.40 | 0.46 | -0.10 | -0.11 | -0.13 | -0.15 | | | | | | |
| SprMWD | 0.15 | 0.14 | 0.16 | -0.26 | 0.30 | 0.29 | 0.28 | -0.32 | -0.27 | -0.23 | -0.32 | 0.35 | 0.36 | 0.43 | -0.08 | -0.09 | -0.10 | -0.12 | 0.86 | | | | | |
| Wselvgr2 | -0.53 | -0.56 | -0.55 | 0.13 | -0.22 | -0.21 | -0.20 | 0.24 | 0.20 | 0.16 | 0.21 | -0.34 | -0.31 | -0.36 | 0.37 | 0.38 | 0.36 | 0.39 | -0.16 | -0.14 | | | | |
| Dsl2 | 0.00 | 0.00 | 0.01 | 0.24 | -0.14 | -0.19 | -0.20 | 0.09 | 0.24 | 0.24 | 0.20 | -0.06 | -0.10 | -0.01 | -0.03 | -0.02 | -0.02 | -0.06 | -0.01 | -0.01 | -0.02 | | | |
| Wsaspgr2 | 0.24 | 0.24 | 0.23 | -0.10 | 0.18 | 0.10 | 0.10 | -0.11 | -0.13 | -0.12 | -0.08 | 0.06 | 0.05 | 0.03 | 0.08 | 0.08 | 0.07 | 0.07 | 0.01 | 0.01 | -0.07 | 0.05 | | |
| Topex1km | 0.01 | 0.02 | 0.03 | 0.28 | -0.22 | -0.25 | -0.26 | 0.13 | 0.28 | 0.28 | 0.28 | -0.12 | -0.19 | -0.07 | -0.07 | -0.05 | -0.04 | -0.13 | -0.06 | -0.03 | -0.16 | 0.51 | 0.02 | |
| Wind1km2 | 0.30 | -0.31 | -0.32 | -0.07 | -0.03 | 0.01 | 0.03 | 0.09 | -0.05 | -0.08 | -0.02 | -0.16 | -0.11 | -0.21 | 0.27 | 0.27 | 0.25 | 0.31 | -0.10 | -0.10 | 0.72 | -0.33 | 0.02 | -0.64 |

Table A5.3: Pearson correlation coefficients: beech sub-compartments

| | Acc temp | Grow seas | Gras seas | Rain fall | Ret Wet | Ret Med | Ret Dry | End Wet | End Med | End Dry | Fcap Days | Mdef gra | Mdef cer | Mdef sbpt | Avwat Gra | Avwat Cer | Avwat Pot | Work abil | Aut MWD | Spr MWD | Wsel vgr2 | Dsl2 | Wsas pgr2 | Topex 1km2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Growseas | 0.98 | | | | | | | | | | | | | | | | | | | | | | | |
| Grazseas | 0.99 | 0.97 | | | | | | | | | | | | | | | | | | | | | | |
| Rainfall | -0.51 | -0.43 | -0.53 | | | | | | | | | | | | | | | | | | | | | |
| RetWet | 0.48 | 0.40 | 0.53 | -0.92 | | | | | | | | | | | | | | | | | | | | |
| RetMed | 0.50 | 0.42 | 0.54 | -0.97 | 0.97 | | | | | | | | | | | | | | | | | | | |
| RetDry | 0.51 | 0.43 | 0.54 | -0.98 | 0.95 | 1.00 | | | | | | | | | | | | | | | | | | |
| EndWet | -0.45 | -0.37 | -0.51 | 0.84 | -0.96 | -0.91 | -0.88 | | | | | | | | | | | | | | | | | |
| EndMed | -0.54 | -0.46 | -0.56 | 0.96 | -0.90 | -0.97 | -0.98 | 0.83 | | | | | | | | | | | | | | | | |
| EndDry | -0.51 | -0.44 | -0.52 | 0.96 | -0.85 | -0.94 | -0.97 | 0.75 | 0.98 | | | | | | | | | | | | | | | |
| FcapDays | -0.50 | -0.42 | -0.54 | 0.96 | -0.95 | -0.99 | -0.98 | 0.88 | 0.97 | 0.74 | | | | | | | | | | | | | | |
| MdefGra | 0.63 | 0.55 | 0.67 | -0.80 | 0.85 | 0.84 | 0.82 | -0.84 | -0.80 | -0.74 | -0.85 | | | | | | | | | | | | | |
| MdefCer | 0.62 | 0.53 | 0.66 | -0.83 | 0.87 | 0.87 | 0.85 | -0.84 | -0.83 | -0.77 | -0.88 | 0.98 | | | | | | | | | | | | |
| MdefSbpt | 0.55 | 0.47 | 0.60 | -0.73 | 0.82 | 0.79 | 0.77 | -0.84 | -0.73 | -0.66 | -0.80 | 0.95 | 0.94 | | | | | | | | | | | |
| AvwatGra | 0.07 | 0.07 | 0.08 | -0.00 | -0.02 | -0.03 | -0.02 | -0.02 | 0.03 | 0.03 | 0.04 | 0.4 | 0.03 | 0.05 | | | | | | | | | | |
| AvwatCer | 0.07 | 0.08 | 0.08 | 0.02 | -0.04 | -0.05 | -0.04 | 0.00 | 0.05 | 0.04 | 0.05 | 0.03 | 0.12 | 0.04 | 0.98 | | | | | | | | | |
| AvwatPot | -0.09 | -0.05 | -0.09 | 0.23 | -0.27 | -0.27 | -0.26 | 0.20 | 0.27 | 0.25 | 0.28 | -0.24 | -0.25 | -0.19 | 0.89 | 0.87 | | | | | | | | |
| Workabil | -0.02 | 0.02 | -0.01 | 0.11 | -0.08 | -0.10 | -0.10 | 0.07 | 0.11 | 0.10 | 0.12 | -0.02 | -0.03 | -0.02 | 0.75 | 0.76 | 0.66 | | | | | | | |
| AutMWD | 0.36 | 0.26 | 0.41 | -0.61 | 0.70 | 0.68 | 0.65 | -0.73 | -0.63 | -0.54 | -0.69 | 0.74 | 0.74 | 0.77 | -0.03 | -0.07 | -0.34 | -0.34 | | | | | | |
| SprMWD | 0.35 | 0.25 | 0.39 | -0.58 | 0.67 | 0.64 | 0.62 | -0.72 | -0.60 | -0.50 | -0.66 | 0.72 | 0.73 | 0.77 | 0.01 | -0.02 | -0.20 | -0.20 | 0.92 | | | | | |
| Wselvgr2 | -0.59 | -0.62 | -0.62 | 0.19 | -0.30 | -0.26 | -0.34 | 0.33 | 0.24 | 0.18 | 0.28 | -0.44 | -0.41 | -0.45 | 0.06 | 0.04 | 0.11 | 0.01 | -0.29 | -0.26 | | | | |
| Dsl2 | -0.34 | -0.34 | -0.23 | 0.31 | -0.26 | -0.29 | -0.29 | 0.22 | 0.31 | 0.31 | 0.31 | -0.29 | -0.30 | -0.25 | -0.01 | -0.02 | 0.06 | -0.07 | -0.15 | -0.09 | 0.22 | | | |
| Wsaspgr2 | 0.10 | 0.14 | 0.08 | 0.03 | -0.09 | -0.06 | -0.05 | 0.08 | 0.03 | 0.01 | 0.06 | -0.11 | -0.13 | -0.11 | 0.04 | 0.04 | 0.12 | 0.07 | -0.14 | -0.14 | -0.03 | -0.21 | | |
| Topex1km | -0.39 | -0.36 | -0.39 | 0.52 | -0.47 | -0.51 | -0.51 | 0.41 | 0.52 | 0.5 | 0.53 | -0.49 | -0.52 | -0.45 | -0.05 | -0.04 | 0.12 | -0.03 | -0.37 | -0.33 | 0.16 | 0.50 | 0.05 | |
| Wind1km2 | -0.29 | -0.25 | -0.32 | 0.07 | -0.20 | -0.13 | -0.10 | 0.25 | 0.10 | 0.02 | 0.14 | -0.32 | -0.29 | -0.36 | 0.04 | 0.04 | 0.10 | 0.07 | -0.31 | -0.31 | 0.66 | -0.12 | 0.10 | -0.34 |

This analysis resulted in a consistent list of predictor variables for both our Sitka spruce and beech datasets with the single exception of AutMWD and SprMWD, both of which could be included for spruce but only SprMWD could be included for beech. As it was considered important to use the same set of variables for each species, the weaker AutMWD variable was deleted from both PCA studies.

While most of our environmental variables were in a form amenable to initial consideration within a PCA, this was not true of our aspect variable (*Wsaspgr2*) which was recorded in terms of compass direction. This is unsuitable for PCA which simply focuses on linear correlations so that values of 1° and 359° would be interpreted as very different rather than virtually identical. The solution adopted was to calculate both the sine and cosine of aspect (*Sinasp* and *Cosasp* respectively) and include these variables in the PCA instead. The combination of these two transformations allows aspect to be interpreted in linear terms.

## A5.2.1: PCA FOR SITKA SPRUCE ENVIRONMENTAL VARIABLES

### A5.2.1.1: Examining the correlation matrix

The first task was to calculate the degree of sampling adequacy for both individual variables and the entire sample. This shows the extent to which individual variables can be explained by other variables and the extent to which factors describing the variation of the overall dataset can be created. With respect to the entire sample this is given by the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy. KMO compares the magnitude of observed correlation coefficients to partial correlation coefficients. If partial correlations are relatively high then KMO will be low, suggesting that correlations between pairs of variables cannot be explained by other variables. Conversely when partial correlation coefficients are low, KMO is high and communality is high. KMO ranges from 0 (totally inadequate) to 1 (perfectly adequate) with values below 0.5 indicating samples for which PCA is inappropriate. Calculating KMO for the Sitka spruce dataset gave a value of 0.75538 (significance = 0.00000) which Kaiser (1974) describes as middling to meritorious. Sampling adequacy for individual variables is given by the 'anti-image' correlation matrix which is the negative of the partial correlation coefficient matrix. Ideally this should have high KMO scores on the diagonal and low scores elsewhere. Table A5.4 details the anti-image correlation matrix for our Sitka spruce environmental variables showing that this conforms reasonably well to these requirements.

Table A5.4: Anti-image correlation matrix: environmental variables in Sitka spruce sub-compartments

| | Acc temp | Rain fall | Ret Med | End Med | Fcap Days | Mdef Gra | Avwat Gra | Work abil | Spr MWD | Wsel vgr2 | Dal2 | Topex 1km | Wind 1km2 | Cos asp | Sin asp |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Acctemp | 0.71 | | | | | | | | | | | | | | |
| Rainfall | -0.07 | 0.85 | | | | | | | | | | | | | |
| RetMed | 0.04 | 0.50 | 0.85 | | | | | | | | | | | | |
| EndMed | 0.31 | -0.40 | 0.28 | 0.86 | | | | | | | | | | | |
| FcapDays | -0.24 | 0.19 | 0.57 | -0.31 | 0.84 | | | | | | | | | | |
| MdefGra | -0.47 | 0.24 | -0.03 | -0.37 | 0.34 | 0.81 | | | | | | | | | |
| AvwatGra | -0.03 | 0.14 | -0.03 | -0.02 | -0.16 | 0.06 | 0.69 | | | | | | | | |
| Workabil | 0.11 | -0.14 | 0.06 | 0.05 | 0.11 | -0.11 | -0.70 | 0.68 | | | | | | | |
| SprMWD | 0.04 | -0.05 | 0.05 | 0.04 | 0.11 | -0.17 | -0.10 | 0.09 | 0.87 | | | | | | |
| Wselvgr2 | 0.27 | 0.23 | 0.07 | -0.09 | -0.01 | 0.06 | 0.00 | -0.15 | -0.04 | 0.58 | | | | | |
| Dal2 | -0.10 | -0.12 | -0.11 | -0.10 | 0.03 | -0.04 | -0.01 | 0.03 | -0.13 | -0.18 | 0.76 | | | | |
| Topex1km | 0.03 | -0.85 | -0.03 | 0.00 | -0.11 | -0.04 | -0.06 | 0.14 | 0.04 | -0.45 | -0.25 | 0.56 | | | |
| Wind1km2 | -0.04 | -0.10 | 0.01 | 0.11 | -0.01 | -0.01 | -0.06 | 0.09 | 0.07 | -0.77 | 0.12 | 0.69 | 0.54 | | |
| Cosasp | 0.16 | -0.27 | 0.01 | 0.04 | 0.02 | 0.02 | -0.03 | 0.09 | 0.01 | -0.01 | -0.18 | 0.09 | 0.06 | 0.37 | |
| Sinasp | 0.23 | -0.10 | -0.03 | -0.03 | -0.01 | -0.10 | 0.00 | 0.12 | 0.01 | -0.12 | 0.03 | 0.14 | 0.16 | 0.12 | 0.50 |

Notes:
1. There are 20 (9.5%) off-diagonal elements of AIC matrix > 0.09
2. Measures of sampling adequacy (MSA) are printed on the diagonal

### A5.2.1.2: Component extraction

Here linear combinations of the variables are formed. The first principal component (or factor) will be that which accounts for the largest amount of variance in the data. The second factor accounts for a lesser amount of variation and is uncorrelated with the first. We can carry on defining factors up to the number of variables in the sample but this would be a rather pointless exercise. Therefore we need to consider the amount of variation explained by each factor and devise some rule to determine where we will draw the line with respect to the minimum number of factors which we can reduce our input variables to. The most common approach is to standardise all variables and factors with a mean of zero and variance of one. This will mean that the total standardised variance of the sample will be equal to the number of input variables, here 15. The total amount of standardised variance explained by any one factor (known as its eigenvalue) can then be compared to the total standardised variance of the sample and the percentage variance explained calculated. Table A5.5 lists factor eigenvalues and associated statistics for the Sitka spruce dataset.

Factors which have eigenvalues of less than 1 perform less well than simple variables (which are constrained to have a standardised variance of 1) and so this is commonly used as a cut-off point below which factors are discarded. In this case we can see that the first five factors account for 76.9% of the total variance in the sample.

Table A5.5: Principal component (factor) eigenvalues: Sitka spruce sub-compartments

| Factor | Eigenvalue | % of total variation | Cum % |
|---|---|---|---|
| 1 | 5.22 | 34.8 | 34.8 |
| 2 | 2.76 | 18.4 | 53.2 |
| 3 | 1.30 | 8.7 | 61.9 |
| 4 | 1.22 | 8.2 | 70.0 |
| 5 | 1.03 | 6.9 | 76.9 |
| 6 | 0.86 | 5.7 | 82.6 |
| 7 | 0.79 | 5.3 | 87.9 |
| 8 | 0.63 | 4.2 | 92.1 |
| 9 | 0.39 | 2.6 | 94.7 |
| 10 | 0.34 | 2.2 | 97.0 |
| 11 | 0.23 | 1.5 | 98.5 |
| 12 | 0.10 | 0.7 | 99.2 |
| 13 | 0.07 | 0.4 | 99.6 |
| 14 | 0.04 | 0.2 | 99.9 |
| 15 | 0.02 | 0.1 | 100.0 |

### A5.2.1.3: Improving interpretability: factor rotation

Interpretation of the factors may be achieved by calculating a correlation coefficient or 'component loading' between each factor and each variable, as detailed in the 'factor matrix' reported in table A5.6.

While the factor matrix shows the connections between factors and variable, it also highlights certain difficulties in clearly interpreting these factors. For example factor 1 is obviously strongly linked to the soil moisture variables. This seems straightforward until we notice that the same factor also has a significant if lesser correlation with elevation. Factor interpretability now becomes more complex than variable interpretation which is straightforward. In many instances (although not all) interpretability may be improved by 'rotating' factors (Johnston, 1978). There are several methods by which this can be achieved and here the common 'varimax' approach of Kaiser (1958) is adopted. This rotates components such that the number of variables having high loading on a factor is minimised and interpretability is enhanced[1]. Such a transformation is offered as an option on most appropriate statistical packages and the varimax approach provides the default in SPSS-X. Table A5.7 details component loadings for our rotated Sitka spruce factor matrix.

Table A5.6: Factor matrix: Sitka spruce sub-compartments

| | Factor 1 | Factor 2 | Factor 3 | Factor 4 | Factor 5 |
|---|---|---|---|---|---|
| Acctemp | -0.54 | -0.36 | 0.30 | -0.40 | -0.17 |
| Rainfall | 0.91 | -0.26 | -0.03 | -0.14 | -0.04 |
| RetMed | -0.94 | 0.19 | 0.02 | 0.16 | 0.05 |
| EndMed | 0.92 | -0.22 | -0.03 | -0.12 | 0.00 |
| FcapDays | 0.93 | -0.20 | -0.01 | -0.16 | -0.07 |
| MdefGra | -0.79 | -0.07 | 0.21 | -0.04 | 0.16 |
| AvwatGra | 0.45 | 0.45 | 0.61 | 0.03 | 0.18 |
| Workabil | 0.47 | 0.49 | 0.57 | -0.01 | 0.16 |
| SprMWD | -0.38 | -0.04 | 0.21 | 0.14 | 0.43 |
| Wselvgr2 | 0.41 | 0.67 | -0.09 | 0.33 | 0.08 |
| Dsl2 | 0.21 | -0.51 | 0.21 | 0.54 | 0.11 |
| Topex1km | 0.23 | -0.72 | 0.19 | 0.28 | 0.18 |
| Wind1km2 | 0.12 | 0.88 | -0.16 | 0.01 | -0.13 |
| Cosasp | 0.00 | -0.05 | -0.06 | 0.69 | -0.45 |
| Sinasp | 0.16 | -0.02 | -0.55 | 0.04 | 0.67 |

Table A5.7: Rotated factor matrix: Sitka spruce sub-compartments

| | Factor 1 | Factor 2 | Factor 3 | Factor 4 | Factor 5 |
|---|---|---|---|---|---|
| Acctemp | -0.34 | 0.15 | -0.28 | -0.59 | -0.38 |
| Rainfall | 0.92 | 0.20 | 0.13 | 0.08 | -0.06 |
| RetMed | -0.94 | -0.14 | -0.18 | -0.09 | 0.05 |
| EndMed | 0.91 | 0.20 | 0.17 | 0.13 | -0.05 |
| FcapDays | 0.94 | 0.15 | 0.17 | 0.06 | 0.05 |
| MdefGra | -0.77 | 0.11 | -0.14 | -0.19 | -0.22 |
| AvwatGra | 0.16 | -0.04 | 0.88 | -0.04 | -0.04 |
| Workabil | 0.19 | -0.10 | 0.87 | -0.03 | -0.06 |
| SprMWD | -0.51 | 0.27 | 0.12 | 0.15 | -0.16 |
| Wselvgr2 | 0.16 | -0.38 | 0.51 | 0.41 | 0.38 |
| Dsl2 | 0.10 | 0.73 | 0.06 | 0.06 | 0.31 |
| Topex1km | 0.21 | 0.81 | -0.07 | 0.02 | 0.04 |
| Wind1km2 | 0.00 | -0.78 | 0.36 | 0.18 | 0.23 |
| Cosasp | -0.03 | 0.13 | -0.09 | -0.10 | 0.81 |
| Sinasp | 0.07 | 0.05 | -0.16 | 0.84 | -0.22 |

The rotated factor matrix is substantially easier to interpret. In the case of factor 1 we can see that its correlation with elevation (Wselvgr2) has reduced to insignificant levels while correlations with soil wetness variables have if anything improved (note the increased correlation with SprMWD, itself a function of soil wetness). The outcome of the rotation

[1]Johnston (1978, p.172) is critical of rotating factors, but does recognise that the enhanced interpretability may be useful if, as here, the scores are to be used as independent variables in a regression analysis.

suggests each factor has a relatively clear interpretation as follows:

| Factor No. | Label (Sitka spruce analysis) |
|---|---|
| 1. | Soil Wetness/Rainfall |
| 2. | Steeper Slopes/Low Windiness |
| 3. | Waterlogging/Poor Workability/Higher Elevations |
| 4. | Cold/High Sine Aspect Value |
| 5. | High Cosine Aspect Value/Elevation |

While rotation does not affect the overall proportion of total variance explained by our five factors, it does alter the way in which this variance is distributed between factors. After rotation the eigenvalues for our factors were as follows:

| Factor | Eigenvalue |
|---|---|
| 1. | 4.55 |
| 2. | 2.21 |
| 3. | 2.19 |
| 4. | 1.36 |
| 5. | 1.23 |
| | 11.54 |

We can also calculate the 'communality' or proportion of variance in each input variable which is 'explained' by the 5 components[2]. Table A5.8 details communality for all the Sitka spruce site environmental variables considered in our PCA.

Table A5.8: Communality coefficients: Sitka spruce sub-compartments

| Variable | Communality |
|---|---|
| Acctemp | 0.71 |
| Rainfall | 0.92 |
| RetMed | 0.95 |
| EndMed | 0.92 |
| FcapDays | 0.94 |
| MdefGra | 0.70 |
| AvwatGra | 0.81 |
| Workabil | 0.81 |
| SprMWD | 0.39 |
| Wselvgr2 | 0.74 |
| Dsl2 | 0.65 |
| Topex1km | 0.71 |
| Wind1km2 | 0.83 |
| Cosasp | 0.69 |
| Sinasp | 0.79 |

Inspecting table A5.8 we can see that in general our 5 factors explain a reasonable proportion of the variance of our input variables. The only variable for which the degree of explanation is poor is SprMWD.

[2]The communality is the sum of the squared factor loadings

Table A5.10: Input environmental variables (prior to PCA): first 18 Sitka spruce sub-compartments

| Site | Acctemp | Rainfall | Retmed | Endmed | MdefGra | Avwatgra | SprMWD | Wselvgr2 |
|---|---|---|---|---|---|---|---|---|
| 1 | 1569 | 1338 | 243 | 142 | 25 | 115 | 0 | 107 |
| 2 | 1776 | 1146 | 264 | 134 | 61 | 120 | 0 | 85 |
| 3 | 1776 | 1146 | 264 | 134 | 61 | 120 | 0 | 85 |
| 4 | 1569 | 1338 | 243 | 142 | 25 | 115 | 0 | 172 |
| 5 | 1569 | 1338 | 243 | 142 | 25 | 115 | 0 | 172 |
| 6 | 1371 | 1460 | 229 | 146 | 0 | 115 | 0 | 207 |
| 7 | 1371 | 1460 | 229 | 146 | 0 | 115 | 0 | 207 |
| 8 | 1371 | 1460 | 229 | 146 | 0 | 115 | 0 | 207 |
| 9 | 1878 | 1001 | 279 | 128 | 96 | 120 | 3 | 84 |
| 10 | 1748 | 1058 | 273 | 129 | 71 | 120 | 2 | 62 |
| 11 | 1695 | 1250 | 253 | 138 | 53 | 120 | 0 | 130 |
| 12 | 1732 | 1049 | 274 | 129 | 76 | 120 | 2 | 111 |
| 13 | 1732 | 1049 | 274 | 129 | 76 | 120 | 2 | 111 |
| 14 | 1569 | 1338 | 243 | 142 | 25 | 115 | 0 | 247 |
| 15 | 1569 | 1338 | 243 | 142 | 25 | 115 | 0 | 247 |
| 16 | 1371 | 1460 | 229 | 146 | 0 | 115 | 0 | 262 |
| 17 | 1371 | 1460 | 229 | 146 | 0 | 115 | 0 | 262 |
| 18 | 1371 | 1460 | 229 | 146 | 0 | 115 | 0 | 262 |

| Site | Dsl2 | Topex1km | CosAsp | SinAsp |
|---|---|---|---|---|
| 1 | 4.55 | 10.96 | 0.99436 | 0.10602 |
| 2 | 3.29 | 15.65 | -0.98871 | 0.14985 |
| 3 | 3.29 | 15.65 | -0.98871 | 0.14985 |
| 4 | 4.44 | 19.51 | -0.31740 | -0.94829 |
| 5 | 4.44 | 19.51 | -0.31740 | -0.94829 |
| 6 | 4.37 | 17.11 | 0.81931 | -0.57336 |
| 7 | 4.37 | 17.11 | 0.81931 | -0.57336 |
| 8 | 4.37 | 17.11 | 0.81931 | -0.57336 |
| 9 | 4.69 | 12.27 | 0.56243 | 0.82685 |
| 10 | 2.97 | 13.18 | 0.88386 | 0.46775 |
| 11 | 3.90 | 5.30 | 0.65362 | 0.75682 |
| 12 | 2.31 | 7.12 | 0.40808 | 0.91295 |
| 13 | 2.31 | 7.12 | 0.40808 | 0.91295 |
| 14 | 5.50 | 9.09 | 0.99233 | 0.12360 |
| 15 | 5.50 | 9.09 | 0.99233 | 0.12360 |
| 16 | 6.34 | 7.51 | 0.40001 | -0.91651 |
| 17 | 6.34 | 7.51 | 0.40001 | -0.91651 |
| 18 | 6.34 | 7.51 | 0.40001 | -0.91651 |

Table A5.11: Z scores for input environmental variables: first 18 Sitka spruce sub-compartments

| Site | ZAcctemp | ZRainfall | ZRetmed | ZEndmed | ZMdefGra | ZAvwatgra | ZSprMWD |
|---|---|---|---|---|---|---|---|
| 1 | 0.62581 | -0.75404 | 0.79126 | -0.77448 | 0.20279 | -0.65043 | -0.09580 |
| 2 | 1.42713 | -1.15321 | 1.38884 | -1.48542 | 1.13552 | 0.00758 | -0.09580 |
| 3 | 1.42713 | -1.15321 | 1.38884 | -1.48542 | 1.13552 | 0.00758 | -0.09580 |
| 4 | 0.62581 | -0.75404 | 0.79126 | -0.77448 | 0.20279 | -0.65043 | -0.09580 |
| 5 | 0.62581 | -0.75404 | 0.79126 | -0.77448 | 0.20279 | -0.65043 | -0.09580 |
| 6 | -0.05406 | -0.48574 | 0.50198 | -0.66108 | -1.14218 | -0.65043 | -0.09580 |
| 7 | -0.05406 | -0.48574 | 0.50198 | -0.66108 | -1.14218 | -0.65043 | -0.09580 |
| 8 | -0.05406 | -0.48574 | 0.50198 | -0.66108 | -1.14218 | -0.65043 | -0.09580 |
| 9 | 1.90282 | -2.10801 | 2.15573 | -1.98372 | 2.26004 | 0.00758 | 1.95690 |
| 10 | 1.29011 | -1.80159 | 1.94581 | -1.93495 | 1.44787 | 0.00758 | 1.92608 |
| 11 | 1.12864 | -0.90888 | 0.92646 | -1.00127 | 1.00864 | 0.00758 | -0.09580 |
| 12 | 1.27050 | -1.89612 | 1.97398 | -1.93495 | 1.58140 | 0.00758 | 1.92608 |
| 13 | 1.27050 | -1.89612 | 1.97398 | -1.93495 | 1.58140 | 0.00758 | 1.92608 |
| 14 | 0.62581 | -0.75404 | 0.79126 | -0.77448 | 0.20279 | -0.65043 | -0.09580 |
| 15 | 0.62581 | -0.75404 | 0.79126 | -0.77448 | 0.20279 | -0.65043 | -0.09580 |
| 16 | -0.05406 | -0.48574 | 0.50198 | -0.66108 | -1.14218 | -0.65043 | -0.09580 |
| 17 | -0.05406 | -0.48574 | 0.50198 | -0.66108 | -1.14218 | -0.65043 | -0.09580 |
| 18 | -0.05406 | -0.48574 | 0.50198 | -0.66108 | -1.14218 | -0.65043 | -0.09580 |

| Site | ZWselvgr2 | ZDsl2 | ZTopex1km | ZCosAsp | ZSinAsp |
|---|---|---|---|---|---|
| 1 | -1.90198 | 0.35497 | 0.08944 | 1.87251 | 0.09511 |
| 2 | -2.12339 | -0.24934 | 0.84401 | -1.66598 | 0.12104 |
| 3 | -2.12339 | -0.24934 | 0.84401 | -1.66598 | 0.12104 |
| 4 | -1.35492 | 0.32674 | 1.46721 | -0.28150 | -1.34418 |
| 5 | -1.35492 | 0.32674 | 1.46721 | -0.28150 | -1.34418 |
| 6 | -1.01119 | 0.29041 | 1.05656 | 0.80865 | -0.53584 |
| 7 | -1.01119 | 0.29041 | 1.05656 | 0.80865 | -0.53584 |
| 8 | -1.01119 | 0.29041 | 1.05656 | 0.80865 | -0.53584 |
| 9 | -2.15157 | 0.41778 | 0.33505 | 0.44507 | 0.86745 |
| 10 | -2.33822 | -0.42185 | 0.46023 | 0.99189 | 0.38321 |
| 11 | -1.74238 | 0.07464 | -0.96252 | 0.56368 | 0.72541 |
| 12 | -1.86696 | -0.78067 | -0.52835 | 0.29531 | 1.10859 |
| 13 | -1.86696 | -0.78067 | -0.52835 | 0.29531 | 1.10859 |
| 14 | -0.69332 | 0.72848 | -0.18186 | 1.74238 | 0.10869 |
| 15 | -0.69332 | 0.72848 | -0.18186 | 1.74238 | 0.10869 |
| 16 | -0.59247 | 0.99645 | -0.43928 | 0.28825 | -1.13287 |
| 17 | -0.59247 | 0.99645 | -0.43928 | 0.28825 | -1.13287 |
| 18 | -0.59247 | 0.99645 | -0.43928 | 0.28825 | -1.13287 |

Table A5.12: Site specific factor scores: first 18 Sitka spruce sub-compartments

| Site | Factor 1 | Factor 2 | Factor 3 | Factor 4 | Factor 5 |
|---|---|---|---|---|---|
| 1 | -0.484 | 0.423 | -1.037 | -1.682 | -0.018 |
| 2 | -1.231 | 1.333 | -1.206 | -1.687 | 0.189 |
| 3 | -1.231 | 1.333 | -1.206 | -1.687 | 0.189 |
| 4 | -0.555 | 0.957 | -0.833 | -1.423 | 0.162 |
| 5 | -0.555 | 0.957 | -0.833 | -1.423 | 0.162 |
| 6 | -0.111 | 0.427 | -0.832 | -1.012 | 0.474 |
| 7 | -0.111 | 0.427 | -0.832 | -1.012 | 0.474 |
| 8 | -0.111 | 0.427 | -0.832 | -1.012 | 0.474 |
| 9 | -2.309 | 1.707 | -0.345 | -1.664 | -0.549 |
| 10 | -1.894 | 1.126 | -0.800 | 0.009 | -2.087 |
| 11 | -0.945 | -0.299 | -1.167 | -1.083 | 0.662 |
| 12 | -1.908 | 0.411 | -0.923 | -0.471 | -0.140 |
| 13 | -1.908 | 0.411 | -0.923 | -0.471 | -0.140 |
| 14 | -0.588 | -0.045 | -0.813 | -1.212 | 1.253 |
| 15 | -0.588 | -0.045 | -0.813 | -1.212 | 1.253 |
| 16 | -0.178 | -0.257 | -0.826 | -0.806 | 1.732 |
| 17 | -0.178 | -0.257 | -0.826 | -0.806 | 1.732 |
| 18 | -0.178 | -0.257 | -0.826 | -0.806 | 1.732 |

## A5.2.2: PCA FOR BEECH ENVIRONMENTAL VARIABLES

The PCA procedure applied to the beech sub-compartments was identical to that used for the Sitka spruce sites and so results will be presented in brief.

### A5.2.2.1: Examining the correlation matrix

The KMO measure of sampling adequacy was calculated to be 0.76721 (significance = 0.00000), a figure similar to that for Sitka spruce. Table A5.13 details the anti-image correlation matrix for beech. Generally these are as desired for a successful PCA although the individual values for Avwatgra and Workabil are rather lower than for Sitka spruce.

Table A5.13: Anti-image correlation matrix: environmental variables in beech sub-compartments

| | Acc temp | Rain fall | Ret Med | End Med | Fcap Days | Mdef Gra | Avwat Gra | Work abil | Spr MWD | Wsel vgr2 | Dsl2 | Topex 1km | Wind 1km2 | Cos asp | Sin asp |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Acctemp | 0.73 | | | | | | | | | | | | | | |
| Rainfall | -0.06 | 0.89 | | | | | | | | | | | | | |
| RetMed | 0.00 | 0.45 | 0.85 | | | | | | | | | | | | |
| EndMed | 0.39 | -0.28 | 0.10 | 0.90 | | | | | | | | | | | |
| FcapDays | -0.31 | 0.01 | 0.65 | -0.42 | 0.85 | | | | | | | | | | |
| MdefGra | -0.43 | 0.08 | 0.01 | -0.27 | 0.31 | 0.86 | | | | | | | | | |
| AvwatGra | -0.20 | 0.29 | 0.19 | -0.09 | 0.07 | 0.17 | 0.38 | | | | | | | | |
| Workabil | 0.22 | -0.29 | -0.24 | 0.09 | -0.15 | -0.28 | -0.80 | 0.38 | | | | | | | |
| SprMWD | 0.14 | -0.24 | -0.11 | -0.02 | 0.07 | -0.39 | -0.31 | 0.39 | 0.80 | | | | | | |
| Wselvgr2 | 0.42 | 0.20 | 0.08 | 0.15 | -0.12 | -0.05 | -0.13 | 0.07 | -0.16 | 0.59 | | | | | |
| Dsl2 | -0.12 | -0.08 | -0.07 | -0.05 | 0.01 | 0.07 | -0.65 | 0.06 | -0.11 | -0.15 | 0.82 | | | | |
| Topex1km | 0.11 | -0.05 | -0.12 | -0.01 | -0.11 | 0.10 | 0.03 | 0.03 | 0.19 | -0.37 | -0.29 | 0.71 | | | |
| Wind1km2 | -0.06 | -0.03 | -0.05 | -0.05 | 0.01 | 0.17 | 0.07 | -0.04 | 0.23 | -0.69 | 0.04 | 0.66 | 0.46 | | |
| Cosasp | 0.21 | -0.05 | -0.04 | 0.03 | -0.00 | 0.02 | 0.01 | 0.05 | 0.05 | -0.01 | -0.12 | 0.13 | 0.11 | 0.38 | |
| Sinasp | 0.22 | -0.02 | -0.06 | -0.03 | -0.10 | -0.20 | -0.01 | 0.10 | 0.05 | -0.14 | -0.10 | 0.23 | 0.19 | 0.12 | 0.34 |

Notes: 1. There are 26 (12.4%) off-diagonal elements of AIC matrix > 0.09
2. Measures of sampling adequacy (MSA) are printed on the diagonal.

#### A5.2.2.2: Component extraction

Factors were extracted producing eigenvalues as reported in table A5.14.

Table A5.14: Principal component (factor) eigenvalues: beech sub-compartments

| Factor | Eigenvalue | Pct of var | Cum pct |
|---|---|---|---|
| 1 | 6.16 | 41.0 | 41.0 |
| 2 | 1.92 | 12.8 | 53.8 |
| 3 | 1.80 | 12.0 | 65.8 |
| 4 | 1.26 | 8.4 | 74.2 |
| 5 | 1.07 | 7.1 | 81.3 |
| 6 | 0.89 | 5.9 | 87.2 |
| 7 | 0.57 | 3.8 | 91.0 |
| 8 | 0.52 | 3.5 | 94.5 |
| 9 | 0.31 | 2.0 | 96.6 |
| 10 | 0.22 | 1.4 | 98.0 |
| 11 | 0.13 | 0.8 | 98.8 |
| 12 | 0.11 | 0.7 | 99.6 |
| 13 | 0.03 | 0.2 | 99.8 |
| 14 | 0.32 | 0.2 | 99.9 |
| 15 | 0.01 | 0.1 | 100.0 |

Using our previous criteria, the five factors with eigenvalues greater than 1 were selected for further analysis.

#### A5.2.2.3: Improving interpretability: factor rotation

An initial factor matrix was calculated as detailed in table A5.15. Factors were then rotated via the varimax method to produce the matrix detailed in table A5.16.

Table A5.15: Factor matrix: beech sub-compartments

| | Factor 1 | Factor 2 | Factor 3 | Factor 4 | Factor 5 |
|---|---|---|---|---|---|
| Acctemp | -0.66 | -0.07 | 0.40 | -0.31 | 0.02 |
| Rainfall | 0.93 | -0.11 | 0.17 | -0.12 | 0.08 |
| RetMed | -0.95 | 0.05 | -0.13 | 0.14 | -0.08 |
| EndMed | 0.94 | -0.07 | 0.14 | -0.09 | 0.09 |
| FcapDays | 0.96 | -0.04 | 0.14 | -0.12 | 0.08 |
| MdefGra | -0.02 | -0.04 | 0.13 | 0.10 | 0.07 |
| AvwatGra | 0.02 | 0.65 | 0.57 | 0.38 | -0.02 |
| Workabil | 0.11 | 0.67 | 0.59 | 0.24 | -0.06 |
| SprMWD | -0.72 | -0.20 | -0.01 | 0.29 | 0.09 |
| Wselvgr2 | 0.43 | 0.41 | -0.61 | 0.34 | 0.03 |
| Dsl2 | 0.39 | -0.35 | 0.02 | 0.60 | -0.06 |
| Topex1km | 0.60 | -0.44 | 0.21 | 0.31 | -0.09 |
| Wind1km2 | 0.23 | 0.67 | -0.60 | -0.15 | -0.00 |
| Cosasp | 0.02 | -0.17 | -0.22 | 0.26 | -0.71 |
| Sinasp | -0.11 | -0.13 | -0.20 | 0.38 | 0.71 |

Table A5.16: Rotated factor matrix: beech sub-compartments

| | Factor 1 | Factor 2 | Factor 3 | Factor 4 | Factor 5 |
|---|---|---|---|---|---|
| Acctemp | -0.44 | -0.60 | 0.06 | -0.38 | -0.01 |
| Rainfall | 0.94 | 0.03 | 0.02 | 0.19 | 0.03 |
| RetMed | -0.96 | -0.09 | -0.03 | -0.15 | -0.02 |
| EndMed | 0.94 | 0.08 | 0.04 | 0.29 | 0.04 |
| FcapDays | 0.96 | 0.10 | 0.05 | 0.16 | 0.02 |
| MdefGra | -0.85 | -0.35 | 0.05 | -0.14 | 0.12 |
| AvwatGra | -0.03 | 0.02 | 0.95 | 0.03 | 0.02 |
| Workabil | 0.10 | 0.01 | 0.92 | -0.07 | -0.14 |
| SprMWD | -0.74 | -0.22 | -0.06 | 0.14 | 0.17 |
| Wselvgr2 | 0.16 | 0.89 | 0.04 | 0.16 | 0.06 |
| Dsl2 | 0.19 | 0.07 | -0.00 | 0.77 | 0.04 |
| Topex1km | 0.51 | -0.14 | -0.03 | 0.65 | -0.05 |
| Wind1km2 | 0.11 | 0.83 | 0.04 | -0.42 | -0.05 |
| Cosasp | -0.15 | 0.17 | -0.13 | 0.39 | -0.65 |
| Sinasp | -0.19 | 0.14 | -0.11 | 0.24 | 0.77 |

We can interpreted these rotated factors as follows:

| Factor No. | Label (beech analysis) |
|---|---|
| 1. | Soil Wetness/Rainfall |
| 2. | High Elevation/Cold/Windiness |
| 3. | Waterlogging/Poor Workability |
| 4. | Steep Slopes/Low Windiness |
| 5. | High Sine Aspect Value/Low Cosine Aspect Value |

These 5 factors are similar to those for Sitka spruce, but their relative importance and interpretation (e.g. Factor 5) differ. Rotated factor eigenvalues were calculated as follows:

| Factor | Eigenvalue |
|---|---|
| 1. | 5.48 |
| 2. | 2.11 |
| 3. | 1.79 |
| 4. | 1.73 |
| 5. | 1.08 |
| | 12.19 |

Communality coefficients were calculated as reported in table A5.17. Communality is relatively high for all input variables, none have values under 0.60.

Table A5.17: Communality coefficients: beech sub-compartments

| Variable | Communality |
|---|---|
| Acctemp | 0.70 |
| Rainfall | 0.92 |
| RetMed | 0.95 |
| EndMed | 0.93 |
| FcapDays | 0.96 |
| MdefGra | 0.88 |
| AvwatGra | 0.89 |
| Workabil | 0.87 |
| SprMWD | 0.64 |
| Wselvgr2 | 0.85 |
| Dsl2 | 0.63 |
| Topex1km | 0.71 |
| Wind1km2 | 0.89 |
| Cosasp | 0.65 |
| Sinasp | 0.72 |

### A5.2.2.4: Calculating factor scores

Factor scores were calculated as discussed previously and are reported in table A5.18.

Table A5.18: Factor score coefficient matrix: beech sub-compartments

| | Factor 1 | Factor 2 | Factor 3 | Factor 4 | Factor 5 |
|---|---|---|---|---|---|
| Acctemp | 0.02 | -0.28 | 0.02 | -0.21 | -0.02 |
| Rainfall | 0.20 | -0.09 | -0.01 | -0.02 | 0.05 |
| RetMed | -0.20 | 0.06 | 0.01 | 0.04 | -0.05 |
| EndMed | 0.19 | -0.06 | 0.00 | -0.01 | 0.07 |
| FcapDays | 0.20 | -0.05 | 0.00 | -0.04 | 0.05 |
| MdefGra | -0.14 | -0.09 | 0.05 | 0.03 | 0.08 |
| AvwatGra | -0.05 | 0.02 | 0.54 | 0.10 | 0.02 |
| Workabil | -0.00 | -0.00 | 0.52 | 0.01 | -0.03 |
| SprMWD | -0.17 | -0.02 | 0.00 | 0.20 | 0.13 |
| Wselvgr2 | -0.09 | 0.46 | 0.03 | 0.12 | 0.06 |
| Dsl2 | -0.08 | 0.04 | 0.05 | 0.50 | 0.03 |
| Topex1km | 0.04 | -0.11 | 0.01 | 0.36 | -0.04 |
| Wind1km2 | -0.01 | 0.42 | -0.01 | -0.27 | -0.03 |
| Cosasp | -0.14 | 0.12 | -0.04 | 0.30 | -0.62 |
| Sinasp | -0.07 | 0.11 | -0.04 | 0.18 | 0.71 |

As before, we close this section with an example of a calculation of a component score for one sub-compartment. Table A5.19 shows all the necessary workings for the calculation of one factor score (Factor 1) for a single beech sub-compartment (No. 20001).

Table A5.19: Calculation of a component score: Factor 1 - beech sub-compartment 20001

| Variable | Raw Values | Z Scores | Score Coef Factor 1 | Z * Coef |
|---|---|---|---|---|
| Acctemp | 1878.00 | 1.19 | 0.02 | 0.03 |
| Rainfall | 1001.00 | -0.91 | 0.20 | -0.18 |
| RetMed | 279.00 | 0.97 | -0.20 | -0.19 |
| EndMed | 128.00 | -0.79 | 0.19 | -0.15 |
| FcapDays | 214.00 | -0.95 | 0.20 | -0.19 |
| MdefGra | 96.00 | 1.02 | -0.14 | -0.15 |
| AvwatGra | 120.00 | -0.31 | -0.05 | 0.02 |
| Workabil | 2.00 | -0.51 | -0.00 | 0.00 |
| SprMWD | 3.00 | 0.39 | -0.17 | -0.07 |
| Wselvgr2 | 84.00 | -1.13 | -0.09 | 0.10 |
| Dsl2 | 4.69 | 0.30 | -0.08 | -0.02 |
| Topex1km | 12.27 | 0.20 | 0.04 | 0.01 |
| Wind1km2 | 9.54 | -1.10 | -0.01 | 0.01 |
| Cosasp | 0.34 | 0.65 | -0.14 | -0.09 |
| Sinasp | -0.94 | -1.53 | -0.07 | 0.11 |
| Component score | | | | -0.76 |

We can see that the score on a particular component for an individual sub-compartment reflects:

i. the values for that sub-compartment on the input variables;

ii. how those variables are correlated with the component.

The calculations above for sub-compartment 20001 on Factor 1 (Soil Wetness/Rainfall) indicate that it is in a relatively dry location. Table A5.20 reports component scores on all five factors for beech sub-compartments 20001-20005.

Table A5.20: Component scores on all factors: beech sub-compartments 20001-20005

| | Component | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| 20001 | -0.76 | -1.29 | -0.32 | 0.24 | -1.6 |
| 20002 | -0.37 | -1.08 | -0.43 | -0.29 | 0.86 |
| 20003 | 0.50 | 1.11 | -0.49 | -0.01 | 0.34 |
| 20004 | 0.50 | 1.11 | -0.49 | -0.01 | 0.34 |
| 20005 | 0.50 | 1.11 | -0.49 | -0.01 | 0.34 |

## A5.3: SITKA SPRUCE AND BEECH YIELD MODELS: REGRESSION DETAILS

Here we report in full details from the regression analysis of yield models for Sitka spruce and beech described in chapter 7.

### A5.3.1: YIELD MODELS FOR SITKA SPRUCE

Initial investigations deleted sub-compartments which had key data variables missing or illogical (e.g. negative survey age). The resultant dataset (filename: YCSS6.MTW) is described in table A5.21.

Analysis of this dataset showed that a mixed (factor and variable) model provided the best fit as detailed in model A5.1.

Table A5.21: Initial dataset for Sitka spruce sub-compartments

| Column | Name | Count | Missing |
|---|---|---|---|
| C12 | plantyr | 6082 | 0 |
| C13 | yc | 6082 | 2 |
| C34 | survdate | 6082 | 0 |
| C37 | SbCpCode | 6082 | 0 |
| C40 | uncleard | 6082 | 3 |
| C41 | research | 6082 | 3 |
| C42 | Area | 6082 | 0 |
| C43 | unprod | 6082 | 0 |
| C45 | 1st Rot | 6082 | 0 |
| C46 | 2nd Rot | 6082 | 0 |
| C47 | semi-nat | 6082 | 0 |
| C52 | Mixed | 6082 | 203 |
| C102 | Acctemp | 6082 | 0 |
| C103 | Growseas | 6082 | 0 |
| C104 | Grazseas | 6082 | 0 |
| C105 | Rainfall | 6082 | 0 |
| C107 | Retmed | 6082 | 0 |
| C110 | Endmed | 6082 | 0 |
| C112 | Fcapdays | 6082 | 0 |
| C113 | MdefGra | 6082 | 0 |
| C116 | Avwatgra | 6082 | 0 |
| C119 | Workabil | 6082 | 0 |
| C120 | AutMWD | 6082 | 0 |
| C121 | SprMWD | 6082 | 0 |
| C122 | Soils | 6082 | 0 |
| C123 | Wselvgr2 | 6082 | 0 |
| C124 | Dsl2 | 6082 | 0 |
| C127 | Topex1km | 6082 | 0 |
| C128 | Wind1km2 | 6082 | 0 |
| C130 | North | 6082 | 0 |
| C132 | Factor 1 | 6082 | 0 |
| C133 | Factor 2 | 6082 | 0 |
| C134 | Factor 3 | 6082 | 0 |
| C135 | Factor 4 | 6082 | 0 |
| C136 | Factor 5 | 6082 | 0 |
| C137 | SinAsp | 6082 | 0 |
| C138 | CosAsp | 6082 | 0 |
| C142 | reserve | 6082 | 0 |
| C143 | park | 6082 | 0 |
| C144 | notsingl | 6082 | 0 |
| C145 | ancient | 6082 | 0 |
| C146 | soil1 | 6082 | 0 |
| C147 | soil2 | 6082 | 0 |
| C148 | soil3 | 6082 | 0 |
| C149 | soil4 | 6082 | 0 |
| C150 | soil5 | 6082 | 0 |
| C151 | soil6 | 6082 | 0 |
| C152 | soil7 | 6082 | 0 |
| C153 | soil8 | 6082 | 0 |
| C154 | soil4568 | 6082 | 0 |

| | | | |
|---|---|---|---|
| C155 | soil23 | 6082 | 0 |
| C156 | soil46 | 6082 | 0 |
| C157 | soil57 | 6082 | 0 |
| C158 | soil234 | 6082 | 0 |
| C163 | | 6082 | 3 |
| C164 | MixCrop | 6082 | 0 |
| C165 | plYear | 6082 | 0 |
| C166 | survAge | 6082 | 0 |
| C300 | | 6086 | 0 |

## Model A5.1: Initial regression model: Sitka spruce

```
yc = 17.1 - 0.00178 Rainfall - 0.00708 Wselvgr2 + 0.0747 Factor 2
           - 0.166 Factor 5 + 0.00370 Area + 0.0304 plantyr - 1.53 1st Rot
           - 0.213 MixCrop + 1.18 ancient - 0.0768 unprod - 0.366 reserve
           + 0.911 park + 2.46 uncleard - 4.55 semi-nat + 0.898 soil23
           - 4.95 soil1
```

6079 cases used 3 cases contain missing values

| Predictor | Coef | Stdev | t-ratio | p |
|---|---|---|---|---|
| Constant | 17.0792 | 0.2482 | 68.83 | 0.000 |
| Rainfall | -0.00177733 | 0.00008489 | -20.94 | 0.000 |
| Wselvgr2 | -0.0070769 | 0.0003906 | -18.12 | 0.000 |
| Factor 2 | 0.07469 | 0.03586 | 2.08 | 0.038 |
| Factor 5 | -0.16595 | 0.03365 | -4.93 | 0.000 |
| Area | 0.0037050 | 0.0003260 | 11.36 | 0.000 |
| plantyr | 0.030379 | 0.002682 | 11.33 | 0.000 |
| 1st Rot | -1.52753 | 0.08576 | -17.81 | 0.000 |
| MixCrop | -0.21314 | 0.06524 | -3.27 | 0.001 |
| ancient | 1.1777 | 0.2783 | 4.23 | 0.000 |
| unprod | -0.076776 | 0.007079 | -10.85 | 0.000 |
| reserve | -0.36615 | 0.07685 | -4.76 | 0.000 |
| park | 0.91121 | 0.07692 | 11.85 | 0.000 |
| uncleard | 2.4639 | 0.1808 | 13.63 | 0.000 |
| semi-nat | -4.5487 | 0.5983 | -7.60 | 0.000 |
| soil23 | 0.89814 | 0.06729 | 13.35 | 0.000 |
| soil1 | -4.9538 | 0.7437 | -6.66 | 0.000 |

s = 2.297 R-sq = 40.9% R-sq(adj) = 40.7%

Analysis of Variance

| SOURCE | DF | SS | MS | F | p |
|---|---|---|---|---|---|
| Regression | 16 | 22122.7 | 1382.7 | 262.10 | 0.000 |
| Error | 6062 | 31978.7 | 5.3 | | |
| Total | 6078 | 54101.4 | | | |

| SOURCE | DF | SEQ SS |
|---|---|---|
| Rainfall | 1 | 5765.6 |
| Wselvgr2 | 1 | 6395.2 |
| Factor 2 | 1 | 162.9 |
| Factor 5 | 1 | 0.2 |
| Area | 1 | 389.7 |
| plantyr | 1 | 2380.3 |
| 1st Rot | 1 | 2380.4 |
| MixCrop | 1 | 120.7 |
| ancient | 1 | 2.2 |
| unprod | 1 | 688.5 |
| reserve | 1 | 519.3 |
| park | 1 | 707.2 |
| uncleard | 1 | 1036.7 |
| semi-nat | 1 | 311.4 |
| soil23 | 1 | 1028.1 |
| soil1 | 1 | 234.1 |

Table A5.23: Tally for *sage*

| sage | COUNT | CUMCNT | PERCENT | CUMPCT |
|---|---|---|---|---|
| 0 | 89 | 89 | 1.46 | 1.46 |
| 1 | 91 | 180 | 1.50 | 2.96 |
| 2 | 98 | 278 | 1.61 | 4.57 |
| 3 | 116 | 394 | 1.91 | 6.48 |
| 4 | 107 | 501 | 1.76 | 8.24 |
| 5 | 74 | 575 | 1.22 | 9.45 |
| 6 | 77 | 652 | 1.27 | 10.72 |
| 7 | 69 | 721 | 1.13 | 11.85 |
| 8 | 102 | 823 | 1.68 | 13.53 |
| 9 | 88 | 911 | 1.45 | 14.98 |
| 10 | 88 | 999 | 1.45 | 16.43 |
| 11 | 83 | 1082 | 1.36 | 17.79 |
| 12 | 129 | 1211 | 2.12 | 19.91 |
| 13 | 116 | 1327 | 1.91 | 21.82 |
| 14 | 119 | 1446 | 1.96 | 23.78 |
| 15 | 121 | 1567 | 1.99 | 25.76 |
| 16 | 128 | 1695 | 2.10 | 27.87 |
| 17 | 143 | 1838 | 2.35 | 30.22 |
| 18 | 157 | 1995 | 2.58 | 32.80 |
| 19 | 119 | 2114 | 1.96 | 34.76 |
| 20 | 150 | 2264 | 2.47 | 37.22 |
| 21 | 161 | 2425 | 2.65 | 39.87 |
| 22 | 156 | 2581 | 2.56 | 42.44 |
| 23 | 200 | 2781 | 3.29 | 45.73 |
| 24 | 192 | 2973 | 3.16 | 48.88 |
| 25 | 212 | 3185 | 3.49 | 52.37 |
| 26 | 188 | 3373 | 3.09 | 55.46 |
| 27 | 230 | 3603 | 3.78 | 59.24 |
| 28 | 196 | 3799 | 3.22 | 62.46 |
| 29 | 225 | 4024 | 3.70 | 66.16 |
| 30 | 243 | 4267 | 4.00 | 70.16 |
| 31 | 196 | 4463 | 3.22 | 73.38 |
| 32 | 168 | 4631 | 2.76 | 76.14 |
| 33 | 155 | 4786 | 2.55 | 78.69 |
| 34 | 195 | 4981 | 3.21 | 81.90 |
| 35 | 136 | 5117 | 2.24 | 84.13 |
| 36 | 104 | 5221 | 1.71 | 85.84 |
| 37 | 85 | 5306 | 1.40 | 87.24 |
| 38 | 93 | 5399 | 1.53 | 88.77 |
| 39 | 70 | 5469 | 1.15 | 89.92 |
| 40 | 67 | 5536 | 1.10 | 91.02 |
| 41 | 64 | 5600 | 1.05 | 92.07 |
| 42 | 46 | 5646 | 0.76 | 92.83 |
| 43 | 55 | 5701 | 0.90 | 93.74 |
| 44 | 46 | 5747 | 0.76 | 94.49 |
| 45 | 32 | 5779 | 0.53 | 95.02 |
| 46 | 27 | 5806 | 0.44 | 95.46 |
| 47 | 17 | 5823 | 0.28 | 95.74 |
| 48 | 33 | 5856 | 0.54 | 96.28 |
| 49 | 25 | 5881 | 0.41 | 96.70 |
| 50 | 19 | 5900 | 0.31 | 97.01 |
| 51 | 32 | 5932 | 0.53 | 97.53 |
| 52 | 27 | 5959 | 0.44 | 97.98 |
| 53 | 23 | 5982 | 0.38 | 98.36 |
| 54 | 25 | 6007 | 0.41 | 98.77 |
| 55 | 15 | 6022 | 0.25 | 99.01 |
| 56 | 8 | 6030 | 0.13 | 99.15 |
| 57 | 10 | 6040 | 0.16 | 99.31 |
| 58 | 11 | 6051 | 0.18 | 99.49 |
| 59 | 6 | 6057 | 0.10 | 99.59 |
| 60 | 4 | 6061 | 0.07 | 99.65 |
| 61 | 7 | 6068 | 0.12 | 99.77 |
| 62 | 6 | 6074 | 0.10 | 99.87 |
| 63 | 1 | 6075 | 0.02 | 99.88 |
| 64 | 1 | 6076 | 0.02 | 99.90 |
| 65 | 2 | 6078 | 0.03 | 99.93 |
| 68 | 1 | 6079 | 0.02 | 99.95 |
| 70 | 2 | 6081 | 0.03 | 99.98 |
| 72 | 1 | 6082 | 0.02 | 100.00 |
| N= | 6082 | | | |

Starting at *sage* = 0 sub-compartments are successively omitted on the basis of their age at survey and model 1 re-estimated at each stage to produce the analysis of *sage* impacts detailed in table A5.24.

Table A5.24: Analysis of *sage* impacts: Sitka spruce

| Survey age below which all observations omitted[1] | Number of observations[2] | $R^2$(adj) using best fit mixed model[3] (%) |
|---|---|---|
| 0 | 6079 | 40.7 |
| 1 | 5990 | 41.2 |
| 2 | 5899 | 41.4 |
| 3 | 5801 | 41.5 |
| 4 | 5685 | 41.7 |
| 5 | 5578 | 41.9 |
| 6 | 5504 | 41.8 |
| 7 | 5427 | 41.9 |

| Survey age below which all observations omitted[1] | Number of observations[2] | $R^2$(adj) using best fit mixed model[3] (%) |
|---|---|---|
| 8 | 5358 | 41.8 |
| 9 | 5256 | 42.0 |
| 10 | 5168 | 42.0 |
| 11 | 5080 | 41.9 |
| 12 | 4997 | 41.8 |
| 13 | 4868 | 41.7 |
| 14 | 4752 | 41.6 |
| 15 | 4633 | 41.9 |
| 16 | 4512 | 41.8 |
| 17 | 4382 | 41.5 |
| 18 | 4241 | 41.6 |
| 19 | 4084 | 41.5 |
| 20 | 3966 | 41.6 |
| 21 | 3816 | 41.4 |
| 22 | 3655 | 41.3 |
| 23 | 3499 | 41.5 |
| 24 | 3299 | 41.2 |
| 25 | 3107 | 41.4 |
| 26 | 2895 | 41.7 |
| 27 | 2707 | 41.7 |
| 28 | 2478 | 41.7 |
| 29 | 2282 | 41.4 |
| 30 | 2057 | 41.4 |
| 31 | 1815 | 40.2 |
| 32 | 1619 | 39.7 |
| 33 | 1451 | 39.4 |
| 34 | 1296 | 39.8 |
| 35 | 1101 | 41.5 |
| 36 | 965 | 41.6 |
| 37 | 861 | 41.6 |
| 38 | 776 | 39.9 |
| 39 | 683 | 38.3 |

| Survey age below which all observations omitted[1] | Number of observations[2] | $R^2$(adj) using best fit mixed model[3] (%) |
|---|---|---|
| 40 | 613 | 37.9 |
| 41 | 546 | 35.5 |
| 42 | 482 | 31.3 |
| 43 | 436 | 27.7 |
| 44 | 381 | 27.6 |
| 45 | 335 | 26.7 |
| 46 | 303 | 25.9 |
| 47 | 276 | 23.7 |
| 48 | 259 | 22.8 |
| 49 | 226 | 22.3 |
| 50 | 201 | 22.8 |
| 51 | 182 | 25.1 |
| 52 | 150 | 26.9 |
| 53 | 123 | 28.6 |
| 54 | 100 | 37.3 |
| 55 | 75 | 42.2 |
| 56 | 60 | 46.2 |
| 57 | 52 | 41.1 |
| 58 | 42 | 37.8 |
| 59 | 31 | 53.7 |
| 60 | 25 | 60.0 |
| 61 | 21 | 60.9 |

Notes:
1. For example a value of 10 in column 1 indicates that all stands with an age at survey of less than 10 years were omitted from the analysis. Note that a few observations had negative survey ages and are therefore omitted at the first row of the table.
2. Excludes any observations with missing values for the variables used in the regression model (generally these were few).
3. This uses the mixed (factors and variables) model (model A5.1).

Truncation of low sage values results in an increase in model fit. Ignoring models with low df shows that this is maximised by omitting sites with sage<10. This leaves us with a sample size of 5171 sub-compartments. All three model types were re-estimated from scratch using this revised dataset. Our best fitting model which describes site environmental characteristics via PCA factors alone (no raw data environmental variables) is detailed as model A5.2.

Model A5.2: Optimal factor only model for Sitka spruce: sites with *sage*<10 omitted

```
YC = 11.7 - 0.734 Factor 1 + 0.287 Factor 2 - 0.892 Factor 3 - 0.234 Factor 4
          - 0.385 Factor 5 + 0.00360 Area + 0.0506 plantyr - 1.93 1st Rot
          - 0.238 MixCrop + 0.868 ancient - 0.0889 unprod - 0.398 reserve
          + 0.718 park + 2.49 uncleard - 3.88 semi-nat + 0.082 soil23
          - 4.45 soil1
```

5168 cases used 3 cases contain missing values

| Predictor | Coef | Stdev | t-ratio | p |
|---|---|---|---|---|
| Constant | 11.7236 | 0.2145 | 54.65 | 0.000 |
| Factor 1 | -0.73404 | 0.03777 | -19.43 | 0.000 |
| Factor 2 | 0.28735 | 0.03834 | 7.50 | 0.000 |
| Factor 3 | -0.89214 | 0.06265 | -14.24 | 0.000 |
| Factor 4 | -0.23439 | 0.03320 | -7.06 | 0.000 |
| Factor 5 | -0.38472 | 0.03336 | -11.53 | 0.000 |
| Area | 0.0036000 | 0.0003721 | 9.68 | 0.000 |
| plantyr | 0.050608 | 0.003308 | 15.30 | 0.000 |
| 1st Rot | -1.9328 | 0.1026 | -18.83 | 0.000 |
| MixCrop | -0.23812 | 0.07090 | -3.36 | 0.001 |
| ancient | 0.8676 | 0.3060 | 2.84 | 0.005 |
| unprod | -0.088914 | 0.008076 | -11.01 | 0.000 |
| reserve | -0.39807 | 0.08533 | -4.66 | 0.000 |
| park | 0.71803 | 0.08554 | 8.39 | 0.000 |
| uncleard | 2.4930 | 0.1864 | 13.38 | 0.000 |
| semi-nat | -3.8833 | 0.7473 | -5.20 | 0.000 |
| soil23 | 0.0818 | 0.1264 | 0.65 | 0.518 |
| soil1 | -4.4524 | 0.7659 | -5.81 | 0.000 |

s = 2.359 R-sq = 39.4% R-sq(adj) = 39.2%

Analysis of Variance

| SOURCE | DF | SS | MS | F | p |
|---|---|---|---|---|---|
| Regression | 17 | 18652.1 | 1097.2 | 197.14 | 0.000 |
| Error | 5150 | 28663.0 | 5.6 | | |
| Total | 5167 | 47315.1 | | | |

| SOURCE | DF | SEQ SS |
|---|---|---|
| Factor 1 | 1 | 3431.0 |
| Factor 2 | 1 | 859.0 |
| Factor 3 | 1 | 5985.9 |
| Factor 4 | 1 | 265.7 |
| Factor 5 | 1 | 629.8 |
| Area | 1 | 384.0 |
| plantyr | 1 | 2047.0 |
| 1st Rot | 1 | 2141.2 |
| MixCrop | 1 | 140.1 |
| ancient | 1 | 7.7 |
| unprod | 1 | 722.3 |
| reserve | 1 | 318.6 |
| park | 1 | 362.1 |
| uncleard | 1 | 1006.5 |
| semi-nat | 1 | 151.1 |
| soil23 | 1 | 12.1 |
| soil1 | 1 | 188.1 |

Table A5.25: Pearson correlation matrix for model A5.2

| | yc | Factor 1 | Factor 2 | Factor 3 | Factor 4 | Factor 5 | Area | plantyr |
|---|---|---|---|---|---|---|---|---|
| Factor 1 | -0.270 | | | | | | | |
| Factor 2 | 0.145 | -0.037 | | | | | | |
| Factor 3 | -0.360 | -0.001 | -0.035 | | | | | |
| Factor 4 | -0.074 | -0.023 | -0.013 | 0.008 | | | | |
| Factor 5 | -0.132 | 0.039 | -0.009 | 0.016 | -0.012 | | | |
| Area | -0.034 | 0.114 | -0.185 | 0.165 | -0.006 | 0.085 | | |
| plantyr | 0.185 | -0.049 | -0.169 | 0.066 | -0.014 | 0.011 | 0.190 | |
| 1st Rot | -0.393 | 0.255 | -0.160 | 0.212 | 0.011 | -0.008 | 0.147 | -0.175 |
| MixCrop | -0.046 | -0.009 | 0.171 | -0.031 | -0.001 | -0.024 | -0.156 | -0.122 |
| ancient | 0.119 | -0.145 | 0.099 | -0.047 | 0.017 | 0.012 | -0.040 | 0.008 |
| unprod | -0.132 | 0.057 | -0.013 | 0.039 | -0.006 | 0.037 | 0.176 | 0.072 |
| reserve | -0.181 | -0.028 | -0.160 | 0.269 | 0.027 | 0.045 | 0.127 | 0.154 |
| park | 0.055 | 0.342 | 0.355 | -0.052 | -0.001 | -0.006 | -0.030 | -0.082 |
| uncleard | 0.136 | 0.019 | -0.021 | -0.035 | -0.001 | 0.002 | -0.116 | -0.080 |
| semi-nat | -0.002 | -0.005 | 0.081 | -0.039 | -0.023 | 0.044 | -0.026 | -0.010 |
| soil23 | 0.349 | -0.119 | 0.157 | -0.826 | 0.046 | 0.058 | -0.138 | -0.043 |
| soil1 | -0.041 | -0.070 | -0.030 | -0.040 | -0.071 | -0.066 | -0.023 | -0.026 |

| | 1st Rot | MixCrop | ancient | unprod | reserve | park | uncleard | semi-nat |
|---|---|---|---|---|---|---|---|---|
| MixCrop | -0.012 | | | | | | | |
| ancient | -0.228 | 0.007 | | | | | | |
| unprod | 0.027 | -0.035 | -0.006 | | | | | |
| reserve | 0.107 | -0.022 | -0.059 | 0.041 | | | | |
| park | 0.047 | 0.096 | -0.027 | 0.008 | -0.246 | | | |
| uncleard | 0.008 | -0.134 | 0.013 | -0.033 | -0.049 | 0.008 | | |
| semi-nat | -0.113 | -0.004 | 0.395 | 0.004 | -0.026 | 0.065 | -0.009 | |
| soil123 | -0.240 | 0.019 | 0.057 | -0.035 | -0.209 | 0.010 | 0.035 | 0.041 |
| soil1 | 0.019 | -0.025 | -0.005 | -0.002 | 0.080 | -0.029 | 0.016 | -0.002 |

| | soil123 |
|---|---|
| soil1 | -0.043 |

Two versions of the no-factor model were estimated. The first of these includes the aspect variables Sinasp and Cosasp as reported in model A5.3.

Model A5.3: No-factor model for Sitka spruce (including aspect variables): sites with *sage*<10 omitted

```
YC = 16.6 - 0.00177 Rainfall - 0.00843 Wselvgr2 + 0.0259 Topex1km
          + 0.0787 SinAsp - 0.0684 CosAsp + 0.00388 Area + 0.0506 plantyr
          - 1.76 1st Rot - 0.289 MixCrop + 0.935 ancient - 0.0867 unprod
          - 0.441 reserve + 0.862 park + 2.43 uncleard - 4.63 semi-nat
          + 0.825 soil123 - 4.86 soil1
```

5168 cases used 3 cases contain missing values

| Predictor | Coef | Stdev | t-ratio | p |
|---|---|---|---|---|
| Constant | 16.6333 | 0.2697 | 61.66 | 0.000 |
| Rainfall | -0.00176521 | 0.00009584 | -18.42 | 0.000 |
| Wselvgr2 | -0.0084288 | 0.0003633 | -23.20 | 0.000 |
| Topex1km | 0.025931 | 0.006818 | 3.80 | 0.000 |
| SinAsp | 0.7872 | 0.4540 | 1.73 | 0.083 |
| CosAsp | -0.6841 | 0.4592 | -1.49 | 0.137 |
| Area | 0.0038847 | 0.0003639 | 10.67 | 0.000 |
| plantyr | 0.050639 | 0.003230 | 15.68 | 0.000 |
| 1st Rot | -1.7636 | 0.1005 | -17.56 | 0.000 |
| MixCrop | -0.28948 | 0.06928 | -4.18 | 0.000 |
| ancient | 0.9345 | 0.2985 | 3.13 | 0.002 |
| unprod | -0.086657 | 0.007912 | -10.95 | 0.000 |
| reserve | -0.44077 | 0.08421 | -5.23 | 0.000 |
| park | 0.86170 | 0.08295 | 10.39 | 0.000 |
| uncleard | 2.4261 | 0.1821 | 13.32 | 0.000 |
| semi-nat | -4.6318 | 0.7299 | -6.35 | 0.000 |

| | | | | |
|---|---|---|---|---|
| soil23 | 0.82527 | 0.07273 | 11.35 | 0.000 |
| soil1 | -4.8614 | 0.7504 | -6.48 | 0.000 |

s = 2.306 R-sq = 42.1% R-sq(adj) = 41.9%

Analysis of Variance

| SOURCE | DF | SS | MS | F | p |
|---|---|---|---|---|---|
| Regression | 17 | 19921.2 | 1171.8 | 220.30 | 0.000 |
| Error | 5150 | 27394.0 | 5.3 | | |
| Total | 5167 | 47315.1 | | | |

| SOURCE | DF | SEQ SS |
|---|---|---|
| Rainfall | 1 | 4828.0 |
| Wselvgr2 | 1 | 6056.5 |
| Topex1km | 1 | 242.1 |
| SinAsp | 1 | 2.3 |
| CosAsp | 1 | 29.1 |
| Area | 1 | 411.3 |
| plantyr | 1 | 1885.2 |
| 1st Rot | 1 | 2260.8 |
| MixCrop | 1 | 188.0 |
| ancient | 1 | 3.6 |
| unprod | 1 | 715.6 |
| reserve | 1 | 611.7 |
| park | 1 | 509.4 |
| uncleard | 1 | 1002.0 |
| semi-nat | 1 | 204.9 |
| soil23 | 1 | 747.4 |
| soil1 | 1 | 223.2 |

Table A5.26: Pearson correlation matrix for model A5.3

| | yc | Rainfall | Wselvgr2 | Topex1km | SinAsp | CosAsp | Area | plantyr |
|---|---|---|---|---|---|---|---|---|
| Rainfall | -0.320 | | | | | | | |
| Wselvgr2 | -0.410 | 0.181 | | | | | | |
| Topex1km | 0.059 | 0.276 | -0.171 | | | | | |
| SinAsp | -0.007 | 0.019 | 0.027 | 0.004 | | | | |
| CosAsp | 0.004 | -0.038 | -0.045 | 0.026 | 0.045 | | | |
| Area | -0.034 | 0.097 | 0.247 | -0.138 | -0.016 | -0.023 | | |
| plantyr | 0.185 | -0.089 | 0.106 | -0.148 | -0.031 | -0.004 | 0.190 | |
| 1st Rot | -0.393 | 0.265 | 0.226 | -0.095 | 0.031 | -0.008 | 0.147 | -0.175 |
| MixCrop | -0.046 | 0.015 | -0.114 | 0.138 | -0.007 | 0.024 | -0.156 | -0.122 |
| ancient | 0.119 | -0.121 | -0.086 | 0.054 | -0.047 | -0.005 | -0.040 | 0.008 |
| unprod | -0.132 | 0.082 | 0.044 | 0.006 | -0.022 | -0.038 | 0.176 | 0.072 |
| reserve | -0.181 | -0.043 | 0.245 | -0.018 | -0.036 | 0.059 | 0.127 | 0.154 |
| park | 0.055 | 0.430 | -0.123 | 0.278 | 0.005 | -0.017 | -0.030 | -0.082 |
| uncleard | 0.136 | 0.003 | -0.014 | -0.024 | 0.005 | -0.010 | -0.116 | -0.080 |
| semi-nat | -0.002 | -0.000 | -0.070 | 0.067 | 0.005 | -0.003 | -0.026 | -0.010 |
| soil23 | 0.349 | -0.198 | -0.366 | 0.184 | -0.019 | 0.029 | -0.138 | -0.043 |
| soil1 | -0.041 | -0.067 | -0.137 | -0.075 | 0.009 | 0.041 | -0.023 | -0.026 |

| | 1st Rot | MixCrop | ancient | unprod | reserve | park | uncleard | semi-nat |
|---|---|---|---|---|---|---|---|---|
| MixCrop | -0.012 | | | | | | | |
| ancient | -0.228 | 0.007 | | | | | | |
| unprod | 0.027 | -0.035 | -0.006 | | | | | |
| reserve | 0.107 | -0.022 | -0.059 | 0.041 | | | | |
| park | 0.047 | 0.096 | -0.027 | 0.008 | -0.246 | | | |
| uncleard | 0.008 | -0.134 | 0.013 | -0.033 | -0.049 | 0.008 | | |
| semi-nat | -0.113 | -0.004 | 0.395 | 0.004 | -0.026 | 0.065 | -0.009 | |
| soil23 | -0.240 | 0.019 | 0.057 | -0.035 | -0.209 | 0.010 | 0.035 | 0.041 |
| soil1 | 0.019 | -0.025 | -0.005 | -0.002 | 0.080 | -0.029 | 0.016 | -0.002 |

| | soil23 |
|---|---|
| soil1 | -0.043 |

Descriptive statistics for the aspect variables are given in table A5.27 while a histogram is given in figure A5.2. This shows a good spread of sites across the full range of possible aspects.

Table A5.27: Descriptive statistics for the aspect variables

| | N | MEAN | MEDIAN | TRMEAN | STDEV | SEMEAN |
|---|---|---|---|---|---|---|
| SinAsp | 5171 | 0.00213 | -0.02652 | 0.00222 | 0.71045 | 0.00988 |
| CosAsp | 5171 | 0.02405 | 0.05750 | 0.02680 | 0.70347 | 0.00978 |

| | MIN | MAX | Q1 | Q3 |
|---|---|---|---|---|
| SinAsp | -0.99999 | 0.99991 | -0.72714 | 0.72106 |
| CosAsp | -1.00000 | 0.99996 | -0.67348 | 0.73017 |

Figure A5.2: Histogram of aspect variables

```
Histogram of Sinasp   N = 5171    Each * represents 20 obs.

Midpoint   Count
  -1.0      770   **************************************
  -0.8      573   ****************************
  -0.6      350   *****************
  -0.4      416   ********************
  -0.2      324   ****************
   0.0      304   ***************
   0.2      297   **************
   0.4      411   ********************
   0.6      382   *******************
   0.8      562   ****************************
   1.0      782   ***************************************

Histogram of Cosasp   N = 5171    Each * represents 15 obs.

Midpoint   Count
  -1.0      709   ***********************************************
  -0.8      497   *********************************
  -0.6      441   *****************************
  -0.4      402   **************************
  -0.2      315   ********************
   0.0      315   ********************
   0.2      301   ********************
   0.4      441   *****************************
   0.6      410   ***************************
   0.8      612   ****************************************
   1.0      728   ************************************************
```

While the aspect effects are interesting these variables were also of somewhat doubtful significance and so the no-factor model was re-estimated in their absence as detailed in model A5.4.

Model A5.4: Best fit no-factor model for Sitka spruce: sites with *sage*<10 omitted

```
YC = 16.6 - 0.00176 Rainfall - 0.00839 Wselvgr2 + 0.0259 Topex1km
          + 0.00388 Area + 0.0506 plantyr - 1.76 1st Rot - 0.292 MixCrop
          + 0.911 ancient - 0.0865 unprod - 0.456 reserve + 0.860 park
          + 2.43 uncleard - 4.59 semi-nat + 0.822 soil23 - 4.87 soil1
```

5168 cases used 3 cases contain missing values

| Predictor | Coef | Stdev | t-ratio | p |
|---|---|---|---|---|
| Constant | 16.6245 | 0.2698 | 61.62 | 0.000 |
| Rainfall | -0.00176199 | 0.00009585 | -18.38 | 0.000 |

| | | | | |
|---|---|---|---|---|
| Factor 5 | -0.17788 | 0.03647 | -4.88 | 0.000 |
| Area | 0.0038486 | 0.0003634 | 10.59 | 0.000 |
| plantyr | 0.049153 | 0.003229 | 15.22 | 0.000 |
| 1st Rot | -1.8054 | 0.1006 | -17.94 | 0.000 |
| MixCrop | -0.27664 | 0.06929 | -3.99 | 0.000 |
| ancient | 0.9203 | 0.2983 | 3.08 | 0.002 |
| unprod | -0.084903 | 0.007905 | -10.74 | 0.000 |
| reserve | -0.41819 | 0.08298 | -5.04 | 0.000 |
| park | 0.89863 | 0.08451 | 10.63 | 0.000 |
| uncleard | 2.4212 | 0.1820 | 13.30 | 0.000 |
| semi-nat | -4.3427 | 0.7305 | -5.95 | 0.000 |
| soil23 | 0.94104 | 0.07297 | 12.90 | 0.000 |
| soil1 | -4.9501 | 0.7492 | -6.61 | 0.000 |

s = 2.305 R-sq = 42.2% R-sq(adj) = 42.0%

Analysis of Variance

| SOURCE | DF | SS | MS | F | p |
|---|---|---|---|---|---|
| Regression | 16 | 19953.5 | 1247.1 | 234.77 | 0.000 |
| Error | 5151 | 27361.6 | 5.3 | | |
| Total | 5167 | 47315.1 | | | |

| SOURCE | DF | SEQ SS |
|---|---|---|
| Rainfall | 1 | 4828.0 |
| Wselvgr2 | 1 | 6056.5 |
| Factor 2 | 1 | 109.6 |
| Factor 5 | 1 | 4.3 |
| Area | 1 | 382.9 |
| plantyr | 1 | 1851.9 |
| 1st Rot | 1 | 2342.9 |
| MixCrop | 1 | 182.1 |
| ancient | 1 | 3.2 |
| unprod | 1 | 697.1 |
| reserve | 1 | 562.1 |
| park | 1 | 552.2 |
| uncleard | 1 | 988.1 |
| semi-nat | 1 | 186.4 |
| soil23 | 1 | 974.4 |
| soil1 | 1 | 231.9 |

Table A5.28: Pearson correlation matrix for model A5.5

| | yc | Rainfall | Wselvgr2 | Factor 2 | Factor 5 | Area | plantyr | 1st Rot |
|---|---|---|---|---|---|---|---|---|
| Rainfall | -0.320 | | | | | | | |
| Wselvgr2 | -0.410 | 0.181 | | | | | | |
| Factor 2 | 0.145 | 0.171 | -0.400 | | | | | |
| Factor 5 | -0.132 | -0.020 | 0.377 | -0.009 | | | | |
| Area | -0.034 | 0.097 | 0.247 | -0.185 | 0.085 | | | |
| plantyr | 0.185 | -0.089 | 0.106 | -0.169 | 0.011 | 0.190 | | |
| 1st Rot | -0.393 | 0.265 | 0.226 | -0.160 | -0.008 | 0.147 | -0.175 | |
| MixCrop | -0.046 | 0.015 | -0.114 | 0.171 | -0.024 | -0.156 | -0.122 | -0.012 |
| ancient | 0.119 | -0.121 | -0.086 | 0.099 | 0.012 | -0.040 | 0.008 | -0.228 |
| unprod | -0.132 | 0.082 | 0.044 | -0.013 | 0.037 | 0.176 | 0.072 | 0.027 |
| reserve | -0.181 | -0.043 | 0.245 | -0.160 | 0.045 | 0.127 | 0.154 | 0.107 |
| park | 0.055 | 0.430 | -0.123 | 0.355 | -0.006 | -0.030 | -0.082 | 0.047 |
| uncleard | 0.136 | 0.003 | -0.014 | -0.021 | 0.002 | -0.116 | -0.080 | 0.008 |
| semi-nat | -0.002 | -0.000 | -0.070 | 0.081 | 0.044 | -0.026 | -0.010 | -0.113 |
| soil23 | 0.349 | -0.198 | -0.366 | 0.157 | 0.058 | -0.138 | -0.043 | -0.240 |
| soil1 | -0.041 | -0.067 | -0.137 | -0.030 | -0.066 | -0.023 | -0.026 | 0.019 |

| | MixCrop | ancient | unprod | reserve | park | uncleard | semi-nat | soil23 |
|---|---|---|---|---|---|---|---|---|
| ancient | 0.007 | | | | | | | |
| unprod | -0.035 | -0.006 | | | | | | |
| reserve | -0.022 | -0.059 | 0.041 | | | | | |
| park | 0.096 | -0.027 | 0.008 | -0.246 | | | | |
| uncleard | -0.134 | 0.013 | -0.033 | -0.049 | 0.008 | | | |
| semi-nat | -0.004 | 0.395 | 0.004 | -0.026 | 0.065 | -0.009 | | |
| soil23 | 0.019 | 0.057 | -0.035 | -0.209 | 0.010 | 0.035 | 0.041 | |
| soil1 | -0.025 | -0.005 | -0.002 | 0.080 | -0.029 | 0.016 | -0.002 | -0.043 |

Inspection of table A5.24 shows that sites with very high *sage* values exhibit relatively high degrees of variance. A sensitivity analysis determined that model fit could be substantially improved by omission of those sites with *sage*>36. This produced a dataset of 5171 observations (filename YCSS7.MTW). Again our three model types were re-estimated from scratch. However, no new explanatory variables entered the models and so correlation matrices are not reported for any but our overall best fit model (given at the end of this section). Model A5.6 details our final mixed model, model A5.7 gives results for our final factor only model, while our final no-factor model is reported as model A5.8.

Model A5.6: Best fit mixed (factor and variable) model for Sitka spruce: sites with *sage*<10 and *sage*>36 omitted

```
YC = 16.6 - 0.00164 Rainfall - 0.00787 Wselvgr2 + 0.0695 Factor 2
          - 0.171 Factor 5 + 0.00393 Area + 0.0495 plantyr - 1.97 1st Rot
          - 0.289 MixCrop + 0.941 ancient - 0.0841 unprod - 0.419 reserve
          + 0.988 park + 2.63 uncleard - 4.89 semi-nat + 0.933 soil23
          - 4.83 soil1
```

4307 cases used 3 cases contain missing values

| Predictor | Coef | Stdev | t-ratio | p |
|---|---|---|---|---|
| Constant | 16.5916 | 0.3509 | 47.28 | 0.000 |
| Rainfall | -0.0016406 | 0.0001043 | -15.73 | 0.000 |
| Wselvgr2 | -0.0078720 | 0.0004664 | -16.88 | 0.000 |
| Factor 2 | 0.06951 | 0.04237 | 1.64 | 0.101 |
| Factor 5 | -0.17127 | 0.04030 | -4.25 | 0.000 |
| Area | 0.0039302 | 0.0003782 | 10.39 | 0.000 |
| plantyr | 0.049461 | 0.004838 | 10.22 | 0.000 |
| 1st Rot | -1.9710 | 0.1094 | -18.01 | 0.000 |
| MixCrop | -0.28865 | 0.07665 | -3.77 | 0.000 |
| ancient | 0.9411 | 0.3091 | 3.04 | 0.002 |
| unprod | -0.084062 | 0.008139 | -10.33 | 0.000 |
| reserve | -0.41869 | 0.09386 | -4.46 | 0.000 |
| park | 0.98753 | 0.09537 | 10.35 | 0.000 |
| uncleard | 2.6329 | 0.2274 | 11.58 | 0.000 |
| semi-nat | -4.8872 | 0.7653 | -6.39 | 0.000 |
| soil23 | 0.93251 | 0.08078 | 11.54 | 0.000 |
| soil1 | -4.8331 | 0.9656 | -5.01 | 0.000 |

s = 2.317 R-sq = 43.1% R-sq(adj) = 42.9%

Analysis of Variance

| SOURCE | DF | SS | MS | F | p |
|---|---|---|---|---|---|
| Regression | 16 | 17439.1 | 1089.9 | 202.99 | 0.000 |
| Error | 4290 | 23034.5 | 5.4 | | |
| Total | 4306 | 40473.6 | | | |

| SOURCE | DF | SEQ SS |
|---|---|---|
| Rainfall | 1 | 3860.5 |
| Wselvgr2 | 1 | 5973.6 |
| Factor 2 | 1 | 199.0 |
| Factor 5 | 1 | 0.8 |
| Area | 1 | 265.9 |
| plantyr | 1 | 1082.4 |
| 1st Rot | 1 | 2381.3 |
| MixCrop | 1 | 158.1 |
| ancient | 1 | 1.0 |
| unprod | 1 | 640.3 |
| reserve | 1 | 422.7 |
| park | 1 | 531.7 |
| uncleard | 1 | 796.8 |
| semi-nat | 1 | 219.3 |
| soil23 | 1 | 771.2 |
| soil1 | 1 | 134.5 |

Model A5.7: Best fit factor only model for Sitka spruce: sites with *sage*<10 and *sage*>36 omitted

```
YC = 11.9 - 0.709 Factor 1 + 0.295 Factor 2 - 0.922 Factor 3 - 0.239 Factor 4
          - 0.408 Factor 5 + 0.00365 Area + 0.0492 plantyr - 2.09 1st Rot
          - 0.269 MixCrop + 0.881 ancient - 0.0867 unprod - 0.430 reserve
          + 0.803 park + 2.74 uncleard - 4.36 semi-nat + 0.044 soil23
          - 4.24 soil1
```

4307 cases used 3 cases contain missing values

| Predictor | Coef | Stdev | t-ratio | p |
|---|---|---|---|---|
| Constant | 11.8800 | 0.3090 | 38.45 | 0.000 |
| Factor 1 | -0.70932 | 0.04135 | -17.15 | 0.000 |
| Factor 2 | 0.29481 | 0.04177 | 7.06 | 0.000 |
| Factor 3 | -0.92229 | 0.06664 | -13.84 | 0.000 |
| Factor 4 | -0.23857 | 0.03667 | -6.51 | 0.000 |
| Factor 5 | -0.40778 | 0.03685 | -11.07 | 0.000 |
| Area | 0.0036537 | 0.0003872 | 9.44 | 0.000 |
| plantyr | 0.049234 | 0.004954 | 9.94 | 0.000 |
| 1st Rot | -2.0853 | 0.1117 | -18.67 | 0.000 |
| MixCrop | -0.26907 | 0.07848 | -3.43 | 0.001 |
| ancient | 0.8805 | 0.3171 | 2.78 | 0.006 |
| unprod | -0.086739 | 0.008315 | -10.43 | 0.000 |
| reserve | -0.42987 | 0.09636 | -4.46 | 0.000 |
| park | 0.80303 | 0.09635 | 8.33 | 0.000 |
| uncleard | 2.7353 | 0.2329 | 11.75 | 0.000 |
| semi-nat | -4.3591 | 0.7831 | -5.57 | 0.000 |
| soil23 | 0.0441 | 0.1366 | 0.32 | 0.747 |
| soil1 | -4.2384 | 0.9869 | -4.29 | 0.000 |

s = 2.372    R-sq = 40.4%    R-sq(adj) = 40.1%

Analysis of Variance

| SOURCE | DF | SS | MS | F | p |
|---|---|---|---|---|---|
| Regression | 17 | 16342.51 | 961.32 | 170.86 | 0.000 |
| Error | 4289 | 24131.05 | 5.63 | | |
| Total | 4306 | 40473.56 | | | |

| SOURCE | DF | SEQ SS |
|---|---|---|
| Factor 1 | 1 | 2872.50 |
| Factor 2 | 1 | 1182.68 |
| Factor 3 | 1 | 5364.91 |
| Factor 4 | 1 | 247.44 |
| Factor 5 | 1 | 562.80 |
| Area | 1 | 257.41 |
| plantyr | 1 | 1153.39 |
| 1st Rot | 1 | 2186.81 |
| MixCrop | 1 | 132.40 |
| ancient | 1 | 5.52 |
| unprod | 1 | 642.76 |
| reserve | 1 | 297.94 |
| park | 1 | 351.24 |
| uncleard | 1 | 802.65 |
| semi-nat | 1 | 174.27 |
| soil23 | 1 | 4.04 |
| soil1 | 1 | 103.77 |

Model A5.8: Best fit no-factor only model for Sitka spruce: sites with *sage*<10 and *sage*>36 omitted

```
YC = 16.7 - 0.00167 Rainfall - 0.00878 Wselvgr2 + 0.0243 Topex1km
         + 0.00395 Area + 0.0499 plantyr - 1.93 1st Rot - 0.308 MixCrop
         + 0.927 ancient - 0.0854 unprod - 0.434 reserve + 0.948 park
         + 2.64 uncleard - 5.14 semi-nat + 0.805 soil23 - 4.88 soil1
```

4307 cases used 3 cases contain missing values

| Predictor | Coef | Stdev | t-ratio | p |
|---|---|---|---|---|
| Constant | 16.7097 | 0.3487 | 47.92 | 0.000 |
| Rainfall | -0.0016700 | 0.0001067 | -15.65 | 0.000 |
| Wselvgr2 | -0.0087750 | 0.0003933 | -22.31 | 0.000 |
| Topex1km | 0.024262 | 0.007592 | 3.20 | 0.001 |
| Area | 0.0039518 | 0.0003788 | 10.43 | 0.000 |
| plantyr | 0.049890 | 0.004838 | 10.31 | 0.000 |
| 1st Rot | -1.9280 | 0.1093 | -17.64 | 0.000 |
| MixCrop | -0.30832 | 0.07670 | -4.02 | 0.000 |
| ancient | 0.9266 | 0.3089 | 3.00 | 0.003 |
| unprod | -0.085426 | 0.008143 | -10.49 | 0.000 |
| reserve | -0.43395 | 0.09452 | -4.59 | 0.000 |
| park | 0.94769 | 0.09385 | 10.10 | 0.000 |
| uncleard | 2.6411 | 0.2276 | 11.61 | 0.000 |
| semi-nat | -5.1415 | 0.7644 | -6.73 | 0.000 |
| soil23 | 0.80489 | 0.08046 | 10.00 | 0.000 |
| soil1 | -4.8827 | 0.9660 | -5.05 | 0.000 |

s = 2.319        R-sq = 43.0%        R-sq(adj) = 42.8%

Analysis of Variance

| SOURCE | DF | SS | MS | F | p |
|---|---|---|---|---|---|
| Regression | 15 | 17391.3 | 1159.4 | 215.54 | 0.000 |
| Error | 4291 | 23082.2 | 5.4 | | |
| Total | 4306 | 40473.6 | | | |

| SOURCE | DF | SEQ SS |
|---|---|---|
| Rainfall | 1 | 3860.5 |
| Wselvgr2 | 1 | 5973.6 |
| Topex1km | 1 | 366.4 |
| Area | 1 | 291.4 |
| plantyr | 1 | 1052.1 |
| 1st Rot | 1 | 2313.6 |
| MixCrop | 1 | 169.0 |
| ancient | 1 | 0.9 |
| unprod | 1 | 649.7 |
| reserve | 1 | 471.6 |
| park | 1 | 492.0 |
| uncleard | 1 | 802.9 |
| semi-nat | 1 | 236.3 |
| soil23 | 1 | 573.8 |
| soil1 | 1 | 137.4 |

In all cases the additional omission of sites with *sage*>36 results in a noticeable improvement in fit. Of these the factor-only model is the weaker with our no-factor and mixed models performing equally well. As the no-factor model is the easiest to interpret (and less controversial) of these, it is our preferred model for Sitka spruce (dataset saved in file YCSS8.MTW). In order to facilitate extrapolation of the results given in our best fit model, table A5.29 gives summary statistics for all the variables used in models A5.6 to A5.8[4] while table A5.30 reports Pearson correlation coefficients for these variables.

Table A5.29: Summary statistics for all variables used in Sitka spruce models with sites *sage*<10 and *sage*>36 omitted

| | N | N* | MEAN | MEDIAN | TRMEAN | STDEV | SEMEAN |
|---|---|---|---|---|---|---|---|
| yc | 4308 | 2 | 12.924 | 12.000 | 12.916 | 3.066 | 0.047 |
| plantyr | 4310 | 0 | 52.120 | 51.000 | 51.892 | 8.016 | 0.122 |
| uncleard | 4307 | 3 | 0.02577 | 0.00000 | 0.00000 | 0.15847 | 0.00241 |
| Area | 4310 | 0 | 72.91 | 33.00 | 58.70 | 101.12 | 1.54 |
| unprod | 4310 | 0 | 0.9780 | 0.0000 | 0.2803 | 4.4307 | 0.0675 |
| 1st Rot | 4310 | 0 | 0.83364 | 1.00000 | 0.87081 | 0.37244 | 0.00567 |
| 2nd Rot | 4310 | 0 | 0.06311 | 0.00000 | 0.01444 | 0.24319 | 0.00370 |
| semi-nat | 4310 | 0 | 0.00255 | 0.00000 | 0.00000 | 0.05046 | 0.00077 |
| Acctemp | 4310 | 0 | 1397.2 | 1373.0 | 1393.2 | 239.3 | 3.6 |
| Rainfall | 4310 | 0 | 1690.8 | 1700.0 | 1679.6 | 416.7 | 6.3 |
| Wselvgr2 | 4310 | 0 | 332.87 | 351.00 | 336.49 | 105.77 | 1.61 |
| Topex1km | 4310 | 0 | 10.426 | 9.530 | 10.167 | 5.333 | 0.081 |
| Factor 1 | 4310 | 0 | -0.0343 | 0.0540 | 0.0161 | 1.0063 | 0.0153 |
| Factor 2 | 4310 | 0 | -0.0877 | -0.1995 | -0.1180 | 1.0165 | 0.0155 |
| Factor 3 | 4310 | 0 | 0.0872 | -0.1020 | 0.0421 | 1.0174 | 0.0155 |
| Factor 4 | 4310 | 0 | -0.0060 | -0.0045 | -0.0054 | 1.0002 | 0.0152 |
| Factor 5 | 4310 | 0 | -0.0010 | -0.0620 | -0.0045 | 0.9996 | 0.0152 |
| reserve | 4310 | 0 | 0.23063 | 0.00000 | 0.20062 | 0.42128 | 0.00642 |
| park | 4310 | 0 | 0.27680 | 0.00000 | 0.25193 | 0.44747 | 0.00682 |
| ancient | 4310 | 0 | 0.01671 | 0.00000 | 0.00000 | 0.12818 | 0.00195 |
| soil1 | 4310 | 0 | 0.00139 | 0.00000 | 0.00000 | 0.03729 | 0.00057 |
| soil2 | 4310 | 0 | 0.09165 | 0.00000 | 0.04616 | 0.28856 | 0.00440 |
| soil3 | 4310 | 0 | 0.39930 | 0.00000 | 0.38809 | 0.48981 | 0.00746 |
| soil4 | 4310 | 0 | 0.43225 | 0.00000 | 0.42470 | 0.49545 | 0.00755 |
| soil5 | 4310 | 0 | 0.01323 | 0.00000 | 0.00000 | 0.11425 | 0.00174 |
| soil6 | 4310 | 0 | 0.04200 | 0.00000 | 0.00000 | 0.20060 | 0.00306 |
| soil7 | 4310 | 0 | 0.01740 | 0.00000 | 0.00000 | 0.13078 | 0.00199 |
| soil8 | 4310 | 0 | 0.00278 | 0.00000 | 0.00000 | 0.05270 | 0.00080 |
| soil4568 | 4310 | 0 | 0.49026 | 0.00000 | 0.48917 | 0.49996 | 0.00762 |
| soil23 | 4310 | 0 | 0.49095 | 0.00000 | 0.48994 | 0.49998 | 0.00762 |
| soil46 | 4310 | 0 | 0.47425 | 0.00000 | 0.47138 | 0.49939 | 0.00761 |
| soil57 | 4310 | 0 | 0.03063 | 0.00000 | 0.00000 | 0.17232 | 0.00262 |
| soil234 | 4310 | 0 | 0.92320 | 1.00000 | 0.97035 | 0.26630 | 0.00406 |
| MixCrop | 4310 | 0 | 0.36520 | 0.00000 | 0.35018 | 0.48154 | 0.00733 |
| survAge | 4310 | 0 | 24.204 | 25.000 | 24.322 | 7.118 | 0.108 |
| YCfits | 4307 | 3 | 12.923 | 12.612 | 12.868 | 2.010 | 0.031 |
| YCfitCat | 4307 | 3 | 12.918 | 12.000 | 12.851 | 2.082 | 0.032 |

| | MIN | MAX | Q1 | Q3 |
|---|---|---|---|---|
| yc | 4.000 | 22.000 | 10.000 | 16.000 |
| plantyr | 30.000 | 75.000 | 46.000 | 57.000 |
| uncleard | 0.00000 | 1.00000 | 0.00000 | 0.00000 |
| Area | 1.00 | 1130.00 | 10.00 | 95.00 |
| unprod | 0.0000 | 80.0000 | 0.0000 | 0.0000 |
| 1st Rot | 0.00000 | 1.00000 | 1.00000 | 1.00000 |
| 2nd Rot | 0.00000 | 1.00000 | 0.00000 | 0.00000 |
| semi-nat | 0.00000 | 1.00000 | 0.00000 | 0.00000 |
| Acctemp | 712.0 | 2027.0 | 1210.0 | 1580.0 |
| Rainfall | 774.0 | 3200.0 | 1369.0 | 1971.0 |
| Wselvgr2 | 4.00 | 689.00 | 262.00 | 413.00 |
| Topex1km | 1.260 | 28.400 | 6.205 | 13.920 |

[4]The statistical package used (MINITAB for VAX mainframes) could not readily manipulate all the variables included in the entire original dataset so only those used in any of models A5.6 to A5.8 are described and included in the subsequent correlation matrix.

| | | | | |
|---|---|---|---|---|
| Factor 1 | -5.0600 | 2.2350 | -0.5773 | 0.7080 |
| Factor 2 | -2.2650 | 4.2810 | -0.8835 | 0.6240 |
| Factor 3 | -1.6280 | 2.9190 | -0.8422 | 1.0040 |
| Factor 4 | -2.6940 | 3.8880 | -0.7890 | 0.7815 |
| Factor 5 | -3.4640 | 3.3010 | -0.7320 | 0.7420 |
| reserve | 0.00000 | 1.00000 | 0.00000 | 0.00000 |
| park | 0.00000 | 1.00000 | 0.00000 | 1.00000 |
| ancient | 0.00000 | 1.00000 | 0.00000 | 0.00000 |
| soil1 | 0.00000 | 1.00000 | 0.00000 | 0.00000 |
| soil2 | 0.00000 | 1.00000 | 0.00000 | 0.00000 |
| soil3 | 0.00000 | 1.00000 | 0.00000 | 1.00000 |
| soil4 | 0.00000 | 1.00000 | 0.00000 | 1.00000 |
| soil5 | 0.00000 | 1.00000 | 0.00000 | 0.00000 |
| soil6 | 0.00000 | 1.00000 | 0.00000 | 0.00000 |
| soil7 | 0.00000 | 1.00000 | 0.00000 | 0.00000 |
| soil8 | 0.00000 | 1.00000 | 0.00000 | 0.00000 |
| soil4568 | 0.00000 | 1.00000 | 0.00000 | 1.00000 |
| soil23 | 0.00000 | 1.00000 | 0.00000 | 1.00000 |
| soil46 | 0.00000 | 1.00000 | 0.00000 | 1.00000 |
| soil57 | 0.00000 | 1.00000 | 0.00000 | 0.00000 |
| soil234 | 0.00000 | 1.00000 | 1.00000 | 1.00000 |
| MixCrop | 0.00000 | 1.00000 | 0.00000 | 1.00000 |
| survAge | 10.000 | 36.000 | 18.000 | 30.000 |
| YCfits | 4.621 | 19.709 | 11.445 | 14.271 |
| YCfitCat | 4.000 | 20.000 | 12.000 | 14.000 |

Table A5.30: Pearson correlation coefficients for all variables used in models A5.6 to A5.8

| | yc | plantyr | uncleard | Area | unprod | 1st Rot | 2nd Rot | semi-nat |
|---|---|---|---|---|---|---|---|---|
| plantyr | 0.132 | | | | | | | |
| uncleard | 0.148 | -0.076 | | | | | | |
| Area | -0.056 | 0.136 | -0.104 | | | | | |
| unprod | -0.140 | 0.080 | -0.029 | 0.178 | | | | |
| 1st Rot | -0.410 | -0.198 | -0.006 | 0.162 | 0.033 | | | |
| 2nd Rot | 0.189 | 0.306 | -0.036 | -0.082 | -0.003 | -0.581 | | |
| semi-nat | -0.006 | -0.015 | -0.008 | -0.028 | 0.004 | -0.113 | -0.013 | |
| Acctemp | 0.253 | -0.030 | 0.013 | -0.102 | -0.057 | -0.103 | -0.008 | 0.004 |
| Rainfall | -0.309 | -0.024 | -0.013 | 0.123 | 0.089 | 0.276 | -0.141 | -0.005 |
| Wselvgr2 | -0.439 | 0.103 | -0.034 | 0.250 | 0.046 | 0.221 | -0.025 | -0.074 |
| Topex1km | 0.099 | -0.047 | -0.024 | -0.127 | 0.010 | -0.112 | 0.033 | 0.077 |
| Factor 1 | -0.267 | 0.015 | 0.004 | 0.137 | 0.063 | 0.263 | -0.109 | -0.009 |
| Factor 2 | 0.189 | -0.090 | -0.022 | -0.176 | -0.011 | -0.172 | 0.015 | 0.087 |
| Factor 3 | -0.379 | 0.066 | -0.051 | 0.172 | 0.045 | 0.220 | -0.104 | -0.041 |
| Factor 4 | -0.077 | -0.022 | -0.003 | -0.009 | -0.007 | 0.000 | 0.032 | -0.030 |
| Factor 5 | -0.123 | 0.030 | -0.006 | 0.084 | 0.035 | -0.027 | 0.079 | 0.049 |
| reserve | -0.197 | 0.231 | -0.061 | 0.133 | 0.042 | 0.126 | -0.056 | -0.028 |
| park | 0.079 | -0.003 | -0.006 | -0.017 | 0.013 | 0.054 | -0.080 | 0.071 |
| ancient | 0.125 | -0.027 | 0.025 | -0.052 | -0.007 | -0.238 | -0.011 | 0.388 |
| soil1 | -0.036 | -0.020 | -0.006 | -0.020 | 0.002 | 0.017 | -0.010 | -0.002 |
| soil2 | 0.193 | 0.048 | 0.030 | -0.069 | -0.025 | -0.169 | 0.053 | -0.016 |
| soil3 | 0.248 | -0.093 | 0.038 | -0.112 | -0.025 | -0.150 | 0.081 | 0.053 |
| soil4 | -0.305 | 0.066 | -0.047 | 0.125 | 0.010 | 0.194 | -0.078 | -0.035 |
| soil5 | 0.007 | -0.053 | 0.007 | -0.054 | -0.010 | 0.003 | -0.030 | -0.006 |
| soil6 | -0.086 | 0.007 | -0.005 | 0.076 | 0.055 | 0.084 | -0.040 | -0.011 |
| soil7 | -0.068 | 0.022 | -0.022 | 0.031 | 0.042 | 0.055 | -0.027 | -0.007 |
| soil8 | 0.013 | 0.033 | -0.009 | 0.001 | -0.012 | 0.024 | -0.014 | -0.003 |
| soil4568 | -0.334 | 0.059 | -0.048 | 0.143 | 0.028 | 0.229 | -0.102 | -0.040 |
| soil23 | 0.354 | -0.063 | 0.054 | -0.149 | -0.040 | -0.244 | 0.110 | 0.042 |
| soil46 | -0.337 | 0.068 | -0.049 | 0.155 | 0.032 | 0.226 | -0.094 | -0.039 |
| soil57 | -0.047 | -0.018 | -0.012 | -0.012 | 0.025 | 0.043 | -0.041 | -0.009 |
| soil234 | 0.097 | 0.003 | 0.014 | -0.047 | -0.055 | -0.098 | 0.061 | 0.015 |
| MixCrop | -0.046 | -0.150 | -0.117 | -0.157 | -0.033 | -0.011 | -0.078 | -0.000 |
| survAge | 0.009 | -0.788 | 0.143 | -0.100 | -0.114 | 0.143 | -0.251 | -0.010 |
| YCfits | 0.656 | 0.203 | 0.226 | -0.084 | -0.214 | -0.625 | 0.326 | -0.010 |
| YCfitCat | 0.628 | 0.196 | 0.220 | -0.074 | -0.204 | -0.603 | 0.312 | -0.009 |

| | Acctemp | Rainfall | Wselvgr2 | Topex1km | Factor 1 | Factor 2 | Factor 3 | Factor 4 |
|---|---|---|---|---|---|---|---|---|
| Rainfall | -0.326 | | | | | | | |
| Wselvgr2 | -0.581 | 0.204 | | | | | | |
| Topex1km | 0.050 | 0.266 | -0.180 | | | | | |
| Factor 1 | -0.348 | 0.920 | 0.231 | 0.172 | | | | |
| Factor 2 | 0.224 | 0.145 | -0.409 | 0.818 | -0.070 | | | |
| Factor 3 | -0.309 | 0.144 | 0.526 | -0.111 | 0.018 | -0.060 | | |
| Factor 4 | -0.565 | 0.052 | 0.413 | 0.016 | -0.033 | -0.010 | 0.016 | |
| Factor 5 | -0.379 | -0.015 | 0.365 | 0.027 | 0.048 | -0.016 | -0.022 | -0.013 |
| reserve | -0.208 | -0.025 | 0.271 | -0.045 | -0.005 | -0.192 | 0.260 | 0.063 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| park | -0.075 | 0.429 | -0.118 | 0.279 | 0.340 | 0.341 | -0.063 | -0.014 |
| ancient | 0.039 | -0.135 | -0.093 | 0.065 | -0.163 | 0.113 | -0.045 | 0.015 |
| soil1 | 0.096 | -0.055 | -0.115 | -0.063 | -0.058 | -0.022 | -0.036 | -0.064 |
| soil2 | 0.178 | -0.360 | -0.181 | -0.083 | -0.376 | 0.015 | -0.228 | 0.005 |
| soil3 | 0.166 | 0.005 | -0.266 | 0.276 | 0.083 | 0.192 | -0.698 | 0.057 |
| soil4 | -0.177 | 0.052 | 0.357 | -0.226 | 0.039 | -0.249 | 0.655 | -0.070 |
| soil5 | 0.072 | 0.098 | -0.146 | 0.074 | -0.008 | 0.153 | 0.000 | -0.028 |
| soil6 | -0.189 | 0.175 | 0.123 | -0.023 | 0.136 | 0.042 | 0.457 | 0.007 |
| soil7 | -0.154 | 0.246 | 0.013 | 0.016 | 0.197 | 0.008 | -0.057 | 0.067 |
| soil8 | 0.014 | -0.017 | 0.007 | -0.045 | -0.022 | -0.026 | 0.003 | 0.009 |
| soil4568 | -0.233 | 0.142 | 0.370 | -0.221 | 0.089 | -0.198 | 0.833 | -0.072 |
| soil23 | 0.266 | -0.203 | -0.365 | 0.222 | -0.136 | 0.197 | -0.816 | 0.059 |
| soil46 | -0.251 | 0.122 | 0.403 | -0.234 | 0.093 | -0.230 | 0.834 | -0.067 |
| soil57 | -0.069 | 0.252 | -0.087 | 0.061 | 0.144 | 0.108 | -0.043 | 0.032 |
| soil234 | 0.170 | -0.284 | -0.022 | -0.004 | -0.183 | -0.093 | -0.312 | -0.019 |
| MixCrop | -0.004 | -0.007 | -0.093 | 0.136 | -0.030 | 0.160 | -0.028 | 0.013 |
| survAge | 0.034 | -0.046 | -0.063 | 0.028 | -0.035 | 0.041 | -0.049 | 0.019 |
| YCfits | 0.458 | -0.471 | -0.670 | 0.151 | -0.445 | 0.311 | -0.542 | -0.200 |
| YCfitCat | 0.430 | -0.457 | -0.638 | 0.139 | -0.433 | 0.295 | -0.511 | -0.185 |

| | Factor 5 | reserve | park | ancient | soil1 | soil2 | soil3 | soil4 |
|---|---|---|---|---|---|---|---|---|
| reserve | 0.021 | | | | | | | |
| park | 0.004 | -0.246 | | | | | | |
| ancient | 0.016 | -0.063 | -0.024 | | | | | |
| soil1 | -0.035 | 0.068 | -0.023 | -0.005 | | | | |
| soil2 | 0.049 | -0.101 | -0.040 | 0.115 | -0.012 | | | |
| soil3 | 0.065 | -0.147 | 0.047 | -0.010 | -0.030 | -0.259 | | |
| soil4 | -0.052 | 0.248 | -0.160 | -0.044 | -0.033 | -0.277 | -0.711 | |
| soil5 | -0.144 | -0.054 | 0.146 | 0.017 | -0.004 | -0.037 | -0.094 | -0.101 |
| soil6 | -0.035 | -0.038 | 0.108 | -0.027 | -0.008 | -0.067 | -0.171 | -0.183 |
| soil7 | 0.040 | -0.069 | 0.215 | -0.017 | -0.005 | -0.042 | -0.108 | -0.116 |
| soil8 | -0.018 | -0.029 | 0.036 | -0.007 | -0.002 | -0.017 | -0.043 | -0.046 |
| soil4568 | -0.100 | 0.216 | -0.078 | -0.052 | -0.037 | -0.312 | -0.800 | 0.890 |
| soil23 | 0.092 | -0.203 | 0.023 | 0.057 | -0.037 | 0.323 | 0.830 | -0.857 |
| soil46 | -0.065 | 0.231 | -0.115 | -0.055 | -0.035 | -0.302 | -0.774 | 0.919 |
| soil57 | -0.065 | -0.088 | 0.260 | -0.002 | -0.007 | -0.056 | -0.145 | -0.155 |
| soil234 | 0.076 | 0.081 | -0.254 | 0.024 | -0.129 | 0.092 | 0.235 | 0.252 |
| MixCrop | -0.014 | -0.021 | 0.080 | 0.006 | -0.028 | -0.024 | 0.032 | -0.030 |
| survAge | -0.036 | -0.069 | 0.027 | 0.030 | 0.037 | -0.011 | 0.080 | -0.086 |
| YCfits | -0.122 | -0.301 | 0.121 | 0.191 | -0.054 | 0.348 | 0.347 | -0.461 |
| YCfitCat | -0.123 | -0.291 | 0.113 | 0.190 | -0.052 | 0.334 | 0.325 | -0.432 |

| | soil5 | soil6 | soil7 | soil8 | soil4568 | soil23 | soil46 | soil57 |
|---|---|---|---|---|---|---|---|---|
| soil6 | -0.024 | | | | | | | |
| soil7 | -0.015 | -0.028 | | | | | | |
| soil8 | -0.006 | -0.011 | -0.007 | | | | | |
| soil4568 | 0.118 | 0.213 | -0.131 | 0.054 | | | | |
| soil23 | -0.114 | -0.206 | -0.131 | -0.052 | -0.963 | | | |
| soil46 | -0.110 | 0.220 | -0.126 | -0.050 | 0.968 | -0.933 | | |
| soil57 | 0.651 | -0.037 | 0.749 | -0.009 | -0.021 | -0.175 | -0.169 | |
| soil234 | -0.401 | -0.726 | -0.461 | -0.183 | -0.153 | 0.283 | -0.042 | -0.616 |
| MixCrop | 0.060 | -0.024 | 0.035 | 0.006 | -0.025 | 0.018 | -0.039 | 0.067 |
| survAge | 0.018 | 0.052 | -0.055 | 0.004 | -0.060 | 0.072 | -0.065 | -0.030 |
| YCfits | 0.030 | -0.157 | -0.089 | -0.002 | -0.513 | 0.540 | -0.520 | -0.047 |
| YCfitCat | 0.023 | -0.145 | -0.098 | -0.006 | -0.481 | 0.511 | -0.487 | -0.059 |

| | soil234 | MixCrop | survAge | YCfits |
|---|---|---|---|---|
| MixCrop | -0.022 | | | |
| survAge | -0.026 | 0.097 | | |
| YCfits | 0.157 | -0.069 | -0.111 | |
| YCfitCat | 0.156 | -0.069 | -0.108 | 0.961 |

## A5.3.2: YIELD MODELS FOR BEECH

The analysis of YC for beech sub-compartments followed the same methodology adopted in our investigation of Sitka spruce sites. Consequently only brief notes regarding methods are included with the following detailed results. However, there was one initial concern regarding the use of OLS type statistical techniques on this dataset. While the dependent variable (YC) in our analysis of Sitka spruce sites varies from 4 to 22 (i.e. across 10 possible, ratio scale, even numbers), our beech data only varied from 2 to 10 (i.e. across 5 possible, ratio scale, even numbers). Given that the dependent is on a ratio scale then OLS is not invalid. However, the lack of variation in YC will result in relatively high standard errors on parameter estimates. Again in the Sitka spruce experiment this is not an issue as the very large sample size appears to have more than compensated for this problem. However, with our beech analysis we have a significantly smaller dataset and must therefore expect to identify fewer significant explanatory variables than before. This indeed proved to be the case. Nevertheless given that this is a fundamental problem inherent it the way in which YC is calculated which cannot be fully overcome by any statistical technique however refined[5], and the knowledge that estimates will not be biased, OLS techniques seem a reasonable approach to this problem.

Following the deletion of sites for which key data was missing or illogical (giving us a dataset of 766 observations in file YCBE2.MTW), initial investigations again confirmed the suitability of a linear functional form for our model. However, now a no-factor model provided the best initial fit to the data as reported in model A5.9.

Model A5.9: Initial regression model: beech

```
yc = 5.51 -0.000249 Rainfall - 0.00431 Wselvgr2 + 0.00318 Avwatgra
          + 0.00844 plantyr + 0.523 historic - 0.929 monument
          + 0.498 NpAonbSa - 0.499 othESA - 0.388 forPark + 1.03 national
          - 0.603 FCcons + 0.242 soil2
```

| Predictor | Coef | Stdev | t-ratio | p |
|---|---|---|---|---|
| Constant | 5.5089 | 0.5600 | 9.84 | 0.000 |
| Rainfall | -0.0002490 | 0.0001686 | -1.48 | 0.140 |
| Wselvgr2 | -0.0043064 | 0.0005302 | -8.12 | 0.000 |
| Avwatgra | 0.003182 | 0.002302 | 1.38 | 0.167 |
| plantyr | 0.008443 | 0.002452 | 3.44 | 0.001 |
| historic | 0.5229 | 0.1067 | 4.90 | 0.000 |
| monument | -0.9295 | 0.6180 | -1.50 | 0.133 |
| NpAonbSa | 0.4978 | 0.1444 | 3.45 | 0.001 |
| othESA | -0.4987 | 0.2998 | -1.66 | 0.097 |
| forPark | -0.3877 | 0.1894 | -2.05 | 0.041 |
| national | 1.0305 | 0.3223 | 3.20 | 0.001 |
| FCcons | -0.6026 | 0.1468 | -4.10 | 0.000 |
| soil2 | 0.2423 | 0.1323 | 1.83 | 0.067 |

s = 1.363     R-sq = 22.2%     R-sq(adj) = 21.0%

Analysis of Variance

| SOURCE | DF | SS | MS | F | p |
|---|---|---|---|---|---|
| Regression | 12 | 399.763 | 33.314 | 17.94 | 0.000 |
| Error | 753 | 1398.070 | 1.857 | | |
| Total | 765 | 1797.833 | | | |

| SOURCE | DF | SEQ SS |
|---|---|---|
| Rainfall | 1 | 47.425 |
| Wselvgr2 | 1 | 167.712 |
| Avwatgra | 1 | 5.055 |
| plantyr | 1 | 41.663 |
| historic | 1 | 43.876 |
| monument | 1 | 3.197 |
| NpAonbSa | 1 | 25.862 |
| othESA | 1 | 6.518 |
| forPark | 1 | 3.017 |
| national | 1 | 17.912 |
| FCcons | 1 | 31.298 |
| soil2 | 1 | 6.228 |

[5]Discussions with highly respected authorities in the field of statistics (including Professor Harvey Goldstein, Professor Toby Lewis and Dr. Ian Langford) confirmed that while stepwise analyses of variance, multi-level models and Bayesian techniques could all reasonably be applied to this issue, none would adequately overcome the inherent problem set up by the way in which YC data is defined. All of these authorities concluded that OLS techniques would produce as good a model as could reasonably be obtained.

Clearly some of the variables included in model A5.9 are rather weak. However, it was felt that this model provided an adequate base to analyse the impact of omitting sub-compartments on the basis of increasing survey age. This analysis was undertaken as before with results reported in table A5.31.

Table A5.31: Analysis of *sage* impacts: beech

| Survey age below which all observations omitted[1] | Number of observations[2] | $R^2$(adj) using best fit mixed model[3] (%) |
|---|---|---|
| 0 | 766 | 21.0 |
| 1 | 764 | 20.6 |
| 2 | 762 | 20.7 |
| 3 | 757 | 20.5 |
| 4 | 748 | 20.6 |
| 5 | 748 | 20.6 |
| 6 | 747 | 20.9 |
| 7 | 747 | 20.9 |
| 8 | 747 | 20.9 |
| 9 | 746 | 20.9 |
| 10 | 746 | 20.9 |
| 11 | 744 | 20.7 |
| 12 | 742 | 20.4 |
| 13 | 736 | 20.6 |
| 14 | 733 | 20.7 |
| 15 | 730 | 20.8 |
| 16 | 725 | 20.8 |
| 17 | 720 | 20.7 |
| 18 | 716 | 20.8 |
| 19 | 701 | 21.7 |
| 20 | 692 | 21.9 |
| 21 | 677 | 21.8 |
| 22 | 659 | 21.9 |
| 23 | 632 | 21.2 |
| 24 | 606 | 21.2 |
| 25 | 586 | 21.9 |
| 26 | 563 | 23.3 |
| 27 | 524 | 22.2 |

| Survey age below which all observations omitted[1] | Number of observations[2] | $R^2$(adj) using best fit mixed model[3] (%) |
|---|---|---|
| 28 | 493 | 21.6 |
| 29 | 452 | 23.8 |
| 30 | 428 | 24.2 |
| 31 | 401 | 24.8 |
| 32 | 385 | 25.0 |
| 33 | 376 | 25.6 |
| 34 | 359 | 25.4 |
| 35 | 340 | 27.3 |
| 36 | 310 | 28.1 |
| 37 | 295 | 28.9 |
| 38 | 275 | 29.0 |
| 39 | 259 | 26.8 |
| 40 | 241 | 28.6 |
| 41 | 231 | 27.7 |
| 42 | 220 | 26.1 |
| 43 | 206 | 24.7 |
| 44 | 193 | 24.8 |
| 45 | 182 | 22.4 |
| 46 | 177 | 23.7 |
| 47 | 165 | 23.8 |
| 48 | 150 | 22.3 |
| 49 | 142 | 22.9 |
| 50 | 134 | 22.6 |
| 51 | 121 | 22.0 |
| 52 | 111 | 20.6 |
| 53 | 101 | 16.7 |
| 54 | 93 | 14.4 |
| 55 | 90 | 14.1 |
| 60 | 77 | 14.2 |
| 65 | 69 | 10.1 |
| 70 | 63 | 24.4 |
| 75 | 62 | 19.9 |

| Survey age below which all observations omitted[1] | Number of observations[2] | $R^2$(adj) using best fit mixed model[3] (%) |
|---|---|---|
| 80 | 60 | 24.7 |
| 85 | 57 | 24.2 |
| 90 | 42 | 59.0 |
| 95 | 42 | 59.0 |
| 100 | 39 | 62.9 |
| 105 | 39 | 62.9 |
| 110 | 18 | 67.1 |
| 115 | 18 | 67.1 |

Notes:

1. For example a value of 10 in column 1 indicates that all stands with an age at survey of less than 10 years were omitted from the analysis. Note that a few observations hade negative survey ages and are therefore omitted at the first row of the table.
2. Excludes any observations with missing values for the variables used in the regression model (generally these were few).
3. Analysis based on model A5.9.

The increase in fit from about *sage*=20 is very probably due to the exclusion of stands surveyed at an early age. Note that this trend in increasing fit with *sage* is much longer lasting than with the Sitka spruce analysis indicating, as expected, that it is much more difficult to assess the YC of a beech stand at say *sage*=10 than a Sitka spruce stand. Here the optimal fit excluding only low *sage* observations is achieved by omitting all sites with *sage*<38 (this compares with an optimal lower truncation at *sage*<10 for Sitka spruce). This gave a dataset of 359 observations for which our optimal model is reported as model A5.10.

Model A5.10: Optimal (no-factor) model for beech: sites with *sage*<38 omitted

```
YC = 4.77 -0.000175 Rainfall - 0.00432 Wselvgr2 + 0.00330 Avwatgra
          + 0.0134 plantyr + 0.470 historic - 0.094 monument
          + 0.635 NpAonbSa - 1.06 othESA - 0.415 forPark + 0.416 national
          - 0.345 FCcons + 0.214 soil2

Predictor        Coef        Stdev     t-ratio       p
Constant       4.7663       0.7357        6.48   0.000
Rainfall   -0.0001754    0.0002479       -0.71   0.480
Wselvgr2   -0.0043157    0.0007218       -5.98   0.000
Avwatgra     0.003301     0.003648        0.90   0.366
plantyr      0.013391     0.003044        4.40   0.000
historic       0.4699       0.1535        3.06   0.002
monument      -0.0937       0.9340       -0.10   0.920
NpAonbSa       0.6353       0.2317        2.74   0.006
othESA        -1.0556       0.4753       -2.22   0.027
forPark       -0.4153       0.2602       -1.60   0.111
national       0.4156       0.5096        0.82   0.415
FCcons        -0.3452       0.2238       -1.54   0.124
soil2          0.2145       0.1863        1.15   0.250

s = 1.258        R-sq = 27.9%      R-sq(adj) = 25.4%
```

Analysis of Variance

| SOURCE | DF | SS | MS | F | p |
|---|---|---|---|---|---|
| Regression | 12 | 211.712 | 17.643 | 11.14 | 0.000 |
| Error | 346 | 547.798 | 1.583 | | |
| Total | 358 | 759.510 | | | |

| SOURCE | DF | SEQ SS |
|---|---|---|
| Rainfall | 1 | 8.173 |
| Wselvgr2 | 1 | 97.599 |
| Avwatgra | 1 | 3.919 |
| plantyr | 1 | 49.712 |
| historic | 1 | 17.642 |
| monument | 1 | 0.038 |
| NpAonbSa | 1 | 14.676 |
| othESA | 1 | 8.935 |
| forPark | 1 | 3.878 |
| national | 1 | 1.115 |
| FCcons | 1 | 3.928 |
| soil2 | 1 | 2.098 |

Table A5.32 also shows (as observed in our Sitka spruce data) that the degree of explanation afforded by models falls as we consider stands with *sage* of over about 50 years. As previously postulated this seems likely to be connected to such stands being consequently quite old at the time of surveying. Uneven introduction of advances in silviculture may in part account for the increase in variance here. Furthermore it may be that planting date is less certain in these stands. This is more likely to be a problem with beech sub-compartments than with Sitka spruce as the latter were almost all originally planted by the FC, who generally keep good records, (and may apply new silvicultural techniques in a more uniform manner) while older beech stands may have been planted by a variety of private agents for which complete and accurate planting records may not be available. Given the importance of accurate age measurements in calculating YC, such uncertainty may well translate into higher variance within such stands.

Given this we felt justified in additionally omitting those stands with high sage. A sensitivity analysis suggested that omission of sage <49 would optimise the fit of our model. This gave an effective dataset of some 205 observations (in file YCBE3.MTW) for which our optimal model is reported as model A5.11.

Model A5.11: Preliminary (no-factor) model for beech: sites with *sage*<38 and *sage*>49 omitted

```
YC = - 3.96 -0.000119 Rainfall - 0.00428 Wselvgr2 + 0.00560 Avwatgra
          + 0.0722 plantyr + 0.047 historic - 1.42 monument + 0.549 NpAonbSa
          - 1.24 othESA - 0.342 forPark + 0.420 national - 0.088 FCcons
          + 0.250 soil2
```

| Predictor | Coef | Stdev | t-ratio | p |
|---|---|---|---|---|
| Constant | -3.958 | 2.325 | -1.70 | 0.090 |
| Rainfall | -0.0001191 | 0.0003140 | -0.38 | 0.705 |
| Wselvgr2 | -0.004275 | 0.001035 | -4.13 | 0.000 |
| Avwatgra | 0.005604 | 0.004810 | 1.17 | 0.245 |
| plantyr | 0.07224 | 0.01439 | 5.02 | 0.000 |
| historic | 0.0474 | 0.2340 | 0.20 | 0.840 |
| monument | -1.416 | 1.458 | -0.97 | 0.333 |
| NpAonbSa | 0.5487 | 0.3168 | 1.73 | 0.085 |
| othESA | -1.2422 | 0.5506 | -2.26 | 0.025 |
| forPark | -0.3418 | 0.3608 | -0.95 | 0.345 |
| national | 0.4199 | 0.5527 | 0.76 | 0.448 |
| FCcons | -0.0883 | 0.3616 | -0.24 | 0.807 |
| soil2 | 0.2503 | 0.2260 | 1.11 | 0.270 |

s = 1.291 R-sq = 37.1% R-sq(adj) = 33.1%

Analysis of Variance

| SOURCE | DF | SS | MS | F | p |
|---|---|---|---|---|---|
| Regression | 12 | 189.289 | 15.774 | 9.47 | 0.000 |
| Error | 192 | 321.546 | 1.666 | | |
| Total | 204 | 510.835 | | | |

| SOURCE | DF | SEQ SS |
|---|---|---|
| Rainfall | 1 | 11.034 |
| Wselvgr2 | 1 | 92.790 |
| Avwatgra | 1 | 6.932 |
| plantyr | 1 | 53.202 |
| historic | 1 | 0.047 |
| monument | 1 | 1.067 |
| NpAonbSa | 1 | 9.718 |
| othESA | 1 | 10.098 |
| forPark | 1 | 1.209 |
| national | 1 | 1.003 |
| FCcons | 1 | 0.146 |
| soil2 | 1 | 2.043 |

Clearly model A5.11 has a number of very weak explanatory variables. Given the extent of the omission of observations, regression analysis was begun again afresh so as to redefine an appropriate set of explanatory variables. Here many variables failed to enter the model while the variable *AONB/NSA* made it's first entry. Model A5.12 reports results derived from only describing site environmental characteristics through all of the PCA factors for beech derived previously. As this uses a relatively small dataset unusual observations are also reported although none of these are sufficiently strong to signal any fundamental problem in our model.

Model A5.12: Preliminary factor-only model for beech: sites with *sage*<38 and *sage*>49 omitted

```
YC = - 4.84 - 0.0547 Factor 1 - 0.365 Factor 2 + 0.131 Factor 3
          - 0.110 Factor 4 + 0.120 Factor 5 + 0.0777 plantyr
          + 0.436 AONB/NSA - 1.38 othESA
```

205 cases used 1 cases contain missing values

| Predictor | Coef | Stdev | t-ratio | p |
|---|---|---|---|---|
| Constant | -4.844 | 1.901 | -2.55 | 0.012 |
| Factor 1 | -0.05466 | 0.09757 | -0.56 | 0.576 |
| Factor 2 | -0.36482 | 0.08763 | -4.16 | 0.000 |
| Factor 3 | 0.1310 | 0.1031 | 1.27 | 0.206 |
| Factor 4 | -0.10985 | 0.09855 | -1.11 | 0.266 |
| Factor 5 | 0.11968 | 0.09674 | 1.24 | 0.218 |
| plantyr | 0.07767 | 0.01308 | 5.94 | 0.000 |
| AONB/NSA | 0.4357 | 0.3056 | 1.43 | 0.156 |
| othESA | -1.3770 | 0.5041 | -2.73 | 0.007 |

s = 1.262 R-sq = 37.3% R-sq(adj) = 34.7%

Analysis of Variance

| SOURCE | DF | SS | MS | F | p |
|---|---|---|---|---|---|
| Regression | 8 | 185.411 | 23.176 | 14.56 | 0.000 |
| Error | 196 | 312.033 | 1.592 | | |
| Total | 204 | 497.444 | | | |

| SOURCE | DF | SEQ SS |
|---|---|---|
| Factor 1 | 1 | 11.536 |
| Factor 2 | 1 | 96.756 |
| Factor 3 | 1 | 4.546 |
| Factor 4 | 1 | 3.638 |
| Factor 5 | 1 | 3.766 |
| plantyr | 1 | 49.983 |
| AONB/NSA | 1 | 3.309 |
| othESA | 1 | 11.877 |

Unusual Observations

| Obs. | Factor 1 | yc | Fit | Stdev.Fit | Residual | St.Resid |
|---|---|---|---|---|---|---|
| 7 | 0.81 | 4.0000 | 5.3281 | 0.4921 | -1.3281 | -1.14 X |
| 8 | 0.62 | 6.0000 | 5.0994 | 0.4936 | 0.9006 | 0.78 X |
| 9 | 0.79 | 4.0000 | 5.2855 | 0.4870 | -1.2855 | -1.10 X |
| 10 | 0.35 | 4.0000 | 5.0224 | 0.5079 | -1.0224 | -0.89 X |
| 14 | 0.04 | 4.0000 | 7.1490 | 0.1831 | -3.1490 | -2.52R |
| 15 | 0.04 | 4.0000 | 7.1490 | 0.1831 | -3.1490 | -2.52R |
| 16 | -0.10 | 10.0000 | 7.3778 | 0.2114 | 2.6222 | 2.11R |
| 24 | -1.27 | 10.0000 | 7.3602 | 0.3088 | 2.6398 | 2.16R |
| 42 | -1.06 | 10.0000 | 7.5006 | 0.2899 | 2.4994 | 2.04R |
| 53 | -0.22 | 8.0000 | 5.5196 | 0.2612 | 2.4804 | 2.01R |
| 84 | 1.29 | 4.0000 | 6.6005 | 0.4025 | -2.6005 | -2.17R |
| 87 | 0.52 | 4.0000 | 6.9980 | 0.2146 | -2.9980 | -2.41R |
| 108 | 0.46 | 4.0000 | 6.5488 | 0.1962 | -2.5488 | -2.04R |
| 145 | 0.87 | 6.0000 | 4.2521 | 0.4981 | 1.7479 | 1.51 X |
| 146 | 0.87 | 4.0000 | 4.2521 | 0.4981 | -0.2521 | -0.22 X |
| 152 | 0.62 | 6.0000 | 4.7605 | 0.4857 | 1.2395 | 1.06 X |
| 157 | 1.74 | 8.0000 | 5.4278 | 0.2840 | 2.5722 | 2.09R |
| 160 | -0.33 | 8.0000 | 5.3907 | 0.2417 | 2.6093 | 2.11R |
| 161 | -0.25 | 2.0000 | 5.4844 | 0.2256 | -3.4844 | -2.81R |

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

Clearly several of the factors used in model A5.12 have proven statistically insignificant. Furthermore, as we are now examining a subset of the original dataset the possibility of collinearity between factors exists. To check for this a Pearson correlation matrix was calculated as detailed in table A5.33.

Table A5.33: Pearson correlation matrix for model A5.12

| | yc | Factor 1 | Factor 2 | Factor 3 | Factor 4 | Factor 5 | plantyr | AONB/NSA |
|---|---|---|---|---|---|---|---|---|
| Factor 1 | -0.152 | | | | | | | |
| Factor 2 | -0.434 | -0.044 | | | | | | |
| Factor 3 | 0.113 | -0.069 | -0.012 | | | | | |
| Factor 4 | -0.019 | -0.019 | -0.134 | 0.040 | | | | |
| Factor 5 | 0.136 | 0.143 | -0.128 | 0.075 | -0.118 | | | |
| plantyr | 0.480 | -0.196 | -0.348 | 0.048 | 0.023 | -0.002 | | |
| AONB/NSA | 0.250 | -0.418 | -0.239 | -0.011 | 0.165 | 0.056 | 0.193 | |
| othESA | -0.178 | 0.126 | 0.086 | -0.091 | 0.055 | -0.101 | 0.094 | -0.073 |

Inspection of model A5.12 suggests that factors 1,3,4 and 5 are insignificant (table A5.33 also highlights collinearity between factors 1 and 2). Dropping these we obtain model A5.13.

Model A5.13: Best factor-only model for beech: sites with *sage*<38 and sage><49 omitted

YC = - 5.23 - 0.354 Factor 2 + 0.0804 plantyr + 0.461 AONB/NSA - 1.58 othESA

205 cases used 1 cases contain missing values

| Predictor | Coef | Stdev | t-ratio | p |
|---|---|---|---|---|
| Constant | -5.227 | 1.854 | -2.82 | 0.005 |
| Factor 2 | -0.35371 | 0.08458 | -4.18 | 0.000 |
| plantyr | 0.08038 | 0.01278 | 6.29 | 0.000 |
| AONB/NSA | 0.4614 | 0.2719 | 1.70 | 0.091 |
| othESA | -1.5826 | 0.4941 | -3.20 | 0.002 |

s = 1.266 R-sq = 35.6% R-sq(adj) = 34.3%

Analysis of Variance

| SOURCE | DF | SS | MS | F | p |
|---|---|---|---|---|---|
| Regression | 4 | 177.140 | 44.285 | 27.65 | 0.000 |
| Error | 200 | 320.303 | 1.602 | | |
| Total | 204 | 497.444 | | | |

| SOURCE | DF | SEQ SS |
|---|---|---|
| Factor 2 | 1 | 93.676 |
| plantyr | 1 | 61.063 |
| AONB/NSA | 1 | 5.971 |
| othESA | 1 | 16.430 |

Unusual Observations

| Obs. | Factor 2 | yc | Fit | Stdev.Fit | Residual | St.Resid |
|---|---|---|---|---|---|---|
| 7 | 0.70 | 4.0000 | 5.1602 | 0.4802 | -1.1602 | -0.99 X |
| 8 | 0.30 | 6.0000 | 5.3031 | 0.4808 | 0.6969 | 0.60 X |
| 9 | 0.66 | 4.0000 | 5.1761 | 0.4801 | -1.1761 | -1.00 X |
| 10 | 1.04 | 4.0000 | 5.2815 | 0.4871 | -1.2815 | -1.10 X |
| 14 | -0.08 | 4.0000 | 7.0177 | 0.1359 | -3.0177 | -2.40R |
| 15 | -0.08 | 4.0000 | 7.0177 | 0.1359 | -3.0177 | -2.40R |
| 16 | 0.18 | 10.0000 | 7.2476 | 0.1770 | 2.7524 | 2.20R |
| 24 | -0.83 | 10.0000 | 7.5060 | 0.2456 | 2.4940 | 2.01R |
| 42 | -1.22 | 10.0000 | 7.2406 | 0.2636 | 2.7594 | 2.23R |
| 53 | -0.57 | 8.0000 | 5.4261 | 0.2390 | 2.5739 | 2.07R |
| 72 | -0.35 | 10.0000 | 7.4372 | 0.1735 | 2.5628 | 2.04R |
| 87 | 0.69 | 4.0000 | 6.9096 | 0.1691 | -2.9096 | -2.32R |
| 101 | -0.53 | 4.0000 | 6.6170 | 0.1202 | -2.6170 | -2.08R |
| 145 | 1.02 | 6.0000 | 4.0842 | 0.4896 | 1.9158 | 1.64 X |
| 146 | 1.02 | 4.0000 | 4.0842 | 0.4896 | -0.0842 | -0.07 X |
| 152 | 0.73 | 6.0000 | 4.9106 | 0.4784 | 1.0894 | 0.93 X |
| 160 | 2.31 | 8.0000 | 5.0480 | 0.1861 | 2.9520 | 2.36R |
| 161 | 1.96 | 2.0000 | 5.1733 | 0.1646 | -3.1733 | -2.53R |

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

A no-factor alternative was also estimated and is reported as model A5.14.

Model A5.14: Optimal (no-factor) model for beech: sites with *sage*<38 and *sage*>49 omitted

YC = - 4.43 - 0.00386 Wselvgr2 + 0.0799 plantyr + 0.475 AONB/NSA
 - 1.48 othESA

| Predictor | Coef | Stdev | t-ratio | p |
|---|---|---|---|---|
| Constant | -4.428 | 1.923 | -2.30 | 0.022 |
| Wselvgr2 | -0.0038638 | 0.0009149 | -4.22 | 0.000 |
| plantyr | 0.07995 | 0.01279 | 6.25 | 0.000 |
| AONB/NSA | 0.4751 | 0.2710 | 1.75 | 0.081 |
| othESA | -1.4812 | 0.4969 | -2.98 | 0.003 |

s = 1.265 R-sq = 35.7% R-sq(adj) = 34.4%

Analysis of Variance

| SOURCE | DF | SS | MS | F | p |
|---|---|---|---|---|---|
| Regression | 4 | 177.649 | 44.412 | 27.78 | 0.000 |
| Error | 200 | 319.794 | 1.599 | | |
| Total | 204 | 497.444 | | | |

| SOURCE | DF | SEQ SS |
|---|---|---|
| Wselvgr2 | 1 | 96.940 |
| plantyr | 1 | 60.420 |
| AONB/NSA | 1 | 6.083 |
| othESA | 1 | 14.207 |

Unusual Observations

| Obs. | Wselvgr2 | yc | Fit | Stdev.Fit | Residual | St.Resid |
|---|---|---|---|---|---|---|
| 7 | 308 | 4.0000 | 5.0529 | 0.4809 | -1.0529 | -0.90 X |
| 8 | 212 | 6.0000 | 5.4238 | 0.4828 | 0.5762 | 0.49 X |
| 9 | 277 | 4.0000 | 5.1727 | 0.4797 | -1.1727 | -1.00 X |
| 10 | 285 | 4.0000 | 5.3816 | 0.4848 | -1.3816 | -1.18 X |
| 14 | 162 | 4.0000 | 7.0982 | 0.1375 | -3.0982 | -2.46R |
| 15 | 162 | 4.0000 | 7.0982 | 0.1375 | -3.0982 | -2.46R |
| 16 | 192 | 10.0000 | 7.3020 | 0.1747 | 2.6980 | 2.15R |
| 24 | 115 | 10.0000 | 7.5150 | 0.2456 | 2.4850 | 2.00R |
| 42 | 73 | 10.0000 | 7.2775 | 0.2660 | 2.7225 | 2.20R |
| 87 | 302 | 4.0000 | 6.7171 | 0.1920 | -2.7171 | -2.17R |
| 118 | 366 | 8.0000 | 5.3506 | 0.1576 | 2.6494 | 2.11R |
| 145 | 316 | 6.0000 | 4.0626 | 0.4891 | 1.9374 | 1.66 X |
| 146 | 316 | 4.0000 | 4.0626 | 0.4891 | -0.0626 | -0.05 X |
| 152 | 300 | 6.0000 | 4.8439 | 0.4781 | 1.1561 | 0.99 X |
| 160 | 369 | 8.0000 | 5.1791 | 0.1629 | 2.8209 | 2.25R |
| 161 | 347 | 2.0000 | 5.2641 | 0.1502 | -3.2641 | -2.60R |

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

Models A5.13 and A5.14 are extremely similar both in terms of their degree of explanation and their choice of explanatory variables; *Factor 1* in model A5.13 is essentially the effect of elevation which is the raw data environmental variable *Wselvgr2* used in model A5.14. Consequently we cannot have a mixed model for beech. Given its ease of interpretation we prefer model A5.14 as our optimal model for predicting YC in beech sub-compartments.

An interesting supplementary analysis concerns the consideration of aspect effects. In building up our best fit model these had been investigated and rejected as statistically insignificant. Nevertheless it is interesting to see if the logical relationship between aspect effects for Sitka spruce in Northern Britain and Wales noted previously had any implications for aspect effects upon beech in Wales. The aspect variables Sinasp and Cosasp were therefore added into our best fit model which was then re-estimated to produce model A5.15.

Model A5.15: Including aspect effects within our preferred beech model.

YC = - 4.37 - 0.00378 Wselvgr2 + 0.120 sinasp - 0.191 cosasp + 0.0795 plantyr
+ 0.486 AONB/NSA - 1.45 othESA

| Predictor | Coef | Stdev | t-ratio | p |
|---|---|---|---|---|
| Constant | -4.375 | 1.921 | -2.28 | 0.024 |
| Wselvgr2 | -0.0037821 | 0.0009141 | -4.14 | 0.000 |
| sinasp | 0.1203 | 0.1274 | 0.94 | 0.346 |
| cosasp | -0.1905 | 0.1242 | -1.53 | 0.127 |
| plantyr | 0.07952 | 0.01278 | 6.22 | 0.000 |
| AONB/NSA | 0.4856 | 0.2703 | 1.80 | 0.074 |
| othESA | -1.4455 | 0.5007 | -2.89 | 0.004 |

s = 1.261 R-sq = 36.7% R-sq(adj) = 34.8%

Analysis of Variance

| SOURCE | DF | SS | MS | F | p |
|---|---|---|---|---|---|
| Regression | 6 | 182.734 | 30.456 | 19.16 | 0.000 |
| Error | 198 | 314.710 | 1.589 | | |

| | | |
|---|---|---|
| Total | 204 | 497.444 |

| SOURCE | DF | SEQ SS |
|---|---|---|
| Wselvgr2 | 1 | 96.940 |
| sinasp | 1 | 1.632 |
| cosasp | 1 | 4.320 |
| plantyr | 1 | 60.309 |
| AONB/NSA | 1 | 6.287 |
| othESA | 1 | 13.246 |

As can be seen, both of the aspect variables are of very low significance. This of itself is interesting as aspect was clearly significant in the study conducted by Worrell and Malcolm (1990) and on the edge of statistical significance in our Sitka spruce study. Similarly, consideration of coefficient estimates shows that the absolute magnitude of predicted effects was largest in the Worrell and Malcolm study, less sizeable in our Sitka spruce study and smallest here. Inspection of the summary statistics given at the end of this section gives us a consistent explanation of all these results. While the Worrell and Malcolm study considered only sites in upland areas of Northern Britain, our Sitka spruce analysis considers both upland and lowland sites in the less harsh climate of Wales. Furthermore comparison of descriptive statistics for our Sitka spruce and beech studies shows that beech is generally planted at substantially lower altitudes than those of Sitka spruce sites. So it seems that the impact of aspect upon tree growth depends upon altitude such that on lowland sites it may be insignificant while at upland sites aspect can have a major effect upon tree growth.

Finally, for extrapolation and inspection purposes tables A5.30 and A5.31 detail summary statistics and Pearson correlation coefficients for the entire beech dataset used in models where sites with sites with *sage*<38 and *sage*>49 are omitted.

Table A5.34: Summary statistics for all variables used in beech models with sites *sage*<38 and *sage*>49 omitted

| | N | N* | MEAN | MEDIAN | TRMEAN | STDEV | SEMEAN |
|---|---|---|---|---|---|---|---|
| yc | 205 | 1 | 6.332 | 6.000 | 6.324 | 1.562 | 0.109 |
| plantyr | 206 | 0 | 144.83 | 144.50 | 144.99 | 7.50 | 0.52 |
| noLandsc | 206 | 0 | 0.6408 | 1.0000 | 0.6559 | 0.4809 | 0.0335 |
| area | 206 | 0 | 17.58 | 10.00 | 14.48 | 22.36 | 1.56 |
| unprod | 206 | 0 | 0.1796 | 0.0000 | 0.0000 | 0.8789 | 0.0612 |
| 1st rot | 206 | 0 | 0.4175 | 0.0000 | 0.4086 | 0.4943 | 0.0344 |
| 2nd rot | 206 | 0 | 0.0340 | 0.0000 | 0.0000 | 0.1816 | 0.0127 |
| semi-nat | 206 | 0 | 0.00485 | 0.00000 | 0.00000 | 0.06967 | 0.00485 |
| historic | 206 | 0 | 0.5437 | 1.0000 | 0.5484 | 0.4993 | 0.0348 |
| purchasd | 206 | 0 | 0.7816 | 1.0000 | 0.8118 | 0.4142 | 0.0289 |
| leased | 206 | 0 | 0.2136 | 0.0000 | 0.1828 | 0.4108 | 0.0286 |
| extra | 206 | 0 | 0.00485 | 0.00000 | 0.00000 | 0.06967 | 0.00485 |
| mixed | 206 | 0 | 0.5728 | 1.0000 | 0.5806 | 0.4959 | 0.0345 |
| NatPark | 206 | 0 | 0.1942 | 0.0000 | 0.1613 | 0.3965 | 0.0276 |
| AONB/NSA | 206 | 0 | 0.1311 | 0.0000 | 0.0914 | 0.3383 | 0.0236 |
| othESA | 206 | 0 | 0.0340 | 0.0000 | 0.0000 | 0.1816 | 0.0127 |
| forPark | 206 | 0 | 0.1699 | 0.0000 | 0.1344 | 0.3765 | 0.0262 |
| SSSI | 206 | 0 | 0.01456 | 0.00000 | 0.00000 | 0.12009 | 0.00837 |
| NNR | 206 | 0 | 0.01942 | 0.00000 | 0.00000 | 0.13832 | 0.00964 |
| FCNR | 206 | 0 | 0.0777 | 0.0000 | 0.0323 | 0.2683 | 0.0187 |
| FCcons | 206 | 0 | 0.0777 | 0.0000 | 0.0323 | 0.2683 | 0.0187 |
| ACodeNo | 206 | 0 | 3.9612 | 4.0000 | 4.0000 | 0.2174 | 0.0151 |
| Acctemp | 206 | 0 | 1551.7 | 1577.5 | 1560.1 | 265.0 | 18.5 |
| Growseas | 206 | 0 | 238.15 | 241.00 | 239.32 | 33.96 | 2.37 |
| Grazseas | 206 | 0 | 142.66 | 149.00 | 145.39 | 61.97 | 4.32 |
| Rainfall | 206 | 0 | 1372.4 | 1284.0 | 1348.2 | 424.7 | 29.6 |
| Retwet | 206 | 0 | 214.89 | 218.00 | 215.78 | 34.00 | 2.37 |
| Retmed | 206 | 0 | 240.50 | 246.50 | 242.56 | 41.73 | 2.91 |
| Retdry | 206 | 0 | 260.22 | 272.00 | 262.85 | 49.79 | 3.47 |
| Endwet | 206 | 0 | 172.78 | 173.50 | 172.67 | 18.71 | 1.30 |
| Endmed | 206 | 0 | 146.10 | 138.00 | 144.53 | 23.99 | 1.67 |
| Enddry | 206 | 0 | 126.67 | 116.00 | 124.17 | 30.30 | 2.11 |
| Fcapdays | 206 | 0 | 266.49 | 256.50 | 265.44 | 57.29 | 3.99 |
| MdefGra | 206 | 0 | 54.36 | 45.50 | 53.30 | 39.20 | 2.73 |
| MdefCer | 206 | 0 | 36.40 | 32.00 | 35.81 | 25.99 | 1.81 |
| Mdefsbpt | 206 | 0 | 24.27 | 13.00 | 22.32 | 27.27 | 1.90 |
| Avwatgra | 206 | 0 | 125.79 | 120.00 | 122.83 | 19.49 | 1.36 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Avwatcer | 206 | 0 | 126.22 | 115.00 | 122.94 | 22.97 | 1.60 |
| Avwatpot | 206 | 0 | 113.31 | 115.00 | 111.22 | 14.08 | 0.98 |
| Workabil | 206 | 0 | 3.136 | 2.000 | 2.774 | 2.534 | 0.177 |
| AutMWD | 206 | 0 | 15.12 | 0.00 | 13.22 | 24.27 | 1.69 |
| SprMWD | 206 | 0 | 1.796 | 0.000 | 1.435 | 3.149 | 0.219 |
| Soils | 206 | 0 | 2.6893 | 3.0000 | 2.6290 | 0.7655 | 0.0533 |
| Wselvgr2 | 206 | 0 | 215.08 | 192.00 | 212.47 | 105.90 | 7.38 |
| Dsl2 | 206 | 0 | 3.592 | 3.190 | 3.467 | 1.949 | 0.136 |
| Wsaspgr2 | 206 | 0 | 158.66 | 143.00 | 156.33 | 95.21 | 6.63 |
| EngFlag | 206 | 0 | 1.0000 | 1.0000 | 1.0000 | 0.0000 | 0.0000 |
| Topex1km | 206 | 0 | 10.391 | 10.205 | 10.226 | 4.881 | 0.340 |
| Wind1km2 | 206 | 0 | 12.538 | 12.500 | 12.532 | 2.496 | 0.174 |
| East | 206 | 0 | 300032 | 298750 | 300472 | 31453 | 2191 |
| North | 206 | 0 | 262407 | 249000 | 260986 | 61228 | 4266 |
| num | 206 | 0 | 20647 | 20633 | 20647 | 382 | 27 |
| Factor 1 | 206 | 0 | -0.0056 | -0.0165 | -0.0211 | 1.0610 | 0.0739 |
| Factor 2 | 206 | 0 | 0.2561 | 0.0600 | 0.2186 | 1.1420 | 0.0796 |
| Factor 3 | 206 | 0 | -0.1172 | -0.4660 | -0.2458 | 0.8677 | 0.0605 |
| Factor 4 | 206 | 0 | -0.1557 | -0.1710 | -0.1710 | 0.9279 | 0.0646 |
| Factor 5 | 206 | 0 | 0.0568 | 0.2670 | 0.0839 | 0.9518 | 0.0663 |
| cosasp | 206 | 0 | 0.0523 | 0.0751 | 0.0580 | 0.7166 | 0.0499 |
| sinasp | 206 | 0 | -0.0169 | -0.0266 | -0.0185 | 0.6988 | 0.0487 |
| upper | 206 | 0 | 0.01456 | 0.00000 | 0.00000 | 0.12009 | 0.00837 |
| NpAonbSa | 206 | 0 | 0.3252 | 0.0000 | 0.3065 | 0.4696 | 0.0327 |
| Rotate | 206 | 0 | 2.675 | 4.000 | 2.694 | 1.467 | 0.102 |
| notsingl | 206 | 0 | 0.0243 | 0.0000 | 0.0000 | 0.1543 | 0.0107 |
| monument | 206 | 0 | 0.00485 | 0.00000 | 0.00000 | 0.06967 | 0.00485 |
| national | 206 | 0 | 0.0340 | 0.0000 | 0.0000 | 0.1816 | 0.0127 |
| park2 | 206 | 0 | 0.3252 | 0.0000 | 0.3065 | 0.4696 | 0.0327 |
| status | 206 | 0 | 1.2282 | 1.0000 | 1.1882 | 0.4541 | 0.0316 |
| YCfits | 206 | 1 | 6.3322 | 6.4211 | 6.3470 | 0.9309 | 0.0649 |

| | MIN | MAX | Q1 | Q3 |
|---|---|---|---|---|
| yc | 2.000 | 10.000 | 6.000 | 8.000 |
| plantyr | 127.00 | 157.00 | 138.75 | 151.00 |
| noLandsc | 0.0000 | 1.0000 | 0.0000 | 1.0000 |
| area | 1.00 | 162.00 | 5.00 | 25.00 |
| unprod | 0.0000 | 5.0000 | 0.0000 | 0.0000 |
| 1st rot | 0.0000 | 1.0000 | 0.0000 | 1.0000 |
| 2nd rot | 0.0000 | 1.0000 | 0.0000 | 0.0000 |
| semi-nat | 0.00000 | 1.00000 | 0.00000 | 0.00000 |
| historic | 0.0000 | 1.0000 | 0.0000 | 1.0000 |
| purchasd | 0.0000 | 1.0000 | 1.0000 | 1.0000 |
| leased | 0.0000 | 1.0000 | 0.0000 | 0.0000 |
| extra | 0.00000 | 1.00000 | 0.00000 | 0.00000 |
| mixed | 0.0000 | 1.0000 | 0.0000 | 1.0000 |
| NatPark | 0.0000 | 1.0000 | 0.0000 | 0.0000 |
| AONB/NSA | 0.0000 | 1.0000 | 0.0000 | 0.0000 |
| othESA | 0.0000 | 1.0000 | 0.0000 | 0.0000 |
| forPark | 0.0000 | 1.0000 | 0.0000 | 0.0000 |
| SSSI | 0.00000 | 1.00000 | 0.00000 | 0.00000 |
| NNR | 0.00000 | 1.00000 | 0.00000 | 0.00000 |
| FCNR | 0.0000 | 1.0000 | 0.0000 | 0.0000 |
| FCcons | 0.0000 | 1.0000 | 0.0000 | 0.0000 |
| ACodeNo | 2.0000 | 4.0000 | 4.0000 | 4.0000 |
| Acctemp | 745.0 | 2000.0 | 1323.0 | 1770.5 |
| Growseas | 130.00 | 292.00 | 211.00 | 264.00 |
| Grazseas | -64.00 | 241.00 | 86.00 | 197.00 |
| Rainfall | 701.0 | 2611.0 | 1030.0 | 1638.0 |
| Retwet | 144.00 | 279.00 | 184.00 | 248.00 |
| Retmed | 145.00 | 311.00 | 211.00 | 279.00 |
| Retdry | 143.00 | 348.00 | 229.00 | 303.00 |
| Endwet | 127.00 | 212.00 | 155.50 | 185.25 |
| Endmed | 115.00 | 205.00 | 125.00 | 156.50 |
| Enddry | 92.00 | 205.00 | 106.00 | 134.00 |
| Fcapdays | 169.00 | 365.00 | 211.00 | 310.00 |
| MdefGra | 0.00 | 146.00 | 22.00 | 93.00 |
| MdefCer | 0.00 | 97.00 | 17.00 | 62.00 |
| Mdefsbpt | 0.00 | 96.00 | 0.00 | 49.00 |
| Avwatgra | 100.00 | 200.00 | 115.00 | 130.00 |
| Avwatcer | 100.00 | 215.00 | 115.00 | 132.00 |
| Avwatpot | 100.00 | 175.00 | 105.00 | 115.00 |
| Workabil | 2.000 | 11.000 | 2.000 | 2.250 |
| AutMWD | 0.00 | 88.00 | 0.00 | 37.00 |
| SprMWD | 0.000 | 16.000 | 0.000 | 4.000 |
| Soils | 2.0000 | 5.0000 | 2.0000 | 3.0000 |
| Wselvgr2 | 28.00 | 444.00 | 135.50 | 300.50 |
| Dsl2 | 0.380 | 11.740 | 2.303 | 4.540 |
| Wsaspgr2 | 4.00 | 359.00 | 74.00 | 227.00 |
| EngFlag | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| Topex1km | 2.420 | 24.330 | 6.695 | 14.110 |
| Wind1km2 | 5.740 | 18.180 | 10.395 | 14.188 |

| | | | | |
|---|---|---|---|---|
| East | 227550 | 353250 | 275625 | 319525 |
| North | 170750 | 376450 | 205675 | 319225 |
| num | 20002 | 21282 | 20308 | 21043 |
| Factor 1 | -2.3430 | 2.2980 | -0.8190 | 0.7968 |
| Factor 2 | -1.8250 | 2.8750 | -0.6187 | 0.9068 |
| Factor 3 | -0.7720 | 3.0480 | -0.5638 | -0.1622 |
| Factor 4 | -2.2570 | 2.0110 | -0.8770 | 0.4792 |
| Factor 5 | -1.7280 | 1.4310 | -0.6953 | 0.8932 |
| cosasp | -1.0000 | 1.0000 | -0.6961 | 0.7767 |
| sinasp | -1.0000 | 0.9978 | -0.6435 | 0.6961 |
| upper | 0.00000 | 1.00000 | 0.00000 | 0.00000 |
| NpAonbSa | 0.0000 | 1.0000 | 0.0000 | 1.0000 |
| Rotate | 1.000 | 4.000 | 1.000 | 4.000 |
| notsingl | 0.0000 | 1.0000 | 0.0000 | 0.0000 |
| monument | 0.00000 | 1.00000 | 0.00000 | 0.00000 |
| national | 0.0000 | 1.0000 | 0.0000 | 0.0000 |
| park2 | 0.0000 | 1.0000 | 0.0000 | 1.0000 |
| status | 1.0000 | 4.0000 | 1.0000 | 1.0000 |
| YCfits | 4.0626 | 8.3374 | 5.5176 | 7.1392 |

Table A5.35: Pearson correlation matrix for all variables used in beech models with sites *sage*<38 and *sage*>49 omitted

| | yc | plantyr | noLandsc | area | unprod | 1st rot | 2nd rot | semi-nat |
|---|---|---|---|---|---|---|---|---|
| plantyr | 0.472 | | | | | | | |
| noLandsc | -0.104 | -0.104 | | | | | | |
| area | 0.160 | 0.223 | -0.034 | | | | | |
| unprod | -0.116 | -0.083 | 0.061 | -0.042 | | | | |
| 1st rot | -0.288 | -0.380 | 0.121 | -0.293 | 0.186 | | | |
| 2nd rot | -0.076 | -0.221 | 0.140 | 0.125 | -0.038 | -0.159 | | |
| semi-nat | -0.104 | -0.064 | -0.093 | 0.086 | -0.014 | -0.059 | -0.013 | |
| historic | 0.327 | 0.465 | -0.158 | 0.233 | -0.168 | -0.924 | -0.205 | -0.076 |
| purchasd | -0.136 | -0.164 | -0.175 | -0.094 | 0.108 | 0.090 | 0.099 | -0.132 |
| leased | 0.125 | 0.155 | 0.193 | 0.104 | -0.107 | -0.081 | -0.098 | 0.134 |
| extra | 0.073 | 0.058 | -0.093 | -0.052 | -0.014 | -0.059 | -0.013 | -0.005 |
| mixed | 0.005 | -0.057 | -0.033 | -0.116 | -0.170 | 0.094 | -0.109 | -0.081 |
| NatPark | 0.000 | -0.081 | -0.656 | -0.068 | -0.017 | 0.132 | -0.092 | 0.142 |
| AONB/NSA | 0.243 | 0.193 | -0.519 | 0.126 | -0.047 | -0.270 | -0.073 | -0.027 |
| othESA | -0.178 | 0.094 | -0.250 | 0.006 | -0.038 | -0.104 | -0.035 | -0.013 |
| forPark | 0.129 | 0.024 | -0.604 | 0.047 | -0.093 | -0.121 | -0.085 | -0.032 |
| SSSI | 0.024 | 0.084 | 0.007 | 0.013 | -0.025 | -0.021 | -0.023 | -0.008 |
| NNR | 0.058 | 0.106 | 0.032 | 0.231 | -0.029 | -0.119 | -0.026 | -0.010 |
| FCcons | -0.064 | -0.098 | -0.085 | 0.085 | 0.003 | 0.012 | 0.146 | -0.020 |
| ACodeNo | -0.074 | -0.165 | -0.041 | -0.196 | 0.037 | 0.152 | 0.034 | -0.310 |
| Acctemp | 0.411 | 0.320 | 0.246 | 0.203 | -0.150 | -0.299 | 0.001 | -0.117 |
| Growseas | 0.392 | 0.310 | 0.278 | 0.221 | -0.140 | -0.268 | 0.030 | -0.110 |
| Grazseas | 0.416 | 0.338 | 0.235 | 0.204 | -0.136 | -0.312 | -0.028 | -0.111 |
| Rainfall | -0.147 | -0.220 | -0.375 | -0.088 | -0.053 | 0.218 | 0.115 | 0.204 |
| Retwet | 0.197 | 0.187 | 0.265 | 0.090 | 0.033 | -0.256 | -0.221 | -0.115 |
| Retmed | 0.171 | 0.197 | 0.329 | 0.093 | 0.038 | -0.257 | -0.141 | -0.138 |
| Retdry | 0.156 | 0.211 | 0.357 | 0.098 | 0.045 | -0.256 | -0.116 | -0.148 |
| Endwet | -0.219 | -0.168 | -0.182 | -0.094 | 0.005 | 0.269 | 0.176 | 0.102 |
| Endmed | -0.141 | -0.198 | -0.369 | -0.113 | -0.021 | 0.285 | 0.055 | 0.151 |
| Enddry | -0.098 | -0.202 | -0.421 | -0.096 | -0.067 | 0.239 | 0.034 | 0.169 |
| Fcapdays | -0.159 | -0.186 | -0.308 | -0.107 | -0.025 | 0.253 | 0.139 | 0.120 |
| MdefGra | 0.314 | 0.290 | 0.153 | 0.156 | -0.059 | -0.335 | -0.122 | -0.097 |
| MdefCer | 0.308 | 0.298 | 0.183 | 0.134 | -0.042 | -0.327 | -0.199 | -0.098 |
| Mdefsbpt | 0.309 | 0.254 | 0.008 | 0.171 | -0.152 | -0.368 | -0.122 | -0.062 |
| Avwatgra | 0.125 | 0.052 | -0.020 | 0.051 | 0.126 | -0.024 | -0.104 | -0.039 |
| Avwatcer | 0.115 | 0.034 | 0.017 | 0.079 | 0.127 | -0.034 | -0.092 | -0.034 |
| Avwatpot | 0.060 | -0.008 | -0.087 | 0.020 | 0.080 | 0.043 | 0.023 | 0.008 |
| Workabil | 0.056 | 0.008 | 0.044 | 0.087 | 0.381 | 0.102 | -0.084 | -0.031 |
| AutMWD | 0.287 | 0.246 | -0.075 | 0.064 | -0.122 | -0.323 | -0.117 | -0.044 |
| SprMWD | 0.222 | 0.238 | -0.058 | 0.081 | -0.114 | -0.315 | -0.107 | -0.040 |
| Soils | -0.128 | -0.066 | 0.053 | 0.106 | 0.323 | 0.151 | 0.076 | 0.028 |
| Wselvgr2 | -0.440 | -0.345 | 0.037 | -0.370 | 0.199 | 0.480 | -0.051 | -0.091 |
| Dsl2 | -0.074 | -0.030 | -0.265 | -0.087 | -0.124 | -0.006 | 0.012 | 0.157 |
| Wsaspgr2 | -0.117 | -0.055 | 0.097 | -0.067 | 0.052 | 0.027 | 0.122 | -0.108 |
| Topex1km | -0.137 | -0.132 | -0.342 | -0.051 | -0.146 | 0.065 | 0.098 | 0.157 |
| Wind1km2 | -0.384 | -0.358 | 0.348 | -0.247 | 0.262 | 0.432 | 0.096 | -0.034 |
| East | 0.186 | 0.115 | -0.160 | -0.077 | -0.051 | -0.256 | -0.303 | -0.050 |
| North | -0.198 | -0.077 | 0.011 | -0.009 | 0.178 | 0.177 | -0.096 | 0.104 |
| Factor 1 | -0.155 | -0.196 | -0.259 | -0.069 | -0.010 | 0.245 | 0.159 | 0.125 |
| Factor 2 | -0.428 | -0.348 | 0.173 | -0.305 | 0.247 | 0.429 | -0.037 | -0.049 |
| Factor 3 | 0.104 | 0.048 | 0.017 | 0.071 | 0.255 | 0.022 | -0.097 | -0.046 |
| Factor 4 | -0.012 | 0.023 | -0.407 | -0.039 | -0.179 | -0.103 | -0.125 | 0.158 |
| Factor 5 | 0.128 | -0.002 | -0.165 | -0.097 | 0.052 | 0.064 | -0.063 | -0.051 |
| cosasp | -0.115 | 0.003 | 0.020 | 0.085 | 0.041 | 0.029 | 0.020 | 0.077 |
| sinasp | 0.041 | 0.065 | -0.108 | 0.013 | 0.180 | 0.107 | -0.112 | -0.052 |
| upper | -0.078 | -0.051 | -0.078 | -0.023 | -0.025 | -0.021 | -0.023 | -0.008 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| NpAonbSa | 0.175 | 0.071 | -0.927 | 0.033 | -0.048 | -0.083 | -0.130 | 0.101 |
| Rotate | 0.315 | 0.442 | -0.153 | 0.261 | -0.178 | -0.969 | -0.086 | 0.016 |
| notsingl | -0.075 | -0.039 | -0.079 | 0.037 | -0.032 | -0.070 | 0.145 | -0.011 |
| monument | -0.016 | 0.076 | 0.052 | 0.214 | -0.014 | -0.059 | -0.013 | -0.005 |
| national | 0.060 | 0.137 | 0.029 | 0.185 | -0.038 | -0.104 | -0.035 | -0.013 |
| park2 | 0.170 | 0.055 | -0.861 | 0.043 | -0.074 | -0.110 | -0.121 | 0.046 |
| status | 0.147 | 0.167 | 0.131 | 0.070 | -0.103 | -0.100 | -0.094 | 0.119 |

| | historic | purchasd | leased | extra | mixed | NatPark | AONB/NSA | othESA |
|---|---|---|---|---|---|---|---|---|
| purchasd | -0.107 | | | | | | | |
| leased | 0.097 | -0.986 | | | | | | |
| extra | 0.064 | -0.132 | -0.036 | | | | | |
| mixed | -0.042 | 0.042 | -0.029 | -0.081 | | | | |
| NatPark | -0.117 | 0.111 | -0.136 | 0.142 | 0.077 | | | |
| AONB/NSA | 0.298 | 0.066 | -0.062 | -0.027 | 0.045 | -0.191 | | |
| othESA | 0.118 | 0.099 | -0.098 | -0.013 | -0.163 | -0.092 | -0.073 | |
| forPark | 0.155 | 0.114 | -0.110 | -0.032 | 0.156 | 0.105 | 0.782 | -0.085 |
| SSSI | 0.030 | -0.132 | 0.134 | -0.008 | -0.141 | -0.060 | -0.047 | 0.201 |
| NNR | 0.129 | 0.074 | -0.073 | -0.010 | -0.021 | -0.069 | 0.050 | -0.026 |
| FCcons | -0.062 | 0.110 | -0.107 | -0.020 | 0.031 | 0.224 | -0.113 | -0.054 |
| ACodeNo | -0.119 | 0.122 | -0.125 | 0.013 | -0.019 | 0.031 | 0.003 | 0.034 |
| Acctemp | 0.312 | -0.225 | 0.220 | 0.035 | 0.088 | -0.428 | 0.235 | -0.154 |
| Growseas | 0.270 | -0.228 | 0.221 | 0.047 | 0.063 | -0.400 | 0.149 | -0.141 |
| Grazseas | 0.335 | -0.256 | 0.251 | 0.041 | 0.107 | -0.424 | 0.256 | -0.174 |
| Rainfall | -0.286 | 0.156 | -0.169 | 0.067 | -0.012 | 0.699 | -0.340 | 0.102 |
| Retwet | 0.350 | -0.184 | 0.199 | -0.082 | 0.084 | -0.579 | 0.399 | -0.180 |
| Retmed | 0.325 | -0.180 | 0.194 | -0.075 | 0.025 | -0.665 | 0.381 | -0.129 |
| Retdry | 0.317 | -0.191 | 0.204 | -0.068 | -0.000 | -0.686 | 0.353 | -0.105 |
| Endwet | -0.345 | 0.209 | -0.224 | 0.079 | -0.151 | 0.520 | -0.432 | 0.153 |
| Endmed | -0.323 | 0.149 | -0.162 | 0.073 | 0.041 | 0.731 | -0.357 | 0.046 |
| Enddry | -0.273 | 0.148 | -0.158 | 0.056 | 0.080 | 0.741 | -0.285 | 0.026 |
| Fcapdays | -0.318 | 0.177 | -0.194 | 0.090 | -0.018 | 0.656 | -0.400 | 0.127 |
| MdefGra | 0.390 | -0.281 | 0.293 | -0.058 | 0.137 | -0.496 | 0.469 | -0.197 |
| MdefCer | 0.410 | -0.306 | 0.321 | -0.074 | 0.124 | -0.536 | 0.466 | -0.182 |
| Mdefsbpt | 0.417 | -0.280 | 0.287 | -0.029 | 0.175 | -0.369 | 0.499 | -0.144 |
| Avwatgra | 0.067 | -0.055 | 0.062 | -0.039 | 0.113 | 0.065 | 0.008 | -0.104 |
| Avwatcer | 0.072 | -0.050 | 0.057 | -0.034 | 0.114 | 0.054 | -0.039 | -0.092 |
| Avwatpot | -0.052 | -0.012 | 0.011 | 0.008 | 0.096 | 0.238 | -0.167 | 0.023 |
| Workabil | -0.066 | -0.046 | 0.052 | -0.031 | 0.027 | 0.042 | -0.066 | -0.084 |
| AutMWD | 0.368 | -0.270 | 0.279 | -0.044 | 0.134 | -0.307 | 0.528 | -0.117 |
| SprMWD | 0.356 | -0.352 | 0.362 | -0.040 | 0.116 | -0.281 | 0.469 | -0.107 |
| Soils | -0.181 | -0.138 | 0.134 | 0.028 | -0.056 | 0.152 | -0.294 | 0.076 |
| Wselvgr2 | -0.444 | 0.178 | -0.168 | -0.066 | 0.016 | 0.092 | -0.229 | 0.129 |
| Dsl2 | -0.020 | -0.068 | 0.055 | 0.078 | -0.059 | 0.346 | -0.107 | 0.146 |
| Wsaspgr2 | -0.056 | 0.111 | -0.109 | -0.013 | -0.060 | -0.019 | -0.205 | 0.167 |
| Topex1km | -0.122 | 0.167 | -0.185 | 0.101 | -0.019 | 0.455 | -0.142 | 0.176 |
| Wind1km2 | -0.458 | 0.091 | -0.074 | -0.100 | -0.080 | -0.137 | -0.375 | 0.075 |
| East | 0.371 | -0.097 | 0.108 | -0.059 | 0.229 | -0.217 | 0.567 | -0.157 |
| North | -0.155 | -0.104 | 0.098 | 0.045 | -0.010 | 0.297 | -0.360 | -0.008 |
| Factor 1 | -0.318 | 0.233 | -0.249 | 0.086 | -0.035 | 0.613 | -0.418 | 0.126 |
| Factor 2 | -0.405 | 0.130 | -0.114 | -0.101 | -0.060 | -0.045 | -0.239 | 0.086 |
| Factor 3 | 0.020 | -0.067 | 0.074 | -0.035 | 0.082 | 0.031 | -0.011 | -0.091 |
| Factor 4 | 0.125 | -0.084 | 0.076 | 0.048 | 0.001 | 0.328 | 0.165 | 0.055 |
| Factor 5 | -0.034 | -0.005 | -0.009 | 0.081 | 0.206 | 0.198 | 0.056 | -0.101 |
| cosasp | -0.047 | 0.020 | -0.004 | -0.096 | -0.123 | -0.075 | -0.004 | 0.118 |
| sinasp | -0.058 | 0.015 | -0.021 | 0.038 | -0.161 | 0.087 | -0.007 | 0.110 |
| upper | 0.030 | 0.064 | -0.063 | -0.008 | 0.105 | -0.060 | 0.193 | -0.023 |
| NpAonbSa | 0.116 | 0.141 | -0.160 | 0.101 | 0.097 | 0.707 | 0.559 | -0.130 |
| Rotate | 0.988 | -0.109 | 0.100 | 0.063 | -0.065 | -0.117 | 0.293 | 0.115 |
| notsingl | 0.018 | 0.083 | -0.082 | -0.011 | 0.136 | -0.077 | 0.219 | -0.030 |
| monument | 0.064 | 0.037 | -0.036 | -0.005 | 0.060 | -0.034 | -0.027 | -0.013 |
| national | 0.118 | -0.031 | 0.033 | -0.013 | -0.109 | -0.092 | 0.007 | 0.113 |
| park2 | 0.146 | 0.142 | -0.151 | 0.046 | 0.135 | 0.482 | 0.724 | -0.121 |
| status | 0.117 | -0.953 | 0.888 | 0.427 | -0.063 | -0.058 | -0.069 | -0.094 |

| | forPark | SSSI | NNR | FCcons | ACodeNo | Acctemp | Growseas |
|---|---|---|---|---|---|---|---|
| SSSI | -0.055 | | | | | | |
| NNR | 0.030 | -0.017 | | | | | |
| FCcons | 0.062 | -0.035 | 0.091 | | | | |
| ACodeNo | 0.021 | -0.165 | -0.299 | -0.199 | | | |
| Acctemp | 0.091 | -0.030 | 0.039 | -0.133 | -0.052 | | |
| Growseas | 0.026 | -0.030 | 0.034 | -0.119 | -0.055 | 0.990 | |
| Grazseas | 0.118 | -0.035 | 0.049 | -0.141 | -0.069 | 0.990 | 0.981 |
| Rainfall | -0.023 | 0.034 | -0.107 | 0.241 | 0.050 | -0.493 | -0.431 |
| Retwet | 0.125 | -0.041 | 0.111 | -0.226 | -0.079 | 0.494 | 0.423 |
| Retmed | 0.060 | -0.036 | 0.105 | -0.239 | -0.067 | 0.506 | 0.438 |
| Retdry | 0.017 | -0.026 | 0.106 | -0.239 | -0.071 | 0.499 | 0.436 |
| Endwet | -0.173 | 0.001 | -0.093 | 0.204 | 0.082 | -0.487 | -0.417 |
| Endmed | -0.011 | 0.016 | -0.098 | 0.231 | 0.058 | -0.541 | -0.480 |
| Enddry | 0.076 | 0.020 | -0.101 | 0.228 | 0.048 | -0.473 | -0.419 |
| Fcapdays | -0.120 | 0.042 | -0.107 | 0.202 | 0.076 | -0.486 | -0.416 |
| MdefGra | 0.281 | -0.017 | 0.086 | -0.179 | -0.097 | 0.600 | 0.534 |
| MdefCer | 0.256 | -0.016 | 0.093 | -0.218 | -0.101 | 0.590 | 0.519 |
| Mdefsbpt | 0.338 | 0.002 | 0.083 | -0.118 | -0.105 | 0.513 | 0.443 |
| Avwatgra | -0.060 | 0.214 | -0.022 | 0.044 | -0.096 | -0.012 | -0.033 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Avwatcer | -0.097 | 0.197 | -0.046 | 0.032 | -0.054 | -0.005 | -0.021 |
| Avwatpot | -0.133 | 0.231 | -0.068 | 0.132 | -0.053 | -0.169 | -0.145 |
| Workabil | -0.137 | 0.186 | -0.049 | 0.077 | -0.150 | -0.112 | -0.107 |
| AutMWD | 0.371 | -0.047 | 0.132 | 0.075 | 0.025 | 0.447 | 0.370 |
| SprMWD | 0.317 | 0.072 | 0.043 | 0.017 | -0.097 | 0.384 | 0.318 |
| Soils | -0.239 | 0.209 | -0.127 | -0.067 | -0.161 | -0.271 | -0.209 |
| Wselvgr2 | -0.235 | 0.062 | -0.058 | -0.062 | 0.107 | -0.637 | -0.650 |
| Dsl2 | -0.057 | 0.238 | -0.123 | -0.084 | -0.134 | -0.175 | -0.161 |
| Wsaspgr2 | -0.152 | 0.140 | 0.104 | -0.059 | -0.089 | -0.008 | 0.014 |
| Topex1km | 0.029 | 0.066 | 0.045 | -0.120 | -0.063 | -0.323 | -0.291 |
| Wind1km2 | -0.429 | 0.014 | -0.086 | -0.051 | 0.121 | -0.392 | -0.368 |
| East | 0.413 | 0.001 | 0.049 | 0.099 | -0.025 | 0.168 | 0.037 |
| North | -0.193 | -0.007 | 0.011 | -0.114 | -0.081 | -0.512 | -0.443 |
| Factor 1 | -0.116 | -0.007 | -0.083 | 0.213 | 0.069 | -0.422 | -0.345 |
| Factor 2 | -0.304 | 0.025 | -0.065 | 0.003 | 0.119 | -0.638 | -0.648 |
| Factor 3 | -0.096 | 0.227 | -0.034 | 0.038 | -0.147 | -0.019 | -0.030 |
| Factor 4 | 0.200 | 0.154 | -0.004 | 0.017 | -0.114 | -0.300 | -0.330 |
| Factor 5 | 0.079 | -0.095 | -0.164 | 0.063 | 0.142 | 0.055 | 0.050 |
| cosasp | -0.088 | 0.005 | -0.055 | -0.074 | 0.041 | 0.004 | 0.010 |
| sinasp | 0.030 | 0.083 | 0.064 | -0.059 | -0.045 | -0.036 | -0.027 |
| upper | 0.161 | -0.015 | -0.017 | -0.035 | 0.022 | 0.055 | 0.037 |
| NpAonbSa | 0.652 | -0.084 | -0.023 | 0.108 | 0.029 | -0.192 | -0.230 |
| Rotate | 0.145 | 0.027 | 0.127 | -0.047 | -0.147 | 0.308 | 0.269 |
| notsingl | 0.181 | -0.019 | -0.022 | 0.072 | 0.028 | 0.058 | 0.040 |
| monument | -0.032 | -0.008 | 0.496 | 0.241 | -0.632 | 0.024 | 0.035 |
| national | -0.014 | 0.648 | 0.750 | 0.046 | -0.337 | 0.010 | 0.005 |
| park2 | 0.887 | -0.078 | 0.001 | 0.096 | 0.028 | -0.073 | -0.128 |
| status | -0.114 | 0.118 | -0.071 | -0.106 | -0.107 | 0.216 | 0.222 |

| | Grazseas | Rainfall | Retwet | Retmed | Retdry | Endwet | Endmed | Enddry |
|---|---|---|---|---|---|---|---|---|
| Rainfall | -0.523 | | | | | | | |
| Retwet | 0.534 | -0.945 | | | | | | |
| Retmed | 0.537 | -0.986 | 0.977 | | | | | |
| Retdry | 0.529 | -0.991 | 0.957 | 0.996 | | | | |
| Endwet | -0.540 | 0.895 | -0.962 | -0.933 | -0.911 | | | |
| Endmed | -0.553 | 0.972 | -0.924 | -0.977 | -0.982 | 0.870 | | |
| Enddry | -0.486 | 0.969 | -0.875 | -0.954 | -0.973 | 0.807 | 0.980 | |
| Fcapdays | -0.513 | 0.969 | -0.967 | -0.986 | -0.979 | 0.920 | 0.968 | 0.936 |
| MdefGra | 0.640 | -0.789 | 0.844 | 0.817 | 0.796 | -0.865 | -0.773 | -0.702 |
| MdefCer | 0.633 | -0.832 | 0.881 | 0.859 | 0.840 | -0.886 | -0.808 | -0.746 |
| Mdefsbpt | 0.555 | -0.686 | 0.767 | 0.723 | 0.697 | -0.836 | -0.670 | -0.582 |
| Avwatgra | -0.026 | 0.026 | 0.005 | -0.029 | -0.032 | -0.011 | 0.043 | 0.054 |
| Avwatcer | -0.021 | 0.044 | -0.019 | -0.048 | -0.050 | 0.012 | 0.058 | 0.067 |
| Avwatpot | -0.176 | 0.350 | -0.347 | -0.368 | -0.360 | 0.270 | 0.367 | 0.359 |
| Workabil | -0.104 | 0.007 | 0.001 | -0.024 | -0.016 | 0.013 | 0.052 | 0.027 |
| AutMWD | 0.481 | -0.597 | 0.684 | 0.643 | 0.612 | -0.751 | -0.596 | -0.499 |
| SprMWD | 0.431 | -0.584 | 0.666 | 0.623 | 0.603 | -0.758 | -0.572 | -0.478 |
| Soils | -0.235 | 0.295 | -0.334 | -0.333 | -0.304 | 0.277 | 0.337 | 0.283 |
| Wselvgr2 | -0.643 | 0.114 | -0.205 | -0.163 | -0.142 | 0.222 | 0.183 | 0.091 |
| Dsl2 | -0.171 | 0.290 | -0.260 | -0.274 | -0.266 | 0.187 | 0.256 | 0.260 |
| Wsaspgr2 | -0.027 | 0.031 | -0.115 | -0.066 | -0.043 | 0.111 | 0.022 | -0.006 |
| Topex1km | -0.329 | 0.603 | -0.587 | -0.603 | -0.599 | 0.527 | 0.589 | 0.578 |
| Wind1km2 | -0.409 | -0.020 | -0.084 | -0.017 | 0.012 | 0.136 | -0.001 | -0.087 |
| East | 0.195 | -0.556 | 0.634 | 0.593 | 0.561 | -0.647 | -0.508 | -0.457 |
| North | -0.412 | 0.232 | -0.198 | -0.245 | -0.234 | 0.124 | 0.350 | 0.284 |
| Factor 1 | -0.455 | 0.949 | -0.955 | -0.965 | -0.958 | 0.935 | 0.936 | 0.902 |
| Factor 2 | -0.641 | -0.042 | -0.039 | 0.007 | 0.027 | 0.087 | 0.010 | -0.082 |
| Factor 3 | -0.020 | -0.028 | 0.045 | 0.017 | 0.021 | -0.047 | 0.004 | -0.001 |
| Factor 4 | -0.277 | 0.177 | -0.082 | -0.142 | -0.158 | 0.001 | 0.178 | 0.212 |
| Factor 5 | 0.069 | 0.143 | -0.086 | -0.132 | -0.149 | 0.059 | 0.186 | 0.196 |
| cosasp | 0.004 | -0.056 | 0.046 | 0.059 | 0.065 | -0.047 | -0.077 | -0.076 |
| sinasp | -0.044 | 0.187 | -0.220 | -0.211 | -0.202 | 0.230 | 0.199 | 0.180 |
| upper | 0.075 | -0.010 | 0.041 | 0.019 | 0.007 | -0.057 | -0.006 | 0.021 |
| NpAonbSa | -0.174 | 0.345 | -0.201 | -0.287 | -0.325 | 0.128 | 0.360 | 0.421 |
| Rotate | 0.327 | -0.258 | 0.319 | 0.301 | 0.295 | -0.320 | -0.309 | -0.259 |
| notsingl | 0.070 | -0.021 | 0.034 | 0.026 | 0.017 | -0.061 | -0.027 | -0.005 |
| monument | 0.020 | -0.004 | 0.000 | 0.003 | 0.005 | 0.038 | -0.021 | -0.020 |
| national | 0.014 | -0.059 | 0.057 | 0.056 | 0.063 | -0.070 | -0.063 | -0.064 |
| park2 | -0.048 | 0.199 | -0.062 | -0.146 | -0.190 | -0.007 | 0.214 | 0.294 |
| status | 0.246 | -0.122 | 0.142 | 0.141 | 0.153 | -0.166 | -0.113 | -0.118 |

| | Fcapdays | MdefGra | MdefCer | Mdefsbpt | Avwatgra | Avwatcer | Avwatpot | Workabil |
|---|---|---|---|---|---|---|---|---|
| MdefGra | -0.841 | | | | | | | |
| MdefCer | -0.878 | 0.972 | | | | | | |
| Mdefsbpt | -0.750 | 0.937 | 0.910 | | | | | |
| Avwatgra | 0.027 | 0.110 | 0.111 | 0.114 | | | | |
| Avwatcer | 0.047 | 0.100 | 0.101 | 0.106 | 0.975 | | | |
| Avwatpot | 0.375 | -0.208 | -0.222 | -0.147 | 0.821 | 0.784 | | |
| Workabil | 0.031 | 0.036 | 0.052 | -0.008 | 0.830 | 0.815 | 0.721 | |
| AutMWD | -0.673 | 0.789 | 0.789 | 0.833 | 0.015 | 0.003 | -0.196 | -0.140 |
| SprMWD | -0.652 | 0.780 | 0.778 | 0.853 | 0.127 | 0.107 | -0.089 | -0.035 |
| Soils | 0.352 | -0.290 | -0.285 | -0.271 | 0.415 | 0.437 | 0.616 | 0.696 |
| Wselvgr2 | 0.204 | -0.456 | -0.405 | -0.464 | -0.026 | -0.057 | 0.028 | 0.057 |
| Dsl2 | 0.291 | -0.267 | -0.279 | -0.163 | -0.012 | -0.036 | 0.104 | -0.091 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Wsaspgr2 | 0.082 | -0.165 | -0.179 | -0.173 | -0.007 | -0.018 | 0.036 | -0.003 |
| Topex1km | 0.614 | -0.506 | -0.545 | -0.409 | -0.093 | -0.102 | 0.175 | -0.147 |
| Wind1km2 | 0.049 | -0.355 | -0.312 | -0.434 | -0.118 | -0.127 | -0.060 | 0.066 |
| East | -0.595 | 0.590 | 0.638 | 0.611 | 0.134 | 0.109 | -0.187 | 0.008 |
| North | 0.271 | -0.247 | -0.230 | -0.203 | -0.106 | -0.088 | 0.139 | 0.134 |
| Factor 1 | 0.968 | -0.850 | -0.882 | -0.797 | -0.047 | -0.021 | 0.301 | -0.004 |
| Factor 2 | 0.019 | -0.345 | -0.287 | -0.371 | -0.058 | -0.082 | -0.055 | 0.082 |
| Factor 3 | -0.011 | 0.122 | 0.130 | 0.097 | 0.957 | 0.934 | 0.795 | 0.946 |
| Factor 4 | 0.128 | -0.020 | -0.039 | 0.144 | 0.104 | 0.069 | 0.126 | -0.051 |
| Factor 5 | 0.135 | 0.058 | 0.058 | 0.038 | 0.067 | 0.091 | 0.081 | 0.082 |
| cosasp | -0.049 | 0.020 | 0.040 | 0.010 | 0.088 | 0.141 | -0.002 | 0.041 |
| sinasp | 0.224 | -0.219 | -0.213 | -0.244 | -0.012 | -0.005 | -0.047 | 0.029 |
| upper | -0.010 | 0.068 | 0.058 | 0.067 | -0.032 | -0.044 | -0.049 | -0.055 |
| NpAonbSa | 0.266 | -0.081 | -0.117 | 0.048 | 0.061 | 0.018 | 0.081 | -0.013 |
| Rotate | -0.296 | 0.374 | 0.385 | 0.405 | 0.052 | 0.059 | -0.049 | -0.081 |
| notsingl | -0.021 | 0.110 | 0.049 | 0.100 | -0.044 | -0.058 | -0.053 | -0.071 |
| monument | -0.005 | -0.015 | -0.020 | -0.034 | -0.021 | -0.034 | -0.041 | -0.031 |
| national | -0.054 | 0.054 | 0.060 | 0.064 | 0.125 | 0.095 | 0.101 | 0.085 |
| park2 | 0.104 | 0.088 | 0.054 | 0.194 | 0.008 | -0.036 | -0.016 | -0.075 |
| status | -0.134 | 0.238 | 0.256 | 0.246 | 0.039 | 0.035 | 0.013 | 0.032 |

| | AutMWD | SprMWD | Soils | Wselvgr2 | Dsl2 | Wsaspgr2 | Topex1km | Wind1km2 |
|---|---|---|---|---|---|---|---|---|
| SprMWD | 0.887 | | | | | | | |
| Soils | -0.402 | -0.198 | | | | | | |
| Wselvgr2 | -0.361 | -0.312 | 0.090 | | | | | |
| Dsl2 | -0.201 | -0.041 | 0.154 | 0.053 | | | | |
| Wsaspgr2 | -0.175 | -0.126 | 0.074 | 0.184 | 0.030 | | | |
| Topex1km | -0.448 | -0.379 | 0.187 | 0.018 | 0.547 | 0.168 | | |
| Wind1km2 | -0.310 | -0.316 | 0.096 | 0.783 | -0.180 | 0.161 | -0.349 | |
| East | 0.599 | 0.565 | -0.368 | 0.043 | -0.127 | -0.177 | -0.301 | -0.195 |
| North | -0.283 | -0.132 | 0.516 | 0.232 | 0.111 | -0.021 | 0.179 | 0.192 |
| Factor 1 | -0.718 | -0.735 | 0.316 | 0.131 | 0.191 | 0.133 | 0.597 | 0.043 |
| Factor 2 | -0.273 | -0.252 | 0.064 | 0.918 | -0.061 | 0.052 | -0.231 | 0.888 |
| Factor 3 | -0.031 | 0.095 | 0.569 | 0.007 | -0.015 | 0.029 | -0.121 | -0.046 |
| Factor 4 | 0.061 | 0.202 | 0.055 | -0.050 | 0.732 | -0.172 | 0.593 | -0.470 |
| Factor 5 | 0.101 | 0.047 | 0.008 | -0.076 | -0.041 | -0.501 | -0.082 | -0.114 |
| cosasp | 0.006 | 0.068 | 0.077 | 0.073 | -0.053 | 0.099 | -0.062 | 0.075 |
| sinasp | -0.144 | -0.123 | 0.136 | 0.007 | -0.024 | 0.105 | 0.162 | -0.089 |
| upper | 0.110 | 0.085 | -0.057 | -0.042 | -0.028 | -0.013 | 0.077 | -0.105 |
| NpAonbSa | 0.122 | 0.101 | -0.084 | -0.088 | 0.215 | -0.164 | 0.282 | -0.385 |
| Rotate | 0.357 | 0.347 | -0.173 | -0.469 | -0.004 | -0.052 | -0.098 | -0.459 |
| notsingl | 0.123 | 0.091 | -0.060 | -0.073 | 0.014 | 0.061 | 0.094 | -0.122 |
| monument | -0.044 | -0.040 | -0.063 | -0.015 | -0.061 | 0.066 | -0.030 | 0.033 |
| national | 0.069 | 0.080 | 0.041 | -0.003 | 0.064 | 0.171 | 0.078 | -0.056 |
| park2 | 0.255 | 0.217 | -0.168 | -0.168 | 0.104 | -0.175 | 0.186 | -0.445 |
| status | 0.233 | 0.309 | 0.135 | -0.182 | 0.086 | -0.105 | -0.121 | -0.113 |

| | East | North | Factor 1 | Factor 2 | Factor 3 | Factor 4 | Factor 5 |
|---|---|---|---|---|---|---|---|
| North | -0.307 | | | | | | |
| Factor 1 | -0.644 | 0.233 | | | | | |
| Factor 2 | 0.030 | 0.261 | -0.044 | | | | |
| Factor 3 | 0.105 | -0.004 | -0.069 | -0.012 | | | |
| Factor 4 | 0.180 | 0.133 | -0.019 | -0.134 | 0.040 | | |
| Factor 5 | 0.089 | 0.040 | 0.143 | -0.128 | 0.075 | -0.118 | |
| cosasp | -0.009 | 0.041 | -0.051 | 0.056 | 0.078 | -0.081 | -0.088 |
| sinasp | -0.086 | -0.034 | 0.242 | -0.093 | 0.004 | -0.048 | 0.060 |
| upper | 0.101 | -0.049 | -0.012 | -0.095 | -0.037 | 0.027 | 0.064 |
| NpAonbSa | 0.225 | -0.008 | 0.216 | -0.210 | 0.018 | 0.396 | 0.208 |
| Rotate | 0.337 | -0.161 | -0.293 | -0.423 | 0.004 | 0.128 | -0.047 |
| notsingl | 0.075 | -0.084 | -0.023 | -0.123 | -0.044 | 0.047 | -0.013 |
| monument | -0.090 | -0.014 | 0.019 | -0.009 | -0.026 | -0.099 | -0.078 |
| national | 0.038 | 0.004 | -0.068 | -0.033 | 0.124 | 0.099 | -0.187 |
| park2 | 0.339 | -0.099 | 0.075 | -0.277 | -0.036 | 0.339 | 0.165 |
| status | 0.071 | 0.109 | -0.186 | -0.150 | 0.050 | 0.091 | 0.030 |

| | cosasp | sinasp | upper | NpAonbSa | Rotate | notsingl | monument | national |
|---|---|---|---|---|---|---|---|---|
| sinasp | 0.025 | | | | | | | |
| upper | 0.007 | -0.004 | | | | | | |
| NpAonbSa | -0.066 | 0.068 | 0.089 | | | | | |
| Rotate | -0.038 | -0.078 | 0.027 | 0.112 | | | | |
| notsingl | 0.003 | -0.073 | 0.771 | 0.093 | 0.035 | | | |
| monument | -0.101 | 0.020 | -0.008 | -0.048 | 0.063 | -0.011 | | |
| national | -0.039 | 0.103 | -0.023 | -0.073 | 0.115 | -0.030 | 0.372 | |
| park2 | -0.083 | 0.056 | 0.133 | 0.929 | 0.139 | 0.145 | -0.045 | -0.051 |
| status | -0.048 | -0.002 | -0.061 | -0.098 | 0.119 | -0.079 | -0.035 | 0.024 |

| | park2 |
|---|---|
| status | -0.115 |

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# Appendix 6: Valuing Carbon Sequestration

## A6.1: LITERATURE REVIEW

Here we present an extended review of the literature summarised in chapter 8. Three topics are covered in detail: global warming (section A6.1.1); the cost (or price) of sequestering carbon via afforestation (section A6.1.2.1); and the value of such sequestration (section A6.1.2.2).

### A6.1.1: GLOBAL WARMING

The industrialisation of the worlds economies has entailed a major impact upon the atmospheric constitution of the world. Emissions of greenhouse gases (GHGs) have, by common scientific consent, triggered an enhanced greenhouse effect[1] leading to global warming. Table A6.1 details the common GHGs, their origins, rates of build-up in the atmosphere and their contribution to global warming in the 1980s.

Lashof and Tirpak (1989) estimate the greenhouse contribution of $CO_2$ as being 66% of all GHGs for the period 1880-1980, falling to 49% for the 1980s. Given the continued rise in the absolute concentration of $CO_2$ (see table A6.1), this fall in relative GHG concentration gives some indication of the growing impact of non-$CO_2$ GHGs which have a much higher insulation factor (Kelly, 1990)[2]. This paper focusses upon one specific GHG, carbon dioxide ($CO_2$), and in particular the potential for $CO_2$ sequestration via afforestation.

As Table A6.1 indicates, the major source of $CO_2$ increase is via the burning of fossil fuels (coal, oil and natural gas). Globally, annual emissions of carbon from combustion have risen from under 1 Gt in 1900 to approximately 5.7 Gt.pa. today[3] (Leggett, 1990). This figure is somewhat uncertain and Grayson (1989) reports an annual industrial emissions total of roughly 5 GtC decomposed as per Table A6.2.

In recent years, industrial emissions of carbon have been augmented by the widespread clearance and burning of forests. This provided additional 0.7 GtC in 1980 rising to 1.0-1.5 GtC in the mid 1980s (Grayson, 1989) and currently standing at between 0.6 and 2.5 GtC per year[4] (IPCC, 1990a). Table A6.3 details deforestation in 26 major tropical countries.

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[1]The greenhouse effect is the naturally occurring insulating effect of the atmosphere without which the Earth would freeze overnight (as per the planet Mercury which has not atmosphere). Incoming sunlight penetrates the atmosphere (some is reflected) and warms the Earth directly. This heat is then radiated up from the Earth's surface as invisible infra-red radiation but some of this is trapped by GHGs in the atmosphere, so insulating the Earth permiting life to exist.

[2]Clearly, as table A6.1 shows, any comprehensive attempt to address global warming should not exclude non-$CO_2$ GHG, particularly given their higher insulation values relative to $CO_2$ and recent alarming rates of increase.

[3]A gigatonne (Gt) is 1 billion (1000 million) tonnes.

[4]The IPCC range reflects the uncertainty regarding this figure. Leggett (1990) estimates current deforestation emissions at about 2 GtC pa while Myers (1989) gives an estimate of 1.4 GtC pa for closed (continuous) forests rising to 2.4 GtC pa (range 2.0 to 2.8) when open forests are included. See also Detwiler and Hall (1988); Pearce, F. (1989) (who reports prediction as high as 4 GtC pa); and Park (1990).

Table A6.1: Common GHGs, origin, accretion rate and contribution to global warming in the 1980s

| Gas[1] | Principal sources | Current rate of annual increase and concentration[2] | Contribution to global warming (%)[3] |
|---|---|---|---|
| Carbon dioxide ($CO_2$) | Fossil fuel burning (*c*.77%)<br>Deforestation (*c*.23%) | 0.5%<br>(353 ppmv)[6] | 55 |
| Chlorofluorocarbons (CFCs) and related gases (HFCs and HCFCs)[5] | Various industrial uses:<br>refrigerants<br>foam blowing<br>solvents | 4%<br>(280 pptv CFC-11<br>484 pptv CFC-12) | 24 |
| Methane ($CH_4$) | Rice paddies<br>Enteric fermentation<br>Gas leakage | 0.9%<br>(1.72 ppmv) | 15 |
| Nitrous oxide ($N_2O$) | Biomass burning<br>Fertilizer use<br>Fossil-fuel combustion | 0.8%<br>(310 ppbv) | 6 |

Notes:

1. The contribution from tropospheric ozone is also significant, but is very difficult to quantify. Ozone forms in the troposphere as a result of chemical interactions between uncombusted hydrocarbons and nitrogen oxides, produced by fossil-fuel burning, in the presence of sunlight.
2. IPCC, (1990a) Policymakers' Summary, p.6.
3. ibid., estimates for the decade of the 1980s.
4. ibid., Section 1, p.12, rounded (see original table for error margins).
5. Note that production of CFCs began only a few years before the Second World War. Now that these gases are known to deplete ozone, the chemical industry is preparing replacements - hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs). Though they do not deplete ozone so badly (and are yet to be produced in commercial quantities), they are potent greenhouse gases.
6. ppmv = parts per million volume; ppbv = parts per billion volume; pptv = parts per trillion volume.

Source: Leggett (1990)

Table A6.2: Annual industrial emissions of carbon by country

| Country | % | Million Tons |
|---|---|---|
| USA | 24 | 1200 |
| USSR | 19 | 950 |
| China | 9 | 450 |
| Japan | 5 | 250 |
| West Germany | 4 | 200 |
| UK | 3 | 150 |
| Others | 36 | 1800 |
| Total | 100 | 5000 |

5000 million tons = 5 billion tonnes = 5 gigatons (GT)

Source: Grayson (1989)

Table A6.3: Tropical Deforestation to 1989 (inclusive)

| Country (plus area) | Original forest cover (km²) | Present forest cover (km²) | Present primary forest (km²) | Current deforestation 1989 km² p.a. (%) | Carbon Release in 1989 million tonnes | Carbon Release in 1989 (% of total)[4] |
|---|---|---|---|---|---|---|
| Bolivia (1,098,581) | 90,000 | 70,000 | 45,000 | 1,500 (2.1) | 14 | 1.0 |
| Brazil (8,511,906) | 2,860,000 | 2,200,000 | 1,800,000 | 50,000 (2.3) | 454 | 32.1 |
| Cameroon (475,442) | 220,000 | 164,000 | 60,000 | 2,000 (1.2) | 28 | 2.0 |
| Central America (522,915) | 500,000 | 90,000 | 55,000 | 3,300 (3.7) | 30 | 2.1 |
| Colombia (1,138,891) | 700,000 | 278,500 | 180,000 | 6,500 (2.3) | 59 | 4.2 |
| Congo (342,000) | 100,000 | 90,000 | 80,000 | 700 (0.8) | 10 | 0.7 |
| Ecuador (270,670) | 132,000 | 76,000 | 44,000 | 3,000 (4.0) | 27 | 1.9 |
| Gabon (267,670) | 240,000 | 200,000 | 100,000 | 600 (0.3) | 9 | 0.6 |
| Guyanas[5] (469,790) | 500,000 | 410,000 | 370,000 | 500 (0.12) | 4 | 0.3 |
| India (3,287,000) | 1,600,000 | 165,000 | 70,000 | 4,000 (2.4) | 41 | 2.9 |
| Indonesia (1,919,300) | 1,220,000 | 860,000 | 530,000 | 12,000 (1.4) | 124 | 8.9 |
| Ivory Coast (322,463) | 160,000 | 16,000 | 4,000 | 2,500 (15.6) | 36 | 2.6 |
| Kampuchea (181,035) | 120,000 | 67,000 | 20,000 | 500 (0.75) | 5 | 0.4 |
| Laos (236,800) | 110,000 | 68,000 | 25,000 | 1,000 (1.5) | 10 | 0.7 |
| Madagascar (590,992) | 62,000 | 24,000 | 10,000 | 2,000 (8.3) | 28 | 2.0 |
| Malaysia (329,079) | 305,000 | 157,000 | 84,000 | 4,800 (3.1) | 50 | 3.6 |
| Mexico (1,967,180) | 400,000 | 166,000 | 110,000 | 7,000 (4.2) | 64 | 4.6 |
| Myanma[6] (696,500) | 500,000 | 245,000 | 80,000 | 8,000 (3.3) | 83 | 5.9 |
| Nigeria (924,000) | 72,000 | 28,000 | 10,000 | 4,000 (14.3) | 57 | 4.1 |
| Papua[7] (461,700) | 425,000 | 360,000 | 180,000 | 3,500 (1.0) | 36 | 2.6 |
| Peru (1,285,220) | 700,000 | 515,000 | 420,000 | 3,500 (0.7) | 32 | 2.3 |
| Philippines (299,400) | 250,000 | 50,000 | 8,000 | 2,700 (5.4) | 28 | 2.0 |
| Thailand (513,517) | 435,000 | 74,000 | 22,000 | 6,000 (8.4) | 62 | 4.4 |
| Venezuela (912,050) | 420,000 | 350,000 | 300,000 | 1,500 (0.4) | 14 | 1.0 |
| Vietnam (334,331) | 260,000 | 60,000 | 14,000 | 3,500 (5.8) | 36 | 2.6 |
| Zaire (2,344,886) | 1,245,000 | 1,000,000 | 700,000 | 4,000 (0.4) | 57 | 4.1 |
| Totals | 13,626,000[1] | 7,783,500[2] | 5,321,000[3] | 138,600 (1.8) | 1,398 | 100.0 |

Notes:
1. Equals 97 per cent of estimated total original extent of tropical forests, around 14 million km²
2. Equals 97.5 per cent of present total extent of tropical forests, 8 million km²
3. Equals 67 per cent of total remaining tropical forests, 8 million km²
4. Omits countries not on this list as minor
5. French Guina, Guyana and Suriname
6. Burma
7. Papua New Guinea.

Source: Myers (1990)[5]

Total annual carbon emissions from fossil fuel and forest combustion may therefore be approaching 8 GtC pa. "Of this, slightly less than half remains in the atmosphere, the rest ostensibly disappearing into the oceans or being absorbed by plants (though the so-called fertilizer effect) or by other 'sinks'" (Myers, 1990). Consequently observed levels of atmospheric $CO_2$ have begun to increase. From a 'natural' pre-industrial level of 270-280 ppm, observations at the Mauna Loa observatory in Hawaii have recorded a consistent year on year increase from 1958 to a present day $CO_2$ concentration of about 350 ppm (Lashof and

[5] "Extrapolation of recent trends shows that the tropical-forest component [of carbon emissions] could reach a peak of 5 billion tonnes [annually] by early next century - whereafter it would rapidly decline, on the grounds that there would not be much forest left to burn" (Myers, 1990).

Tirpak, 1989). Assuming a business-as-usual scenario, Kelly (1990) estimates that this will rise to over 450 ppm by 2050[6].

While the impact of these emissions upon the global climate is complex and still not fully understood, "there is general agreement in predicting a globally-averaged temperature rise" (Bowman, 1989). By examining geological records over extensive periods, a close positive correlation between $CO_2$ concentrations and temperature can be established (see upper panel of figure A6.1). Some have argued that the present increase in $CO_2$ has already triggered a rise in mean global temperature (see lower panel figure A6.1). Such an assertion has been hotly debated. Nevertheless, even though "the unequivocal detection of the enhanced greenhouse effect from observations is not likely for a decade or more" (IPCC, 1990a), "there is general agreement in predicting a globally-averaged temperature rise" (Bowman, 1989).

A number of studies have attempted to model the relationship between GHGs and global temperature[7]. Such predictions are complicated not only because of the fundamental difficulties of modelling the global climatic system but also because of extreme uncertainties regarding a number of potential positive feedback routes which may further enhance the greenhouse effect (Leggett, 1990). Whilst many models are still relatively crude, most agree in predicting a steep rise in temperature, having already begun, which will continue throughout the next century. Kelly (1990) estimates that by 1990, in the absence of preventative measures, global temperatures will stand $1.1 \pm 0.5$°C above the pre-industrial level, a figure which he estimates will increase to $2.6 \pm 1.1$°C by 2050. Figure A6.2 illustrates recent estimates from Wigley and Raper (1992) which use a 1990 base year.

The consequences of global warming provides a further area of active debate. Long term effects include serious resource impacts and potential associated political upheavals. However, most commentators have focused upon two areas of more immediate concern: agricultural damage; and sea level rise (SLR).

A number of studies have examined the agricultural impacts of the enhanced greenhouse effect (Parry, 1989, 1993; IPCC 1990b). "The overall effect of global warming on agricultural yields appears to be ambiguous, but could be significantly negative and may result in serious regional or year-to-year food shortages" (Fankhauser, 1993a). There have been a number of economic analyses of this issue, some of which simply multiply expected yield changes with crop prices (Cline, 1992a), whilst others adopt a more detailed general equilibrium approach (e.g. Adams et al., 1990; Kane et al., 1992; Reilly and Hohmann, 1993). Most examine northerly, developed country agricultural systems, generally concluding that overall welfare effects are positive. Such conclusions may not apply to less developed and/or tropical countries particularly where these coincide with subsidence farming systems and Fankhauser (1993a) highlights this as a major focus of ongoing research.

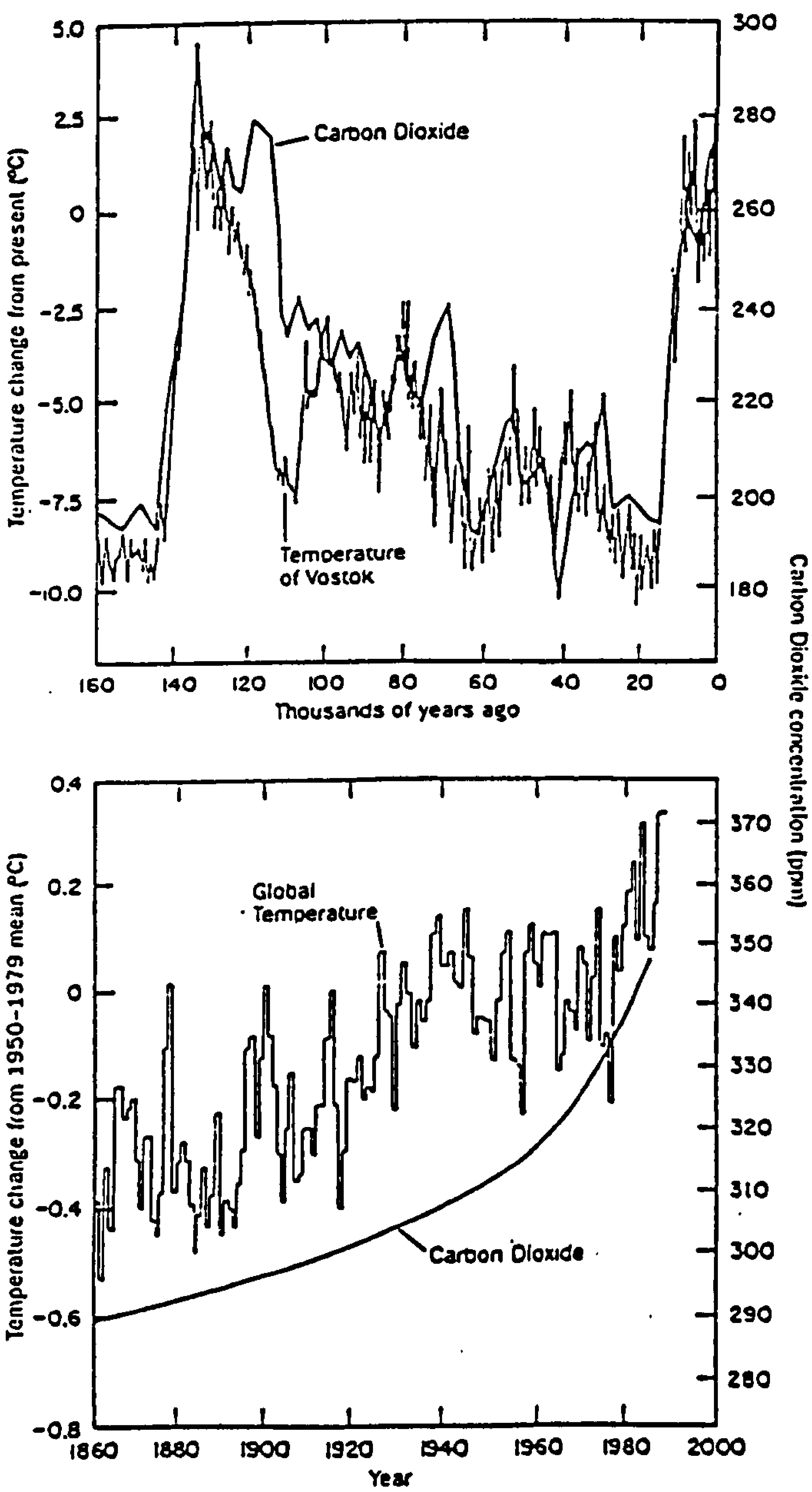
Research into the impacts of temperature induced SLR has also been considerable. Fankhauser (1993a) divides the literature into two groups: studies examining optimal sea level rise strategy (e.g. Turner et al 1993; Den Elzen and Rotmans, 1992; Yohe, 1991; Gleick and Maurer, 1990); and those who estimate the overall costs of SLR assuming a certain mitigation

[6]Kelly (1990) also reports estimates for all GHGs. By taking account of their varying insulation factors, non-$CO_2$ gases can be converted to effective $CO_2$ concentrations. Kelly thereby reports a present day (1990) total GHG concentration $CO_2$ equivalent of just over 400 ppm and a 2050 estimate of over 625 ppm (respectively 1.5 and 2.3 times the pre-industrial level).

[7]The major reports in this area are Houghton et al., 1990 and 1992. For introduction to the subject see Leggett (1990), Mintzer (1993) and Warr and Smith (1993).

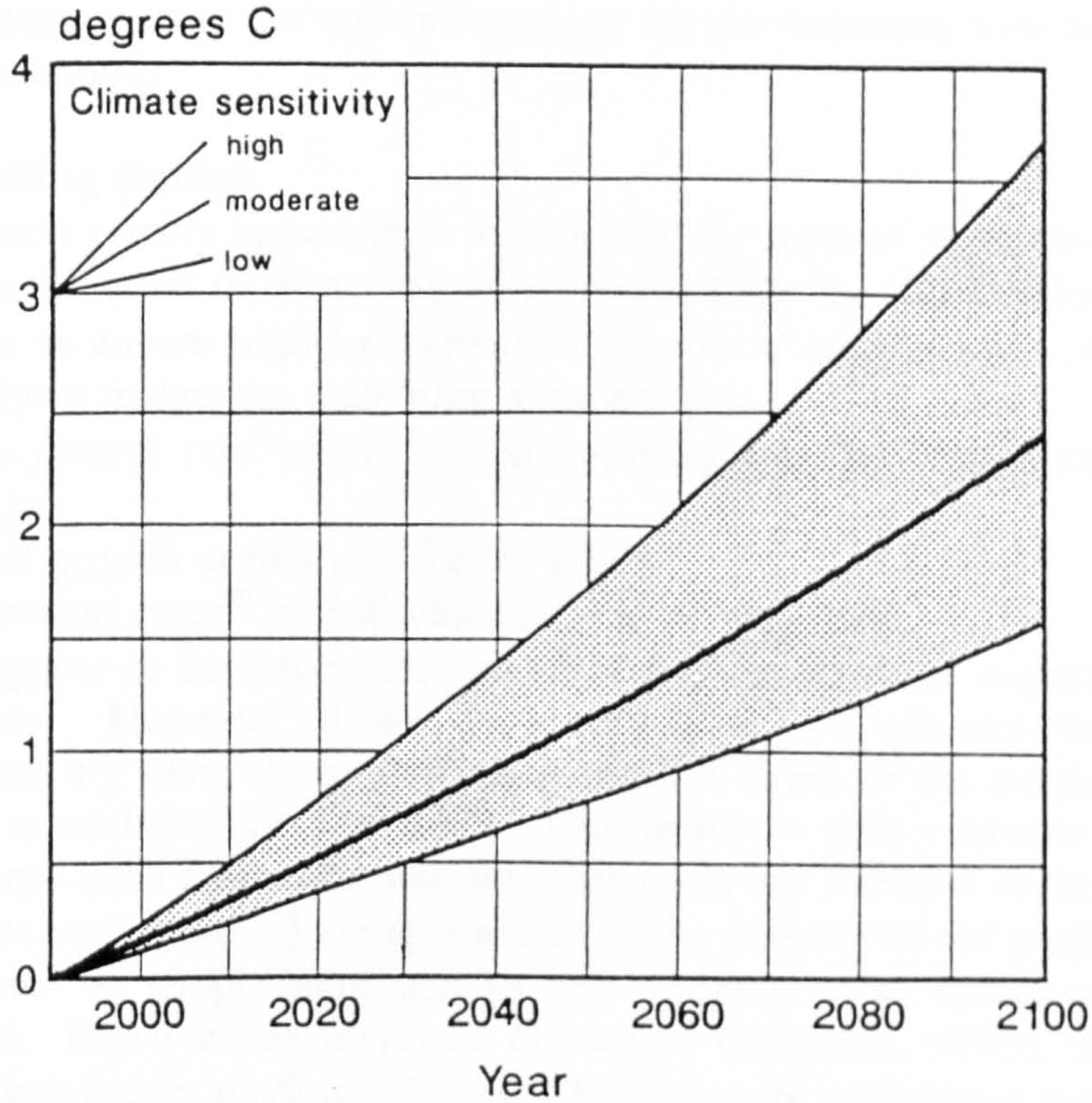
strategy (e.g. Rijsberman, 1991; Titus et al., 1991). The general consensus from such models appears to be that the overall costs of SLR may be very considerable.

Figure A6.1: Relationship of carbon dioxide with temperature change over past 160,000 years (upper panel) and past 100 years (lower panel)




Source: Schneider (1990)

Figure A6.2: Business-as-usual projection of the future rate of global surface air temperature rise




Source: Wigley and Raper (1992)

Recent years have seen the advent of more comprehensive assessments of the costs of global warming (e.g. Nordhaus 1991a,b,c; Cline 1992a; Fankhauser 1992, 1993b, 1994a,b, 1995). These have gone beyond initial studies of agriculture and SLR to include impacts upon human health, amenity, energy, fisheries, forestry, water, air pollution, migration and even wetland and species loss.

### A6.1.2: MONETARY ASSESSMENT OF CARBON DIOXIDE

Since the mid-1980s a large number of studies have addressed the economic problems raised by excessive emissions of carbon dioxide. Many of these have focused upon monetary assessment of such emissions. Bateman (1992, 1994) divides techniques for such assessments into two broad categories:

1. Pricing methods
2. Valuation methods.

In the context of $CO_2$ emissions, pricing methods include approaches such as examining the costs of carbon sequestration options. These produce abatement prices but do not tell us about the net value of such abatement. Such approximations are useful in cases where we have no prior information regarding values or where it is quite clear that the costs of any abatement action are substantially less than resultant benefits. Furthermore, such pricing studies are often relatively simple to conduct. However, the problem of relying upon prices rather than values is that we are never sure that any abatement strategy is actually worthwhile and cannot judge the optimal extent of any such initiative. Consequently, the bulk of the economic literature has concentrated upon valuation rather than abatement pricing.

This section examines, in turn, both pricing and valuation studies before concluding by making recommendations as to the optimal strategy for the monetary assessment of $CO_2$ sequestration via afforestation.

### A6.1.2.1: $CO_2$ pricing studies

The most common pricing approach is to examine the costs of sequestration. Myers (1989, 1990) examines the costs of removing atmospheric $CO_2$ via afforestation. Focusing upon tropical countries to ensure high tree growth and carbon sequestration rates and low establishment costs, Myers makes the following assumptions:

i. Biomass growth rate[8] of 20 t/ha pa implying a carbon sequestration rate[9] of 10 t/ha pa;
ii. Sustained growth at this rate for 30 years;
iii. Establishment costs[10] of $400/ha as a one-off payment.

These figures appear to be somewhat optimistic both in terms of sequestration rates and establishment costs. However, if we do accept these we can see that (ignoring maintenance costs which are likely to be low) over the full terms of the project some 300 tC/ha are sequestered at an initial cost of $400. One problem with evaluating a cost for carbon sequestration from such figures is that, whereas costs are incurred at the start of the project, benefits (carbon sequestration) are spread across the lifetime of the project and must therefore be discounted. A simple approach to this problem is to calculate discounted sequestration quantities. However, as reviewed elsewhere (Bateman, 1993), the choice of discount rate is not immediately obvious. Table A6.4 presents a discount rate sensitivity analysis for such a project based upon Myers assumptions. As can be seen, alterations in the discount rate have a considerable impact upon the consequent estimate of sequestration costs.

Sedjo (1989) and Sedjo and Solomon (1989) look at the afforestation option in both temperate and tropical regions concluding, for the above stated reasons, that the latter region provides a more viable economic prospect. Sedjo and Solomon use an identical tropical establishment cost estimate ($400/ha) to that used by Myers (1990) but assume a lower sequestration rate; 6.24 tC/ha pa rather than 10tC/ha pa. This results in proportionally lower sequestration costs to those reported in table A6.4.

Sedjo and Solomon also calculate the area of land necessary to sequester the entire annual increment of atmospheric carbon which they report as being 2.9 Gtc pa (this is roughly 1 GtC pa less than the present best estimates discussed above[11], and so the land area requirement reported should be seen as a lower bound estimate). Using their estimate of sequestration rates this implies a necessary area of some 465 million hectares or roughly two-thirds the area of the USA. Figure A6.3 illustrates this area.

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[8]Myers reports mean tropical tree growth rates ranging between 15-25 t/ha pa. Myers states that this is a conservative range as higher means may be found in equatorial latitudes, claiming a Brazilian average of over 30 t/ha pa with top productivities approaching 70 t/ha pa (Myers, 1990).

[9]Carbon constitutes about 50% of tree biomass (see subsequent sections for further details).

[10]Myers (1990) assumes that labour is likely to be free "in light of the many local goods and services (construction materials, soil conservation, windbreaks, and so on) that would be supplied by trees". He acknowledges that in the absence of free labour, establishment costs would rise to about $2000/ha.

[11]Sedjo and Solomon (1989) base these estimates on the work of Detwiler & Hall (1988).

Table A6.4: Carbon sequestration costs via tropical afforestation: discount rate sensitivity analysis

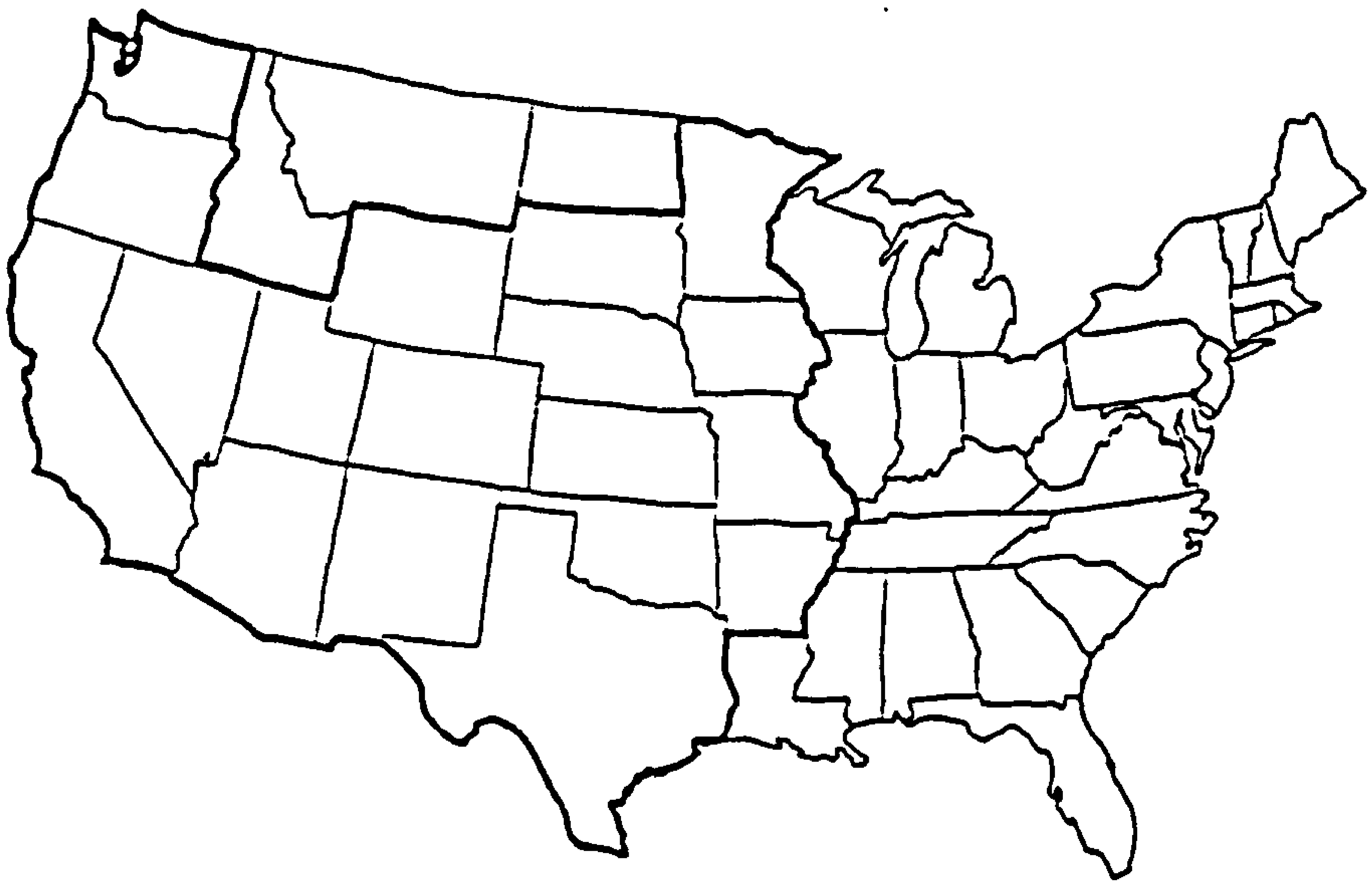
| Year | Annual discounted sequestrated volume (tC/ha) at various discount rates (r) | | | | |
|---|---|---|---|---|---|
| (t) | r=0% | r=2% | r=3% | r=6% | r=10% |
| 0 | 10 | 10.0 | 10.0 | 10.0 | 10.0 |
| 1 | 10 | 9.8 | 9.7 | 9.4 | 9.1 |
| 2 | 10 | 9.6 | 9.4 | 8.9 | 8.3 |
| 3 | 10 | 9.4 | 9.2 | 8.4 | 7.5 |
| 4 | 10 | 9.2 | 8.9 | 7.9 | 6.8 |
| 5 | 10 | 9.1 | 8.6 | 7.5 | 6.2 |
| 6 | 10 | 8.9 | 8.4 | 7.0 | 5.6 |
| 7 | 10 | 8.7 | 8.1 | 6.7 | 5.1 |
| 8 | 10 | 8.5 | 7.9 | 6.3 | 4.7 |
| 9 | 10 | 8.4 | 7.7 | 5.9 | 4.2 |
| 10 | 10 | 8.2 | 7.4 | 5.6 | 3.9 |
| 11 | 10 | 8.0 | 7.2 | 5.3 | 3.5 |
| 12 | 10 | 7.9 | 7.0 | 5.0 | 3.2 |
| 13 | 10 | 7.7 | 6.8 | 4.7 | 2.9 |
| 14 | 10 | 7.6 | 6.6 | 4.4 | 2.6 |
| 15 | 10 | 7.4 | 6.4 | 4.2 | 2.4 |
| 16 | 10 | 7.3 | 6.2 | 3.9 | 2.2 |
| 17 | 10 | 7.1 | 6.1 | 3.7 | 2.0 |
| 18 | 10 | 7.0 | 5.9 | 3.5 | 1.8 |
| 19 | 10 | 6.9 | 5.7 | 3.3 | 1.6 |
| 20 | 10 | 6.7 | 5.5 | 3.1 | 1.5 |
| 21 | 10 | 6.6 | 5.4 | 2.9 | 1.4 |
| 22 | 10 | 6.5 | 5.2 | 2.8 | 1.2 |
| 23 | 10 | 6.3 | 5.1 | 2.6 | 1.1 |
| 24 | 10 | 6.2 | 4.9 | 2.5 | 1.0 |
| 25 | 10 | 6.1 | 4.8 | 2.3 | 0.9 |
| 26 | 10 | 6.0 | 4.6 | 2.2 | 0.8 |
| 27 | 10 | 5.9 | 4.5 | 2.1 | 0.8 |
| 28 | 10 | 5.7 | 4.4 | 2.0 | 0.7 |
| 29 | 10 | 5.6 | 4.2 | 1.8 | 0.6 |
| Total discounted sequestrated volume | 300.0 | 228.4 | 201.9 | 145.9 | 103.7 |
| Measure[1] | Sequestration Cost[2,3] | | | | |
| \$/tC | 1.33 | 1.75 | 1.98 | 2.74 | 3.86 |
| \$/t$CO_2$ | 0.36 | 0.48 | 0.54 | 0.75 | 1.05 |
| £/tC | 0.89 | 1.17 | 1.32 | 1.83 | 2.57 |
| £/t$CO_2$ | 0.24 | 0.32 | 0.36 | 0.50 | 0.70 |

Notes:

1. Uses an exchange rate of £1=\$1.50.
2. These calculations are based on the Myers (1990), and Sedjo and Solomon (1989) establishment cost estimate of \$400/ha occurring as a single cost in year 0. Maintenance costs are likely to be minor and are ignored.
3. One tonne of $CO_2$ contains 273kg of C i.e. 3.66 tonnes of $CO_2$ must be sequestered in order to fix 1 tonne C.

The enormous area needed for full annual sequestration shows that afforestation is unlikely to provide a complete solution to global warming problems. Furthermore, substantial net sequestration only occurs during the rapid growth phase of the first rotation, after which replanting is required just to maintain this the level of carbon lock-up. In reality, therefore, the most likely role which afforestation may play is as a stop-gap measure while non-fossil fuel sources are developed.

Figure A6.3: The area of new afforestation require to fully sequester current[1] net carbon emissions



Note: 1. Assumes current net emissions = 2.9 GtC pa. This may be an underestimate of the total amount.

Source: Sedjo (1989)

The costs of afforestation in developed countries would be considerably higher than those used by either Myers (1990) or Sedjo and Solomon (1989). In January 1990 President Bush set the US Forest Service a target of planting 1 billion trees in the USA with the specific aim of offsetting 5% of US carbon emissions. This scheme was costed at $545 million (Bureau of National Affairs, 1990) which equates to $9.11/ton (or $8.996/tonne)[12] of $CO_2$ removed from the atmosphere[13]. Adapting these estimates to British growth rates[14],

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[12]Each tonne of $CO_2$ contains 273kg of C implying a sequestration cost of $3.3/tonne of C.

[13]This is a simplistic calculation which compares present cost directly with the sum of undiscounted carbon fixed over the first rotation. A more accurate calculation could be made to allow for the effects of discounting and whether or not trees are replanted after felling. Allowance for these factors would increase the costs of sequestration. However, such an analysis would allow consideration of the non-carbon net benefits of forestry. See Price and Willis (1993) for a dynamic analysis of carbon fluxes.

[14]The assumptions used here are:

i. 1990 prices.

ii. An exchange rate of £1 = $1.80 (this has now changed (January 1994 to roughly £1=$1.50).

iii. A carbon fixing rate of 1.7 tonnes C (6.2 tonnes $CO_2$) per ha pa. This is the rate given for upland Sitka Spruce (the major UK planting species) in Pearce (1990).

The carbon fixing rate used in this calculation (1.7 tC/ha pa) is assumed constant in each year. This

Bateman (1991) equates this to an annual carbon fixing value of £31/ha pa for UK forests. However, the BNA costs estimates are possibly optimistic.

A more advanced analysis of the costs of using afforestation as a route for carbon sequestration is provided by Nordhaus (1991a). Nordhaus investigates both the supply and demand side of the timber market. Considering first the demand side, Nordhaus discusses a subsidy payable to those who purchase/harvest trees and sequester the carbon via house building, etc. Various price subsidies are investigated ranging from 5% to 200% of market price[15]. Nordhaus estimates a simple forestry market model yielding increasing marginal costs of sequestration. Results from this analysis are given in table A6.5.

Table A6.5: Costs and carbon sequestration from a timber users price subsidy

| Subsidy Rate % | Annual Sequestration ($10^9$ tonnes C pa) | Cost ($/tonne C) |
|---|---|---|
| 0 | .000 | 0 |
| 5 | .016 | 19 |
| 10 | .031 | 38 |
| 25 | .075 | 97 |
| 50 | .142 | 195 |
| 75 | .204 | 293 |
| 100 | .261 | 391 |

Notes: 1. Relevant (1989) market price given as $50/m$^3$ of timber

Source: Nordhaus (1991a)

As part of this demand side analysis, Nordhaus also looks at the option of purchasing a quantity of wood and, as he puts it, "pickling" the timber to ensure longevity of carbon storage. The main problem of such an option is the sizeable additional forgone-output-loss involved[16] and Nordhaus rejects such an alternative.

Turning to consider the supply side option of afforesting open areas, as with the Sedjo and Solomon (1989) approach outlined above, the costs involved in such afforestation provides a price for, rather than valuation of, carbon sequestration. The assumptions of the Nordhaus model are as follows:

i. Sequestration rate:

tropical areas = 1.60 tons C/ha pa
temperate areas = 0.82 tons C/ha pa

is clearly unrealistic as sequestration follows the tree growth pattern being initially low then rising rapidly before reducing as the tree reaches maturity. Allowing for discounting effects in such an analysis would thereby reduce our estimate of carbon fixing value.

[15]Nordhaus (1991a) quotes a 1989 market price of $50/m$^3$ of wood (equivalent to $200/tonne C), with an annual market volume of 800 million tonnes. These imply potential subsidies from $2-80 billion pa.

[16]At the above prices this would imply a sequestration cost of $200/tonne C.

ii. Growth is logistic;

$$S_t = \alpha/[\beta + \exp\{c + d_t\}]$$

where

$S_t$ = stand in tons

$\alpha$ = location specific (see Table 6)

$\beta$ = 1.0

c = 5

d = -0.0055

iii. Trees mature in 40 years fixing a total of 50 tons C in tropical areas and 30 tons C in temperate areas.

iv. A total of 510 million hectares[17] are available at a price ranging from $20 to $200/ha.

v. Afforestation costs;

planting = $400-450/ha

maintenance = $10-20/ha pa.

This model gives a sequestration cost of between $42 and $114 per ton of C[18]; markedly higher than those implied from the BNA cost estimates. Full details are given in table A6.6.

Even if all the options detailed in table A6.6 were undertaken this would only sequester 21.3 billion tons of C, i.e. approximately 3 years emissions (roughly 0.28 billion tons pa for 75 years). Furthermore this is a one-off sequestration, dependent upon maintenance and replanting if it is not to be eventually reversed.

Table A6.6: Estimates of the cost-effectiveness of forestation option in sequestration of carbon

| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) |
|---|---|---|---|---|---|---|---|---|---|---|
| Location of Land | Removal rate (tC/h/y) | Area (million ha) | Plant cost ($/ha) | Land cost ($/ha) | Manage cost ($/ha/yr) | Stand, mature forest (tC/ha) | Growth period (yr) | Total cost of removal ($/tC) | Mature stand (Billion tons C) | Average removal (Billion tC/yr) |
| Tropical land, low cost | 1.60 | 100.00 | 400.00 | 20.00 | 10.00 | 50.00 | 40.00 | 41.59 | 5.000 | 0.067 |
| Tropical land, med cost | 1.60 | 100.00 | 400.00 | 50.00 | 10.00 | 50.00 | 40.00 | 43.88 | 5.000 | 0.067 |
| Tropical land, high cost | 1.60 | 100.00 | 400.00 | 100.00 | 10.00 | 50.00 | 40.00 | 47.50 | 5.000 | 0.067 |
| U.S. unused land | 0.82 | 10.00 | 450.00 | 20.00 | 20.00 | 30.00 | 40.00 | 91.58 | 0.300 | 0.004 |
| Temperate, marginal | 0.82 | 100.00 | 450.00 | 100.00 | 20.00 | 30.00 | 40.00 | 101.75 | 3.000 | 0.040 |
| U.S. marginal land | 0.82 | 100.00 | 450.00 | 200.00 | 20.00 | 30.00 | 40.00 | 114.47 | 3.000 | 0.040 |

Notes:

Column 2: Different regions are provided in EPA (1989); U.S. and temperate use the average growth U.S. commercial forests 1977; see EPA (1989), p.VII-233. Tropical uses figure for unmanaged forest; average figures given in EPA (1989); p.VII-223.

Column 3: Rough estimates of the amount of land available from EPA (1989); p.VII-238, and by author.

Column 4: Estimates from EPA (1989), pp.VII-245-246.

Column 5: Some estimates from EPA (1989); others are estimates of land prices by author.

Column 6: Estimates from author.

Column 7: Estimates from EPA (1989) and elsewhere.

Column 8: Estimates from EPA (1989) and elsewhere.

Column 9: Assumes a 6 percent real cost of capital; that carbon buildup is according to logistics equation; and that no offsite sequestration is undertaken.

Column 10: Total annual rate of sequestration in reforestation activities.

Column 11: Assumes that the reforestation in column 10 is spread over period of 75 years.

Source: Nordhaus (1991a)

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[17]Roughly one-third of the area of the USA.

[18]$41-113/tonne C; $11-31/tonne $CO_2$.

One unusual approach to the pricing of carbon fixing is given by Wibe (1990) who multiplies the sequestration rate of Sedjo and Solomon (1989) by the then proposed Swedish carbon tax rate of 0.92SK ($0.15 in 1990 prices) per kg of C to give a forestry carbon cleaning value of $750/ha pa. As noted above, such sequestration rates are not applicable to most developed countries situated in northern latitudes. Applying this methodology and tax rate to UK tree growth rates[19] given an annual carbon fixing value of about £140/ha pa. Such sums outstrip the value of other forest benefits and suggest that the prime economic purpose of forestry should be as a carbon sink. However, such an analysis should be rejected on two grounds:

1. The carbon tax used is determined by political rather than economic consideration;
2. As such this approach does not reveal the value of carbon sequestration, only an imputed (and suspect) price. Therefore it cannot be the basis for economic decisionmaking.

A more valid pricing approach is to calculate the cost of substituting low-$CO_2$ technologies for existing fuel capital. Kram and Okken (1989) estimate the cost of $CO_2$ scrubbing from stacks to be $54-118/tonne C ($15-32/tonne $CO_2$). Similarly Edmonds and Barns (1991) investigate the possibility of direct substitution of methane for gas and oil but find this to be a relatively expensive option ($300-700/tonne C; $82-191/tonne $CO_2$).

Another option is to consider the costs of geoengineering. Nordhaus (1991a) discusses two options. In the first particles are deposited in the atmosphere to create a sunscreen thereby increasing the Earths albedo and reducing the greenhouse effect. "These particles could be shot up with 16-inch naval rifles, lifted by hydrogen balloons, or deposited by tuning the engines of aircraft to burn somewhat richer than normal" (Nordhaus, 1991a). The second option is to seed the major oceans with iron so limiting nutrients, increasing photosynthesis and raising the rate of carbon precipitation. Nordhaus claims the direct costs of such options may be minimal, between $0.1 and $10/ton C sequestered. However, the risks of such strategies appear very high given our poor understanding of the world ecosystem.

In a review of pricing approaching, Nordhaus (1991a) standardises some nine separate models reporting results relating different rates of carbon tax to levels of carbon sequestration. He divides these models into two broad categories:

i. Econometric studies:- these model demand and supply for energy and either explicitly or through subsequent extension, estimate the impacts of imposing carbon tax on consumption or production;
ii. Mathematical programming or optimization approaches:- these models consist of functions describing both demand and technology. The models solve for an 'optimal' trajectory of prices, outputs, fuel mix and technologies[20]. To provide results comparable with those from the econometric analyses, Nordhaus re-runs these optimization models imposing $CO_2$ emission constraints.

$CO_2$ reductions for a variety of carbon tax levels as estimated from both the econometric and $CO_2$ constrained optimization models are reported in table A6.7.

[19]This calculation assumes the same price, exchange rate and absorption rates as employed in the previous UK conversion (Bateman, 1991).

[20]The optimal result corresponds to that attained under perfect competition.

Table A6.7: Estimated percentage reduction in $CO_2$ at given levels of carbon tax or marginal cost ($/ton C).

| Tax or Cost [$/tC] | Percentage Reduction in $CO_2$ | | | | | |
|---|---|---|---|---|---|---|
| | Econometric Models | | Optimization Models | | | |
| | Small | Large | Nordhaus | Manne-Richels | Other | Regression |
| 0 | 0 | 0 | 0 | 0 | 0 | 0.0 |
| 10 | 3[8] | 10[1] | 5[9] | | | 6.6 |
| 20 | 7[8] | 18[2] | 9[9] | | 10[5] | 10.9 |
| 30 | 10[8] | 40[1] | 17[9] | | | 15.0 |
| 40 | 13[8] | 36[1] | 20[9] | | 28[6] | 18.9 |
| 50 | 15[8] | | | | | 22.6 |
| 60 | | | | | | 26.1 |
| 70 | | | | | | 29.5 |
| 80 | | | | | | 32.8 |
| 90 | | 40[2] | 43[9] | | 20[5] | 35.9 |
| 100 | 27[8] | | | | | 38.8 |
| 110 | | | | | | 41.6 |
| 120 | | | | | | 44.3 |
| 130 | | 50[2] | | | | 46.8 |
| 140 | | | | | 30[5] | 49.3 |
| 150 | 36[8] | | 60[9] | | | 51.6 |
| 160 | | | | | 63[4] | 53.8 |
| 170 | | | | | | 56.0 |
| 180 | | | | | | 58.0 |
| 190 | | | 92[9] | | | 59.9 |
| 200 | 43[8] | | | | | 61.7 |
| 210 | | | | | | 63.5 |
| 220 | | | | | | 65.2 |
| 230 | | | | | | 66.8 |
| 240 | | | 78[9] | | | 68.3 |
| 250 | | | | | 74[4] | 69.8 |
| 260 | | | 90[9] | 82[7] | | 71.1 |
| 270 | | | 94[9] | | | 72.5 |
| 280 | | | | | | 73.7 |
| 290 | | | | | | 74.9 |
| 300 | | | | | | 76.1 |
| 310 | | | | | | 77.2 |
| 320 | | | | | | 78.2 |
| 330 | | | | | | 79.2 |
| 340 | | | | | | 80.2 |
| 350 | | | | 76[7] | | 81.1 |
| 360 | | | | | | 82.0 |
| 370 | | | | | | 82.8 |
| 380 | | | | | | 83.6 |
| 390 | | | | | | 84.3 |
| 400 | | | | | | 85.1 |
| 410 | | | | | | 85.7 |
| 420 | | | | | | 86.4 |
| 430 | | 50[3] | 98[9] | | | 87.0 |

Figures in brackets refer to model number (see notes below)

Source: Nordhaus (1991a)

Notes: [1]: Jorgensen and Wilcoxen (1990), Interpretation of results is straightforward.

[2]: Edmonds and Reilly (1983). The estimate is derived by taking the carbon equivalent of the energy taxes imposed in simulations.

[3]: Whalley and Wigle (1990). Interpretation of results is straightforward.

[4]: Bodlund et al. (1989). Estimates compare the total cost and the carbon emissions for two scenarios. There appears to be no ambiguity in the results.

[5]: European Community (1990). Estimates use the results for the U.K., which are difficult to convert into the metric used here. Conversion assumes that the discount rate used is 6 percent, that costs are centred on 2005, that the exchange rate is $1.9 per £, and that the data are tons of $CO_2$ rather than C.

[6]: Kram and Okken (1989). Similar difficulties arise in converting the results in this study as in 5.

[7]: Manne and Richels (1990). Because the model is dynamic, there is ambiguity about the cost. We have taken average estimates for costs after the short-run adjustments costs have disappeared. Otherwise, interpretation of results if straightforward.

[8]: All the rectangles are from Nordhaus and Yohe (1983) or the version revised for this survey. Interpretation is straightforward.

[9]: All of the starred points are from one of the vintages of the Nordhaus model or its descendant, the Argonne model. The same ambiguity about cost arises here as in Manne-Richels because of the dynamic nature of the simulation, but in fact the difference between different runs or time periods is small. Interpretation of results is straightforward.

The 'Regression' column reports regression fits to the different estimates. The regression was estimated using ordinary least squares fitted to the estimates from different models. The equation is given as EQN (A6.1) in the text.

Nordhaus uses the observations of table A6.7 to fit a regression line relating percentage reduction in $CO_2$ to carbon tax rate. This gives the marginal cost curve for carbon reduction. The best fit model is reproduced as equation (A6.1):

$$\ln (1 - R) = -0.0223 - 0.0054\ MC \qquad (A6.1)$$

where

R = reduction in $CO_2$ (from present uncontrolled path)

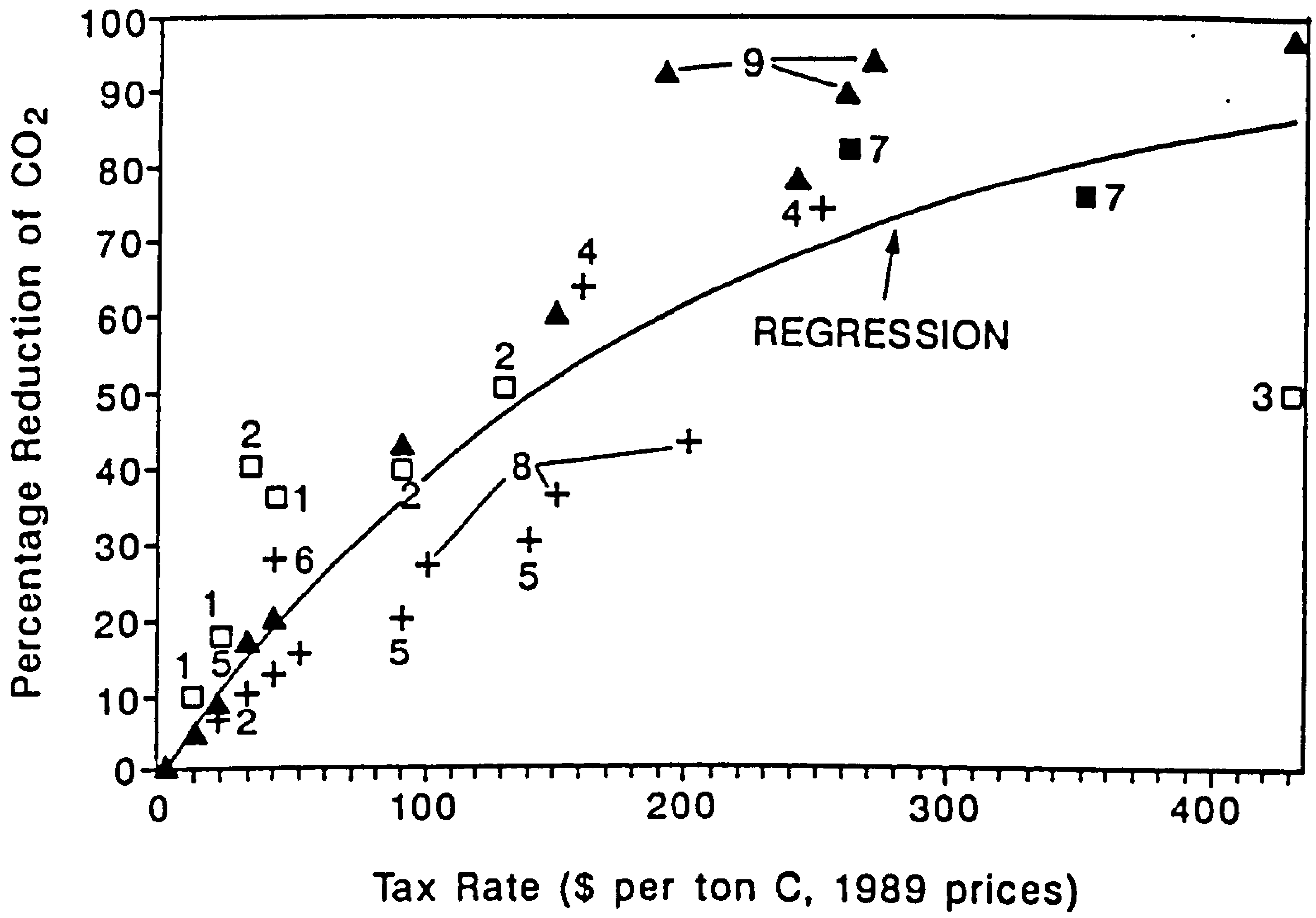
MC = marginal cost of removal (carbon tax rate in 1989 dollars per ton C)

The marginal cost curve estimated by equation (A6.1) is illustrated in figure A6.4 and the implied total cost curve for $CO_2$ reduction is given in figure A6.5.

*Pricing studies: conclusion*

Early pricing studies were beset by poor choice of underlying assumptions and are of little practical use. Recent work, such as that reviewed and summarised by Nordhaus (1991a) allows more realistic estimation of the marginal abatement cost curve. However, knowing the cost of fixing carbon via afforestation does not tell us whether such policies are worthwhile. To answer this question we need to know the value of carbon sequestration.

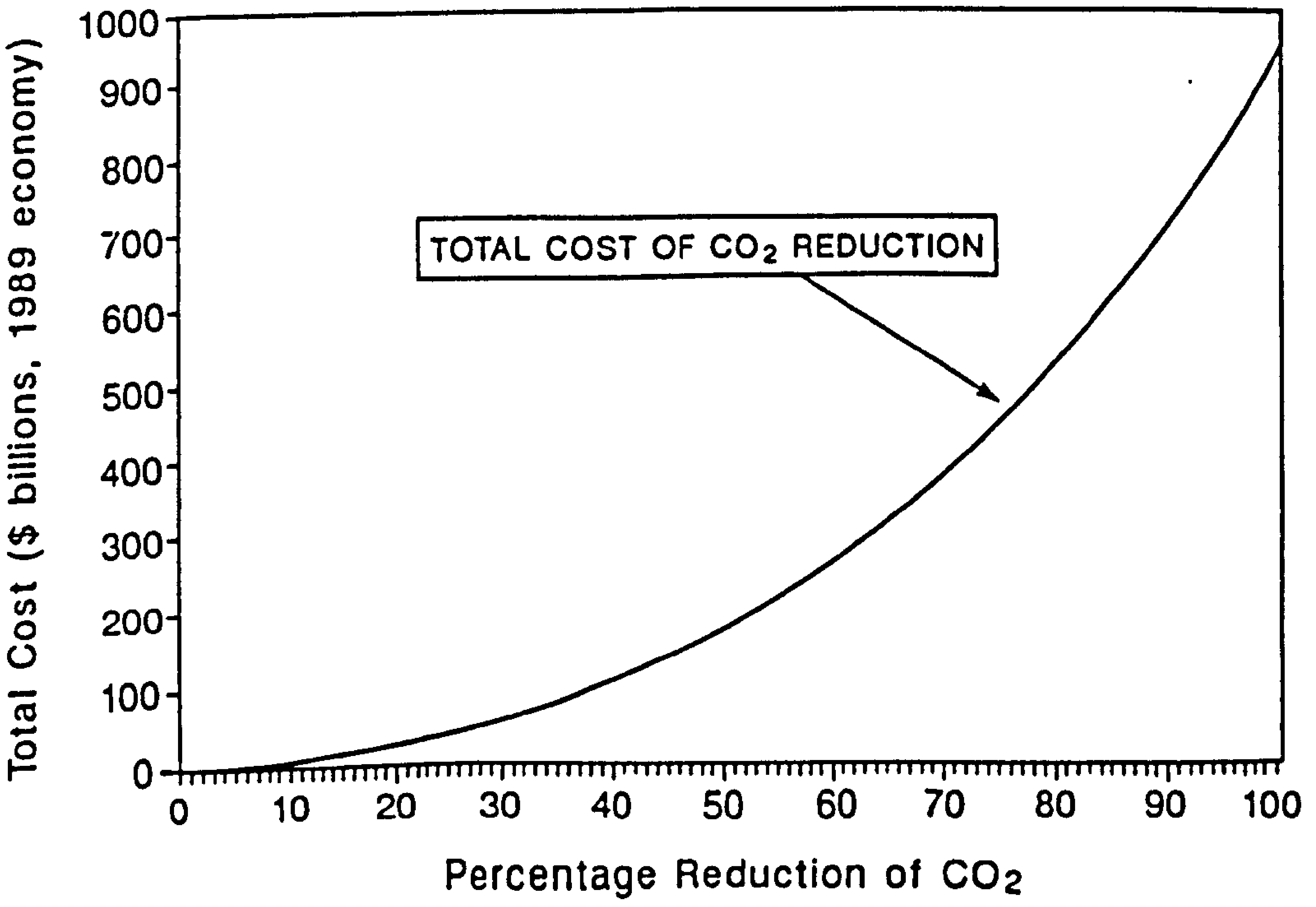
Figure A6.4: Marginal cost of $CO_2$ reduction (cost per ton C, 1989 prices)




Source: Nordhaus (1991a)

Notes: The numbers used in the figure correspond to the studies listed in table A6.7.

Figure A6.5: Global total cost of $CO_2$ reduction (cost at different reduction rates; $ billions, 1989 prices)




Source: Nordhaus (1991a)

A number of overview papers are available many of which attempt to compare results across models[27]. Bottom-up studies have produced consistently lower abatement costs than have economic models. This has generally been attributed to overestimates regarding the scope for cheap abatement options and underestimates of the inertia and costs of technology substitution in the bottom-up models (Grubb et al., 1994; Grubb, 1990). Accordingly most economic analyses have concentrated (not surprisingly) upon the findings of top-down models[28]. These roughly divide the economic damages resulting from global warming into the following categories:

i. Sea level rise costs;
ii. Other market costs (agriculture, forestry, fisheries, etc);
iii. Utility costs (energy, water, etc);
iv. Non-market costs (health, ecosystems loss, pollution, etc).

Most economic studies have concentrated upon a scenario in which the present level of $CO_2$ doubles (2 x $CO_2$). Furthermore most analyses have measured damages in terms of reductions to world GNP although many also report corresponding absolute damage amounts. Table A6.8 lists economic damage for 2 x $CO_2$ as reported in four prominent papers.

The variance in estimates across table A6.8 is due both to different assumptions (reflecting continued scientific uncertainty) and different unit valuations[29] across studies. Despite this there does appear to be a weak consensus across a wide range of studies that the expected economic damage caused by 2 x $CO_2$ is in the order of 1-2% of world GNP[30]. However, for the purposes of the wider study we are more concerned with estimates of the damage cost per ton of emission.

*ii(a): The shadow price of carbon emissions (damage per tonne estimates)*

The pioneering work on the shadow price of $CO_2$ emissions is that of Nordhaus (1991b,c). Using a very simple model he calculates social costs of $7.3/tonne of C emitted. These estimates provoked a number of critical responses (Ayres and Walter, 1991[31]; Daily et al 1991, Grubb, 1992) the most perceptive of which (Cline 1992a) highlights the simple linear structure of the underlying model implying both a constant level of $CO_2$ emissions[32] and constant shadow price through time.

[27]See Grubb et al., (1994), Fankhauser (1993a), UNEP (1992), Hoeller et al., (1991, 1992), Boero et al., (1991), Cline (1992a) and Nordhaus (1991a).

[28]Some commentators recognise the importance of bringing both approaches in line with each other (Fankhauser, 1993a).

[29]For a critique see Grubb (1992).

[30]Recent commentators have argued that reliance upon expected (mean) or best guess (mode) damage values alone may be unwise given that the distribution of damage estimates is positively skewed, i.e. low probability/high damage events should be considered in decisionmaking (Fankhauser, 1993a,b).

[31]It is somewhat ironic that Ayres and Walter criticise the Nordhaus (1991b,c) estimates as too low given that in an earlier paper they assess emissions damage costs at between $5-10/ton $CO_2$ ($18-37/tC) (Walter and Ayres, 1990). In their subsequent critique of Nordhaus they apply different assumptions to his model to produce a damage estimate of $30-35/tonne C (Ayres and Walter, 1991). However, given the problems of the simple linear Nordhaus model, such estimates must be treated with extreme caution (Fankhauser 1993b shows that, in addition to the simplicity of the first Nordhaus model, it also contains a mathematic error).

[32]Annual $CO_2$ emissions are predicted to rise from 7.4 GtC in 1990 to 9-14 GtC by 2025 (IPCC, 1992).

Table A6.8: Economic damages from 2 x $CO_2$
(US economy at present scale; bn$, 1988 prices)

| | Fankhauser (1992)[a] (2.5°C) | Cline (1992a)[b] (2.5°C) | Titus (1992)[b] (4°C) | Nordhaus (1991b,c)[b] (3°C) |
|---|---|---|---|---|
| sea level rise | 7.9 | 6.1 | 5.0 | 10.7 |
| agriculture | 7.4 | 15.2 | 1.0 | 1.0 |
| forest loss | 1.0 | 2.9 | 38.0 | small |
| fishery | - | - | - | small |
| energy | 6.8 | 9.0 | 7.1 | 1.0 |
| water supply | 13.7 | 6.1 | 9.9 | ) |
| other sectors | - | 1.5[c] | - | ) |
| ecosystems loss | 7.4 | 3.5 | - | ) |
| human amenity | - | - | - | ) |
| life/morbidity | 16.6 | 5.0 | 8.2 | )[d] |
| migration | 0.5 | 0.4 | - | ) |
| air pollution | 6.4 | 3.0 | 23.7 | ) |
| water pollution | - | - | 28.4 | ) |
| natural hazards | 0.2 | 0.7 | - | ) |
| TOTAL (bn$) (% GNP, 1988) | 67.9 (1.4) | 53.5 (1.1) | 121.3 (2.5) | 48.6 (1.0) |

[a] revised to 1988 prices
[b] transformed to 1988 values based on % GNP estimates
[c] tourism
[d] not assessed categories, estimated at 0.75% of GNP

Source: Fankhauser (1993a)

In subsequent work Nordhaus (1992a,b) addresses many of these criticisms. His Dynamic Integrated Climate Economy (DICE) model uses optimal economic growth analysis in combination with a climate model which feeds climate changes back into the economy as damages. The resulting carbon shadow prices are similar to his earlier estimates ($5.3/tC in 1995 rising to $10/tC in 2025). However, Nordhaus' results have again been criticised by Cline (1992b) who suggests that the parameter values used result in an underestimation of true costs.

A similar model, utilizing a more detailed economy component, is used by Peck and Teisberg (1992a,b). Their 'Carbon Emission Trajectory Assessment' (CETA) model produces estimates of the shadow price of carbon ranging from $10/tC in 1990 to $22/tC in 2030. Given that the CETA model is structurally similar to DICE, the main reason explaining differences in the shadow price estimates produced appears to be discrepancies in assumptions regarding carbon damages.

Important recent contributions to the shadow pricing debate are provided by the papers of Fankhauser (1993b, 1994a,b, 1995). These introduce a fully stochastic, greenhouse damages model, explicitly recognising the highly non-linear and uncertain aspects of the climate process. Uncertainty is incorporated by modelling all key parameters as random variables[33]. The model consists of modules examining: future emissions; atmospheric concentration; radiative forcing; temperature rise; annual damage; costs of sea level rise protection; and discounting. This last element is particularly interesting as studies prior to Fankhausers employ a 3% discount rate, justifying this with reference to the historical savings and interest rate[34]. Fankhauser notes that arguments regarding the 'correct' discount rate can be dated back to the 19th century (see review in Markandya and Pearce, 1991). With respect to the issues raised by greenhouse economics, a number of papers have re-examined this issue (Cline, 1992a,b; Birdsall and Steer, 1993; Broome, 1992; and Fankhauser, 1993a,b, 1995). To understand this debate we need first to distinguish between the discounting of pure utility and the discounting of commodities. We can define the discount rate (r) as follows:

$$r_t = \rho + w.\gamma_t$$

where

$\rho$ = pure rate of time preference
$w$ = income elasticity of utility
$\gamma_t$ = rate of growth of per capita income
$t$ = time (years from present).

Generally $0<\gamma_t<1$, usually some small growth rate[35]. The nature of w is less clear as the income elasticity of utility can be thought of as the rate of risk aversion. However, commonly w is set to 1 (which corresponds to a logarithmic utility function). Therefore the $w\gamma_t$ term, which denotes diminishing marginal utility of income as individuals become richer over time, usually implies some low, positive rate of discount. More controversial is $\rho$, the pure rate of time preference. If we accept that society has a different $\rho$ to that of individuals[36] then many have argued against a positive rate for this $\rho^s$ (Ramsey, 1928; Pigou, 1932; Solow, 1974, 1992; Cline, 1992a, 1993; Broome, 1992; Price, 1993). Such a positive rate appears to contradict Rawlsian notions of intergenerational equity. Accepting these arguments leaves us with a social discount rate ($r^s$) based only upon diminishing marginal utility of income which Price (1993) argues may be very low[37].

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[33]Here triangular distributions (using upper/lower bounds and the best guess estimate) are generally assumed although where upper and lower bounds were unknown a modest range of ±10% around the best guess was used. These assumptions are to be improved in a later paper.

[34]For example see Manne and Richels (1992).

[35]This is usually true of developed countries but not always of developing countries (see Turner, Pearce and Bateman, 1994).

[36]The conventional economic argument against separating out a social discount rate from a private rate is that social decisions should be based upon individual preferences. However, as Fankhauser (1993a) points out, "Drug legislation, safety regulations, speed limits or state pension schemes are all examples of a paternalistic state ignoring individual preferences .... [if these problems] warrant paternalism, it seems hard to find reasons why a fundamental issue like intergenerational equity should not. This then seems to speak for a zero rate of time preference" [p.25].

[37]"Based on a range of methods and speculations, values for elasticity of marginal utility of income between -0.5 (Squire and van der Tak, 1975) and -3 (Little and Mirrless, 1974) have been suggested in the literature of project appraisal. Stern (1977) finds many values in the region of -2, with an extreme value of -10" (Price, 1993), p.233.

Given the above arguments Fankhauser (1994b) addresses the discounting problem in a more detailed manner than other shadow pricing assessments of carbon. Considering the literature on the subject, he sets ρ as a random variable with upper and lower bounds of 0% and 3% respectively and with a best guess (mode) value of 0.5%. However, to allow comparability with other studies, a sensitivity analysis using r = 3% (and 0%) is also conducted (see below).

Given this we can see that the Fankhauser (1993b) model differs from the other shadow pricing models in at least three important aspects:

(i) It models climate feedback mechanisms in a more detailed and realistic manner;

(ii) It uses expected (means) rather than best guess (mode) values;

(iii) It uses a lower discount rate (r = 0.5%) than that used in other studies (r = 3%).

Table A6.9 contrasts results from Fankhausers (1994b) model with those discussed previously. For the latter only a best guess (mode) value is reported while, emphasising the importance of damage distributions, Fankhauser reports expected (mean) values as well as 5% and 95% percentiles, standard deviation and skewedness. Given factors (i) to (iii) above the discrepancy between Fankhauser's results and those of other studies[38] are to be expected.

Table A6.9: The social costs of $CO_2$ emissions ($/tC)

| Study | Measure | 1991-2000 | 2001-2010 | 2011-2020 | 2021-2030 |
|---|---|---|---|---|---|
| Nordhaus (1991a,b) | Best guess (mode) | 7.3<br>(0.3-65.9) | | | |
| Ayres and Walter (1991) | Best guess (mode) | 30 - 35 | | | |
| Nordhaus (1992a) | Best guess (mode) | 5.3 | 6.8 | 8.6[a] | 10.0 |
| Peck and Teisberg (1992b) | Best guess (mode) | 10-12[a] | 12-14[a] | 14-18[a] | 18-22[a]<br>(3.4-57.6) |
| Frankhauser (1994b) | Expected (mean)<br>5th percentile<br>95th percentile<br>standard dev.<br>skewedness | 20.4<br>6.3<br>47.7<br>15.1<br>2.8 | 22.9<br>7.2<br>53.8<br>16.6<br>2.8 | 25.4<br>8.1<br>60.3<br>18.2<br>2.6 | 27.8<br>8.8<br>66.2<br>19.9<br>2.6 |

Notes: a. Figures measured from graph as reported in Fankhauser (1993b).
Figures in brackets denote confidence intervals

Sources: as indicated.

[38]Ignoring Ayres and Walter (1991) for reasons given previously.

To allow easier comparison across studies Fankhauser (1993b) conducts a sensitivity analysis upon his discount rate assumptions. Table A6.10 reports expected (mean) shadow price values for carbon emissions in the year 1990 using values of ρ of 0%, 0.5% (his best guess) and 3% (comparable to other studies).

As can be seen, using a common time preference rate of 3% the estimates of Fankhauser (1993b) and Nordhaus (1992a) are quite comparable. Arguably this could be taken as evidence that differences (i) and (ii) above are not particularly significant. However, more surely it reflects the fact that the choice of discount rate in calculating damage estimates is of prime importance. Global warming is a very long term issue and discounting effects are consequently large.

Table A6.10: Discount rate sensitivity analysis: (Fankhauser 1993b model)

| ρ | Mean shadow price in 1990 ($/tC) | 90% Confidence interval ($/tC) |
|---|---|---|
| 0% | 46.6 | 25.6-82.9 |
| 0.5% | 20.4 | 6.3-47.7 |
| 3% | 5.5 | 3.6-7.7 |

Source: Fankhauser (1993b)

In conclusion it appears that the analysis provided by Fankhauser is the most sophisticated available to date. Furthermore when consideration is given to differences in approach, the damage estimates provided by this model do not appear out of line with earlier studies but do appear to be a significant improvement upon the latter. Given this, it appears that these results provide the most reliable estimates for use in the wider study although attention is drawn to the fact that these are expected (mean) rather than best guess (mode) values.

*ii(b) Shadow price evaluations: efficiency versus equity*

It should be noted that all the above papers by Fankhauser, Cline, Nordhaus and others have been subject to recent strong condemnation by groups such as The Global Commons Institute (London) and the Washington based Instituted for Policy Studies for preaching what Wysham (1994) describes as 'The Economics of Genocide'. This criticism arises because, as all these studies are ultimately based upon willingness-to-pay, they result in differing values of life in differing countries such that, in the Fankhauser papers the life of a US citizen is valued at $1.5 million while the life of an African is valued at $0.15 million, i.e. ten times less. The obvious inequity of such a valuation has caused a considerable outcry against such studies.

While we note that these complaints are not against the physical science underpinning realism of the Fankhauser model (a criticism which can be levelled against some earlier papers), this does highlight a shortcoming in the commonplace application of cost-benefit analysis (CBA) with which we have some sympathy. CBA, as it is now almost universally applied, analyses the economic efficiency of decisions as they occur in the real world. As such it is a very useful tool as, surely the comparison of costs and benefits is a necessary part of correct decisionmaking. However, such an approach says nothing about the equity of results obtained. Indeed it implicitly (and perhaps this lack of exposition is the methods major weakness) assumes that the present distribution of income (i.e. ability to pay) is somehow correct. If that were the case or if income were reasonably evenly shared out amongst society then the results of CBA would be both efficient and equitable. The problem raised by global warming is that it is a global issue and here income is very clearly not evenly or equitably distributed.

So then, in the work of Fankhauser which is in our opinion probably the most sophisticated and soundly based CBA efficiency analysis of global warming impacts to date. But, as Fankhauser is quite aware, this efficiency analysis is not the same as a socially equitable result. And this we do feel is an area where the common practice of economics is rightly open to strong criticism. The great thinkers of economics such as John Maynard Keynes (writing to his grandchildren in 1932) recognised that economics should not ultimately be about money but rather about morals; and that one of the hallmarks of any moral society (whether national or international) must surely be consideration for the disadvantaged.

But the practice of economic analysis has tended to overlook the equity side of true 'growth' in the Keynesian sense, in favour of the more readily measurable yardstick of efficiency. This is more than unfortunate, indeed it is a preference for means at the expense of ends. Furthermore it does not have to be that way. Concern to provide rules for respecting equity within economic analysis has a considerable pedigree (Squire and van der Tak, 1975). Pearce (1986) discusses ways in which the efficiency analysis of CBA can be complemented by consideration of distributional issues to produce an equitable result. One relatively simple method which he discusses is the use of inverse income weightings whereby the net benefits received by the poor are given relatively more weight in the decision process. Such techniques would go a long way to addressing these problems.

In essence then we do not criticise the studies of Fankhauser et al. for they did not set out to consider equity and have produced excellent efficiency analyses. Rather we would highlight the differences between efficient and equitable solutions and note that the former is a very necessary prerequisite for the latter. Our only criticism is that the discipline of economics seems generally to have given up on attempting to go that extra step.

What implications does this have for our own study. Given the above comments, we have to be a little embarrassed to admit that we too have only gone as far as CBA style, efficiency analysis. In effect we are accepting the present income distribution as given. Our only defence is that while the greenhouse debate is by its nature global, our study is very much UK based. In fact just Wales is under consideration and while income differentials may seem large within the country, they are very small on a global scale[39].

### Appendix A6.1.A: The Yield Class Concept

The productivity of trees is most usually measured in $m^3$/ha. As for any productive system, trees exhibit eventually declining marginal product (or 'current annual increment'; CAI). This CAI therefore initially rises steeply as the tree grows, reaches a maximum and then declines as the tree ages. This will result in a similarly dome shaped average product (or 'mean annual volume increment', MAI) curve. These curves are illustrated in Figure A1.

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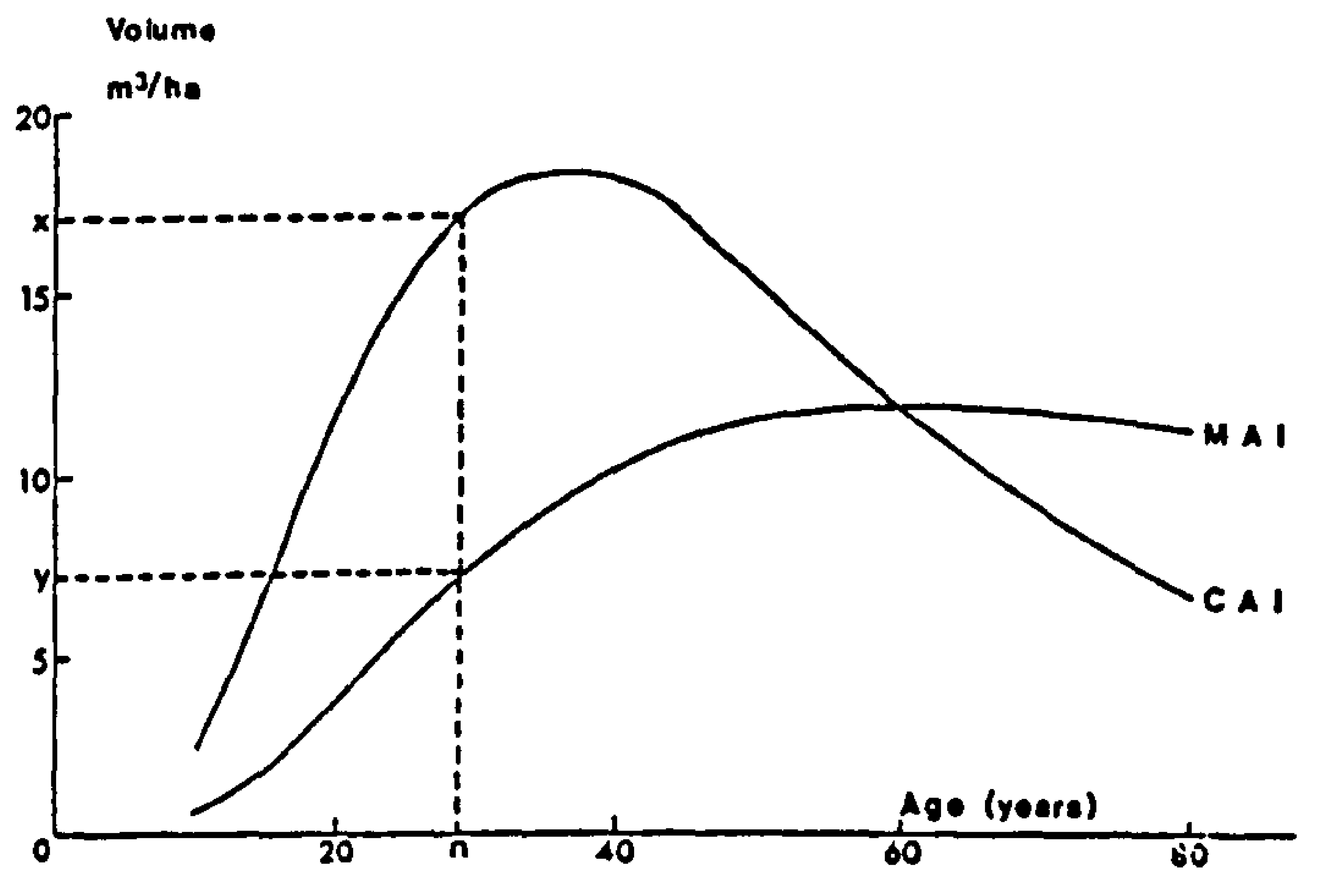
[39]This is in effect arguing that efficient and equitable solutions are similar within our study. The only fly in the ointment is that an equity solution for global warming may substantially alter the carbon sequestration values used in our study.

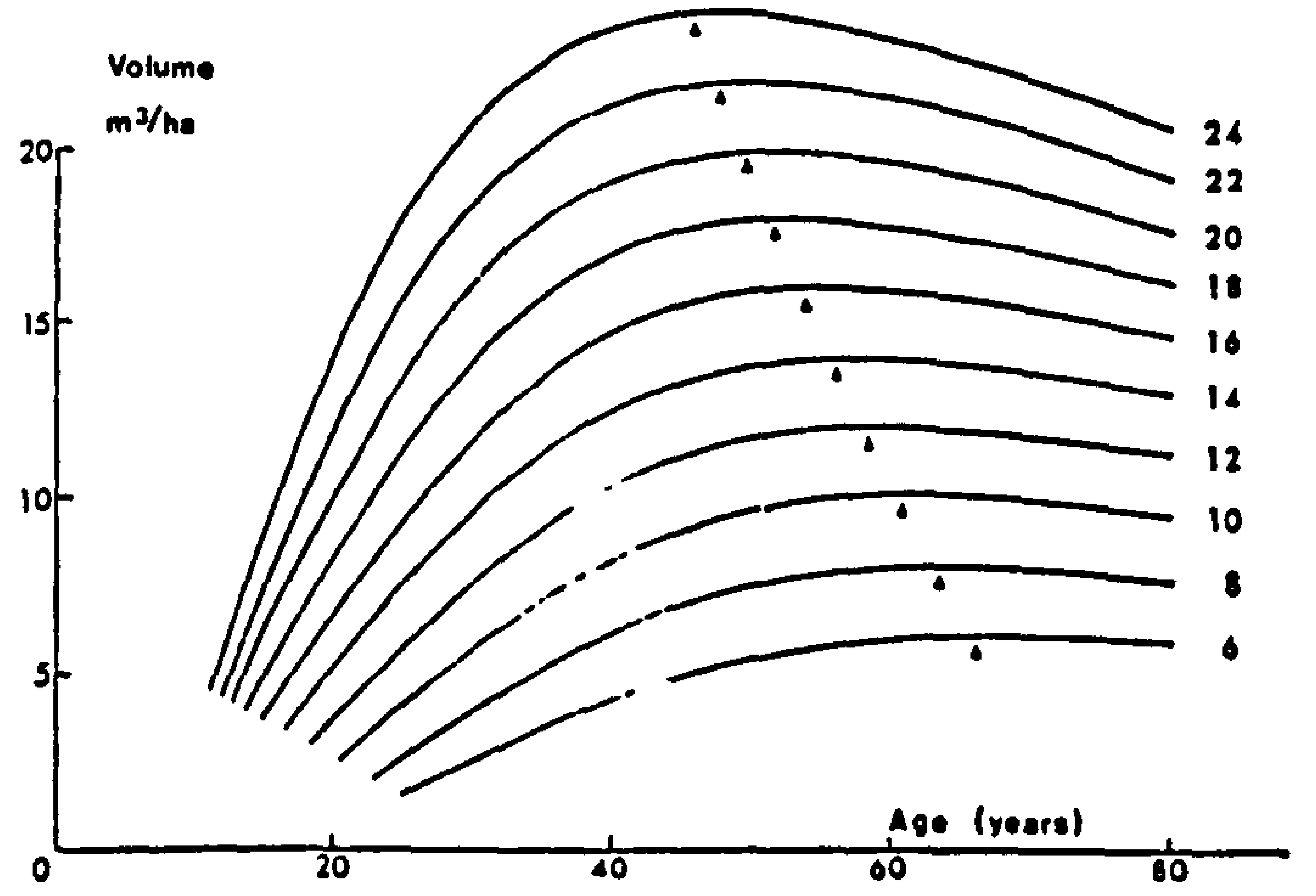
Figure A1: Marginal (CAI) and Average (MAX) Physical Product Curves for an Even-Aged Stand of Trees




Source: Edwards and Christie (1981)

Marginal product (CAI) will equal average product (MAI) when the latter is at its maximum. This maximum level defines the maximum average rate of annual timber increment (m³/ha/pa) which a particular stand can generate. This measure is known as the stands 'yield class' (YC). Figure A2 illustrates YC for Sitka Spruce MAI curves.

Figure A2: MAI curves for Sitka Spruce showing YC and corresponding age of maximum MAI




Source: Edwards and Christie (1981)

Since its inception in 1919 the Forestry Commission has collected data quantifying the characteristics of plantations growing at differing YC. These 'yield models' have now been collated across varying species and management regimes (Edwards and Christie, 1981). Table A1 illustrates the yield model for YC12 Sitka Spruce planted at 2.0m spacing and thinned under the Forestry Commission's standard guidelines.

Table A1: Yield model for YC12 Sitka Spruce (2.0m spacing; intermediate thinning)

| MAINCROP after Thinning | | | | | | | Yield from THINNINGS | | | | | CUMULATIVE PRODUCTION | | MAI | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Age yrs* | *Top Ht* | *Trees /ha* | *Mean dbh* | *BA /ha* | *Mean vol* | *Vol /ha* | *Trees /ha* | *Mean dbh* | *BA /ha* | *Mean vol* | *Vol /ha* | *BA /ha* | *Vol /ha* | *Vol /ha* | *Age yrs* |
| 20 | 7.3 | 2309 | 11 | 24 | 0.03 | 66 | 0 | 0 | 0 | 0.00 | 0 | 24 | 66 | 3.3 | 20 |
| 25 | 10.0 | 1450 | 15 | 25 | 0.06 | 91 | 799 | 12 | 9 | 0.05 | 42 | 34 | 133 | 5.3 | 25 |
| 30 | 12.5 | 1057 | 18 | 28 | 0.12 | 131 | 393 | 15 | 7 | 0.11 | 42 | 44 | 215 | 7.2 | 30 |
| 35 | 14.9 | 827 | 22 | 32 | 0.22 | 180 | 230 | 18 | 6 | 0.18 | 42 | 53 | 306 | 8.7 | 35 |
| 40 | 17.2 | 678 | 25 | 34 | 0.34 | 231 | 150 | 21 | 5 | 0.28 | 42 | 61 | 399 | 10.0 | 40 |
| 45 | 19.2 | 571 | 29 | 36 | 0.49 | 278 | 107 | 23 | 5 | 0.39 | 42 | 68 | 488 | 10.8 | 45 |
| 50 | 21.0 | 492 | 31 | 38 | 0.65 | 319 | 79 | 26 | 4 | 0.51 | 40 | 73 | 570 | 11.4 | 50 |
| 55 | 22.5 | 439 | 34 | 39 | 0.81 | 357 | 53 | 28 | 3 | 0.64 | 34 | 78 | 642 | 11.7 | 55 |
| 60 | 23.7 | 401 | 36 | 40 | 0.97 | 390 | 37 | 30 | 3 | 0.78 | 29 | 82 | 704 | 11.7 | 60 |
| 65 | 24.8 | 373 | 37 | 41 | 1.12 | 418 | 28 | 32 | 2 | 0.93 | 26 | 85 | 758 | 11.7 | 65 |
| 70 | 25.7 | 351 | 39 | 42 | 1.26 | 443 | 22 | 33 | 2 | 1.05 | 23 | 88 | 805 | 11.5 | 70 |
| 75 | 26.5 | 332 | 40 | 43 | 1.40 | 465 | 19 | 35 | 2 | 1.10 | 21 | 90 | 848 | 11.3 | 75 |

Glossary of terms:

*Age:* The number of growing seasons that have elapsed since the stand was planted.

*Top Ht:* Top height; the average height of a number of 'top height trees' in a stand, where a 'top height tree' is the tree of largest breast height diameter in a 0.01 ha sample plot.

*MAINCROP after Thinning:* All the live trees left in the stand, at a given age, after any thinnings have been removed.

*Yield from THINNINGS:* All the live trees removed in the thinning.

*Trees/ha:* The number of live trees in the stand, per hectare.

*Mean dbh:* The quadratic mean diameter (the diameter of the tree of mean basal area) in centimetres, of all live trees measured at 1.3m above ground-level.

*BA/ha:* Basal area. The sum of the overbark cross-sectional areas of the stems of all live trees, measured at 1.3m above ground-level, and given in square metres per hectare.

*Mean vol:* The average volume, in cubic metres, of all live trees, including any with a breast height diameter of less than 7cm.

*Vol/ha:* The overbark volume, in cubic metres per hectare, of the live trees. In conifers, all timber on the main stem which has an overbark diameter of at least 7cm is included. In broadleaves, the measurement limit is either to 7 cm, or to the point at which no main stem is distinguishable, whichever comes first.

*CUMULATIVE PRODUCTION:* This is the main crop basal area or volume, plus the basal area or volume of the present and all previous thinnings.

*MAI:* The mean annual volume increment; i.e. the cumulative volume production to date divided by the age.

Note: All trees which die through natural mortality are excluded, except that in models of unthinned stands the volume of dead trees, expressed as a percentage of the cumulative volume production, is given under the heading *per cent mortality.*

Source: Edwards and Christie (1981).

# APPENDIX 6.2: CARBON FLUX CALCULATION PROGRAMMES

## APPENDIX 6.2.1: THE CARBON FLUX VALUATION PROGRAMME

This appendix details the Fortran programme written to calculate and value the the net carbon flux associated with the planting of either Sitka spruce or beech (the following programme is for Sitka spruce). The programme allows the operator to specify from a range of discount rates and yield classes and calculates net present value sums for both the first optimal rotation and for a perpetual series of optimal rotations as well as the annuity equivalent of the latter. These results are reported for both exponential and hyperbolic discounting. The programme is as follows:

```
C     FILE = C:\PHD\CHAPTERS\DRAFTS\CH8\NOTES\AP62.WP
      PROGRAM CARBT3
C     PROGRAM TO CALCULATE VARIATIONS IN TREE CARBON
C     STORAGE FOR SITKA SPRUCE : INTERACTIVE VERSION
      CHARACTER FILOUT*20
      DIMENSION R(4),YC(12),TTWCS(48,90),FCS(48,90),CV(4)
      DIMENSION SFCS(48),CL(1000),CNS(1000),CVAL(1000)
      DIMENSION CDE(1000),CDH(1000)
      INTEGER F(4,12),TD1(4,12),P,W,RT,S,Q,T
      REAL NPVEF,NPVEP,NPVHF,NPVHP,ANNE,ANNH
C     INITIALISE VARIABLES
      DATA (R(I),I=1,4)/0.02,0.03,0.05,0.06/
      DATA (YC(J),J=1,12)/4,6,8,10,12,14,16,18,20,22,24,26/
      DATA (CV(I),I=1,4)/20.3,22.8,25.3,27.8/
C     CALCULATE YEAR OF FELLING (F) AND FIRST THINNING (TD1)
      DO 20 I=1,4
       DO 10 J=1,12
        T1=114.43-(997.3*R(I))+(7167*(R(I)**2))
        F(I,J)=INT((T1-(2.8657*YC(J))+(0.05919*(YC(J)**2)))+0.5)
        TD1(I,J)=INT((0.4815-(0.004906*YC(J)))*F(I,J)+0.5)
   10  CONTINUE
   20 CONTINUE
C     NOW CALCULATE CARBON STORAGE VALUES
C     UTWCS = UNTHINNED CARBON STORAGE
C     TF = THINNING FACTOR
C     TTWCS = CARBON STORAGE FOR THINNED SITKA SPRUCE
C     FCS = FIXED CARBON STORAGE (ANNUAL CHANGE)
C     SFCS = SUM OF FCS OVER ROTATION
      DO 50 I=1,4
       DO 40 J=1,12
        K=((I-1)*12)+J
        M=TD1(I,J)
        N=F(I,J)
        SFCS(K)=0
        DO 30 L=1,N
         UTWCS=(0.43727*L)+(0.10747*(L**2))-(0.0010267*(L**3))
         UTWCS=UTWCS*(0.08333*YC(J))
         TTWCS(K,L)=UTWCS
         IF (L.GT.M) THEN
          D=(L-M)
          D=LOG(D)
          TF=1-(0.1158*D)
```

```
      TTWCS(K,L)=UTWCS*TF
      END IF
C      NOW CALCULATE CHANGE IN VALUES (REPRESENTS ANNUAL FIXING)
      IF (L.EQ.1) THEN
       FCS(K,L)=TTWCS(K,L)
       ELSE
       FCS(K,L)=TTWCS(K,L)-TTWCS(K,L-1)
      END IF
C      SET ANY NEGATIVE CHANGE VALUES TO ZERO
      IF (FCS(K,L).LT.0) THEN
       FCS(K,L)=0
      END IF
      SFCS(K)=SFCS(K)+FCS(K,L)
   30 CONTINUE
   40 CONTINUE
   50 CONTINUE
C    NOW DISPLAY DISCOUNT RATE AND YIELD CLASS OPTIONS
C    AND PROMPT FOR OUTPUT FILE NAME
   60 PRINT *,' '
     PRINT *,'  DISCOUNT RATE AND YIELD CLASS OPTIONS FOR SCENARIO'
     PRINT *,' '
     PRINT *,'        DISCOUNT          YIELD           YIELD'
     PRINT *,'NUMBER    RATE    NUMBER  CLASS   NUMBER  CLASS'
     PRINT *,' '
     PRINT *,'  1       0.02      1       4       7       16'
     PRINT *,'  2       0.03      2       6       8       18'
     PRINT *,'  3       0.05      3       8       9       20'
     PRINT *,'  4       0.06      4      10      10       22'
     PRINT *,'                    5      12      11       24'
     PRINT *,'                    6      14      12       26'
     PRINT *,' '
     PRINT *,' '
     PRINT *,'TYPE IN CODE NUMBER FOR DISCOUNT RATE (FORMAT I1) '
     READ(*,70)I
   70 FORMAT(I1)
     PRINT *,'TYPE IN CODE NUMBER FOR YIELD CLASS (FORMAT I2) '
     READ(*,80)J
   80 FORMAT(I2)
     PRINT *,' '
     PRINT *,'NAME OF FILE FOR RESULTS'
     READ(*,90)FILOUT
   90 FORMAT(A20)
     OPEN (8, FILE=FILOUT, STATUS='NEW')
C    NOW CALCULATE ACCUMULATED VALUES OVER 1000 YEAR SPAN
C    FIRST DEFINE VARIABLES AND COUNTERS
     K=((I-1)*12)+J
     N=F(I,J)
C    CL = QUANTITY OF CARBON LIBERATED
C    CV = VALUES FOR CARBON STORAGE (FROM FANKHAUSER)
C    W = INDEX FOR CV VALUES
C    RT = ROTATION NUMBER
C    PROLIB = PROPORTION OF STORED CARBON LIBERATED
C    CNS = CARBON NET STORAGE
C    CVAL = MONETARY VALUE OF NET CARBON STORAGE
C    CDE = NORMAL DISCOUNTED VALUE OF NET CARBON STORAGE
```

```
C     CDH = HYPERBOLIC DISCOUNTED VALUE OF NET CARBON STORAGE
      NPVEP = 0
      NPVHP = 0
      NPVEF = 0
      NPVHF = 0
      DO 120 P=1,1000
       CL(P)=0
       W=INT(P/10)
       IF (W.GE.4) THEN
        W=4
        ELSE
        W=W+1
       END IF
      RT=INT((P-1)/N)
      L=P-(RT*N)
      PROLIB=0.0017146+(0.110363/(L+1))
      IF (RT.EQ.0) GO TO 110
      IF (RT.EQ.1) THEN
       CL(P)=SFCS(K)*PROLIB
       ELSE
       DO 100 S=1,RT
       Q=P-(S*N)
       PROLIB=0.0017146+(0.110363/(Q+1))
       IF (Q.GT.200) THEN
        PROLIB=0
       END IF
       CL(P)=CL(P)+(SFCS(K)*PROLIB)
 100   CONTINUE
      END IF
 110  PRINT *,' '
C     NOW CALCULATE NET STORAGE AND VALUES
      CNS(P)=FCS(K,L)-CL(P)
      CVAL(P)=CNS(P)*CV(W)
      T=P-1
      CDE(P)=CVAL(P)*(1/((1+R(I))**T))
      CDH(P)=CVAL(P)*(1/(1+(R(I)*T)))
C     CALCULATE NET PRESENT VALUES FOR DISCOUNTING OPTIONS
      NPVEP=NPVEP+CDE(P)
      NPVHP=NPVHP+CDH(P)
      IF (P.GT.N) GO TO 120
      NPVEF=NPVEF+CDE(P)
      NPVHF=NPVHF+CDH(P)
 120 CONTINUE
     ANNE=NPVEP/((1/R(I))-(1/(R(I)*((1+R(I))**1000))))
     ANNH=NPVHP/((1/R(I))-(1/(R(I)*(1+(R(I)*1000)))))
C    NOW PRINT OUT RESULTS
     PRINT *,'                DISCOUNTING OPTION'
     PRINT *,' '
     PRINT *,'MEASURE      EXPONENTIAL      HYPERBOLIC'
     PRINT *,' '
     PRINT *,'NPV FIRST',NPVEF,NPVHF
     PRINT *,'NPV PERP ',NPVEP,NPVHP
     PRINT *,'ANNUITY  ',ANNE,ANNH
     WRITE(8,130) R(I),YC(J),SFCS(K)
 130 FORMAT(2F6.2,F9.2)
```

```
      DO 150 P=1,1000
      RT=INT((P-1)/N)
      L=P-(RT*N)
      WRITE(8,140) P,L,FCS(K,L),CL(P),CNS(P),CVAL(P),CDE(P),CDH(P)
  140 FORMAT(2I5,6F9.2)
  150 CONTINUE
      PRINT *,' '
      PRINT *,'ANOTHER SCENARIO ? (1=YES,2=NO) '
      READ(*,160)I
  160 FORMAT(I1)
      IF (I.EQ.1) GOTO 60
  999 STOP
      END
```

## APPENDIX 6.2.2: OUTPUT FROM THE CARBON FLUX VALUATION PROGRAMME

This appendix details the calculations performed and output obtained from running the fortran program designed to calculate tree carbon storage values for Sitka spruce[40].

*Calculations:*

Table A6.11 reports the full set of results calculated by our program. This is headed by a single row reporting three items: (i) the specified discount rate; (ii) the specified yield class; (iii) the total amount of carbon fixed over the full period under analysis (1000 years). Note that this latter figure refers only to carbon stored, not to net storage, and is therefore not a focus variable. In this case we have set the discount rate at 2% (i.e. r = 0.02) while yield class is set to 26.

Following this row the programme calculates eight columns of results as follows:

1. The analysis year. This runs from 1 to 1000;
2. The rotation year. This runs from 1 to F, where F is the optimal felling year, which varies according to discount rate, yield class and species (see chapter 6). This counter returns to 1 after each F and restarts its progress;
3. The marginal carbon storage. This is the increase in carbon storage generated by tree growth in that year. It is measured in tC/ha/year;
4. Marginal carbon liberation. This is the amount of carbon liberated from tree products and waste in that year. Again it is measured in tC/ha/year;
5. Marginal net carbon flux. This is calculated by subtracting column 4 from column 3. Again this is measured in tC/ha/year;
6. Marginal undiscounted net benefit value of carbon flux. This is calculated by multiplying column 5 by our best estimate of per tonne sequestration values (a variable which increases over the first 40 years and then becomes constant; see literature review in chapter 8);
7. The present value of the net benefit value given in column 6 calculated using exponential discounting at the specified rate;
8. The present value of the net benefit value given in column 6 calculated using hyperbolic discounting at the specified rate.

[40]File C:\PHD\CHAPTERS\DRAFTS\CH8\NOTES\FORTRAN\CARBT3.FOR and Appendix A6.2.1 detail this programme

Table A6.11: Results calculated by carbon flux valuation program:
Species = Sitka spruce; discount rate = 2%; yield class = 26
Columns as described in text.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| .02 | 26.00 | 245.65 | | | | | |
| 1 | 1 | 1.18 | .00 | 1.18 | 23.91 | 23.91 | 23.91 |
| 2 | 2 | 1.63 | .00 | 1.63 | 33.10 | 32.45 | 32.45 |
| 3 | 3 | 2.07 | .00 | 2.07 | 42.01 | 40.38 | 40.39 |
| 4 | 4 | 2.49 | .00 | 2.49 | 50.65 | 47.73 | 47.78 |
| 5 | 5 | 2.91 | .00 | 2.91 | 59.02 | 54.52 | 54.65 |
| 6 | 6 | 3.31 | .00 | 3.31 | 67.12 | 60.79 | 61.01 |
| 7 | 7 | 3.69 | .00 | 3.69 | 74.94 | 66.55 | 66.91 |
| 8 | 8 | 4.06 | .00 | 4.06 | 82.50 | 71.82 | 72.37 |
| 9 | 9 | 4.42 | .00 | 4.42 | 89.79 | 76.63 | 77.40 |
| 10 | 10 | 4.77 | .00 | 4.77 | 100.72 | 90.97 | 92.14 |
| 11 | 11 | 5.10 | .00 | 5.10 | 116.30 | 95.40 | 96.91 |
| 12 | 12 | 5.42 | .00 | 5.42 | 123.57 | 99.38 | 101.29 |
| 13 | 13 | 5.73 | .00 | 5.73 | 130.53 | 102.93 | 105.27 |
| 14 | 14 | 6.02 | .00 | 6.02 | 137.20 | 106.06 | 108.89 |
| 15 | 15 | 6.30 | .00 | 6.30 | 143.55 | 108.80 | 112.15 |
| 16 | 16 | 6.56 | .00 | 6.56 | 149.61 | 111.16 | 115.08 |
| 17 | 17 | 6.81 | .00 | 6.81 | 155.36 | 113.17 | 117.69 |
| 18 | 18 | 7.05 | .00 | 7.05 | 160.80 | 114.84 | 120.00 |
| 19 | 19 | 7.28 | .00 | 7.28 | 165.94 | 116.18 | 122.01 |
| 20 | 20 | 7.49 | .00 | 7.49 | 189.50 | 130.08 | 137.32 |
| 21 | 21 | 7.69 | .00 | 7.69 | 194.53 | 130.91 | 138.98 |
| 22 | 22 | 7.87 | .00 | 7.87 | 199.22 | 131.44 | 140.30 |
| 23 | 23 | 8.05 | .00 | 8.05 | 203.57 | 131.68 | 141.37 |
| 24 | 24 | .00 | .00 | .00 | .00 | .00 | .00 |
| 25 | 25 | 1.37 | .00 | 1.37 | 34.59 | 21.51 | 23.37 |
| 26 | 26 | 2.64 | .00 | 2.64 | 66.83 | 40.74 | 44.55 |
| 27 | 27 | 3.30 | .00 | 3.30 | 83.61 | 49.96 | 55.01 |
| 28 | 28 | 3.70 | .00 | 3.70 | 93.63 | 54.85 | 60.80 |
| 29 | 29 | 3.96 | .00 | 3.96 | 100.07 | 57.48 | 64.15 |
| 30 | 30 | 4.13 | .00 | 4.13 | 114.69 | 64.50 | 72.59 |
| 31 | 31 | 4.24 | .00 | 4.24 | 117.08 | 65.08 | 73.68 |
| 32 | 32 | 4.32 | .00 | 4.32 | 119.09 | 64.94 | 74.07 |
| 33 | 33 | 4.36 | .00 | 4.36 | 121.29 | 64.36 | 73.96 |
| 34 | 34 | 4.39 | .00 | 4.39 | 121.96 | 63.45 | 73.47 |
| 35 | 35 | 4.39 | .00 | 4.39 | 122.13 | 62.29 | 72.69 |
| 36 | 36 | 4.38 | .00 | 4.38 | 121.86 | 60.93 | 71.68 |
| 37 | 37 | 4.36 | .00 | 4.36 | 121.22 | 59.42 | 70.48 |
| 38 | 38 | 4.33 | .00 | 4.33 | 120.25 | 57.80 | 69.11 |
| 39 | 39 | 4.28 | .00 | 4.28 | 118.99 | 56.07 | 67.61 |
| 40 | 40 | 4.23 | .00 | 4.23 | 117.47 | 54.26 | 65.99 |
| 41 | 41 | 4.16 | .00 | 4.16 | 115.69 | 52.39 | 64.27 |
| 42 | 42 | 4.09 | .00 | 4.09 | 113.67 | 50.47 | 62.46 |
| 43 | 43 | 4.01 | .00 | 4.01 | 111.44 | 48.51 | 60.57 |
| 44 | 44 | 3.92 | .00 | 3.92 | 109.00 | 46.52 | 58.60 |
| 45 | 45 | 3.83 | .00 | 3.83 | 106.35 | 44.50 | 56.57 |
| 46 | 46 | 3.72 | .00 | 3.72 | 103.51 | 42.46 | 54.48 |
| 47 | 47 | 3.61 | .00 | 3.61 | 100.48 | 40.41 | 52.33 |
| 48 | 48 | 3.50 | .00 | 3.50 | 97.26 | 38.35 | 50.14 |
| 49 | 49 | 3.38 | .00 | 3.38 | 93.87 | 36.29 | 47.89 |
| 50 | 50 | 3.25 | .00 | 3.25 | 90.31 | 34.22 | 45.61 |
| 51 | 51 | 3.11 | .00 | 3.11 | 86.57 | 32.16 | 43.29 |
| 52 | 52 | 2.97 | .00 | 2.97 | 82.67 | 30.11 | 40.93 |
| 53 | 53 | 2.83 | .00 | 2.83 | 78.61 | 28.07 | 38.53 |
| 54 | 54 | 2.68 | .00 | 2.68 | 74.38 | 26.04 | 36.11 |
| 55 | 55 | 2.52 | .00 | 2.52 | 69.99 | 24.02 | 33.65 |
| 56 | 56 | 2.35 | .00 | 2.35 | 65.45 | 22.03 | 31.17 |
| 57 | 57 | 2.19 | .00 | 2.19 | 60.76 | 20.04 | 28.66 |
| 58 | 58 | 2.01 | .00 | 2.01 | 55.91 | 18.08 | 26.13 |
| 59 | 59 | 1.83 | .00 | 1.83 | 50.91 | 16.14 | 23.57 |
| 60 | 60 | 1.65 | .00 | 1.65 | 45.77 | 14.23 | 20.99 |
| 61 | 61 | 1.46 | .00 | 1.46 | 40.40 | 12.34 | 18.40 |
| 62 | 62 | 1.26 | .00 | 1.26 | 35.04 | 10.47 | 15.70 |
| 63 | 63 | 1.06 | .00 | 1.06 | 29.46 | 8.63 | 13.15 |
| 64 | 1 | 1.18 | 13.98 | -12.80 | -355.80 | -102.19 | -157.43 |
| 65 | 2 | 1.63 | 9.46 | -7.83 | -217.61 | -61.27 | -95.44 |
| 66 | 3 | 2.07 | 7.20 | -5.13 | -142.60 | -39.36 | -62.00 |
| 67 | 4 | 2.49 | 5.84 | -3.35 | -93.08 | -25.19 | -40.12 |
| 68 | 5 | 2.91 | 4.94 | -2.03 | -56.50 | -14.99 | -24.15 |
| 69 | 6 | 3.31 | 4.29 | -.99 | -27.46 | -7.14 | -11.64 |
| 70 | 7 | 3.69 | 3.81 | -.12 | -3.29 | -.84 | -1.30 |
| 71 | 8 | 4.06 | 3.43 | .63 | 17.53 | 4.30 | 7.30 |
| 72 | 9 | 4.42 | 3.13 | 1.29 | 35.90 | 8.80 | 14.83 |
| 73 | 10 | 4.77 | 2.89 | 1.88 | 52.34 | 12.50 | 21.45 |
| 74 | 11 | 5.10 | 2.68 | 2.42 | 67.29 | 15.85 | 27.35 |
| 75 | 12 | 5.42 | 2.51 | 2.91 | 80.90 | 18.71 | 32.65 |
| 76 | 13 | 5.73 | 2.36 | 3.37 | 93.62 | 21.20 | 37.45 |
| 77 | 14 | 6.02 | 2.23 | 3.79 | 105.33 | 23.38 | 41.80 |
| 78 | 15 | 6.30 | 2.12 | 4.18 | 116.22 | 25.30 | 45.76 |
| 79 | 16 | 6.56 | 2.02 | 4.55 | 126.37 | 26.97 | 49.36 |
| 80 | 17 | 6.81 | 1.93 | 4.89 | 135.84 | 28.42 | 52.65 |
| 81 | 18 | 7.05 | 1.85 | 5.20 | 144.69 | 29.68 | 55.65 |
| 82 | 19 | 7.28 | 1.78 | 5.50 | 152.94 | 30.75 | 58.37 |
| 83 | 20 | 7.49 | 1.71 | 5.78 | 160.63 | 31.67 | 60.84 |
| 84 | 21 | 7.69 | 1.65 | 6.04 | 167.70 | 32.43 | 63.08 |
| 85 | 22 | 7.87 | 1.60 | 6.27 | 174.43 | 33.05 | 65.09 |
| 86 | 23 | 8.05 | 1.55 | 6.50 | 180.58 | 33.55 | 66.88 |
| 87 | 24 | .00 | 1.51 | -1.51 | -41.86 | -7.62 | -15.39 |
| 88 | 25 | 1.37 | 1.46 | -.10 | -2.69 | -.40 | -.98 |
| 89 | 26 | 2.64 | 1.43 | 1.22 | 33.01 | 5.92 | 12.25 |
| 90 | 27 | 3.30 | 1.39 | 1.92 | 53.24 | 9.14 | 19.15 |
| 91 | 28 | 3.70 | 1.36 | 2.34 | 65.18 | 10.97 | 23.28 |
| 92 | 29 | 3.96 | 1.32 | 2.63 | 73.13 | 12.06 | 25.93 |
| 93 | 30 | 4.13 | 1.30 | 2.83 | 78.67 | 12.72 | 27.70 |
| 94 | 31 | 4.24 | 1.27 | 2.97 | 82.62 | 13.10 | 28.89 |
| 95 | 32 | 4.32 | 1.24 | 3.07 | 85.44 | 13.28 | 29.67 |
| 96 | 33 | 4.36 | 1.22 | 3.14 | 87.42 | 13.32 | 30.14 |
| 97 | 34 | 4.39 | 1.20 | 3.19 | 88.72 | 13.26 | 30.38 |
| 98 | 35 | 4.39 | 1.17 | 3.22 | 89.48 | 13.11 | 30.44 |
| 99 | 36 | 4.38 | 1.15 | 3.23 | 89.78 | 12.89 | 30.33 |
| 100 | 37 | 4.36 | 1.13 | 3.23 | 89.68 | 12.63 | 30.09 |
| 101 | 38 | 4.33 | 1.12 | 3.21 | 89.22 | 12.32 | 29.74 |
| 102 | 39 | 4.28 | 1.10 | 3.18 | 88.44 | 11.97 | 29.29 |
| 103 | 40 | 4.23 | 1.08 | 3.14 | 87.37 | 11.59 | 28.74 |
| 104 | 41 | 4.16 | 1.07 | 3.09 | 86.03 | 11.19 | 28.12 |
| 105 | 42 | 4.09 | 1.05 | 3.04 | 84.44 | 10.77 | 27.41 |
| 106 | 43 | 4.01 | 1.04 | 2.97 | 82.60 | 10.33 | 26.65 |
| 107 | 44 | 3.92 | 1.02 | 2.90 | 80.54 | 9.87 | 25.81 |
| 108 | 45 | 3.83 | 1.01 | 2.81 | 78.25 | 9.40 | 24.92 |
| 109 | 46 | 3.72 | 1.00 | 2.73 | 75.76 | 8.93 | 23.98 |
| 110 | 47 | 3.61 | .99 | 2.63 | 73.07 | 8.44 | 22.98 |
| 111 | 48 | 3.50 | .97 | 2.52 | 70.17 | 7.95 | 21.93 |
| 112 | 49 | 3.38 | .96 | 2.41 | 67.09 | 7.45 | 20.84 |
| 113 | 50 | 3.25 | .95 | 2.30 | 63.82 | 6.95 | 19.70 |
| 114 | 51 | 3.11 | .94 | 2.17 | 60.37 | 6.44 | 18.52 |
| 115 | 52 | 2.97 | .93 | 2.04 | 56.74 | 5.94 | 17.30 |
| 116 | 53 | 2.83 | .92 | 1.90 | 52.94 | 5.43 | 16.04 |
| 117 | 54 | 2.68 | .92 | 1.76 | 48.97 | 4.92 | 14.75 |
| 118 | 55 | 2.52 | .91 | 1.61 | 44.83 | 4.42 | 13.42 |
| 119 | 56 | 2.35 | .90 | 1.46 | 40.52 | 3.92 | 12.06 |
| 120 | 57 | 2.19 | .89 | 1.30 | 36.05 | 3.42 | 10.67 |
| 121 | 58 | 2.01 | .89 | 1.13 | 31.43 | 2.92 | 9.24 |
| 122 | 59 | 1.83 | .88 | .96 | 26.64 | 2.43 | 7.79 |
| 123 | 60 | 1.65 | .87 | .78 | 21.70 | 1.94 | 6.31 |
| 124 | 61 | 1.46 | .86 | .60 | 16.61 | 1.45 | 4.80 |
| 125 | 62 | 1.26 | .85 | .41 | 11.37 | .96 | 3.27 |
| 126 | 63 | 1.06 | .84 | .21 | 5.98 | .48 | 1.71 |
| 127 | 1 | 1.18 | 16.81 | -15.64 | -378.10 | -31.27 | -187.70 |
| 128 | 2 | 1.63 | 10.29 | -8.66 | -240.74 | -19.47 | -68.01 |
| 129 | 3 | 2.07 | 8.02 | -5.96 | -165.56 | -13.13 | -46.51 |
| 130 | 4 | 2.49 | 6.66 | -4.17 | -115.80 | -9.01 | -32.37 |
| 131 | 5 | 2.91 | 5.75 | -2.85 | -79.13 | -6.03 | -21.98 |
| 132 | 6 | 3.31 | 5.10 | -1.80 | -49.94 | -3.73 | -13.80 |
| 133 | 7 | 3.69 | 4.61 | -.92 | -25.61 | -1.88 | -7.04 |
| 134 | 8 | 4.06 | 4.23 | -.17 | -4.65 | -.33 | -1.27 |
| 135 | 9 | 4.42 | 3.92 | .50 | 13.85 | .98 | 3.76 |
| 136 | 10 | 4.77 | 3.67 | 1.10 | 30.45 | 2.10 | 8.23 |
| 137 | 11 | 5.10 | 3.46 | 1.64 | 45.53 | 3.08 | 12.24 |
| 138 | 12 | 5.42 | 3.28 | 2.14 | 59.36 | 3.94 | 15.87 |
| 139 | 13 | 5.73 | 3.13 | 2.59 | 72.12 | 4.69 | 19.18 |
| 140 | 14 | 6.02 | 3.00 | 3.02 | 83.96 | 5.35 | 22.21 |
| 141 | 15 | 6.30 | 2.88 | 3.42 | 94.97 | 5.94 | 24.99 |
| 142 | 16 | 6.56 | 2.78 | 3.79 | 105.24 | 6.45 | 27.55 |
| 143 | 17 | 6.81 | 2.68 | 4.13 | 114.83 | 6.90 | 29.92 |
| 144 | 18 | 7.05 | 2.60 | 4.45 | 123.79 | 7.29 | 32.07 |
| 145 | 19 | 7.28 | 2.52 | 4.75 | 132.15 | 7.63 | 34.06 |
| 146 | 20 | 7.49 | 2.46 | 5.03 | 139.95 | 7.92 | 35.88 |
| 147 | 21 | 7.69 | 2.39 | 5.30 | 147.21 | 8.17 | 37.55 |
| 148 | 22 | 7.87 | 2.34 | 5.54 | 153.96 | 8.38 | 39.08 |
| 149 | 23 | 8.05 | 2.28 | 5.77 | 160.21 | 8.55 | 40.46 |
| 150 | 24 | .00 | 2.23 | -2.23 | -62.13 | -3.25 | -15.61 |
| 151 | 25 | 1.37 | 2.19 | -.82 | -22.87 | -1.17 | -5.72 |
| 152 | 26 | 2.64 | 2.15 | .49 | 13.73 | .40 | 3.42 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 153 | 27 | 3.30 | 2.11 | 1.20 | 33.25 | 1.64 | 8.83 |
| 154 | 28 | 3.70 | 2.07 | 1.63 | 45.28 | 2.19 | 11.15 |
| 155 | 29 | 3.96 | 2.04 | 1.92 | 53.32 | 2.53 | 13.07 |
| 156 | 30 | 4.13 | 2.01 | 2.12 | 58.94 | 2.74 | 14.38 |
| 157 | 31 | 4.24 | 1.97 | 2.27 | 62.90 | 2.87 | 15.29 |
| 158 | 32 | 4.32 | 1.95 | 2.37 | 65.68 | 2.94 | 15.91 |
| 159 | 33 | 4.36 | 1.92 | 2.44 | 67.94 | 2.97 | 16.33 |
| 160 | 34 | 4.39 | 1.89 | 2.49 | 69.32 | 2.97 | 16.58 |
| 161 | 35 | 4.39 | 1.87 | 2.52 | 70.16 | 2.95 | 16.70 |
| 162 | 36 | 4.38 | 1.85 | 2.54 | 70.53 | 2.91 | 16.71 |
| 163 | 37 | 4.36 | 1.82 | 2.54 | 70.50 | 2.85 | 16.63 |
| 164 | 38 | 4.33 | 1.80 | 2.52 | 70.12 | 2.78 | 16.46 |
| 165 | 39 | 4.28 | 1.78 | 2.50 | 69.42 | 2.70 | 16.22 |
| 166 | 40 | 4.23 | 1.76 | 2.46 | 68.42 | 2.61 | 15.91 |
| 167 | 41 | 4.16 | 1.75 | 2.42 | 67.15 | 2.51 | 15.54 |
| 168 | 42 | 4.09 | 1.73 | 2.36 | 65.62 | 2.40 | 15.12 |
| 169 | 43 | 4.01 | 1.71 | 2.30 | 63.85 | 2.29 | 14.64 |
| 170 | 44 | 3.92 | 1.70 | 2.22 | 61.85 | 2.18 | 14.12 |
| 171 | 45 | 3.83 | 1.68 | 2.15 | 59.63 | 2.06 | 13.55 |
| 172 | 46 | 3.72 | 1.67 | 2.06 | 57.20 | 1.94 | 12.94 |
| 173 | 47 | 3.61 | 1.65 | 1.96 | 54.57 | 1.81 | 12.29 |
| 174 | 48 | 3.50 | 1.64 | 1.86 | 51.74 | 1.68 | 11.60 |
| 175 | 49 | 3.38 | 1.62 | 1.75 | 48.71 | 1.55 | 10.87 |
| 176 | 50 | 3.25 | 1.61 | 1.64 | 45.50 | 1.42 | 10.11 |
| 177 | 51 | 3.11 | 1.60 | 1.51 | 42.11 | 1.29 | 9.32 |
| 178 | 52 | 2.97 | 1.59 | 1.39 | 38.54 | 1.16 | 8.49 |
| 179 | 53 | 2.83 | 1.58 | 1.25 | 34.79 | 1.02 | 7.63 |
| 180 | 54 | 2.68 | 1.57 | 1.11 | 30.87 | .89 | 6.74 |
| 181 | 55 | 2.52 | 1.55 | .96 | 26.78 | .76 | 5.82 |
| 182 | 56 | 2.35 | 1.54 | .81 | 22.53 | .63 | 4.88 |
| 183 | 57 | 2.19 | 1.53 | .65 | 18.12 | .49 | 3.90 |
| 184 | 58 | 2.01 | 1.52 | .49 | 13.54 | .36 | 2.91 |
| 185 | 59 | 1.83 | 1.51 | .32 | 8.81 | .23 | 1.88 |
| 186 | 60 | 1.65 | 1.51 | .14 | 3.92 | .10 | .83 |
| 187 | 61 | 1.46 | 1.50 | -.04 | -1.13 | -.03 | -.24 |
| 188 | 62 | 1.26 | 1.49 | -.23 | -6.32 | -.16 | -1.33 |
| 189 | 63 | 1.06 | 1.48 | -.42 | -11.67 | -.28 | -2.45 |
| 190 | 1 | 1.10 | 15.45 | -14.27 | -396.70 | -9.40 | -82.99 |
| 191 | 2 | 1.63 | 10.92 | -9.29 | -258.29 | -6.00 | -53.81 |
| 192 | 3 | 2.07 | 8.65 | -6.59 | -183.07 | -4.17 | -37.98 |
| 193 | 4 | 2.49 | 7.29 | -4.80 | -133.34 | -2.90 | -27.55 |
| 194 | 5 | 2.91 | 6.30 | -3.47 | -96.55 | -2.11 | -19.87 |
| 195 | 6 | 3.31 | 5.73 | -2.42 | -67.32 | -1.44 | -13.79 |
| 196 | 7 | 3.69 | 5.24 | -1.54 | -42.94 | -.90 | -8.76 |
| 197 | 8 | 4.06 | 4.85 | -.79 | -21.94 | -.45 | -4.46 |
| 198 | 9 | 4.42 | 4.55 | -.12 | -3.40 | -.07 | -.69 |
| 199 | 10 | 4.77 | 4.29 | .48 | 13.24 | .28 | 2.67 |
| 200 | 11 | 5.10 | 4.08 | 1.02 | 28.36 | .55 | 5.69 |
| 201 | 12 | 5.42 | 3.90 | 1.52 | 42.23 | .80 | 8.45 |
| 202 | 13 | 5.73 | 3.75 | 1.98 | 55.03 | 1.03 | 10.96 |
| 203 | 14 | 6.02 | 3.61 | 2.41 | 66.90 | 1.23 | 13.27 |
| 204 | 15 | 6.30 | 3.49 | 2.80 | 77.95 | 1.40 | 15.41 |
| 205 | 16 | 6.56 | 3.39 | 3.17 | 88.26 | 1.55 | 17.37 |
| 206 | 17 | 6.81 | 3.29 | 3.52 | 97.89 | 1.69 | 19.19 |
| 207 | 18 | 7.05 | 3.21 | 3.84 | 106.88 | 1.81 | 20.87 |
| 208 | 19 | 7.28 | 3.13 | 4.15 | 115.28 | 1.91 | 22.43 |
| 209 | 20 | 7.49 | 3.06 | 4.43 | 123.11 | 2.00 | 23.86 |
| 210 | 21 | 7.69 | 3.00 | 4.69 | 130.41 | 2.08 | 25.18 |
| 211 | 22 | 7.87 | 2.94 | 4.93 | 137.19 | 2.14 | 26.38 |
| 212 | 23 | 8.05 | 2.89 | 5.16 | 143.47 | 2.20 | 27.49 |
| 213 | 24 | .00 | 2.84 | -2.84 | -78.83 | -1.18 | -15.04 |
| 214 | 25 | 1.37 | 2.79 | -1.42 | -39.53 | -.50 | -7.52 |
| 215 | 26 | 2.64 | 2.75 | -.10 | -2.91 | -.04 | -.55 |
| 216 | 27 | 3.30 | 2.71 | .60 | 16.65 | .24 | 3.14 |
| 217 | 28 | 3.70 | 2.67 | 1.03 | 28.71 | .40 | 5.40 |
| 218 | 29 | 3.96 | 2.63 | 1.32 | 36.77 | .50 | 6.89 |
| 219 | 30 | 4.13 | 2.60 | 1.53 | 42.43 | .57 | 7.92 |
| 220 | 31 | 4.24 | 2.57 | 1.67 | 46.50 | .61 | 8.64 |
| 221 | 32 | 4.32 | 2.54 | 1.78 | 49.43 | .63 | 9.15 |
| 222 | 33 | 4.36 | 2.51 | 1.85 | 51.52 | .65 | 9.51 |
| 223 | 34 | 4.39 | 2.48 | 1.90 | 52.93 | .65 | 9.73 |
| 224 | 35 | 4.39 | 2.46 | 1.94 | 53.80 | .65 | 9.85 |
| 225 | 36 | 4.38 | 2.43 | 1.95 | 54.20 | .64 | 9.89 |
| 226 | 37 | 4.36 | 2.41 | 1.95 | 54.20 | .63 | 9.85 |
| 227 | 38 | 4.33 | 2.39 | 1.94 | 53.84 | .61 | 9.75 |
| 228 | 39 | 4.28 | 2.37 | 1.91 | 53.17 | .59 | 9.60 |
| 229 | 40 | 4.23 | 2.35 | 1.88 | 52.20 | .57 | 9.39 |
| 230 | 41 | 4.16 | 2.33 | 1.83 | 50.95 | .55 | 9.13 |
| 231 | 42 | 4.09 | 2.31 | 1.78 | 49.45 | .52 | 8.83 |
| 232 | 43 | 4.01 | 2.29 | 1.72 | 47.71 | .49 | 8.49 |
| 233 | 44 | 3.92 | 2.28 | 1.65 | 45.73 | .46 | 8.11 |
| 234 | 45 | 3.83 | 2.26 | 1.57 | 43.54 | .43 | 7.69 |
| 235 | 46 | 3.72 | 2.24 | 1.48 | 41.14 | .40 | 7.24 |
| 236 | 47 | 3.61 | 2.23 | 1.39 | 38.53 | .37 | 6.76 |
| 237 | 48 | 3.50 | 2.21 | 1.28 | 35.72 | .33 | 6.24 |
| 238 | 49 | 3.38 | 2.20 | 1.18 | 32.72 | .30 | 5.70 |
| 239 | 50 | 3.25 | 2.19 | 1.06 | 29.53 | .27 | 5.13 |
| 240 | 51 | 3.11 | 2.17 | .94 | 26.16 | .23 | 4.53 |
| 241 | 52 | 2.97 | 2.16 | .81 | 22.62 | .20 | 3.90 |
| 242 | 53 | 2.83 | 2.15 | .68 | 18.89 | .16 | 3.25 |
| 243 | 54 | 2.68 | 2.14 | .54 | 15.00 | .12 | 2.57 |
| 244 | 55 | 2.52 | 2.12 | .39 | 10.93 | .09 | 1.87 |
| 245 | 56 | 2.35 | 2.11 | .24 | 6.70 | .05 | 1.14 |
| 246 | 57 | 2.19 | 2.10 | .08 | 2.31 | .02 | .39 |
| 247 | 58 | 2.01 | 2.09 | -.08 | -2.24 | -.02 | -.38 |
| 248 | 59 | 1.83 | 2.08 | -.25 | -6.95 | -.05 | -1.17 |
| 249 | 60 | 1.65 | 2.07 | -.43 | -11.82 | -.09 | -1.98 |
| 250 | 61 | 1.46 | 2.06 | -.61 | -16.84 | -.12 | -2.82 |
| 251 | 62 | 1.26 | 2.05 | -.79 | -22.08 | -.16 | -3.67 |
| 252 | 63 | 1.06 | 2.04 | -.98 | -27.34 | -.19 | -4.54 |
| 253 | 1 | 1.10 | 16.01 | -14.83 | -412.35 | -2.81 | -60.27 |
| 254 | 2 | 1.63 | 11.40 | -9.85 | -273.93 | -1.83 | -45.20 |
| 255 | 3 | 2.07 | 9.22 | -7.15 | -198.68 | -1.30 | -32.68 |
| 256 | 4 | 2.49 | 7.85 | -5.36 | -140.93 | -.95 | -24.48 |
| 257 | 5 | 2.91 | 6.94 | -4.03 | -112.12 | -.70 | -18.32 |
| 258 | 6 | 3.31 | 6.29 | -2.90 | -82.87 | -.51 | -13.50 |
| 259 | 7 | 3.69 | 5.80 | -2.10 | -58.40 | -.35 | -9.49 |
| 260 | 8 | 4.06 | 5.41 | -1.35 | -37.45 | -.22 | -6.06 |
| 261 | 9 | 4.42 | 5.10 | -.68 | -18.90 | -.11 | -3.05 |
| 262 | 10 | 4.77 | 4.85 | -.08 | -2.24 | -.01 | -.36 |
| 263 | 11 | 5.10 | 4.64 | .46 | 12.98 | .07 | 2.07 |
| 264 | 12 | 5.42 | 3.90 | 1.52 | 42.23 | .23 | 6.75 |
| 265 | 13 | 5.73 | 3.75 | 1.98 | 55.03 | .30 | 8.76 |
| 266 | 14 | 6.02 | 3.61 | 2.41 | 66.90 | .35 | 10.62 |
| 267 | 15 | 6.30 | 3.49 | 2.80 | 77.95 | .40 | 12.33 |
| 268 | 16 | 6.56 | 3.39 | 3.17 | 88.26 | .45 | 13.92 |
| 269 | 17 | 6.81 | 3.29 | 3.52 | 97.89 | .49 | 15.39 |
| 270 | 18 | 7.05 | 3.21 | 3.84 | 106.88 | .52 | 16.78 |
| 271 | 19 | 7.28 | 3.13 | 4.15 | 115.28 | .55 | 18.01 |
| 272 | 20 | 7.49 | 3.06 | 4.43 | 123.11 | .57 | 19.18 |
| 273 | 21 | 7.69 | 3.00 | 4.69 | 130.41 | .60 | 20.25 |
| 274 | 22 | 7.87 | 2.94 | 4.93 | 137.19 | .62 | 21.24 |
| 275 | 23 | 8.05 | 2.89 | 5.16 | 143.47 | .63 | 22.14 |
| 276 | 24 | .00 | 2.84 | -2.84 | -78.83 | -.34 | -12.13 |
| 277 | 25 | 1.37 | 2.79 | -1.42 | -39.53 | -.17 | -6.06 |
| 278 | 26 | 2.64 | 2.75 | -.10 | -2.91 | -.01 | -.44 |
| 279 | 27 | 3.30 | 2.71 | .60 | 16.65 | .07 | 2.54 |
| 280 | 28 | 3.70 | 2.67 | 1.03 | 28.71 | .11 | 4.36 |
| 281 | 29 | 3.96 | 2.63 | 1.32 | 36.77 | .14 | 5.57 |
| 282 | 30 | 4.13 | 2.60 | 1.53 | 42.43 | .16 | 6.41 |
| 283 | 31 | 4.24 | 2.57 | 1.67 | 46.50 | .17 | 7.00 |
| 284 | 32 | 4.32 | 2.54 | 1.78 | 49.43 | .18 | 7.42 |
| 285 | 33 | 4.36 | 2.51 | 1.85 | 51.52 | .19 | 7.71 |
| 286 | 34 | 4.39 | 2.48 | 1.90 | 52.93 | .19 | 7.90 |
| 287 | 35 | 4.39 | 2.46 | 1.94 | 53.80 | .19 | 8.01 |
| 288 | 36 | 4.38 | 2.43 | 1.95 | 54.20 | .18 | 8.04 |
| 289 | 37 | 4.36 | 2.41 | 1.95 | 54.20 | .18 | 8.02 |
| 290 | 38 | 4.33 | 2.39 | 1.94 | 53.84 | .18 | 7.94 |
| 291 | 39 | 4.28 | 2.37 | 1.91 | 53.17 | .17 | 7.82 |
| 292 | 40 | 4.23 | 2.35 | 1.88 | 52.20 | .16 | 7.65 |
| 293 | 41 | 4.16 | 2.33 | 1.83 | 50.95 | .16 | 7.45 |
| 294 | 42 | 4.09 | 2.31 | 1.78 | 49.45 | .15 | 7.21 |
| 295 | 43 | 4.01 | 2.29 | 1.72 | 47.71 | .14 | 6.93 |
| 296 | 44 | 3.92 | 2.28 | 1.65 | 45.73 | .13 | 6.63 |
| 297 | 45 | 3.83 | 2.26 | 1.57 | 43.54 | .12 | 6.29 |
| 298 | 46 | 3.72 | 2.24 | 1.48 | 41.14 | .11 | 5.93 |
| 299 | 47 | 3.61 | 2.23 | 1.39 | 38.53 | .11 | 5.54 |
| 300 | 48 | 3.50 | 2.21 | 1.28 | 35.72 | .10 | 5.12 |
| 301 | 49 | 3.38 | 2.20 | 1.18 | 32.72 | .09 | 4.67 |
| 302 | 50 | 3.25 | 2.19 | 1.06 | 29.53 | .08 | 4.21 |
| 303 | 51 | 3.11 | 2.17 | .94 | 26.16 | .07 | 3.72 |
| 304 | 52 | 2.97 | 2.16 | .81 | 22.62 | .06 | 3.20 |
| 305 | 53 | 2.83 | 2.15 | .68 | 18.89 | .05 | 2.67 |
| 306 | 54 | 2.68 | 2.14 | .54 | 15.00 | .04 | 2.11 |
| 307 | 55 | 2.52 | 2.12 | .39 | 10.93 | .03 | 1.54 |
| 308 | 56 | 2.35 | 2.11 | .24 | 6.70 | .02 | .94 |
| 309 | 57 | 2.19 | 2.10 | .08 | 2.31 | .01 | .38 |
| 310 | 58 | 2.01 | 2.09 | -.08 | -2.24 | -.00 | -.31 |
| 311 | 59 | 1.83 | 2.08 | -.25 | -6.95 | -.02 | -.97 |
| 312 | 60 | 1.65 | 2.07 | -.43 | -11.82 | -.03 | -1.64 |
| 313 | 61 | 1.46 | 2.06 | -.61 | -16.84 | -.03 | -2.33 |
| 314 | 62 | 1.26 | 2.05 | -.79 | -22.08 | -.04 | -3.03 |
| 315 | 63 | 1.06 | 2.04 | -.98 | -27.34 | -.05 | -3.76 |
| 316 | 1 | 1.10 | 16.01 | -14.83 | -412.35 | -.81 | -56.49 |
| 317 | 2 | 1.63 | 11.40 | -9.85 | -273.93 | -.52 | -37.42 |
| 318 | 3 | 2.07 | 9.22 | -7.15 | -198.68 | -.37 | -27.07 |
| 319 | 4 | 2.49 | 7.85 | -5.36 | -140.93 | -.27 | -20.24 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 320 | 5 | 2.91 | 6.94 | -4.03 | -112.12 | -.20 | -15.19 |
| 321 | 6 | 3.31 | 6.29 | -2.98 | -82.87 | -.15 | -11.20 |
| 322 | 7 | 3.69 | 5.80 | -2.10 | -58.40 | -.10 | -7.88 |
| 323 | 8 | 4.06 | 5.41 | -1.35 | -37.45 | -.06 | -5.03 |
| 324 | 9 | 4.42 | 5.10 | -.68 | -18.90 | -.03 | -2.53 |
| 325 | 10 | 4.77 | 4.85 | -.08 | -2.24 | -.00 | -.30 |
| 326 | 11 | 5.10 | 4.64 | .46 | 12.90 | .02 | 1.72 |
| 327 | 12 | 5.42 | 3.90 | 1.52 | 42.23 | .07 | 5.62 |
| 328 | 13 | 5.73 | 3.75 | 1.98 | 55.03 | .08 | 7.30 |
| 329 | 14 | 6.02 | 3.61 | 2.41 | 66.90 | .10 | 8.88 |
| 330 | 15 | 6.30 | 3.49 | 2.80 | 77.95 | .12 | 10.28 |
| 331 | 16 | 6.56 | 3.39 | 3.17 | 88.26 | .13 | 11.61 |
| 332 | 17 | 6.81 | 3.29 | 3.52 | 97.89 | .14 | 12.85 |
| 333 | 18 | 7.05 | 3.21 | 3.84 | 106.88 | .15 | 13.99 |
| 334 | 19 | 7.28 | 3.13 | 4.15 | 115.28 | .16 | 15.05 |
| 335 | 20 | 7.49 | 3.06 | 4.43 | 123.11 | .17 | 16.03 |
| 336 | 21 | 7.69 | 3.00 | 4.69 | 130.41 | .17 | 16.94 |
| 337 | 22 | 7.87 | 2.94 | 4.93 | 137.19 | .18 | 17.77 |
| 338 | 23 | 8.05 | 2.89 | 5.16 | 143.47 | .18 | 18.54 |
| 339 | 24 | .00 | 2.84 | -2.84 | -78.83 | -.10 | -10.16 |
| 340 | 25 | 1.37 | 2.79 | -1.42 | -39.53 | -.05 | -5.08 |
| 341 | 26 | 2.64 | 2.75 | -.10 | -2.91 | -.00 | -.37 |
| 342 | 27 | 3.30 | 2.71 | .60 | 16.65 | .02 | 2.13 |
| 343 | 28 | 3.70 | 2.67 | 1.03 | 28.71 | .03 | 3.66 |
| 344 | 29 | 3.96 | 2.63 | 1.32 | 36.77 | .04 | 4.68 |
| 345 | 30 | 4.13 | 2.60 | 1.53 | 42.43 | .05 | 5.39 |
| 346 | 31 | 4.24 | 2.57 | 1.67 | 46.50 | .05 | 5.89 |
| 347 | 32 | 4.32 | 2.54 | 1.78 | 49.43 | .05 | 6.24 |
| 348 | 33 | 4.36 | 2.51 | 1.85 | 51.52 | .05 | 6.49 |
| 349 | 34 | 4.39 | 2.48 | 1.90 | 52.93 | .05 | 6.65 |
| 350 | 35 | 4.39 | 2.46 | 1.94 | 53.80 | .05 | 6.74 |
| 351 | 36 | 4.38 | 2.43 | 1.95 | 54.20 | .05 | 6.78 |
| 352 | 37 | 4.36 | 2.41 | 1.95 | 54.20 | .05 | 6.75 |
| 353 | 38 | 4.33 | 2.39 | 1.94 | 53.84 | .05 | 6.70 |
| 354 | 39 | 4.28 | 2.37 | 1.91 | 53.17 | .05 | 6.60 |
| 355 | 40 | 4.23 | 2.35 | 1.88 | 52.20 | .05 | 6.45 |
| 356 | 41 | 4.16 | 2.33 | 1.83 | 50.95 | .05 | 6.29 |
| 357 | 42 | 4.09 | 2.31 | 1.78 | 49.45 | .04 | 6.09 |
| 358 | 43 | 4.01 | 2.29 | 1.72 | 47.71 | .04 | 5.86 |
| 359 | 44 | 3.92 | 2.28 | 1.65 | 45.73 | .04 | 5.60 |
| 360 | 45 | 3.83 | 2.26 | 1.57 | 43.54 | .04 | 5.32 |
| 361 | 46 | 3.72 | 2.24 | 1.48 | 41.14 | .03 | 5.02 |
| 362 | 47 | 3.61 | 2.23 | 1.39 | 38.53 | .03 | 4.69 |
| 363 | 48 | 3.50 | 2.21 | 1.28 | 35.72 | .03 | 4.34 |
| 364 | 49 | 3.38 | 2.20 | 1.18 | 32.72 | .02 | 3.96 |
| 365 | 50 | 3.25 | 2.19 | 1.06 | 29.53 | .02 | 3.57 |
| 366 | 51 | 3.11 | 2.17 | .94 | 26.16 | .02 | 3.15 |
| 367 | 52 | 2.97 | 2.16 | .81 | 22.62 | .02 | 2.72 |
| 368 | 53 | 2.83 | 2.15 | .68 | 18.89 | .01 | 2.27 |
| 369 | 54 | 2.68 | 2.14 | .54 | 15.00 | .01 | 1.79 |
| 370 | 55 | 2.52 | 2.12 | .39 | 10.93 | .01 | 1.30 |
| 371 | 56 | 2.35 | 2.11 | .24 | 6.70 | .00 | .80 |
| 372 | 57 | 2.19 | 2.10 | .08 | 2.31 | .00 | .27 |
| 373 | 58 | 2.01 | 2.09 | -.08 | -2.24 | -.00 | -.27 |
| 374 | 59 | 1.83 | 2.08 | -.25 | -6.95 | -.00 | -.82 |
| 375 | 60 | 1.65 | 2.07 | -.43 | -11.92 | -.01 | -1.39 |
| 376 | 61 | 1.46 | 2.06 | -.61 | -16.84 | -.01 | -1.98 |
| 377 | 62 | 1.26 | 2.05 | -.79 | -22.02 | -.01 | -2.58 |
| 378 | 63 | 1.06 | 2.04 | -.98 | -27.34 | -.02 | -3.20 |
| 379 | 1 | 1.10 | 16.01 | -14.83 | -412.35 | -.23 | -48.17 |
| 380 | 2 | 1.63 | 11.48 | -9.85 | -273.93 | -.15 | -31.93 |
| 381 | 3 | 2.07 | 9.22 | -7.15 | -198.68 | -.11 | -23.10 |
| 382 | 4 | 2.49 | 7.85 | -5.36 | -148.93 | -.08 | -17.28 |
| 383 | 5 | 2.91 | 6.94 | -4.03 | -112.12 | -.06 | -12.95 |
| 384 | 6 | 3.31 | 6.29 | -2.98 | -82.87 | -.04 | -9.57 |
| 385 | 7 | 3.69 | 5.80 | -2.10 | -58.40 | -.03 | -6.74 |
| 386 | 8 | 4.06 | 5.41 | -1.35 | -37.45 | -.02 | -4.30 |
| 387 | 9 | 4.42 | 5.10 | -.68 | -18.90 | -.01 | -2.17 |
| 388 | 10 | 4.77 | 4.85 | -.08 | -2.24 | -.00 | -.26 |
| 389 | 11 | 5.10 | 4.64 | .46 | 12.90 | .01 | 1.47 |
| 390 | 12 | 5.42 | 3.90 | 1.52 | 42.23 | .02 | 4.81 |
| 391 | 13 | 5.73 | 3.75 | 1.98 | 55.03 | .02 | 6.25 |
| 392 | 14 | 6.02 | 3.61 | 2.41 | 66.90 | .03 | 7.59 |
| 393 | 15 | 6.30 | 3.49 | 2.80 | 77.95 | .03 | 8.82 |
| 394 | 16 | 6.56 | 3.39 | 3.17 | 88.26 | .04 | 9.96 |
| 395 | 17 | 6.81 | 3.29 | 3.52 | 97.89 | .04 | 11.02 |
| 396 | 18 | 7.05 | 3.21 | 3.84 | 106.88 | .04 | 12.01 |
| 397 | 19 | 7.28 | 3.13 | 4.15 | 115.28 | .05 | 12.92 |
| 398 | 20 | 7.49 | 3.06 | 4.43 | 123.11 | .05 | 13.77 |
| 399 | 21 | 7.69 | 3.00 | 4.69 | 130.41 | .05 | 14.55 |
| 400 | 22 | 7.87 | 2.94 | 4.93 | 137.19 | .05 | 15.28 |
| 401 | 23 | 8.05 | 2.89 | 5.16 | 143.47 | .05 | 15.94 |
| 402 | 24 | .00 | 2.84 | -2.84 | -78.83 | -.03 | -8.74 |
| 403 | 25 | 1.37 | 2.79 | -1.42 | -39.53 | -.01 | -4.37 |
| 404 | 26 | 2.64 | 2.75 | -.10 | -2.91 | .00 | -.32 |
| 405 | 27 | 3.30 | 2.71 | .60 | 16.65 | .01 | 1.83 |
| 406 | 28 | 3.70 | 2.67 | 1.03 | 28.71 | .01 | 3.15 |
| 407 | 29 | 3.96 | 2.63 | 1.32 | 36.77 | .01 | 4.03 |
| 408 | 30 | 4.13 | 2.60 | 1.53 | 42.43 | .01 | 4.64 |
| 409 | 31 | 4.24 | 2.57 | 1.67 | 46.50 | .01 | 5.08 |
| 410 | 32 | 4.32 | 2.54 | 1.78 | 49.43 | .02 | 5.38 |
| 411 | 33 | 4.36 | 2.51 | 1.85 | 51.52 | .02 | 5.60 |
| 412 | 34 | 4.39 | 2.48 | 1.90 | 52.93 | .02 | 5.74 |
| 413 | 35 | 4.39 | 2.46 | 1.94 | 53.80 | .02 | 5.82 |
| 414 | 36 | 4.38 | 2.43 | 1.95 | 54.20 | .02 | 5.85 |
| 415 | 37 | 4.36 | 2.41 | 1.95 | 54.20 | .01 | 5.84 |
| 416 | 38 | 4.33 | 2.39 | 1.94 | 53.84 | .01 | 5.79 |
| 417 | 39 | 4.28 | 2.37 | 1.91 | 53.17 | .01 | 5.70 |
| 418 | 40 | 4.23 | 2.35 | 1.88 | 52.20 | .01 | 5.59 |
| 419 | 41 | 4.16 | 2.33 | 1.83 | 50.95 | .01 | 5.44 |
| 420 | 42 | 4.09 | 2.31 | 1.78 | 49.45 | .01 | 5.27 |
| 421 | 43 | 4.01 | 2.29 | 1.72 | 47.71 | .01 | 5.08 |
| 422 | 44 | 3.92 | 2.28 | 1.65 | 45.73 | .01 | 4.85 |
| 423 | 45 | 3.83 | 2.26 | 1.57 | 43.54 | .01 | 4.61 |
| 424 | 46 | 3.72 | 2.24 | 1.48 | 41.14 | .01 | 4.35 |
| 425 | 47 | 3.61 | 2.23 | 1.39 | 38.53 | .01 | 4.06 |
| 426 | 48 | 3.50 | 2.21 | 1.28 | 35.72 | .01 | 3.76 |
| 427 | 49 | 3.38 | 2.20 | 1.18 | 32.72 | .01 | 3.44 |
| 428 | 50 | 3.25 | 2.19 | 1.06 | 29.53 | .01 | 3.10 |
| 429 | 51 | 3.11 | 2.17 | .94 | 26.16 | .01 | 2.74 |
| 430 | 52 | 2.97 | 2.16 | .81 | 22.62 | .00 | 2.36 |
| 431 | 53 | 2.83 | 2.15 | .68 | 18.89 | .00 | 1.97 |
| 432 | 54 | 2.68 | 2.14 | .54 | 15.00 | .00 | 1.56 |
| 433 | 55 | 2.52 | 2.12 | .39 | 10.93 | .00 | 1.13 |
| 434 | 56 | 2.35 | 2.11 | .24 | 6.70 | .00 | .69 |
| 435 | 57 | 2.19 | 2.10 | .08 | 2.31 | .00 | .24 |
| 436 | 58 | 2.01 | 2.09 | -.08 | -2.24 | .00 | -.23 |
| 437 | 59 | 1.83 | 2.08 | -.25 | -6.95 | -.00 | -.72 |
| 438 | 60 | 1.65 | 2.07 | -.43 | -11.92 | -.00 | -1.21 |
| 439 | 61 | 1.46 | 2.06 | -.61 | -16.84 | -.00 | -1.73 |
| 440 | 62 | 1.26 | 2.05 | -.79 | -22.02 | -.00 | -2.25 |
| 441 | 63 | 1.06 | 2.04 | -.98 | -27.34 | -.00 | -2.79 |
| 442 | 1 | 1.10 | 16.01 | -14.83 | -412.35 | -.07 | -41.99 |
| 443 | 2 | 1.63 | 11.48 | -9.85 | -273.93 | -.04 | -27.84 |
| 444 | 3 | 2.07 | 9.22 | -7.15 | -198.68 | -.03 | -20.15 |
| 445 | 4 | 2.49 | 7.85 | -5.36 | -148.93 | -.02 | -15.07 |
| 446 | 5 | 2.91 | 6.94 | -4.03 | -112.12 | -.02 | -11.33 |
| 447 | 6 | 3.31 | 6.29 | -2.98 | -82.87 | -.01 | -8.35 |
| 448 | 7 | 3.69 | 5.80 | -2.10 | -58.40 | -.01 | -5.88 |
| 449 | 8 | 4.06 | 5.41 | -1.35 | -37.45 | -.01 | -3.76 |
| 450 | 9 | 4.42 | 5.10 | -.68 | -18.90 | -.00 | -1.89 |
| 451 | 10 | 4.77 | 4.85 | -.08 | -2.24 | .00 | -.22 |
| 452 | 11 | 5.10 | 4.64 | .46 | 12.90 | .00 | 1.29 |
| 453 | 12 | 5.42 | 3.90 | 1.52 | 42.23 | .01 | 4.21 |
| 454 | 13 | 5.73 | 3.75 | 1.98 | 55.03 | .01 | 5.47 |
| 455 | 14 | 6.02 | 3.61 | 2.41 | 66.90 | .01 | 6.64 |
| 456 | 15 | 6.30 | 3.49 | 2.80 | 77.95 | .01 | 7.72 |
| 457 | 16 | 6.56 | 3.39 | 3.17 | 88.26 | .01 | 8.72 |
| 458 | 17 | 6.81 | 3.29 | 3.52 | 97.89 | .01 | 9.65 |
| 459 | 18 | 7.05 | 3.21 | 3.84 | 106.88 | .01 | 10.52 |
| 460 | 19 | 7.28 | 3.13 | 4.15 | 115.28 | .01 | 11.33 |
| 461 | 20 | 7.49 | 3.06 | 4.43 | 123.11 | .01 | 12.07 |
| 462 | 21 | 7.69 | 3.00 | 4.69 | 130.41 | .01 | 12.76 |
| 463 | 22 | 7.87 | 2.94 | 4.93 | 137.19 | .01 | 13.40 |
| 464 | 23 | 8.05 | 2.89 | 5.16 | 143.47 | .01 | 13.98 |
| 465 | 24 | .00 | 2.84 | -2.84 | -78.83 | -.01 | -7.67 |
| 466 | 25 | 1.37 | 2.79 | -1.42 | -39.53 | -.00 | -3.84 |
| 467 | 26 | 2.64 | 2.75 | -.10 | -2.91 | .00 | -.28 |
| 468 | 27 | 3.30 | 2.71 | .60 | 16.65 | .00 | 1.61 |
| 469 | 28 | 3.70 | 2.67 | 1.03 | 28.71 | .00 | 2.77 |
| 470 | 29 | 3.96 | 2.63 | 1.32 | 36.77 | .00 | 3.54 |
| 471 | 30 | 4.13 | 2.60 | 1.53 | 42.43 | .00 | 4.08 |
| 472 | 31 | 4.24 | 2.57 | 1.67 | 46.50 | .00 | 4.46 |
| 473 | 32 | 4.32 | 2.54 | 1.78 | 49.43 | .00 | 4.74 |
| 474 | 33 | 4.36 | 2.51 | 1.85 | 51.52 | .00 | 4.93 |
| 475 | 34 | 4.39 | 2.48 | 1.90 | 52.93 | .00 | 5.08 |
| 476 | 35 | 4.39 | 2.46 | 1.94 | 53.80 | .00 | 5.12 |
| 477 | 36 | 4.38 | 2.43 | 1.95 | 54.20 | .00 | 5.15 |
| 478 | 37 | 4.36 | 2.41 | 1.95 | 54.20 | .00 | 5.14 |
| 479 | 38 | 4.33 | 2.39 | 1.94 | 53.84 | .00 | 5.10 |
| 480 | 39 | 4.28 | 2.37 | 1.91 | 53.17 | .00 | 5.03 |
| 481 | 40 | 4.23 | 2.35 | 1.88 | 52.20 | .00 | 4.92 |
| 482 | 41 | 4.16 | 2.33 | 1.83 | 50.95 | .00 | 4.80 |
| 483 | 42 | 4.09 | 2.31 | 1.78 | 49.45 | .00 | 4.65 |
| 484 | 43 | 4.01 | 2.29 | 1.72 | 47.71 | .00 | 4.48 |
| 485 | 44 | 3.92 | 2.28 | 1.65 | 45.73 | .00 | 4.28 |
| 486 | 45 | 3.83 | 2.26 | 1.57 | 43.54 | .00 | 4.07 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 487 | 46 | 3.72 | 2.24 | 1.48 | 41.14 | .00 | 3.84 |
| 488 | 47 | 3.61 | 2.23 | 1.39 | 38.53 | .00 | 3.59 |
| 489 | 48 | 3.50 | 2.21 | 1.28 | 35.72 | .00 | 3.32 |
| 490 | 49 | 3.38 | 2.20 | 1.18 | 32.72 | .00 | 3.04 |
| 491 | 50 | 3.25 | 2.19 | 1.06 | 29.53 | .00 | 2.73 |
| 492 | 51 | 3.11 | 2.17 | .94 | 26.16 | .00 | 2.42 |
| 493 | 52 | 2.97 | 2.16 | .81 | 22.62 | .00 | 2.09 |
| 494 | 53 | 2.83 | 2.15 | .68 | 18.89 | .00 | 1.74 |
| 495 | 54 | 2.68 | 2.14 | .54 | 15.00 | .00 | 1.38 |
| 496 | 55 | 2.52 | 2.12 | .39 | 10.93 | .00 | 1.00 |
| 497 | 56 | 2.35 | 2.11 | .24 | 6.70 | .00 | .61 |
| 498 | 57 | 2.19 | 2.10 | .08 | 2.31 | .00 | .21 |
| 499 | 58 | 2.01 | 2.09 | -.08 | -2.24 | .00 | -.20 |
| 500 | 59 | 1.83 | 2.08 | -.25 | -6.95 | .00 | -.63 |
| 501 | 60 | 1.65 | 2.07 | -.43 | -11.82 | .00 | -1.07 |
| 502 | 61 | 1.46 | 2.06 | -.61 | -16.84 | .00 | -1.53 |
| 503 | 62 | 1.26 | 2.05 | -.79 | -22.02 | -.00 | -1.99 |
| 504 | 63 | 1.06 | 2.04 | -.98 | -27.34 | -.00 | -2.47 |
| 505 | 1 | 1.18 | 16.01 | -14.03 | -412.35 | -.02 | -37.28 |
| 506 | 2 | 1.63 | 11.48 | -9.85 | -273.93 | -.01 | -24.68 |
| 507 | 3 | 2.07 | 9.22 | -7.15 | -198.60 | -.01 | -17.87 |
| 508 | 4 | 2.49 | 7.85 | -5.36 | -148.93 | -.01 | -13.37 |
| 509 | 5 | 2.91 | 6.94 | -4.03 | -112.12 | -.00 | -10.05 |
| 510 | 6 | 3.31 | 6.29 | -2.98 | -82.87 | -.00 | -7.41 |
| 511 | 7 | 3.69 | 5.80 | -2.10 | -58.48 | -.00 | -5.22 |
| 512 | 8 | 4.06 | 5.41 | -1.35 | -37.45 | -.00 | -3.34 |
| 513 | 9 | 4.42 | 5.10 | -.68 | -18.90 | .00 | -1.68 |
| 514 | 10 | 4.77 | 4.85 | -.08 | -2.24 | .00 | -.20 |
| 515 | 11 | 5.10 | 4.64 | .46 | 12.90 | .00 | 1.14 |
| 516 | 12 | 5.42 | 3.90 | 1.52 | 42.23 | .00 | 3.74 |
| 517 | 13 | 5.73 | 3.75 | 1.98 | 55.03 | .00 | 4.86 |
| 518 | 14 | 6.02 | 3.61 | 2.41 | 66.90 | .00 | 5.90 |
| 519 | 15 | 6.30 | 3.49 | 2.80 | 77.95 | .00 | 6.86 |
| 520 | 16 | 6.56 | 3.39 | 3.17 | 88.26 | .00 | 7.76 |
| 521 | 17 | 6.81 | 3.29 | 3.52 | 97.89 | .00 | 8.59 |
| 522 | 18 | 7.05 | 3.21 | 3.84 | 106.88 | .00 | 9.36 |
| 523 | 19 | 7.28 | 3.13 | 4.15 | 115.28 | .00 | 10.08 |
| 524 | 20 | 7.49 | 3.06 | 4.43 | 123.11 | .00 | 10.74 |
| 525 | 21 | 7.69 | 3.00 | 4.69 | 130.41 | .00 | 11.36 |
| 526 | 22 | 7.87 | 2.94 | 4.93 | 137.19 | .00 | 11.93 |
| 527 | 23 | 8.05 | 2.89 | 5.16 | 143.47 | .00 | 12.45 |
| 528 | 24 | .00 | 2.84 | -2.04 | -70.83 | -.00 | -6.83 |
| 529 | 25 | 1.37 | 2.79 | -1.42 | -39.53 | -.00 | -3.48 |
| 530 | 26 | 2.64 | 2.75 | -.10 | -2.91 | .00 | -.25 |
| 531 | 27 | 3.30 | 2.71 | .60 | 16.65 | .00 | 1.44 |
| 532 | 28 | 3.70 | 2.67 | 1.03 | 28.71 | .00 | 2.47 |
| 533 | 29 | 3.96 | 2.63 | 1.32 | 36.77 | .00 | 3.16 |
| 534 | 30 | 4.13 | 2.60 | 1.53 | 42.43 | .00 | 3.64 |
| 535 | 31 | 4.24 | 2.57 | 1.67 | 46.50 | .00 | 3.98 |
| 536 | 32 | 4.32 | 2.54 | 1.78 | 49.43 | .00 | 4.23 |
| 537 | 33 | 4.36 | 2.51 | 1.85 | 51.52 | .00 | 4.40 |
| 538 | 34 | 4.39 | 2.48 | 1.90 | 52.93 | .00 | 4.51 |
| 539 | 35 | 4.39 | 2.46 | 1.94 | 53.80 | .00 | 4.57 |
| 540 | 36 | 4.38 | 2.43 | 1.95 | 54.20 | .00 | 4.60 |
| 541 | 37 | 4.36 | 2.41 | 1.95 | 54.20 | .00 | 4.59 |
| 542 | 38 | 4.33 | 2.39 | 1.94 | 53.84 | .00 | 4.56 |
| 543 | 39 | 4.28 | 2.37 | 1.91 | 53.17 | .00 | 4.49 |
| 544 | 40 | 4.23 | 2.35 | 1.88 | 52.20 | .00 | 4.40 |
| 545 | 41 | 4.16 | 2.33 | 1.83 | 50.95 | .00 | 4.29 |
| 546 | 42 | 4.09 | 2.31 | 1.78 | 49.45 | .00 | 4.16 |
| 547 | 43 | 4.01 | 2.29 | 1.72 | 47.71 | .00 | 4.00 |
| 548 | 44 | 3.92 | 2.28 | 1.65 | 45.73 | .00 | 3.83 |
| 549 | 45 | 3.83 | 2.26 | 1.57 | 43.54 | .00 | 3.64 |
| 550 | 46 | 3.72 | 2.24 | 1.48 | 41.14 | .00 | 3.43 |
| 551 | 47 | 3.61 | 2.23 | 1.39 | 38.53 | .00 | 3.21 |
| 552 | 48 | 3.50 | 2.21 | 1.28 | 35.72 | .00 | 2.97 |
| 553 | 49 | 3.38 | 2.20 | 1.18 | 32.72 | .00 | 2.72 |
| 554 | 50 | 3.25 | 2.19 | 1.06 | 29.53 | .00 | 2.45 |
| 555 | 51 | 3.11 | 2.17 | .94 | 26.16 | .00 | 2.17 |
| 556 | 52 | 2.97 | 2.16 | .81 | 22.62 | .00 | 1.87 |
| 557 | 53 | 2.83 | 2.15 | .68 | 18.89 | .00 | 1.56 |
| 558 | 54 | 2.68 | 2.14 | .54 | 15.00 | .00 | 1.24 |
| 559 | 55 | 2.52 | 2.12 | .39 | 10.93 | .00 | .90 |
| 560 | 56 | 2.35 | 2.11 | .24 | 6.70 | .00 | .55 |
| 561 | 57 | 2.19 | 2.10 | .08 | 2.31 | .00 | .19 |
| 562 | 58 | 2.01 | 2.09 | -.08 | -2.24 | .00 | -.18 |
| 563 | 59 | 1.83 | 2.08 | -.25 | -6.95 | .00 | -.57 |
| 564 | 60 | 1.65 | 2.07 | -.43 | -11.82 | .00 | -.96 |
| 565 | 61 | 1.46 | 2.06 | -.61 | -16.84 | .00 | -1.37 |
| 566 | 62 | 1.26 | 2.05 | -.79 | -22.02 | .00 | -1.79 |
| 567 | 63 | 1.06 | 2.04 | -.98 | -27.34 | .00 | -2.22 |
| 568 | 1 | 1.18 | 16.01 | -14.03 | -412.35 | -.01 | -33.42 |
| 569 | 2 | 1.63 | 11.48 | -9.85 | -273.93 | -.00 | -22.16 |
| 570 | 3 | 2.07 | 9.22 | -7.15 | -198.60 | -.00 | -16.05 |
| 571 | 4 | 2.49 | 7.85 | -5.36 | -148.93 | -.00 | -12.01 |
| 572 | 5 | 2.91 | 6.94 | -4.03 | -112.12 | -.00 | -9.03 |
| 573 | 6 | 3.31 | 6.29 | -2.98 | -82.87 | .00 | -6.66 |
| 574 | 7 | 3.69 | 5.80 | -2.10 | -58.48 | .00 | -4.69 |
| 575 | 8 | 4.06 | 5.41 | -1.35 | -37.45 | .00 | -3.00 |
| 576 | 9 | 4.42 | 5.10 | -.68 | -18.90 | .00 | -1.51 |
| 577 | 10 | 4.77 | 4.85 | -.08 | -2.24 | .00 | -.18 |
| 578 | 11 | 5.10 | 4.64 | .46 | 12.90 | .00 | 1.03 |
| 579 | 12 | 5.42 | 3.90 | 1.52 | 42.23 | .00 | 3.36 |
| 580 | 13 | 5.73 | 3.75 | 1.98 | 55.03 | .00 | 4.37 |
| 581 | 14 | 6.02 | 3.61 | 2.41 | 66.90 | .00 | 5.31 |
| 582 | 15 | 6.30 | 3.49 | 2.80 | 77.95 | .00 | 6.18 |
| 583 | 16 | 6.56 | 3.39 | 3.17 | 88.26 | .00 | 6.98 |
| 584 | 17 | 6.81 | 3.29 | 3.52 | 97.89 | .00 | 7.73 |
| 585 | 18 | 7.05 | 3.21 | 3.84 | 106.88 | .00 | 8.43 |
| 586 | 19 | 7.28 | 3.13 | 4.15 | 115.28 | .00 | 9.08 |
| 587 | 20 | 7.49 | 3.06 | 4.43 | 123.11 | .00 | 9.68 |
| 588 | 21 | 7.69 | 3.00 | 4.69 | 130.41 | .00 | 10.24 |
| 589 | 22 | 7.87 | 2.94 | 4.93 | 137.19 | .00 | 10.75 |
| 590 | 23 | 8.05 | 2.89 | 5.16 | 143.47 | .00 | 11.23 |
| 591 | 24 | .00 | 2.84 | -2.04 | -70.83 | .00 | -6.14 |
| 592 | 25 | 1.37 | 2.79 | -1.42 | -39.53 | .00 | -3.08 |
| 593 | 26 | 2.64 | 2.75 | -.10 | -2.91 | .00 | -.23 |
| 594 | 27 | 3.30 | 2.71 | .60 | 16.65 | .00 | 1.29 |
| 595 | 28 | 3.70 | 2.67 | 1.03 | 28.71 | .00 | 2.23 |
| 596 | 29 | 3.96 | 2.63 | 1.32 | 36.77 | .00 | 2.85 |
| 597 | 30 | 4.13 | 2.60 | 1.53 | 42.43 | .00 | 3.28 |
| 598 | 31 | 4.24 | 2.57 | 1.67 | 46.50 | .00 | 3.59 |
| 599 | 32 | 4.32 | 2.54 | 1.78 | 49.43 | .00 | 3.81 |
| 600 | 33 | 4.36 | 2.51 | 1.85 | 51.52 | .00 | 3.97 |
| 601 | 34 | 4.39 | 2.48 | 1.90 | 52.93 | .00 | 4.07 |
| 602 | 35 | 4.39 | 2.46 | 1.94 | 53.80 | .00 | 4.13 |
| 603 | 36 | 4.38 | 2.43 | 1.95 | 54.20 | .00 | 4.16 |
| 604 | 37 | 4.36 | 2.41 | 1.95 | 54.20 | .00 | 4.15 |
| 605 | 38 | 4.33 | 2.39 | 1.94 | 53.84 | .00 | 4.12 |
| 606 | 39 | 4.28 | 2.37 | 1.91 | 53.17 | .00 | 4.06 |
| 607 | 40 | 4.23 | 2.35 | 1.88 | 52.20 | .00 | 3.98 |
| 608 | 41 | 4.16 | 2.33 | 1.83 | 50.95 | .00 | 3.88 |
| 609 | 42 | 4.09 | 2.31 | 1.78 | 49.45 | .00 | 3.76 |
| 610 | 43 | 4.01 | 2.29 | 1.72 | 47.71 | .00 | 3.62 |
| 611 | 44 | 3.92 | 2.28 | 1.65 | 45.73 | .00 | 3.46 |
| 612 | 45 | 3.83 | 2.26 | 1.57 | 43.54 | .00 | 3.29 |
| 613 | 46 | 3.72 | 2.24 | 1.48 | 41.14 | .00 | 3.11 |
| 614 | 47 | 3.61 | 2.23 | 1.39 | 38.53 | .00 | 2.91 |
| 615 | 48 | 3.50 | 2.21 | 1.28 | 35.72 | .00 | 2.69 |
| 616 | 49 | 3.38 | 2.20 | 1.18 | 32.72 | .00 | 2.46 |
| 617 | 50 | 3.25 | 2.19 | 1.06 | 29.53 | .00 | 2.22 |
| 618 | 51 | 3.11 | 2.17 | .94 | 26.16 | .00 | 1.96 |
| 619 | 52 | 2.97 | 2.16 | .81 | 22.62 | .00 | 1.69 |
| 620 | 53 | 2.83 | 2.15 | .68 | 18.89 | .00 | 1.41 |
| 621 | 54 | 2.68 | 2.14 | .54 | 15.00 | .00 | 1.12 |
| 622 | 55 | 2.52 | 2.12 | .39 | 10.93 | .00 | .81 |
| 623 | 56 | 2.35 | 2.11 | .24 | 6.70 | .00 | .50 |
| 624 | 57 | 2.19 | 2.10 | .08 | 2.31 | .00 | .17 |
| 625 | 58 | 2.01 | 2.09 | -.08 | -2.24 | .00 | -.17 |
| 626 | 59 | 1.83 | 2.08 | -.25 | -6.95 | .00 | -.52 |
| 627 | 60 | 1.65 | 2.07 | -.43 | -11.82 | .00 | -.87 |
| 628 | 61 | 1.46 | 2.06 | -.61 | -16.84 | .00 | -1.24 |
| 629 | 62 | 1.26 | 2.05 | -.79 | -22.02 | .00 | -1.62 |
| 630 | 63 | 1.06 | 2.04 | -.98 | -27.34 | .00 | -2.01 |
| 631 | 1 | 1.18 | 16.01 | -14.03 | -412.35 | -.00 | -30.32 |
| 632 | 2 | 1.63 | 11.48 | -9.85 | -273.93 | -.00 | -20.11 |
| 633 | 3 | 2.07 | 9.22 | -7.15 | -198.60 | .00 | -14.57 |
| 634 | 4 | 2.49 | 7.85 | -5.36 | -148.93 | .00 | -10.90 |
| 635 | 5 | 2.91 | 6.94 | -4.03 | -112.12 | .00 | -8.20 |
| 636 | 6 | 3.31 | 6.29 | -2.98 | -82.87 | .00 | -6.08 |
| 637 | 7 | 3.69 | 5.80 | -2.10 | -58.48 | .00 | -4.26 |
| 638 | 8 | 4.06 | 5.41 | -1.35 | -37.45 | .00 | -2.73 |
| 639 | 9 | 4.42 | 5.10 | -.68 | -18.90 | .00 | -1.37 |
| 640 | 10 | 4.77 | 4.85 | -.08 | -2.24 | .00 | -.16 |
| 641 | 11 | 5.10 | 4.64 | .46 | 12.90 | .00 | .93 |
| 642 | 12 | 5.42 | 3.90 | 1.52 | 42.23 | .00 | 3.06 |
| 643 | 13 | 5.73 | 3.75 | 1.98 | 55.03 | .00 | 3.98 |
| 644 | 14 | 6.02 | 3.61 | 2.41 | 66.90 | .00 | 4.83 |
| 645 | 15 | 6.30 | 3.49 | 2.80 | 77.95 | .00 | 5.62 |
| 646 | 16 | 6.56 | 3.39 | 3.17 | 88 26 | .00 | 6.35 |
| 647 | 17 | 6.81 | 3.29 | 3.52 | 97.89 | .00 | 7.03 |
| 648 | 18 | 7.05 | 3.21 | 3.84 | 106.88 | .00 | 7.67 |
| 649 | 19 | 7.28 | 3.13 | 4.15 | 115.28 | .00 | 8.26 |
| 650 | 20 | 7.49 | 3.06 | 4.43 | 123.11 | .00 | 8.81 |
| 651 | 21 | 7.69 | 3.00 | 4.69 | 130.41 | .00 | 9.31 |
| 652 | 22 | 7.87 | 2.94 | 4.93 | 137.19 | .00 | 9.79 |
| 653 | 23 | 8.05 | 2.89 | 5.16 | 143.47 | .00 | 10.22 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 654 | 24 | .00 | 2.84 | -2.84 | -78.83 | .00 | -5.61 |
| 655 | 25 | 1.37 | 2.79 | -1.42 | -39.53 | .00 | -2.81 |
| 656 | 26 | 2.64 | 2.75 | -.10 | -2.91 | .00 | -.21 |
| 657 | 27 | 3.30 | 2.71 | .60 | 16.65 | .00 | 1.10 |
| 658 | 28 | 3.70 | 2.67 | 1.03 | 28.71 | .00 | 2.03 |
| 659 | 29 | 3.96 | 2.63 | 1.32 | 36.77 | .00 | 2.60 |
| 660 | 30 | 4.13 | 2.60 | 1.53 | 42.43 | .00 | 2.99 |
| 661 | 31 | 4.24 | 2.57 | 1.67 | 46.50 | .00 | 3.27 |
| 662 | 32 | 4.32 | 2.54 | 1.78 | 49.43 | .00 | 3.48 |
| 663 | 33 | 4.36 | 2.51 | 1.85 | 51.52 | .00 | 3.62 |
| 664 | 34 | 4.39 | 2.48 | 1.90 | 52.93 | .00 | 3.71 |
| 665 | 35 | 4.39 | 2.46 | 1.94 | 53.80 | .00 | 3.77 |
| 666 | 36 | 4.38 | 2.43 | 1.95 | 54.20 | .00 | 3.79 |
| 667 | 37 | 4.36 | 2.41 | 1.95 | 54.20 | .00 | 3.78 |
| 668 | 38 | 4.33 | 2.39 | 1.94 | 53.84 | .00 | 3.75 |
| 669 | 39 | 4.28 | 2.37 | 1.91 | 53.17 | .00 | 3.70 |
| 670 | 40 | 4.23 | 2.35 | 1.88 | 52.20 | .00 | 3.63 |
| 671 | 41 | 4.16 | 2.33 | 1.83 | 50.95 | .00 | 3.54 |
| 672 | 42 | 4.09 | 2.31 | 1.78 | 49.45 | .00 | 3.43 |
| 673 | 43 | 4.01 | 2.29 | 1.72 | 47.71 | .00 | 3.30 |
| 674 | 44 | 3.92 | 2.28 | 1.65 | 45.73 | .00 | 3.16 |
| 675 | 45 | 3.83 | 2.26 | 1.57 | 43.54 | .00 | 3.01 |
| 676 | 46 | 3.72 | 2.24 | 1.48 | 41.14 | .00 | 2.84 |
| 677 | 47 | 3.61 | 2.23 | 1.39 | 38.53 | .00 | 2.65 |
| 678 | 48 | 3.50 | 2.21 | 1.28 | 35.72 | .00 | 2.46 |
| 679 | 49 | 3.38 | 2.20 | 1.18 | 32.72 | .00 | 2.25 |
| 680 | 50 | 3.25 | 2.19 | 1.06 | 29.53 | .00 | 2.03 |
| 681 | 51 | 3.11 | 2.17 | .94 | 26.16 | .00 | 1.79 |
| 682 | 52 | 2.97 | 2.16 | .81 | 22.62 | .00 | 1.55 |
| 683 | 53 | 2.83 | 2.15 | .68 | 18.89 | .00 | 1.29 |
| 684 | 54 | 2.68 | 2.14 | .54 | 15.00 | .00 | 1.02 |
| 685 | 55 | 2.52 | 2.12 | .39 | 10.93 | .00 | .74 |
| 686 | 56 | 2.35 | 2.11 | .24 | 6.70 | .00 | .46 |
| 687 | 57 | 2.19 | 2.10 | .08 | 2.31 | .00 | .16 |
| 688 | 58 | 2.01 | 2.09 | -.08 | -2.24 | .00 | -.15 |
| 689 | 59 | 1.83 | 2.08 | -.25 | -6.95 | .00 | -.47 |
| 690 | 60 | 1.65 | 2.07 | -.43 | -11.82 | .00 | -.80 |
| 691 | 61 | 1.46 | 2.06 | -.61 | -16.84 | .00 | -1.14 |
| 692 | 62 | 1.26 | 2.05 | -.79 | -22.02 | .00 | -1.49 |
| 693 | 63 | 1.06 | 2.04 | -.98 | -27.34 | .00 | -1.84 |
| 694 | 1 | 1.18 | 16.01 | -14.83 | -412.35 | .00 | -27.75 |
| 695 | 2 | 1.63 | 11.48 | -9.85 | -273.93 | .00 | -18.41 |
| 696 | 3 | 2.07 | 9.22 | -7.15 | -198.60 | .00 | -13.33 |
| 697 | 4 | 2.49 | 7.85 | -5.36 | -148.93 | .00 | -9.98 |
| 698 | 5 | 2.91 | 6.94 | -4.03 | -112.12 | .00 | -7.50 |
| 699 | 6 | 3.31 | 6.29 | -2.98 | -82.87 | .00 | -5.54 |
| 700 | 7 | 3.69 | 5.80 | -2.10 | -58.40 | .00 | -3.90 |
| 701 | 8 | 4.06 | 5.41 | -1.35 | -37.45 | .00 | -2.50 |
| 702 | 9 | 4.42 | 5.10 | -.68 | -18.90 | .00 | -1.26 |
| 703 | 10 | 4.77 | 4.85 | -.08 | -2.24 | .00 | -.15 |
| 704 | 11 | 5.10 | 4.64 | .46 | 12.90 | .00 | .86 |
| 705 | 12 | 5.42 | 3.90 | 1.52 | 42.23 | .00 | 2.88 |
| 706 | 13 | 5.73 | 3.75 | 1.98 | 55.03 | .00 | 3.64 |
| 707 | 14 | 6.02 | 3.61 | 2.41 | 66.90 | .00 | 4.42 |
| 708 | 15 | 6.30 | 3.49 | 2.80 | 77.95 | .00 | 5.16 |
| 709 | 16 | 6.56 | 3.39 | 3.17 | 88.26 | .00 | 5.82 |
| 710 | 17 | 6.81 | 3.29 | 3.52 | 97.89 | .00 | 6.45 |
| 711 | 18 | 7.05 | 3.21 | 3.84 | 106.88 | .00 | 7.03 |
| 712 | 19 | 7.28 | 3.13 | 4.15 | 115.28 | .00 | 7.57 |
| 713 | 20 | 7.49 | 3.06 | 4.43 | 123.11 | .00 | 8.08 |
| 714 | 21 | 7.69 | 3.00 | 4.69 | 130.41 | .00 | 8.55 |
| 715 | 22 | 7.87 | 2.94 | 4.93 | 137.19 | .00 | 8.98 |
| 716 | 23 | 8.05 | 2.89 | 5.16 | 143.47 | .00 | 9.38 |
| 717 | 24 | .00 | 2.84 | -2.84 | -78.83 | .00 | -5.15 |
| 718 | 25 | 1.37 | 2.79 | -1.42 | -39.53 | .00 | -2.58 |
| 719 | 26 | 2.64 | 2.75 | -.10 | -2.91 | .00 | -.19 |
| 720 | 27 | 3.30 | 2.71 | .60 | 16.65 | .00 | 1.00 |
| 721 | 28 | 3.70 | 2.67 | 1.03 | 28.71 | .00 | 1.86 |
| 722 | 29 | 3.96 | 2.63 | 1.32 | 36.77 | .00 | 2.38 |
| 723 | 30 | 4.13 | 2.60 | 1.53 | 42.43 | .00 | 2.75 |
| 724 | 31 | 4.24 | 2.57 | 1.67 | 46.50 | .00 | 3.01 |
| 725 | 32 | 4.32 | 2.54 | 1.78 | 49.43 | .00 | 3.19 |
| 726 | 33 | 4.36 | 2.51 | 1.85 | 51.52 | .00 | 3.32 |
| 727 | 34 | 4.39 | 2.48 | 1.90 | 52.93 | .00 | 3.41 |
| 728 | 35 | 4.39 | 2.46 | 1.94 | 53.80 | .00 | 3.46 |
| 729 | 36 | 4.38 | 2.43 | 1.95 | 54.20 | .00 | 3.48 |
| 730 | 37 | 4.36 | 2.41 | 1.95 | 54.20 | .00 | 3.48 |
| 731 | 38 | 4.33 | 2.39 | 1.94 | 53.84 | .00 | 3.45 |
| 732 | 39 | 4.28 | 2.37 | 1.91 | 53.17 | .00 | 3.40 |
| 733 | 40 | 4.23 | 2.35 | 1.88 | 52.20 | .00 | 3.34 |
| 734 | 41 | 4.16 | 2.33 | 1.83 | 50.95 | .00 | 3.25 |
| 735 | 42 | 4.09 | 2.31 | 1.78 | 49.45 | .00 | 3.15 |
| 736 | 43 | 4.01 | 2.29 | 1.72 | 47.71 | .00 | 3.04 |
| 737 | 44 | 3.92 | 2.28 | 1.65 | 45.73 | .00 | 2.91 |
| 738 | 45 | 3.83 | 2.26 | 1.57 | 43.54 | .00 | 2.77 |
| 739 | 46 | 3.72 | 2.24 | 1.48 | 41.14 | .00 | 2.61 |
| 740 | 47 | 3.61 | 2.23 | 1.39 | 38.53 | .00 | 2.44 |
| 741 | 48 | 3.50 | 2.21 | 1.28 | 35.72 | .00 | 2.26 |
| 742 | 49 | 3.38 | 2.20 | 1.18 | 32.72 | .00 | 2.07 |
| 743 | 50 | 3.25 | 2.19 | 1.06 | 29.53 | .00 | 1.86 |
| 744 | 51 | 3.11 | 2.17 | .94 | 26.16 | .00 | 1.65 |
| 745 | 52 | 2.97 | 2.16 | .81 | 22.62 | .00 | 1.42 |
| 746 | 53 | 2.83 | 2.15 | .68 | 18.89 | .00 | 1.19 |
| 747 | 54 | 2.68 | 2.14 | .54 | 15.00 | .00 | .94 |
| 748 | 55 | 2.52 | 2.12 | .39 | 10.93 | .00 | .69 |
| 749 | 56 | 2.35 | 2.11 | .24 | 6.70 | .00 | .42 |
| 750 | 57 | 2.19 | 2.10 | .08 | 2.31 | .00 | .14 |
| 751 | 58 | 2.01 | 2.09 | -.08 | -2.24 | .00 | -.14 |
| 752 | 59 | 1.83 | 2.08 | -.25 | -6.95 | .00 | -.43 |
| 753 | 60 | 1.65 | 2.07 | -.43 | -11.82 | .00 | -.74 |
| 754 | 61 | 1.46 | 2.06 | -.61 | -16.84 | .00 | -1.05 |
| 755 | 62 | 1.26 | 2.05 | -.79 | -22.02 | .00 | -1.37 |
| 756 | 63 | 1.06 | 2.04 | -.98 | -27.34 | .00 | -1.70 |
| 757 | 1 | 1.18 | 16.01 | -14.83 | -412.35 | .00 | -25.60 |
| 758 | 2 | 1.63 | 11.48 | -9.85 | -273.93 | .00 | -16.97 |
| 759 | 3 | 2.07 | 9.22 | -7.15 | -198.60 | .00 | -12.29 |
| 760 | 4 | 2.49 | 7.85 | -5.36 | -148.93 | .00 | -9.20 |
| 761 | 5 | 2.91 | 6.94 | -4.03 | -112.12 | .00 | -6.92 |
| 762 | 6 | 3.31 | 6.29 | -2.98 | -82.87 | .00 | -5.11 |
| 763 | 7 | 3.69 | 5.80 | -2.10 | -58.40 | .00 | -3.60 |
| 764 | 8 | 4.06 | 5.41 | -1.35 | -37.45 | .00 | -2.30 |
| 765 | 9 | 4.42 | 5.10 | -.68 | -18.90 | .00 | -1.16 |
| 766 | 10 | 4.77 | 4.85 | -.08 | -2.24 | .00 | -.14 |
| 767 | 11 | 5.10 | 4.64 | .46 | 12.90 | .00 | .79 |
| 768 | 12 | 5.42 | 3.90 | 1.52 | 42.23 | .00 | 2.50 |
| 769 | 13 | 5.73 | 3.75 | 1.98 | 55.03 | .00 | 3.36 |
| 770 | 14 | 6.02 | 3.61 | 2.41 | 66.90 | .00 | 4.08 |
| 771 | 15 | 6.30 | 3.49 | 2.80 | 77.95 | .00 | 4.75 |
| 772 | 16 | 6.56 | 3.39 | 3.17 | 88.26 | .00 | 5.38 |
| 773 | 17 | 6.81 | 3.29 | 3.52 | 97.89 | .00 | 5.95 |
| 774 | 18 | 7.05 | 3.21 | 3.84 | 106.88 | .00 | 6.49 |
| 775 | 19 | 7.28 | 3.13 | 4.15 | 115.28 | .00 | 6.99 |
| 776 | 20 | 7.49 | 3.06 | 4.43 | 123.11 | .00 | 7.46 |
| 777 | 21 | 7.69 | 3.00 | 4.69 | 130.41 | .00 | 7.89 |
| 778 | 22 | 7.87 | 2.94 | 4.93 | 137.19 | .00 | 8.29 |
| 779 | 23 | 8.05 | 2.89 | 5.16 | 143.47 | .00 | 8.66 |
| 780 | 24 | .00 | 2.84 | -2.84 | -78.83 | .00 | -4.75 |
| 781 | 25 | 1.37 | 2.79 | -1.42 | -39.53 | .00 | -2.38 |
| 782 | 26 | 2.64 | 2.75 | -.10 | -2.91 | .00 | -.17 |
| 783 | 27 | 3.30 | 2.71 | .60 | 16.65 | .00 | 1.00 |
| 784 | 28 | 3.70 | 2.67 | 1.03 | 28.71 | .00 | 1.72 |
| 785 | 29 | 3.96 | 2.63 | 1.32 | 36.77 | .00 | 2.20 |
| 786 | 30 | 4.13 | 2.60 | 1.53 | 42.43 | .00 | 2.54 |
| 787 | 31 | 4.24 | 2.57 | 1.67 | 46.50 | .00 | 2.78 |
| 788 | 32 | 4.32 | 2.54 | 1.78 | 49.43 | .00 | 2.95 |
| 789 | 33 | 4.36 | 2.51 | 1.85 | 51.52 | .00 | 3.07 |
| 790 | 34 | 4.39 | 2.48 | 1.90 | 52.93 | .00 | 3.15 |
| 791 | 35 | 4.39 | 2.46 | 1.94 | 53.80 | .00 | 3.20 |
| 792 | 36 | 4.38 | 2.43 | 1.95 | 54.20 | .00 | 3.22 |
| 793 | 37 | 4.36 | 2.41 | 1.95 | 54.20 | .00 | 3.22 |
| 794 | 38 | 4.33 | 2.39 | 1.94 | 53.84 | .00 | 3.19 |
| 795 | 39 | 4.28 | 2.37 | 1.91 | 53.17 | .00 | 3.15 |
| 796 | 40 | 4.23 | 2.35 | 1.88 | 52.20 | .00 | 3.09 |
| 797 | 41 | 4.16 | 2.33 | 1.83 | 50.95 | .00 | 3.01 |
| 798 | 42 | 4.09 | 2.31 | 1.78 | 49.45 | .00 | 2.92 |
| 799 | 43 | 4.01 | 2.29 | 1.72 | 47.71 | .00 | 2.81 |
| 800 | 44 | 3.92 | 2.28 | 1.65 | 45.73 | .00 | 2.69 |
| 801 | 45 | 3.83 | 2.26 | 1.57 | 43.54 | .00 | 2.56 |
| 802 | 46 | 3.72 | 2.24 | 1.48 | 41.14 | .00 | 2.42 |
| 803 | 47 | 3.61 | 2.23 | 1.39 | 38.53 | .00 | 2.26 |
| 804 | 48 | 3.50 | 2.21 | 1.28 | 35.72 | .00 | 2.09 |
| 805 | 49 | 3.38 | 2.20 | 1.18 | 32.72 | .00 | 1.92 |
| 806 | 50 | 3.25 | 2.19 | 1.06 | 29.53 | .00 | 1.73 |
| 807 | 51 | 3.11 | 2.17 | .94 | 26.16 | .00 | 1.53 |
| 808 | 52 | 2.97 | 2.16 | .81 | 22.62 | .00 | 1.32 |
| 809 | 53 | 2.83 | 2.15 | .68 | 18.89 | .00 | 1.10 |
| 810 | 54 | 2.68 | 2.14 | .54 | 15.00 | .00 | .87 |
| 811 | 55 | 2.52 | 2.12 | .39 | 10.93 | .00 | .64 |
| 812 | 56 | 2.35 | 2.11 | .24 | 6.70 | .00 | .39 |
| 813 | 57 | 2.19 | 2.10 | .08 | 2.31 | .00 | .13 |
| 814 | 58 | 2.01 | 2.09 | -.08 | -2.24 | .00 | -.13 |
| 815 | 59 | 1.83 | 2.08 | -.25 | -6.95 | .00 | -.40 |
| 816 | 60 | 1.65 | 2.07 | -.43 | -11.82 | .00 | -.68 |
| 817 | 61 | 1.46 | 2.06 | -.61 | -16.84 | .00 | -.97 |
| 818 | 62 | 1.26 | 2.05 | -.79 | -22.02 | .00 | -1.27 |
| 819 | 63 | 1.06 | 2.04 | -.98 | -27.34 | .00 | -1.58 |
| 820 | 1 | 1.18 | 16.01 | -14.83 | -412.35 | .00 | -23.73 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 821 | 2 | 1.63 | 11.48 | -9.85 | -273.93 | .00 | -18.74 |
| 822 | 3 | 2.07 | 9.22 | -7.15 | -190.68 | .00 | -11.41 |
| 823 | 4 | 2.49 | 7.85 | -5.36 | -148.93 | .00 | -8.54 |
| 824 | 5 | 2.91 | 6.94 | -4.03 | -112.12 | .00 | -6.42 |
| 825 | 6 | 3.31 | 6.29 | -2.98 | -82.87 | .00 | -4.74 |
| 826 | 7 | 3.69 | 5.80 | -2.10 | -58.48 | .00 | -3.34 |
| 827 | 8 | 4.06 | 5.41 | -1.35 | -37.45 | .00 | -2.14 |
| 828 | 9 | 4.42 | 5.10 | -.68 | -18.90 | .00 | -1.08 |
| 829 | 10 | 4.77 | 4.85 | -.08 | -2.24 | .00 | -.13 |
| 830 | 11 | 5.10 | 4.64 | .46 | 12.90 | .00 | .73 |
| 831 | 12 | 5.42 | 3.90 | 1.52 | 42.23 | .00 | 2.40 |
| 832 | 13 | 5.73 | 3.75 | 1.98 | 55.03 | .00 | 3.12 |
| 833 | 14 | 6.02 | 3.61 | 2.41 | 66.90 | .00 | 3.79 |
| 834 | 15 | 6.30 | 3.49 | 2.80 | 77.95 | .00 | 4.41 |
| 835 | 16 | 6.56 | 3.39 | 3.17 | 88.26 | .00 | 4.99 |
| 836 | 17 | 6.81 | 3.29 | 3.52 | 97.89 | .00 | 5.53 |
| 837 | 18 | 7.05 | 3.21 | 3.84 | 106.88 | .00 | 6.03 |
| 838 | 19 | 7.28 | 3.13 | 4.15 | 115.28 | .00 | 6.50 |
| 839 | 20 | 7.49 | 3.06 | 4.43 | 123.11 | .00 | 6.93 |
| 840 | 21 | 7.69 | 3.00 | 4.69 | 130.41 | .00 | 7.33 |
| 841 | 22 | 7.87 | 2.94 | 4.93 | 137.19 | .00 | 7.71 |
| 842 | 23 | 8.05 | 2.89 | 5.16 | 143.47 | .00 | 8.05 |
| 843 | 24 | .00 | 2.84 | -2.84 | -78.83 | .00 | -4.42 |
| 844 | 25 | 1.37 | 2.79 | -1.42 | -39.53 | .00 | -2.21 |
| 845 | 26 | 2.64 | 2.75 | -.10 | -2.91 | .00 | -.16 |
| 846 | 27 | 3.30 | 2.71 | .60 | 16.65 | .00 | .93 |
| 847 | 28 | 3.70 | 2.67 | 1.03 | 28.71 | .00 | 1.60 |
| 848 | 29 | 3.96 | 2.63 | 1.32 | 36.77 | .00 | 2.05 |
| 849 | 30 | 4.13 | 2.60 | 1.53 | 42.43 | .00 | 2.36 |
| 850 | 31 | 4.24 | 2.57 | 1.67 | 46.50 | .00 | 2.59 |
| 851 | 32 | 4.32 | 2.54 | 1.78 | 49.43 | .00 | 2.75 |
| 852 | 33 | 4.36 | 2.51 | 1.85 | 51.52 | .00 | 2.86 |
| 853 | 34 | 4.39 | 2.48 | 1.90 | 52.93 | .00 | 2.93 |
| 854 | 35 | 4.39 | 2.46 | 1.94 | 53.80 | .00 | 2.98 |
| 855 | 36 | 4.38 | 2.43 | 1.95 | 54.20 | .00 | 3.00 |
| 856 | 37 | 4.36 | 2.41 | 1.95 | 54.20 | .00 | 2.99 |
| 857 | 38 | 4.33 | 2.39 | 1.94 | 53.84 | .00 | 2.97 |
| 858 | 39 | 4.28 | 2.37 | 1.91 | 53.17 | .00 | 2.93 |
| 859 | 40 | 4.23 | 2.35 | 1.88 | 52.20 | .00 | 2.87 |
| 860 | 41 | 4.16 | 2.33 | 1.83 | 50.95 | .00 | 2.80 |
| 861 | 42 | 4.09 | 2.31 | 1.78 | 49.45 | .00 | 2.72 |
| 862 | 43 | 4.01 | 2.29 | 1.72 | 47.71 | .00 | 2.62 |
| 863 | 44 | 3.92 | 2.28 | 1.65 | 45.73 | .00 | 2.51 |
| 864 | 45 | 3.83 | 2.26 | 1.57 | 43.54 | .00 | 2.38 |
| 865 | 46 | 3.72 | 2.24 | 1.48 | 41.14 | .00 | 2.25 |
| 866 | 47 | 3.61 | 2.23 | 1.39 | 38.53 | .00 | 2.11 |
| 867 | 48 | 3.50 | 2.21 | 1.28 | 35.72 | .00 | 1.95 |
| 868 | 49 | 3.38 | 2.20 | 1.18 | 32.72 | .00 | 1.78 |
| 869 | 50 | 3.25 | 2.19 | 1.06 | 29.53 | .00 | 1.61 |
| 870 | 51 | 3.11 | 2.17 | .94 | 26.16 | .00 | 1.42 |
| 871 | 52 | 2.97 | 2.16 | .81 | 22.62 | .00 | 1.23 |
| 872 | 53 | 2.83 | 2.15 | .68 | 18.89 | .00 | 1.03 |
| 873 | 54 | 2.68 | 2.14 | .54 | 15.00 | .00 | .81 |
| 874 | 55 | 2.52 | 2.12 | .39 | 10.93 | .00 | .59 |
| 875 | 56 | 2.35 | 2.11 | .24 | 6.70 | .00 | .36 |
| 876 | 57 | 2.19 | 2.10 | .08 | 2.31 | .00 | .12 |
| 877 | 58 | 2.01 | 2.09 | -.08 | -2.24 | .00 | -.12 |
| 878 | 59 | 1.83 | 2.08 | -.25 | -6.95 | .00 | -.38 |
| 879 | 60 | 1.65 | 2.07 | -.43 | -11.82 | .00 | -.64 |
| 880 | 61 | 1.46 | 2.06 | -.61 | -16.84 | .00 | -.91 |
| 881 | 62 | 1.26 | 2.05 | -.79 | -22.02 | .00 | -1.18 |
| 882 | 63 | 1.06 | 2.04 | -.98 | -27.34 | .00 | -1.47 |
| 883 | 1 | 1.10 | 16.01 | -14.83 | -412.35 | .00 | -22.12 |
| 884 | 2 | 1.63 | 11.48 | -9.85 | -273.93 | .00 | -14.60 |
| 885 | 3 | 2.07 | 9.22 | -7.15 | -190.68 | .00 | -10.64 |
| 886 | 4 | 2.49 | 7.85 | -5.36 | -148.93 | .00 | -7.96 |
| 887 | 5 | 2.91 | 6.94 | -4.03 | -112.12 | .00 | -5.99 |
| 888 | 6 | 3.31 | 6.29 | -2.98 | -82.87 | .00 | -4.42 |
| 889 | 7 | 3.69 | 5.80 | -2.10 | -58.48 | .00 | -3.12 |
| 890 | 8 | 4.06 | 5.41 | -1.35 | -37.45 | .00 | -1.99 |
| 891 | 9 | 4.42 | 5.10 | -.68 | -18.90 | .00 | -1.01 |
| 892 | 10 | 4.77 | 4.85 | -.08 | -2.24 | .00 | -.12 |
| 893 | 11 | 5.10 | 4.64 | .46 | 12.90 | .00 | .68 |
| 894 | 12 | 5.42 | 3.90 | 1.52 | 42.23 | .00 | 2.24 |
| 895 | 13 | 5.73 | 3.75 | 1.98 | 55.03 | .00 | 2.91 |
| 896 | 14 | 6.02 | 3.61 | 2.41 | 66.90 | .00 | 3.54 |
| 897 | 15 | 6.30 | 3.49 | 2.80 | 77.95 | .00 | 4.12 |
| 898 | 16 | 6.56 | 3.39 | 3.17 | 88.26 | .00 | 4.66 |
| 899 | 17 | 6.81 | 3.29 | 3.52 | 97.89 | .00 | 5.16 |
| 900 | 18 | 7.05 | 3.21 | 3.84 | 106.88 | .00 | 5.63 |
| 901 | 19 | 7.28 | 3.13 | 4.15 | 115.28 | .00 | 6.07 |
| 902 | 20 | 7.49 | 3.06 | 4.43 | 123.11 | .00 | 6.47 |
| 903 | 21 | 7.69 | 3.00 | 4.69 | 130.41 | .00 | 6.85 |
| 904 | 22 | 7.87 | 2.94 | 4.93 | 137.19 | .00 | 7.20 |
| 905 | 23 | 8.05 | 2.89 | 5.16 | 143.47 | .00 | 7.52 |
| 906 | 24 | .00 | 2.84 | -2.84 | -78.83 | .00 | -4.13 |
| 907 | 25 | 1.37 | 2.79 | -1.42 | -39.53 | .00 | -2.07 |
| 908 | 26 | 2.64 | 2.75 | -.10 | -2.91 | .00 | -.15 |
| 909 | 27 | 3.30 | 2.71 | .60 | 16.65 | .00 | .87 |
| 910 | 28 | 3.70 | 2.67 | 1.03 | 28.71 | .00 | 1.50 |
| 911 | 29 | 3.96 | 2.63 | 1.32 | 36.77 | .00 | 1.92 |
| 912 | 30 | 4.13 | 2.60 | 1.53 | 42.43 | .00 | 2.21 |
| 913 | 31 | 4.24 | 2.57 | 1.67 | 46.50 | .00 | 2.42 |
| 914 | 32 | 4.32 | 2.54 | 1.78 | 49.43 | .00 | 2.57 |
| 915 | 33 | 4.36 | 2.51 | 1.85 | 51.52 | .00 | 2.67 |
| 916 | 34 | 4.39 | 2.48 | 1.90 | 52.93 | .00 | 2.74 |
| 917 | 35 | 4.39 | 2.46 | 1.94 | 53.80 | .00 | 2.78 |
| 918 | 36 | 4.38 | 2.43 | 1.95 | 54.20 | .00 | 2.80 |
| 919 | 37 | 4.36 | 2.41 | 1.95 | 54.20 | .00 | 2.80 |
| 920 | 38 | 4.33 | 2.39 | 1.94 | 53.84 | .00 | 2.78 |
| 921 | 39 | 4.28 | 2.37 | 1.91 | 53.17 | .00 | 2.74 |
| 922 | 40 | 4.23 | 2.35 | 1.88 | 52.20 | .00 | 2.69 |
| 923 | 41 | 4.16 | 2.33 | 1.83 | 50.95 | .00 | 2.62 |
| 924 | 42 | 4.09 | 2.31 | 1.78 | 49.45 | .00 | 2.54 |
| 925 | 43 | 4.01 | 2.29 | 1.72 | 47.71 | .00 | 2.45 |
| 926 | 44 | 3.92 | 2.28 | 1.65 | 45.73 | .00 | 2.35 |
| 927 | 45 | 3.83 | 2.26 | 1.57 | 43.54 | .00 | 2.23 |
| 928 | 46 | 3.72 | 2.24 | 1.48 | 41.14 | .00 | 2.11 |
| 929 | 47 | 3.61 | 2.23 | 1.39 | 38.53 | .00 | 1.97 |
| 930 | 48 | 3.50 | 2.21 | 1.28 | 35.72 | .00 | 1.82 |
| 931 | 49 | 3.38 | 2.20 | 1.18 | 32.72 | .00 | 1.67 |
| 932 | 50 | 3.25 | 2.19 | 1.06 | 29.53 | .00 | 1.51 |
| 933 | 51 | 3.11 | 2.17 | .94 | 26.16 | .00 | 1.33 |
| 934 | 52 | 2.97 | 2.16 | .81 | 22.62 | .00 | 1.15 |
| 935 | 53 | 2.83 | 2.15 | .68 | 18.89 | .00 | .96 |
| 936 | 54 | 2.68 | 2.14 | .54 | 15.00 | .00 | .76 |
| 937 | 55 | 2.52 | 2.12 | .39 | 10.93 | .00 | .55 |
| 938 | 56 | 2.35 | 2.11 | .24 | 6.70 | .00 | .34 |
| 939 | 57 | 2.19 | 2.10 | .08 | 2.31 | .00 | .12 |
| 940 | 58 | 2.01 | 2.09 | -.08 | -2.24 | .00 | -.11 |
| 941 | 59 | 1.83 | 2.08 | -.25 | -6.95 | .00 | -.35 |
| 942 | 60 | 1.65 | 2.07 | -.43 | -11.82 | .00 | -.60 |
| 943 | 61 | 1.46 | 2.06 | -.61 | -16.84 | .00 | -.85 |
| 944 | 62 | 1.26 | 2.05 | -.79 | -22.02 | .00 | -1.11 |
| 945 | 63 | 1.06 | 2.04 | -.98 | -27.34 | .00 | -1.38 |
| 946 | 1 | 1.10 | 16.01 | -14.83 | -412.35 | .00 | -20.72 |
| 947 | 2 | 1.63 | 11.48 | -9.85 | -273.93 | .00 | -13.75 |
| 948 | 3 | 2.07 | 9.22 | -7.15 | -190.68 | .00 | -9.96 |
| 949 | 4 | 2.49 | 7.85 | -5.36 | -148.93 | .00 | -7.46 |
| 950 | 5 | 2.91 | 6.94 | -4.03 | -112.12 | .00 | -5.61 |
| 951 | 6 | 3.31 | 6.29 | -2.98 | -82.87 | .00 | -4.14 |
| 952 | 7 | 3.69 | 5.80 | -2.10 | -58.48 | .00 | -2.92 |
| 953 | 8 | 4.06 | 5.41 | -1.35 | -37.45 | .00 | -1.87 |
| 954 | 9 | 4.42 | 5.10 | -.68 | -18.90 | .00 | -.94 |
| 955 | 10 | 4.77 | 4.85 | -.08 | -2.24 | .00 | -.11 |
| 956 | 11 | 5.10 | 4.64 | .46 | 12.90 | .00 | .64 |
| 957 | 12 | 5.42 | 3.90 | 1.52 | 42.23 | .00 | 2.10 |
| 958 | 13 | 5.73 | 3.75 | 1.98 | 55.03 | .00 | 2.73 |
| 959 | 14 | 6.02 | 3.61 | 2.41 | 66.90 | .00 | 3.32 |
| 960 | 15 | 6.30 | 3.49 | 2.80 | 77.95 | .00 | 3.86 |
| 961 | 16 | 6.56 | 3.39 | 3.17 | 88.26 | .00 | 4.37 |
| 962 | 17 | 6.81 | 3.29 | 3.52 | 97.89 | .00 | 4.84 |
| 963 | 18 | 7.05 | 3.21 | 3.84 | 106.88 | .00 | 5.28 |
| 964 | 19 | 7.28 | 3.13 | 4.15 | 115.28 | .00 | 5.69 |
| 965 | 20 | 7.49 | 3.06 | 4.43 | 123.11 | .00 | 6.07 |
| 966 | 21 | 7.69 | 3.00 | 4.69 | 130.41 | .00 | 6.42 |
| 967 | 22 | 7.87 | 2.94 | 4.93 | 137.19 | .00 | 6.75 |
| 968 | 23 | 8.05 | 2.89 | 5.16 | 143.47 | .00 | 7.05 |
| 969 | 24 | .00 | 2.84 | -2.84 | -78.83 | .00 | -3.87 |
| 970 | 25 | 1.37 | 2.79 | -1.42 | -39.53 | .00 | -1.94 |
| 971 | 26 | 2.64 | 2.75 | -.10 | -2.91 | .00 | -.14 |
| 972 | 27 | 3.30 | 2.71 | .60 | 16.65 | .00 | .82 |
| 973 | 28 | 3.70 | 2.67 | 1.03 | 28.71 | .00 | 1.40 |
| 974 | 29 | 3.96 | 2.63 | 1.32 | 36.77 | .00 | 1.80 |
| 975 | 30 | 4.13 | 2.60 | 1.53 | 42.43 | .00 | 2.07 |
| 976 | 31 | 4.24 | 2.57 | 1.67 | 46.50 | .00 | 2.27 |
| 977 | 32 | 4.32 | 2.54 | 1.78 | 49.43 | .00 | 2.41 |
| 978 | 33 | 4.36 | 2.51 | 1.85 | 51.52 | .00 | 2.51 |
| 979 | 34 | 4.39 | 2.48 | 1.90 | 52.93 | .00 | 2.57 |
| 980 | 35 | 4.39 | 2.46 | 1.94 | 53.80 | .00 | 2.61 |
| 981 | 36 | 4.38 | 2.43 | 1.95 | 54.20 | .00 | 2.63 |
| 982 | 37 | 4.36 | 2.41 | 1.95 | 54.20 | .00 | 2.63 |
| 983 | 38 | 4.33 | 2.39 | 1.94 | 53.84 | .00 | 2.61 |
| 984 | 39 | 4.28 | 2.37 | 1.91 | 53.17 | .00 | 2.57 |
| 985 | 40 | 4.23 | 2.35 | 1.88 | 52.20 | .00 | 2.52 |
| 986 | 41 | 4.16 | 2.33 | 1.83 | 50.95 | .00 | 2.46 |
| 987 | 42 | 4.09 | 2.31 | 1.78 | 49.45 | .00 | 2.39 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 988 | 43 | 4.01 | 2.29 | 1.78 | 47.71 | .00 | 2.30 |
| 989 | 44 | 3.92 | 2.28 | 1.65 | 45.73 | .00 | 2.20 |
| 990 | 45 | 3.83 | 2.26 | 1.57 | 43.54 | .00 | 2.10 |
| 991 | 46 | 3.72 | 2.24 | 1.48 | 41.14 | .00 | 1.98 |
| 992 | 47 | 3.61 | 2.23 | 1.39 | 38.53 | .00 | 1.85 |
| 993 | 48 | 3.50 | 2.21 | 1.28 | 35.72 | .00 | 1.71 |
| 994 | 49 | 3.38 | 2.20 | 1.18 | 32.72 | .00 | 1.57 |
| 995 | 50 | 3.25 | 2.19 | 1.06 | 29.53 | .00 | 1.41 |
| 996 | 51 | 3.11 | 2.17 | .94 | 26.16 | .00 | 1.25 |
| 997 | 52 | 2.97 | 2.16 | .81 | 22.62 | .00 | 1.08 |
| 998 | 53 | 2.83 | 2.15 | .68 | 18.89 | .00 | .90 |
| 999 | 54 | 2.68 | 2.14 | .54 | 15.00 | .00 | .72 |
| 1000 | 55 | 2.52 | 2.12 | .39 | 10.93 | .00 | .52 |

*Printed Output:*

Our programme also sums columns 7 and 8 to give our exponential and hyperbolic net present value sums. This is calculated both for the first rotation and for the full period (effectively for a perpetual series of rotations) from which annuity equivalents are also calculated. Table A6.12 details the output generated for the above example. All values are in £/ha.

Table A6.12: Output generated by carbon flux valuation program: Species = Sitka spruce; discount rate = 2%; yield class = 26

| | DISCOUNTING OPTION | |
|---|---|---|
| MEASURE | EXPONENTIAL | HYPERBOLIC |
| NPV FIRST | 3651.992 | 4082.724 |
| NPV PERP | 4150.216 | 6521.632 |
| ANNUITY | 83.00432 | 136.9543 |

ANOTHER SCENARIO ? (1=YES,2=NO)

Notes:

NPV FIRST = net present value of the first optimal rotation
NPV PERP = net present value of a perpetual series of optimal rotations
ANNUITY = annuity equivalent of NPV PERP
EXPONENTIAL = discounting using exponential discount factors
HYPERBOLIC = discounting using hyperbolic discount factors

## APPENDIX 6.2.3: CARBON FLUX VALUATION: RESULTS

Tables A6.13 to A6.18 detail calculated net carbon storage values estimated from the program detailed above. For each species three sets of results are given:

1. Net present value of net carbon storage over the first optimal rotation;
2. Net present value of net carbon storage over a perpetual series of optimal rotations;
3. Annuity equivalent of the net present value of net carbon storage over a perpetual series of optimal rotations.

In each case results are reported over the full range of discount rates and yield classes considered. Generally results are as expected, however, note that as a result of the initial carbon liberation being delayed until the first felling date and the relationship between discount rate and that felling date, so the annuity value initially rises and then falls with increases in the discount rate. This is not the case with the NPV values which are less affected by this interaction, being dominated by first rotation carbon sequestration benefits such that these values consistently fall as the discount rate rises.

Table A6.13: NPV of net carbon flux (sequestration in live wood and liberation from products and waste) for an optimal rotation of conifer (Sitka spruce). Excludes all other externalities. Various yield classes and exponential and hyperbolic discount rates. Social values (£; 1990 prices).

| r | YC4 | YC6 | YC8 | YC10 | YC12 | YC14 | YC16 | YC18 | YC20 | YC22 | YC24 | YC26 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.5% | 811.35 | 1165.67 | 1491.21 | 1815.01 | 2121.71 | 2414.74 | 2692.33 | 3001.75 | 3307.78 | 3608.75 | 3901.60 | 4228.45 |
| 2% | 698.90 | 1006.52 | 1289.94 | 1570.32 | 1837.16 | 2089.14 | 2364.22 | 2634.23 | 2897.09 | 3151.26 | 3404.42 | 3651.99 |
| 3% | 535.89 | 773.87 | 1005.20 | 1208.46 | 1415.17 | 1629.19 | 1815.88 | 2014.91 | 2198.56 | 2390.57 | 2566.79 | 2780.69 |
| 5% | 342.45 | 495.55 | 643.20 | 784.73 | 916.29 | 1035.33 | 1160.39 | 1277.68 | 1393.39 | 1503.10 | 1625.63 | 1761.10 |
| 6% | 283.89 | 411.26 | 534.92 | 652.61 | 761.24 | 859.49 | 963.10 | 1060.26 | 1155.64 | 1253.36 | 1367.30 | 1465.69 |
| 6% hyp. | 439.77 | 636.77 | 825.37 | 1002.61 | 1161.13 | 1298.09 | 1441.40 | 1570.43 | 1704.97 | 1840.84 | 2008.19 | 2159.83 |

Table A6.14: NPV of net carbon flux (sequestration in live wood and liberation from products and waste) for a perpetual series of optimal rotations of conifer (Sitka spruce). Excludes all other externalities. Various yield classes and exponential and hyperbolic discount rates. Social values (£; 1990 prices).

| r | YC4 | YC6 | YC8 | YC10 | YC12 | YC14 | YC16 | YC18 | YC20 | YC22 | YC24 | YC26 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.5% | 908.24 | 1322.02 | 1710.11 | 2105.58 | 2483.87 | 2844.14 | 3202.14 | 3579.62 | 3970.37 | 4326.81 | 4691.98 | 5064.37 |
| 2% | 752.00 | 1093.95 | 1414.15 | 1733.30 | 2047.75 | 2339.96 | 2664.11 | 2981.98 | 3288.42 | 3587.49 | 3872.30 | 4150.21 |
| 3% | 553.71 | 803.46 | 1049.10 | 1268.30 | 1492.01 | 1728.11 | 1934.21 | 2151.26 | 2361.28 | 2565.82 | 2763.05 | 2993.30 |
| 5% | 344.37 | 499.12 | 648.95 | 798.19 | 928.50 | 1052.77 | 1183.56 | 1308.07 | 1429.33 | 1545.17 | 1670.15 | 1809.33 |
| 6% | 284.33 | 412.13 | 536.51 | 655.23 | 765.48 | 866.25 | 972.75 | 1073.79 | 1172.08 | 1273.14 | 1388.88 | 1488.17 |
| 6% hyp. | 582.23 | 865.55 | 1145.44 | 1410.58 | 1666.69 | 1906.80 | 2165.76 | 2401.15 | 2620.14 | 2863.86 | 3124.22 | 3357.21 |

Table A6.15: Annuity value of net carbon flux (sequestration in live wood and liberation from products and waste) for a perpetual series of optimal rotations of conifer (Sitka spruce). Excludes all other externalities. Various yield classes and exponential and hyperbolic discount rates. Social values (£; 1990 prices).

| r | YC4 | YC6 | YC8 | YC10 | YC12 | YC14 | YC16 | YC18 | YC20 | YC22 | YC24 | YC26 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.5% | 13.62 | 19.83 | 25.65 | 31.58 | 37.26 | 42.66 | 48.03 | 53.69 | 59.56 | 64.90 | 70.38 | 75.97 |
| 2% | 15.04 | 21.88 | 28.28 | 34.67 | 40.95 | 46.80 | 53.24 | 59.64 | 65.77 | 71.75 | 77.45 | 83.00 |
| 3% | 16.61 | 24.10 | 31.47 | 38.05 | 44.76 | 51.84 | 58.03 | 64.54 | 70.84 | 76.97 | 82.89 | 89.80 |
| 5% | 17.22 | 24.96 | 32.45 | 39.66 | 46.42 | 52.64 | 59.18 | 65.40 | 71.47 | 77.26 | 83.51 | 90.47 |
| 6% | 17.06 | 24.73 | 32.19 | 39.31 | 45.93 | 51.97 | 58.37 | 64.43 | 70.32 | 76.39 | 83.33 | 89.29 |
| 6% hyp. | 35.52 | 52.80 | 69.87 | 86.05 | 101.67 | 116.31 | 132.11 | 146.47 | 159.83 | 174.70 | 190.58 | 204.79 |

Table A6.16: NPV of net carbon flux (sequestration in live wood and liberation from products and waste) for an optimal rotation of broadleaf (beech). Excludes all other externalities. Various yield classes and exponential and hyperbolic discount rates. Social values (£; 1990 prices).

| r | YC2 | YC4 | YC6 | YC8 | YC10 | YC12 |
|---|---|---|---|---|---|---|
| 1.5% | 886.40 | 1672.79 | 2400.93 | 3058.98 | 3690.33 | 4325.52 |
| 2% | 706.48 | 1331.65 | 1888.62 | 2420.52 | 2941.13 | 3437.46 |
| 3% | 466.41 | 875.00 | 1245.67 | 1606.50 | 1923.83 | 2261.71 |
| 5% | 241.62 | 454.12 | 648.64 | 829.58 | 1003.34 | 1178.15 |
| 6% | 186.28 | 348.89 | 496.74 | 638.08 | 775.31 | 907.36 |
| 6% hyp | 371.64 | 665.73 | 914.48 | 1156.26 | 1390.22 | 1639.89 |

Table A6.17: NPV of net carbon flux (sequestration in live wood and liberation from products and waste) for a perpetual series of optimal rotations of broadleaf (beech). Excludes all other externalities. Various yield classes and exponential and hyperbolic discount rates. Social values (£; 1990 prices).

| r | YC2 | YC4 | YC6 | YC8 | YC10 | YC12 |
|---|---|---|---|---|---|---|
| 1.5% | 903.10 | 1699.57 | 2443.52 | 3116.08 | 3758.41 | 4395.11 |
| 2% | 706.81 | 1332.99 | 1891.75 | 2426.07 | 2946.26 | 3439.22 |
| 3% | 463.31 | 868.72 | 1236.59 | 1594.74 | 1908.69 | 2242.48 |
| 5% | 240.17 | 450.90 | 643.70 | 823.09 | 995.23 | 1168.08 |
| 6% | 185.33 | 346.71 | 493.37 | 633.63 | 769.88 | 900.59 |
| 6% hyp | 475.03 | 884.11 | 1254.05 | 1608.58 | 1958.50 | 2317.71 |

Table A6.18: Annuity value of net carbon flux (sequestration in live wood and liberation from products and waste) for a perpetual series of optimal rotations of broadleaf (beech). Excludes all other externalities. Various yield classes and hyperbolic discount rates. Social values (£; 1990 prices).

| r | YC2 | YC4 | YC6 | YC8 | YC10 | YC12 |
|---|---|---|---|---|---|---|
| 1.5% | 13.54 | 25.49 | 36.65 | 46.74 | 56.38 | 65.93 |
| 2% | 14.31 | 26.66 | 37.84 | 48.52 | 58.93 | 68.78 |
| 3% | 13.90 | 26.06 | 37.10 | 47.84 | 57.26 | 67.27 |
| 5% | 12.01 | 22.55 | 32.19 | 41.15 | 46.76 | 58.40 |
| 6% | 11.12 | 20.80 | 29.60 | 38.02 | 46.19 | 54.04 |
| 6% hyp | 28.98 | 53.93 | 76.50 | 98.12 | 119.90 | 141.38 |

## APPENDIX 6.2.4: EQUATIONS FOR MAPPING CARBON FLUX VALUES

As discussed in Chapter 8, for both Sitka spruce and beech species, a series of linear regression equations were estimated linking, for each discount rate, the carbon sequestration value to the yield class. These were estimated for both first optimal rotation net present values and for the annuity equivalent of a perpetual series of optimal rotations. the data for these regressions was taken from tables A6.13 to A6.18 above. The net present value and annuity equivalent equations are detailed in tables A6.19 and A6.20 for Sitka spruce, and in tables A6.21 and A6.22 for beech.

Table A6.19: NPV of carbon in live wood, waste and products from an optimal rotation of Sitka spruce: linear predictive equations with YC as the single explanatory variable (various discount rates).

| Discount rate | Intercept (t-value) | Slope (t-value) | $R^2$ (adj) |
|---|---|---|---|
| 1.5% | 254.32<br>(14.62) | 152.825<br>(145.11) | 99.9 |
| 3% | 187.70<br>(9.90) | 100.460<br>(87.48) | 99.9 |
| 6% | 106.77<br>(9.06) | 52.7081<br>(73.89) | 99.8 |
| 6% hyperbolic | 206.48<br>(8.47) | 75.620<br>(51.24) | 99.6 |

Table A6.20: Carbon flux (in live wood, waste and products) annuity equivalent of a perpetual series of optimal rotation of Sitka spruce: linear predictive equations with YC as the single explanatory variable (various discount rates).

| Discount rate | Intercept (t-value) | Slope (t-value) | $R^2$ (adj) |
|---|---|---|---|
| 1.5% | 3.0377<br>(13.63) | 2.81488<br>(208.53) | 100.0 |
| 3% | 4.8005<br>(9.62) | 3.29052<br>(108.93) | 99.9 |
| 6% | 5.9487<br>(9.45) | 3.23231<br>(84.74) | 99.8 |
| 6% hyperbolic | 8.356<br>(6.96) | 7.61346<br>(104.71) | 99.9 |

Table A6.21: NPV of carbon in live wood, waste and products from an optimal rotation of beech: linear predictive equations with YC as the single explanatory variable (various discount rates).

| Discount rate | Intercept (t-value) | Slope (t-value) | $R^2$ (adj) |
|---|---|---|---|
| 1.5% | 281.86<br>(4.68) | 341.518<br>(44.20) | 99.7 |
| 3% | 148.14<br>(4.92) | 178.340<br>(46.18) | 99.8 |
| 6% | 56.18<br>(5.54) | 71.800<br>(55.19) | 99.8 |
| 6% hyperbolic | 147.39<br>(8.25) | 125.093<br>(54.51) | 99.8 |

Table A6.22: Carbon flux (in live wood, waste and products) annuity equivalent of a perpetual series of optimal rotation of beech: linear predictive equations with YC as the single explanatory variable (various discount rates).

| Discount rate | Intercept (t-value) | Slope (t-value) | $R^2$ (adj) |
|---|---|---|---|
| 1.5% | 4.3173<br>(4.60) | 5.2101<br>(43.21) | 99.7 |
| 3% | 4.4527<br>(4.89) | 5.3027<br>(45.31) | 99.8 |
| 6% | 3.3760<br>(5.58) | 4.27414<br>(55.02) | 99.8 |
| 6% hyperbolic | 8.315<br>(7.18) | 11.1647<br>(75.10) | 99.9 |

## APPENDIX 6.2.5: CARBON FLUX VALUE IMAGES: NET STORAGE IN LIVE WOOD, PRODUCTS AND WASTE

Tables A6.23 and A6.24 respectively detail NPV and annuity values for net carbon flux from live wood, products and waste (note that this does not include soil carbon values) for Sitka spruce plantations. Tables A6.25 and A6.26 repeat this analysis for beech plantations. All values are in £/ha at 1990 prices.

Table A6.23: NPV values for Sitka spruce carbon flux for live wood, waste and products (various discount rates).

| NPV (£/ha) | Discount rate | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1% (SS1cNPV) | | 3% (SS3cNPV) | | 6% (SS6cNPV) | | 6% hyp (SS6HcNPV) | |
| | Freq[1] | % | Freq | % | Freq | % | Freq | % |
| 250-499 | - | - | - | - | 1 | 0.005 | - | - |
| 500-749 | - | - | - | - | 228 | 1.109 | 1 | 0.005 |
| 750-999 | - | - | 5 | 0.024 | 8042 | 39.109 | 53 | 0.258 |
| 1000-1249 | - | - | 50 | 0.243 | 12292 | 59.777 | 1403 | 6.823 |
| 1250-1499 | 5 | 0.024 | 624 | 3.035 | - | - | 7409 | 36.031 |
| 1500-1749 | 27 | 0.131 | 3621 | 17.609 | - | - | 11697 | 56.884 |
| 1750-1999 | 71 | 0.345 | 8648 | 42.056 | - | - | - | - |
| 2000-2249 | 571 | 2.777 | 7615 | 37.033 | - | - | - | - |
| 2250-2749 | 2036 | 9.901 | - | - | - | - | - | - |
| 2500-2749 | 3561 | 17.318 | - | - | - | - | - | - |
| 2750-2999 | 6371 | 30.983 | - | - | - | - | - | - |
| 3000-3249 | 7643 | 37.169 | - | - | - | - | - | - |
| 3250-3499 | 278 | 1.352 | - | - | - | - | - | - |
| Mean | 2859.75 | | 1900.39 | | 1005.36 | | 1495.68 | |
| s.d. | 384.82 | | 319.28 | | 266.81 | | 293.42 | |

Notes: 1. From a total of 20563 1km² land cells
hyp = hyperbolic discounting (otherwise exponential)
Items in brackets are image filenames.

Table A6.24: Annuity values for Sitka spruce carbon flux for live wood, waste and products (various discount rates)

| Annuity value (£) | Discount rate 1% (SS1cANN) | | 3% (SS3cANN) | | 6% (SS6cANN) | | 6% hyp (SS6HcANN) | |
|---|---|---|---|---|---|---|---|---|
| | Freq[1] | % | Freq | % | Freq | % | Freq | % |
| 20-29 | 31 | 0.151 | 1 | 0.005 | 1 | 0.005 | - | - |
| 30-39 | 706 | 3.433 | 55 | 0.267 | 54 | 0.263 | - | - |
| 40-49 | 6679 | 32.481 | 1315 | 6.395 | 1185 | 5.763 | - | - |
| 50-59 | 13147 | 63.935 | 6344 | 30.852 | 6291 | 30.594 | - | - |
| 60-69 | - | - | 12761 | 62.058 | 12946 | 62.958 | 5 | 0.024 |
| 70-79 | - | - | 87 | 0.423 | 86 | 0.418 | 22 | 0.107 |
| 80-89 | - | - | - | - | - | - | 34 | 0.165 |
| 90-99 | - | - | - | - | - | - | 134 | 0.652 |
| 100-109 | - | - | - | - | - | - | 754 | 3.667 |
| 110-119 | - | - | - | - | - | - | 1715 | 8.340 |
| 120-129 | - | - | - | - | - | - | 2594 | 12.615 |
| 130-139 | - | - | - | - | - | - | 4421 | 21.500 |
| 140-149 | - | - | - | - | - | - | 6067 | 29.504 |
| 150-159 | - | - | - | - | - | - | 4791 | 23.300 |
| 160-169 | - | - | - | - | - | - | 26 | 0.126 |
| Mean | 51.03 | | 60.90 | | 61.05 | | 138.15 | |
| s.d. | 11.48 | | 12.09 | | 12.03 | | 17.65 | |

Notes: 1. From a total of 20563 $1km^2$ land cells.
hyp = hyperbolic discounting (otherwise exponential)
Items in brackets are image filenames.

Table A6.25: NPV values for beech carbon flux for live wood, waste and products (various discount rates)

| NPV (£/ha) | Discount rate 1% (BE1cNPV) | | 3% (BE3cNPV) | | 6% (BE6cNPV) | | 6% hyp (BE6HcNPV) | |
|---|---|---|---|---|---|---|---|---|
| | Freq[1] | % | Freq | % | Freq | % | Freq | % |
| 250-499 | - | - | - | - | 161 | 0.783 | - | - |
| 500-749 | - | - | - | - | 20402 | 99.217 | - | - |
| 750-999 | - | - | - | - | - | - | 1493 | 7.261 |
| 1000-1249 | - | - | 159 | 0.773 | - | - | 19070 | 92.739 |
| 1250-1499 | - | - | 7809 | 37.976 | - | - | - | - |
| 1500-1749 | - | - | 12595 | 61.251 | - | - | - | - |
| 1750-1999 | 1 | 0.005 | - | - | - | - | - | - |
| 2000-2249 | 41 | 0.200 | - | - | - | - | - | - |
| 2250-2499 | 387 | 1.882 | - | - | - | - | - | - |
| 2500-2749 | 4057 | 19.730 | - | - | - | - | - | - |
| 2750-2999 | 8457 | 41.127 | - | - | - | - | - | - |
| 3000-3249 | 7620 | 37.057 | - | - | - | - | - | - |
| Mean | 2907.06 | | 1518.99 | | 608.08 | | 1108.96 | |
| s.d. | 320.42 | | 273.61 | | 236.07 | | 260.33 | |

Notes: 1. From a total of 20563 $1km^2$ land cells.
hyp = hyperbolic discounting (otherwise exponential)
Items in brackets are image filenames.

Table A6.26: Annuity values for beech carbon flux for live wood, waste and products (various discount rates)

| Annuity value (£) | Discount rate | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1% (BE1cANN) | | 3% (BE3cANN) | | 6% (BE6cANN) | | 6% hyp (BE6HcANN) | |
| | Freq[1] | % | Freq | % | Freq | % | Freq | % |
| 20-29 | 1 | 0.005 | - | - | 199 | 0.968 | - | - |
| 30-39 | 1633 | 7.941 | 1126 | 5.476 | 20364 | 99.032 | - | - |
| 40-49 | 18929 | 92.054 | 19437 | 94.524 | - | - | - | - |
| 50-59 | - | - | - | - | - | - | - | - |
| 60-69 | - | - | - | - | - | - | 18 | 0.086 |
| 70-79 | - | - | - | - | - | - | 317 | 1.542 |
| 80-89 | - | - | - | - | - | - | 4801 | 23.348 |
| 90-99 | - | - | - | - | - | - | 10996 | 53.475 |
| 100-109 | - | - | - | - | - | - | 4431 | 21.548 |
| Mean | 44.37 | | 45.21 | | 36.23 | | 94.14 | |
| s.d. | 10.52 | | 11.00 | | 11.37 | | 12.03 | |

Notes: 1. From a total of 20563 $1km^2$ land cells.
hyp = hyperbolic discounting (otherwise exponential)
Items in brackets are image filenames.

## APPENDIX 6.2.6: CARBON FLUX VALUE IMAGES: TOTAL NET STORAGE (LIVE WOOD, PRODUCTS, WASTE AND SOIL)

Tables A6.27 and A6.28 respectively detail NPV and annuity values for net carbon flux from live wood, products, waste and soils for Sitka spruce plantations. Tables A6.29 and A6.30 repeat this analysis for beech plantations. All values are in £/ha at 1990 prices.

Table A6.27: Frequency table: NPV sums for net carbon flux (live wood, waste, products and soils): Sitka spruce (£/ha, 1990)

| | Discount rate | | | |
|---|---|---|---|---|
| NPV (£/ha) | 1% (SS1xNPV) | 3% (SS3xNPV) | 6% (SS6xNPV) | 6% hyp (SS6HxNPV) |
| -9500:-9001 | 33 | - | - | - |
| -9000:-8501 | 438 | - | - | - |
| -8500:-8001 | 5 | - | - | - |
| -8000:-7501 | 13 | 177 | - | 356 |
| -7500:-7001 | - | 298 | - | 133 |
| -7000:-6501 | - | 14 | - | - |
| -6500:-6001 | - | - | 489 | - |
| 500:999 | - | - | 3 | - |
| 1000:1499 | - | 1 | 9650 | 25 |
| 1500:1999 | - | 181 | 10421 | 4772 |
| 2000:2499 | 32 | 7907 | - | 15277 |
| 2500:2999 | 538 | 11985 | - | - |
| 3000:3499 | 5349 | - | - | - |
| 3500:3999 | 13933 | - | - | - |
| 4000:4499 | 222 | - | - | - |

Table A6.28: Frequency table: NPV sums for net carbon flux (live wood, waste, products and soils): Beech (£/ha, 1990)

| | Discount rate | | | |
|---|---|---|---|---|
| NPV (£/ha) | 1% (BE1xNPV) | 3% (BE3xNPV) | 6% (BE6xNPV) | 6% hyp (BE6HxNPV) |
| -9000:-8501 | 296 | - | - | - |
| -8500:-8001 | 180 | - | - | - |
| -8000:-7501 | 13 | 470 | - | 489 |
| -7500:-7001 | - | 19 | - | - |
| -7000:-6501 | - | - | 475 | - |
| -6500:-6001 | - | - | 14 | - |
| 500:999 | - | - | 407 | - |
| 1000:1499 | - | - | 19667 | 140 |
| 1500:1999 | - | 2716 | - | 19934 |
| 2000:2499 | - | 17358 | - | - |
| 2500:2999 | 47 | - | - | - |
| 3000:3499 | 4136 | - | - | - |
| 3500:3999 | 15891 | - | - | - |

Table A6.29: Frequency table: annuity sums for net carbon flux (live wood, waste, products and soils): Sitka spruce (£/ha, 1990)

| Annuity (£/ha) | Discount rate 1% (SS1xANN) | 3% (SS3xANN) | 6% (SS6xANN) | 6% hyp (SS6HxANN) |
|---|---|---|---|---|
| -450:-441 | - | - | - | 5 |
| -440:-431 | - | - | - | 64 |
| -430:-421 | - | - | - | 275 |
| -420:-411 | - | - | - | 122 |
| -410:-401 | - | - | - | 9 |
| -400:-391 | - | - | - | - |
| -390:-381 | - | - | 162 | 14 |
| -380:-371 | - | - | 312 | - |
| -370:-361 | - | - | 15 | - |
| -230:-221 | - | 306 | - | - |
| -220:-211 | - | 169 | - | - |
| -210:-201 | - | 14 | - | - |
| -140:-131 | 19 | - | - | - |
| -130:-121 | 452 | - | - | - |
| -120:-111 | 18 | - | - | - |
| 30:39 | 21 | - | - | - |
| 40:49 | 360 | 7 | - | - |
| 50:59 | 5251 | 80 | 3 | - |
| 60:69 | 14360 | 1682 | 67 | - |
| 70:79 | 82 | 7761 | 1405 | - |
| 80:89 | - | 10544 | 7219 | - |
| 90:99 | - | - | 11380 | 1 |
| 100:109 | - | - | - | 9 |
| 110:119 | - | - | - | 26 |
| 120:129 | - | - | - | 51 |
| 130:139 | - | - | - | 250 |
| 140:149 | - | - | - | 951 |
| 150:159 | - | - | - | 1862 |
| 160:169 | - | - | - | 3347 |
| 170:179 | - | - | - | 5185 |
| 180:189 | - | - | - | 6556 |
| 190:199 | - | - | - | 1836 |

Table A6.30: Frequency table: annuity sums for net carbon flux (live wood, waste, products and soils): Beech. Frequency table (£/ha, 1990)

| | Discount rate | | | |
|---|---|---|---|---|
| Annuity (£/ha) | 1% (BE1xANN) | 3% (BE3xANN) | 6% (BE6xANN) | 6% hyp (BE6HxANN) |
| -470:-461 | - | - | - | 3 |
| -460:-451 | - | - | - | 277 |
| -450:-441 | - | - | - | 195 |
| -440:-431 | - | - | - | 14 |
| -410: | - | - | 2 | - |
| -400: | - | - | 473 | - |
| -390: | - | - | 14 | - |
| -240: | - | 236 | - | - |
| -230: | - | 253 | - | - |
| -140: | 24 | - | - | - |
| -130: | 451 | - | - | - |
| -120: | 14 | - | - | - |
| 40:49 | 741 | 2 | - | - |
| 50:59 | 19333 | 3136 | 488 | - |
| 60:69 | - | 16936 | 19586 | - |
| 90:99 | - | - | - | 1 |
| 100:109 | - | - | - | 74 |
| 110:119 | - | - | - | 1153 |
| 120:129 | - | - | - | 7241 |
| 130:139 | - | - | - | 11605 |

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# Appendix 7: Modelling Agricultural Values: Analytical Details

## APPENDIX 7.1: CLUSTER ANALYSIS OF FARM SECTORS

This appendix provides details of the cluster analysis performed to allocate farms to homogeneous sectors. This was achieved by first undertaking a PCA of farm outputs. The factors derived from this process were then entered into the cluster analysis. An introduction to cluster analysis is given in Johnston (1978) with more advanced material being presented in Norusis (1985).

### A7.1.1: CLUSTER ANALYSIS

Table A7.1.1: Calculating eigenvalues for full farm sample (239 farms)

| VARIABLE | COMMUNALITY | * | COMP | EIGENVALUE | PCT OF VAR | CUM PCT |
|---|---|---|---|---|---|---|
| | | * | | | | |
| V2 (Milk) | 1.00000 | * | 1 | 2.14020 | 35.7 | 35.7 |
| V3 (Cattle) | 1.00000 | * | 2 | 1.07986 | 18.0 | 53.7 |
| V4 (Sheep) | 1.00000 | * | 3 | 1.03196 | 17.2 | 70.9 |
| V5 (OLivstck) | 1.00000 | * | 4 | 1.01359 | 16.9 | 87.8 |
| V6 (Crops) | 1.00000 | * | 5 | .73232 | 12.2 | 100.0 |
| V7 (Misc) | 1.00000 | * | 6 | .00207 | .0 | 100.0 |

The eigenvalue for a component is the sum of the squared component loadings for all variables. The communality for a variable is the sum of the squared component loadings for all components. If all components are extracted it equals 1.00.

Table A7.1.2: Component loadings matrix

| | COMP 1 | COMP 2 | COMP 3 | COMP 4 | COMP 5 | COMP 6 |
|---|---|---|---|---|---|---|
| V2 (Milk) | -.98265 | .03316 | -.09660 | -.14582 | .04049 | .03265 |
| V3 (Cattle) | .70545 | -.33290 | -.16892 | -.08503 | .59620 | .01729 |
| V4 (Sheep) | .81964 | .30419 | -.04295 | -.05930 | -.47928 | .02412 |
| V5 (OLivstck) | -.05239 | -.15773 | -.29056 | .94038 | -.06004 | .00584 |
| V6 (Crops) | .03547 | -.47279 | .86185 | .15296 | -.09460 | .00878 |
| V7 (Misc) | .03360 | .79183 | .40624 | .27179 | .36464 | .00304 |

The loadings are identical to the correlations between the input variables and the six components.

Table A7.1.3: Component score coefficient matrix

| | COMP 1 | COMP 2 | COMP 3 | COMP 4 | COMP 5 | COMP 6 |
|---|---|---|---|---|---|---|
| V2 (Milk) | -.45914 | .03071 | -.09361 | -.14387 | .05529 | 15.79180 |
| V3 (Cattle) | .32962 | -.30828 | -.16369 | -.08389 | .81412 | 8.36566 |
| V4 (Sheep) | .38297 | .28170 | -.04162 | -.05850 | -.65447 | 11.66854 |
| V5 (OLivstck) | -.02448 | -.14607 | -.28157 | .92777 | -.08198 | 2.82422 |
| V6 (Crops) | .01658 | -.43782 | .83516 | .15091 | -.12918 | 4.24905 |
| V7 (Misc) | .01570 | .73327 | .39366 | .26815 | .49792 | 1.47274 |

Component score coefficients are obtained through dividing the relevant component loading by the appropriate eigenvalue : e.g. for component 1 V2 (milk) the component score is: -0.98265 / 2.14020 = -0.45914.

Component scores are calculated by multiplying the standardised values (z scores) for an observation (here a particular farm) by the relevant component score coefficients and then summing the results to give an overall score for the observation on that component. Table A7.1.4 details examples for two farms.

Table A7.1.4: Calculating overall component scores for two farms

a) Calculating scores on component 1:

| Farm 10029 | Original | Z Score | Coefficient | |
|---|---|---|---|---|
| Milk | 0.000 | -0.89697 | -0.45914 | 0.412 |
| Cattle | 0.420 | 0.80165 | 0.32962 | 0.264 |
| Sheep | 0.540 | 0.76559 | 0.38297 | 0.293 |
| OLivstck | 0.000 | -0.13880 | -0.02448 | 0.003 |
| Crops | 0.240 | -0.16213 | 0.01658 | -0.003 |
| Misc | 0.000 | -0.22326 | 0.01570 | -0.003 |
| | | | = | 0.966 |

| Farm 10052 | Original | Z Score | Coefficient | |
|---|---|---|---|---|
| Milk | 0.857 | 1.24680 | -0.45914 | -0.573 |
| Cattle | 0.065 | -0.88146 | 0.32962 | -0.291 |
| Sheep | 0.000 | -1.08969 | 0.38297 | -0.417 |
| OLivstck | 0.000 | -0.13880 | -0.02448 | 0.003 |
| Crops | 0.074 | 0.31367 | 0.01658 | 0.005 |
| Misc | 0.000 | -0.22326 | 0.01570 | -0.004 |
| | | | = | -1.275 |

b) Complete component scores for two farms

| Farm | COMP 1 | COMP 2 | COMP 3 | COMP 4 | COMP 5 | COMP 6 |
|---|---|---|---|---|---|---|
| 10029 | 0.966 | -0.131 | -0.263 | -0.196 | 0.023 | 0.065 |
| 10052 | -1.275 | -0.278 | 0.286 | -0.183 | -0.076 | 0.212 |

These component scores were saved (file FCSCORE.DAT) and then used as input to a further SPSSX command file (FARMCLUS.SPS) which undertook a Wards Error Sum hierarchical classification (Ward, 1963) of the 240 farms based on their scores on the six components. Results for this exercise are detailed in table A7.1.5.

Table A7.1.5: Agglomeration schedule using Ward method

| Stage | Clusters Combined Cluster 1 | Cluster 2 | Coefficient | Stage Cluster 1st Appears Cluster 1 | Cluster 2 | Next Stage |
|---|---|---|---|---|---|---|
| 1 | 12 | 207 | .000190 | 0 | 0 | 24 |
| 50 | 16 | 44 | .904298 | 16 | 40 | 83 |
| 100 | 57 | 85 | 4.145593 | 0 | 0 | 139 |
| 150 | 2 | 14 | 15.361076 | 86 | 105 | 178 |
| 200 | 155 | 228 | 62.388351 | 173 | 0 | 224 |
| 213 | 10 | 88 | 104.058807 | 208 | 167 | 218 |
| 225 | 3 | 124 | 203.081863 | 221 | 0 | 227 |
| 226 | 33 | 45 | 220.088425 | 214 | 190 | 232 |
| 227 | 3 | 5 | 239.092621 | 225 | 218 | 238 |
| 228 | 1 | 23 | 264.932800 | 220 | 216 | 231 |
| 229 | 4 | 61 | 295.397980 | 223 | 215 | 230 |
| 230 | 4 | 65 | 335.515350 | 229 | 210 | 233 |
| 231 | 1 | 2 | 379.186432 | 228 | 217 | 235 |
| 232 | 33 | 240 | 429.632904 | 226 | 0 | 235 |
| 233 | 4 | 84 | 497.767700 | 230 | 0 | 234 |
| 234 | 4 | 29 | 610.197144 | 233 | 0 | 236 |
| 235 | 1 | 33 | 727.242859 | 231 | 232 | 236 |
| 236 | 1 | 4 | 854.815674 | 235 | 234 | 237 |
| 237 | 1 | 155 | 1008.367676 | 236 | 224 | 238 |
| 238 | 1 | 3 | 1221.136841 | 237 | 227 | 239 |
| 239 | 1 | 76 | 1434.004028 | 238 | 222 | 0 |

We initially start off with as many clusters as farms. The top row of table A7.1.5 tells us that the two most similar farms are numbers 12 and 207. The coefficient represents the degree of variability captured by joining these farms together, while the next two columns tell us that they were not previously joined with any other farms. The last column gives information concerning the number of farms joined on the next stage. Line two shows the 50th stage of the cluster analysis. Here cluster 16 is joining cluster 44.

These results indicate that a great many of the farms are very similar in characteristics. Identifying significant points in the grouping process is essentially a subjective matter. In this instance Stage 234 is noteworthy as the first stage at which the ESS increment is over 100 and the last instance where a singleton farm becomes a member of an existing cluster. This stage corresponds to moving from seven separate clusters to six and the change in terms of cluster sizes can be seen in table A7.1.6.

Table A7.1.6: Moving from 8 to 3 clusters: Number of farms in each cluster

| No. of Clusters | No. of farms | | | | | |
|---|---|---|---|---|---|---|
| 1 | 86 | 86 | 86 | 96 | 105 | 131 |
| 2 | 107 | 107 | 107 | 107 | 107 | 107 |
| 3 | 27 | 28 | 29 | 29 | 2 | 2 |
| 4 | 1 | 1 | 10 | 2 | 6 | |
| 5 | 10 | 10 | 2 | 6 | | |
| 6 | 2 | 2 | 6 | | | |
| 7 | 1 | 6 | | | | |
| 8 | 6 | | | | | |

Table A7.1.7 shows the characteristics of the eight cluster in terms of mean values on the original variables.

Table A7.1.7: Characteristics of the eight cluster.

| Cluster No. | Farms | Milk | Cattle | Sheep | OLivstck | Crops | Misc | Income (£/Ha) |
|---|---|---|---|---|---|---|---|---|
| 1 | 86 | 0.00365 | 0.29674 | 0.64410 | 0.00121 | 0.03414 | 0.00487 | 83.40 |
| 2 | 107 | 0.77759 | 0.11065 | 0.07050 | 0.00524 | 0.02447 | 0.00362 | 508.64 |
| 3 | 27 | 0.01926 | 0.61904 | 0.29685 | 0.00526 | 0.03656 | -0.00659 | 58.60 |
| 4 | 1 | 0.00000 | 0.50200 | 0.20500 | 0.00000 | 0.00000 | 0.00000 | 146.50 |
| 5 | 10 | 0.17160 | 0.27690 | 0.39510 | 0.00360 | 0.00830 | 0.13490 | 222.84 |
| 6 | 2 | 0.00000 | 0.18150 | 0.07750 | 0.74600 | -0.01100 | 0.00050 | 1145.43 |
| 7 | 1 | 0.00000 | 1.30700 | 0.00000 | 0.00000 | -0.14600 | 0.00000 | -362.96 |
| 8 | 6 | 0.05100 | 0.20083 | 0.14283 | 0.00883 | 0.56550 | 0.01200 | 57.50 |
| All | 240 | 0.35857 | 0.25092 | 0.31717 | 0.00995 | 0.04104 | 0.00854 | 282.61 |

The distinctive nature of the farms in clusters 4 and 7 of table A7.1.7 must be regarded as something of an artefact since in both instances the revenue total is rather different from 1.00. This alone is sufficient to make them stand apart from other farms involved in similar activities. There is consequently a case for settling on the six cluster level for further investigation and the nature of these clusters is summarised in table A7.1.8.

Table A7.1.8: Characteristics of the six cluster.

| Cluster No. | Farms | Milk | Cattle | Sheep | OLivstck | Crops | Misc | Income (£/Ha) |
|---|---|---|---|---|---|---|---|---|
| 1 | 86 | 0.00365 | 0.29674 | 0.64410 | 0.00121 | 0.03414 | 0.00487 | 83.40 |
| 2 | 107 | 0.77759 | 0.11065 | 0.07050 | 0.00524 | 0.02447 | 0.00362 | 508.64 |
| 3 | 29 | 0.01793 | 0.63872 | 0.28345 | 0.00490 | 0.02900 | -0.00614 | 47.09 |
| 4 | 10 | 0.17160 | 0.27690 | 0.39510 | 0.00360 | 0.00830 | 0.13490 | 222.84 |
| 5 | 2 | 0.00000 | 0.18150 | 0.07750 | 0.74600 | -0.01100 | 0.00050 | 1145.43 |
| 6 | 6 | 0.05100 | 0.20083 | 0.14283 | 0.00883 | 0.56550 | 0.01200 | 57.50 |
| All | 240 | 0.35857 | 0.25092 | 0.31717 | 0.00995 | 0.04104 | 0.00854 | 282.61 |

Clusters 5 and 6 in table A7.1.8 are clearly distinctive in their emphasis on crops or other livestock (pigs and poultry). Table A7.1.9 provides descriptive statistics for each farm in these clusters.

Table A7.1.9: Characteristics of farms in clusters 5 and 6

| Cluster | Farm No | Milk | Cattle | Sheep | OLstk | Crops | Misc | Inc/Ha |
|---|---|---|---|---|---|---|---|---|
| 5 | 10885 | 0.000 | 0.352 | 0.099 | 0.604 | -0.062 | 0.001 | 163.81 |
| 5 | 11310 | 0.000 | 0.011 | 0.056 | 0.040 | 0.040 | 0.000 | 2127.04 |
| 6 | 11271 | 0.000 | 0.338 | 0.130 | 0.527 | 0.527 | 0.000 | 87.65 |
| 6 | 11296 | 0.000 | -0.014 | 0.268 | 0.710 | 0.710 | 0.025 | -10.37 |
| 6 | 11441 | 0.000 | 0.075 | 0.149 | 0.724 | 0.724 | 0.004 | 243.76 |
| 6 | 11463 | 0.306 | 0.054 | 0.054 | 0.363 | 0.363 | 0.014 | -90.17 |
| 6 | 11465 | 0.000 | 0.256 | 0.256 | 0.577 | 0.577 | 0.003 | 52.02 |
| 6 | 11478 | 0.000 | 0.000 | 0.000 | 0.492 | 0.492 | 0.026 | 62.12 |

## A7.1.2: DEFINING CLUSTERS

Analysis revealed that the cluster analysis had produced sectors of significantly differing income levels. Table A7.1.10 details descriptive statistics regarding income per hectare for each cluster.

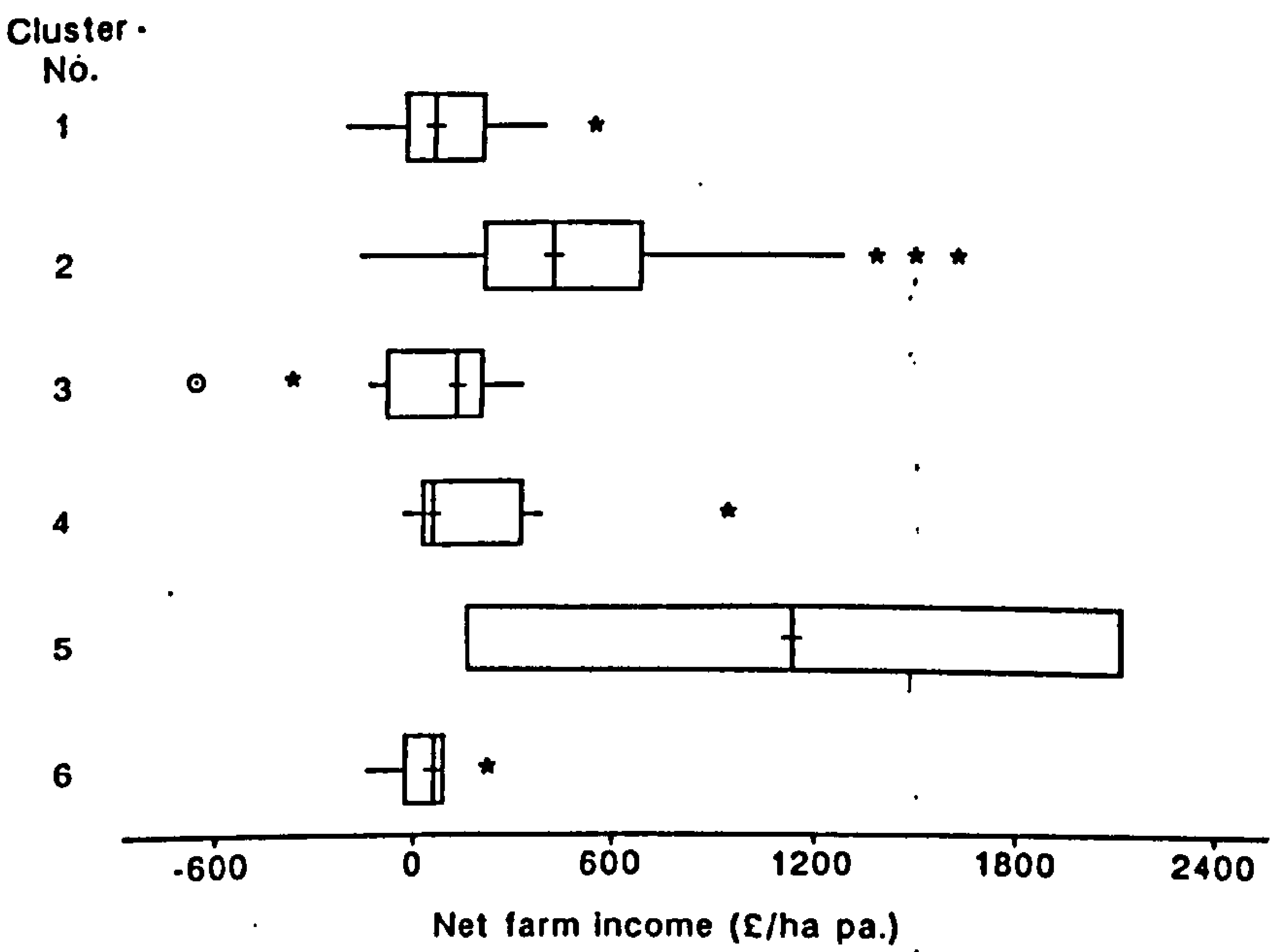
Table A7.1.10: Characteristics of clusters on the net income ha variable

| Cluster No. | N | MEAN | MEDIAN | TRMEAN | STDEV | SEMEAN | MIN | MAX | Q1 | Q3 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 86 | 83.4 | 77.0 | 83.6 | 138.5 | 14.9 | -268.5 | 567.0 | 2.9 | 177.4 |
| 2 | 107 | 508.6 | 448.3 | 491.1 | 325.5 | 31.5 | -110.4 | 1604.7 | 257.8 | 683.2 |
| 3 | 29 | 47.1 | 93.9 | 64.9 | 200.6 | 37.2 | -683.1 | 296.3 | -37.7 | 183.9 |
| 4 | 10 | 222.8 | 82.8 | 151.9 | 297.0 | 93.9 | 27.9 | 985.5 | 36.7 | 306.1 |
| 5 | 2 | 1145.0 | 1145.0 | 1145.0 | 1388.0 | 982.0 | 164.0 | 2127.0 | * | * |
| 6 | 6 | 57.5 | 57.1 | 57.5 | 111.4 | 45.5 | -90.2 | 243.8 | -30.3 | 126.7 |

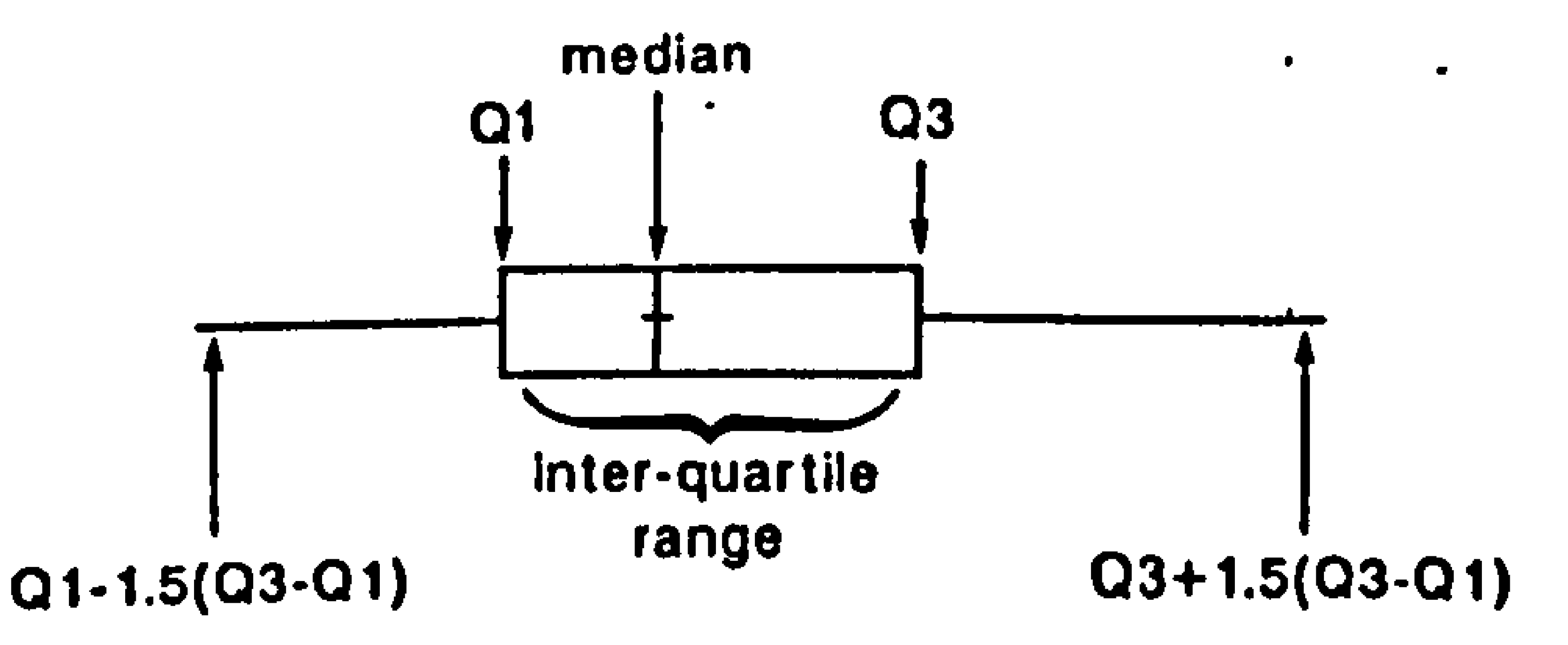
## A7.1.2.1: Identifying Outliers

An important element of this analysis is the identification of outlier farms. This was achieved by resorting to standard diagnostics as defined in MINITAB (1992). Figure A7.1 illustrates the results of an investigation into outliers within the various clusters defined above. An explanatory key is provided together with details of how these diagnostic tests define possible and probable outliers.

Figure A7.1: Boxplots of net income/ha by cluster classification: clusters 1-6




Key




* = value <[Q1-1.5(Q3-Q1)] or [Q3+1.5 (Q3-Q1)] : "possible outlier"[1]

⊙ = value < [Q1-3 (Q3-Q1)] or [Q3+3(Q3-Q1)]: "probable outlier"[1]

Note: 1. Minitab Inc. (1992)

Given the small numbers of farms in clusters 5 and 6 and the evidence of non-homogeneity detailed in table A7.1.9, it was decided to eliminate them from further consideration in the modelling exercise. Furthermore, following the analysis of figure A7.1 it was also decided to omit one outlier from cluster 1, three from cluster 2, two from cluster 3 and one from cluster 4. Boxplots for the resultant clusters are illustrated in figure A7.2 which shows that there were no remaining outliers in the sample.

Figure A7.2: Boxplots of net income/ha by cluster (excluding outliers): clusters 1-4.

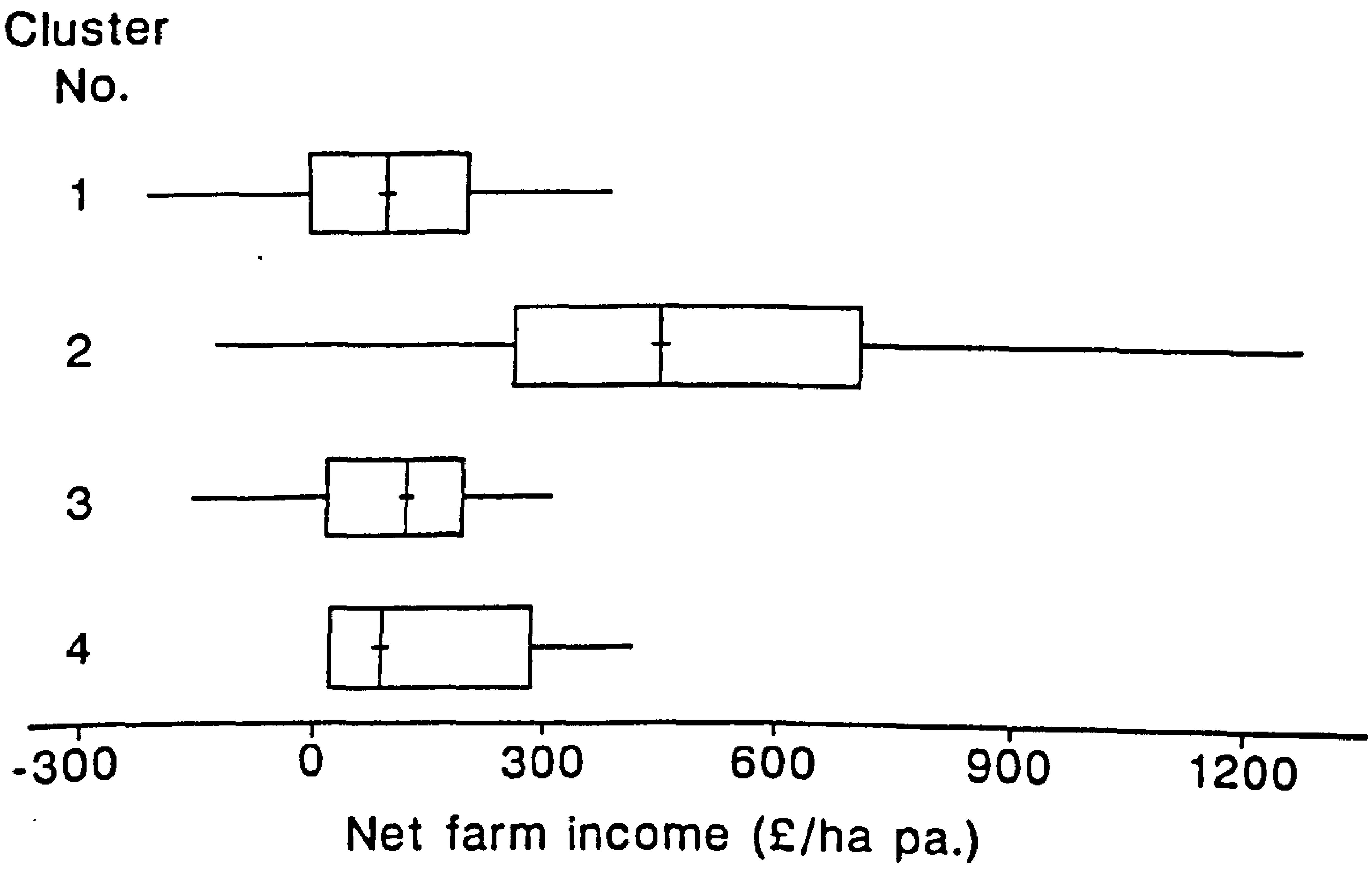



Table A7.1.11 details descriptive statistics for all characteristics of clusters 1-4 while table A7.1.12 gives descriptive statistics and an analysis of variance of income per hectare for each cluster.

Table A7.1.11: Cluster characteristics (excluding outliers): cluster 1-4

| Cluster No. | No. of farms | Milk | Cattle | Sheep | OLvstck | Crops | Misc | NtIn/Ha |
|---|---|---|---|---|---|---|---|---|
| 1 | 85 | 0.00374 | 0.29520 | 0.64504 | 0.00124 | 0.03444 | 0.00499 | 81.83 |
| 2 | 104 | 0.77652 | 0.11049 | 0.07118 | 0.00501 | 0.02509 | 0.00369 | 488.68 |
| 3 | 27 | 0.01926 | 0.59937 | 0.30444 | 0.00526 | 0.03367 | -0.00081 | 89.32 |
| 4 | 9 | 0.11544 | 0.28344 | 0.43900 | 0.00400 | 0.00967 | 0.13867 | 138.11 |
| All | 225 | 0.37070 | 0.24503 | 0.32812 | 0.00359 | 0.02899 | 0.00903 | 274.84 |

Table A7.1.12: Descriptive statistics and analysis of variance on net income/ha (£):

| Cluster No. | No. of farms | MEAN | MEDIAN | TRMEAN | STDEV | SEMEAN | MIN | MAX | Q1 | Q3 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 85 | 81.8 | 77.0 | 84.8 | 123.8 | 13.5 | -205.0 | 370.3 | 5.5 | 173.9 |
| 2 | 104 | 488.7 | 445.4 | 478.6 | 294.0 | 28.7 | -100.4 | 1271.5 | 254.9 | 675.6 |
| 3 | 27 | 89.3 | 109.1 | 90.6 | 120.4 | 23.2 | -149.9 | 296.3 | 20.3 | 188.1 |
| 4 | 9 | 138.1 | 80.6 | 138.1 | 135.8 | 45.3 | 27.9 | 383.1 | 34.5 | 277.1 |

| LEVEL | N | MEAN | STDEV | INDIVIDUAL 95 PCT CI'S FOR MEAN BASED ON POOLED STDEV |
|---|---|---|---|---|
| | | | | -+---------+---------+---------+----- |
| 1 | 85 | 81.8 | 123.8 | (--*---) |
| 2 | 104 | 488.7 | 294.0 | (--*-) |
| 3 | 27 | 89.3 | 120.4 | (-----*-----) |
| 4 | 9 | 138.1 | 135.8 | (---------*---------) |
| | | | | -+---------+---------+---------+----- |
| | | | | 0 150 300 450 |

Pooled standard deviation = 220.9

## A7.1.3: FBSW VARIABLES FOR SHEEP FARMS

This section contains information concerning cluster 1 (file clus1.mtw), the mainly sheep farms. Contents are as follows:

1. Descriptive statistics for all variables
2. Pearson correlation matrix for variables used in the first stage model.
3. Further details regarding the environmental modification ($M_i$) explanatory variables used in stage 1 of the agricultural values model.

### A7.1.3.1: Descriptive statistics for FBSW variables

| | N | N* | MEAN | MEDIAN | TRMEAN | STDEV | SEMEAN |
|---|---|---|---|---|---|---|---|
| surp/ha | 85 | 0 | 110.9 | 108.3 | 109.2 | 115.7 | 12.6 |
| %$milk | 85 | 0 | 0.00459 | 0.00000 | 0.00000 | 0.03949 | 0.00428 |
| %$catt | 85 | 0 | 0.3252 | 0.3674 | 0.3289 | 0.1406 | 0.0153 |
| %$sheep | 85 | 0 | 0.6259 | 0.6127 | 0.6238 | 0.1630 | 0.0177 |
| %$poult | 85 | 0 | 0.00038 | 0.00000 | 0.00000 | 0.00324 | 0.00035 |
| %$othliv | 85 | 0 | 0.00117 | 0.00000 | 0.00050 | 0.00468 | 0.00051 |
| %$crops | 85 | 0 | 0.03872 | 0.02155 | 0.03325 | 0.08432 | 0.00915 |
| %$misc | 85 | 0 | 0.00403 | 0.00000 | 0.00268 | 0.00853 | 0.00093 |
| l/cow | 84 | 1 | 4613.7 | 4722.0 | 4626.9 | 879.2 | 95.9 |
| $mlk/cow | 85 | 0 | 851.1 | 873.9 | 862.1 | 207.2 | 22.5 |
| lamb/ewe | 85 | 0 | 1.1279 | 1.1200 | 1.1266 | 0.2656 | 0.0288 |
| fatl/ewe | 85 | 0 | 0.9275 | 0.8100 | 0.8714 | 0.4928 | 0.0535 |
| %return | 85 | 0 | -3.35 | -0.52 | -2.46 | 16.44 | 1.78 |
| SMDavail | 85 | 0 | 560.6 | 554.0 | 550.5 | 182.7 | 19.8 |
| SMDreq | 85 | 0 | 833.5 | 803.0 | 820.9 | 351.5 | 38.1 |
| $live/eh | 85 | 0 | 619.4 | 593.0 | 609.1 | 269.1 | 29.2 |
| $mech/eh | 85 | 0 | 275.8 | 252.0 | 263.6 | 162.2 | 17.6 |
| $crop/eh | 85 | 0 | 42.06 | 19.00 | 36.03 | 53.76 | 5.83 |
| $stor/eh | 85 | 0 | 6.39 | 1.00 | 4.60 | 11.84 | 1.28 |
| ehaCerl | 85 | 0 | 3.61 | 0.00 | 2.01 | 9.42 | 1.02 |
| ehaRoots | 85 | 0 | 0.918 | 0.000 | 0.286 | 3.296 | 0.357 |
| ehaHay | 85 | 0 | 6.976 | 6.000 | 6.026 | 8.184 | 0.888 |
| ehaSilag | 85 | 0 | 13.29 | 13.00 | 12.65 | 10.99 | 1.19 |
| ehaPast | 85 | 0 | 58.95 | 53.00 | 56.14 | 37.65 | 4.08 |
| ehaRough | 85 | 0 | 18.58 | 3.00 | 12.09 | 39.84 | 4.32 |
| ehaTotal | 85 | 0 | 102.38 | 92.34 | 98.31 | 54.70 | 5.93 |
| %Cerl | 85 | 0 | 0.03719 | 0.00000 | 0.02366 | 0.08514 | 0.00923 |
| %Roots | 85 | 0 | 0.00898 | 0.00000 | 0.00356 | 0.02819 | 0.00306 |
| %Hay | 85 | 0 | 0.08063 | 0.06316 | 0.07138 | 0.09052 | 0.00982 |
| %Silag | 85 | 0 | 0.1466 | 0.1452 | 0.1390 | 0.1210 | 0.0131 |
| %Past | 85 | 0 | 0.5852 | 0.6304 | 0.5898 | 0.2136 | 0.0232 |
| %Rough | 85 | 0 | 0.1414 | 0.0301 | 0.1174 | 0.2179 | 0.0236 |
| BSU | 85 | 0 | 18.467 | 16.730 | 18.003 | 8.712 | 0.945 |
| %$mlk>7% | 85 | 0 | 0.0118 | 0.0000 | 0.0000 | 0.1085 | 0.0118 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 150ha+ | 85 | 0 | 0.1647 | 0.0000 | 0.1299 | 0.3731 | 0.0405 |
| >3hRough | 85 | 0 | 0.4824 | 0.0000 | 0.4805 | 0.5027 | 0.0545 |
| radius | 85 | 0 | 5.532 | 5.400 | 5.484 | 1.419 | 0.154 |
| Easting | 85 | 0 | 2803.6 | 2900.0 | 2817.4 | 307.3 | 33.3 |
| Northing | 85 | 0 | 3012.0 | 3010.0 | 3023.1 | 578.1 | 62.7 |
| Region | 84 | 1 | 3.071 | 2.000 | 3.079 | 1.454 | 0.159 |
| RegCat | 84 | 1 | 0.4524 | 0.0000 | 0.4474 | 0.5007 | 0.0546 |
| Region1 | 84 | 1 | 0.1071 | 0.0000 | 0.0658 | 0.3112 | 0.0339 |
| Region4 | 84 | 1 | 0.1905 | 0.0000 | 0.1579 | 0.3950 | 0.0431 |
| milk%FR | 85 | 0 | 0.00382 | 0.00000 | -0.00000 | 0.03300 | 0.00358 |
| catt%FR | 85 | 0 | 0.2523 | 0.2612 | 0.2541 | 0.1171 | 0.0127 |
| shep%FR | 85 | 0 | 0.4726 | 0.4545 | 0.4695 | 0.1123 | 0.0122 |
| polt%FR | 85 | 0 | 0.00033 | 0.00000 | 0.00000 | 0.00290 | 0.00031 |
| oliv%FR | 85 | 0 | 0.00089 | 0.00000 | 0.00041 | 0.00346 | 0.00038 |
| crop%FR | 85 | 0 | 0.03433 | 0.01638 | 0.02822 | 0.07209 | 0.00782 |
| misc%FR | 85 | 0 | 0.00300 | 0.00000 | 0.00205 | 0.00612 | 0.00066 |
| Fout%FR | 85 | 0 | 0.7673 | 0.7599 | 0.7689 | 0.1023 | 0.0111 |
| gCatt%FR | 85 | 0 | 0.04651 | 0.04559 | 0.04585 | 0.03022 | 0.00328 |
| gShep%FR | 85 | 0 | 0.1840 | 0.1719 | 0.1800 | 0.0974 | 0.0106 |
| gMisc%FR | 85 | 0 | 0.00204 | 0.00000 | 0.00074 | 0.00673 | 0.00073 |
| gTotl%FR | 85 | 0 | 0.2355 | 0.2401 | 0.2331 | 0.1068 | 0.0116 |
| milk%TO | 85 | 0 | 0.00370 | 0.00000 | 0.00000 | 0.03189 | 0.00346 |
| catt%TO | 85 | 0 | 0.2487 | 0.2593 | 0.2505 | 0.1154 | 0.0125 |
| shep%TO | 85 | 0 | 0.4653 | 0.4487 | 0.4623 | 0.1097 | 0.0119 |
| polt%TO | 85 | 0 | 0.00032 | 0.00000 | -0.00000 | 0.00280 | 0.00030 |
| oliv%TO | 85 | 0 | 0.00088 | 0.00000 | 0.00040 | 0.00342 | 0.00037 |
| crop%TO | 85 | 0 | 0.03377 | 0.01627 | 0.02772 | 0.07100 | 0.00770 |
| misc%TO | 85 | 0 | 0.00293 | 0.00000 | 0.00201 | 0.00599 | 0.00065 |
| Fout%TO | 85 | 0 | 0.7556 | 0.7483 | 0.7571 | 0.1011 | 0.0110 |
| gCatt%TO | 85 | 0 | 0.04591 | 0.04510 | 0.04523 | 0.02989 | 0.00324 |
| gShep%TO | 85 | 0 | 0.1811 | 0.1699 | 0.1772 | 0.0952 | 0.0103 |
| gMisc%TO | 85 | 0 | 0.00201 | 0.00000 | 0.00074 | 0.00664 | 0.00072 |
| gTotl%TO | 85 | 0 | 0.2319 | 0.2376 | 0.2294 | 0.1050 | 0.0114 |
| Frev%TO | 85 | 0 | 0.98468 | 0.98730 | 0.98570 | 0.01079 | 0.00117 |
| nOut%TO | 85 | 0 | 0.01532 | 0.01270 | 0.01430 | 0.01079 | 0.00117 |
| lnLive/h | 85 | 0 | 6.3284 | 6.3852 | 6.3458 | 0.4697 | 0.0510 |
| %milk+.1 | 85 | 0 | -2.2839 | -2.3026 | -2.3026 | 0.1526 | 0.0165 |
| %milk+1 | 85 | 0 | 0.00337 | 0.00000 | -0.00000 | 0.02883 | 0.00313 |

| | MIN | MAX | Q1 | Q3 |
|---|---|---|---|---|
| surp/ha | -177.3 | 403.5 | 28.0 | 192.6 |
| %$milk | 0.00000 | 0.36342 | 0.00000 | 0.00000 |
| %$catt | 0.0000 | 0.5877 | 0.2017 | 0.4347 |
| %$sheep | 0.2679 | 1.0000 | 0.5148 | 0.7372 |
| %$poult | 0.00000 | 0.02976 | 0.00000 | 0.00000 |
| %$othliv | -0.00877 | 0.03445 | 0.00000 | 0.00000 |
| %$crops | -0.15073 | 0.32929 | -0.00179 | 0.06941 |
| %$misc | -0.00199 | 0.04815 | 0.00000 | 0.00421 |
| l/cow | 2662.0 | 6718.0 | 4119.8 | 5177.0 |
| $mlk/cow | 0.0 | 1273.2 | 724.0 | 976.4 |
| lamb/ewe | 0.0000 | 1.7600 | 0.9500 | 1.3150 |
| fatl/ewe | 0.2700 | 3.9200 | 0.6400 | 1.1100 |
| %return | -66.76 | 26.30 | -10.20 | 6.64 |
| SMDavail | 300.0 | 1075.0 | 425.0 | 681.0 |
| SMDreq | 163.0 | 2191.0 | 621.5 | 1042.0 |
| $live/eh | 154.0 | 1568.0 | 418.0 | 793.0 |
| $mech/eh | 34.0 | 794.0 | 166.5 | 325.5 |
| $crop/eh | 0.00 | 255.00 | 4.00 | 64.50 |
| $stor/eh | 0.00 | 73.00 | 0.00 | 9.50 |
| ehaCerl | 0.00 | 61.00 | 0.00 | 2.50 |
| ehaRoots | 0.000 | 21.000 | 0.000 | 0.000 |
| ehaHay | 0.000 | 43.000 | 0.000 | 10.000 |
| ehaSilag | 0.00 | 42.00 | 4.00 | 18.00 |
| ehaPast | 9.00 | 230.00 | 34.00 | 80.50 |
| ehaRough | 0.00 | 257.00 | 0.00 | 14.50 |
| ehaTotal | 25.92 | 358.87 | 60.99 | 130.60 |
| %Cerl | 0.00000 | 0.49194 | 0.00000 | 0.03127 |
| %Roots | 0.00000 | 0.15385 | 0.00000 | 0.00000 |
| %Hay | 0.00000 | 0.47059 | 0.00000 | 0.12903 |
| %Silag | 0.0000 | 0.4868 | 0.0300 | 0.2070 |
| %Past | 0.0861 | 1.0000 | 0.4087 | 0.7397 |
| %Rough | 0.0000 | 0.8079 | 0.0000 | 0.1841 |
| BSU | 3.460 | 46.970 | 12.600 | 24.110 |
| %$mlk>7% | 0.0000 | 1.0000 | 0.0000 | 0.0000 |
| 150ha+ | 0.0000 | 1.0000 | 0.0000 | 0.0000 |
| >3hRough | 0.0000 | 1.0000 | 0.0000 | 1.0000 |
| radius | 2.900 | 10.700 | 4.400 | 6.450 |
| Easting | 1910.0 | 3260.0 | 2615.0 | 3025.0 |
| Northing | 1710.0 | 3940.0 | 2495.0 | 3530.0 |
| Region | 1.000 | 5.000 | 2.000 | 5.000 |
| RegCat | 0.0000 | 1.0000 | 0.0000 | 1.0000 |
| Region1 | 0.0000 | 1.0000 | 0.0000 | 0.0000 |
| Region4 | 0.0000 | 1.0000 | 0.0000 | 0.0000 |
| milk%FR | 0.00000 | 0.30374 | 0.00000 | 0.00000 |

| | | | | |
|---|---|---|---|---|
| catt%FR | 0.0000 | 0.4990 | 0.1520 | 0.3430 |
| shep%FR | 0.2239 | 0.8250 | 0.4019 | 0.5274 |
| polt%FR | 0.00000 | 0.02667 | 0.00000 | 0.00000 |
| oliv%FR | -0.00619 | 0.02588 | 0.00000 | 0.00000 |
| crop%FR | -0.09680 | 0.30191 | -0.00142 | 0.05261 |
| misc%FR | -0.00181 | 0.03314 | 0.00000 | 0.00291 |
| Fout%FR | 0.5355 | 1.0000 | 0.6952 | 0.8534 |
| gCatt%FR | 0.00000 | 0.11424 | 0.02210 | 0.07217 |
| gShep%FR | 0.0000 | 0.4279 | 0.1034 | 0.2404 |
| gMisc%FR | 0.00000 | 0.03792 | 0.00000 | 0.00000 |
| gTotl%FR | 0.0000 | 0.5166 | 0.1466 | 0.3067 |
| milk%TO | 0.00000 | 0.29349 | 0.00000 | 0.00000 |
| catt%TO | 0.0000 | 0.4848 | 0.1501 | 0.3403 |
| shep%TO | 0.2164 | 0.7983 | 0.3977 | 0.5208 |
| polt%TO | 0.00000 | 0.02580 | 0.00000 | 0.00000 |
| oliv%TO | -0.00616 | 0.02558 | 0.00000 | 0.00000 |
| crop%TO | -0.09546 | 0.29903 | -0.00140 | 0.05137 |
| misc%TO | -0.00177 | 0.03267 | 0.00000 | 0.00278 |
| Fout%TO | 0.5280 | 0.9776 | 0.6859 | 0.8336 |
| gCatt%TO | 0.00000 | 0.11424 | 0.02174 | 0.07115 |
| gShep%TO | 0.0000 | 0.4219 | 0.1023 | 0.2372 |
| gMisc%TO | 0.00000 | 0.03764 | 0.00000 | 0.00000 |
| gTotl%TO | 0.0000 | 0.5097 | 0.1436 | 0.3006 |
| Frev%TO | 0.92463 | 0.99997 | 0.98188 | 0.99161 |
| nOut%TO | 0.00003 | 0.07537 | 0.00839 | 0.01812 |
| lnLive/h | 5.0370 | 7.3576 | 6.0355 | 6.6755 |
| %milk+.1 | -2.3026 | -0.9070 | -2.3026 | -2.3026 |
| %milk+1 | 0.00000 | 0.26523 | 0.00000 | 0.00000 |

## A7.1.3.2: Pearson correlation matrix for FBSW variables.

| | surp/ha | %$milk | %$catt | %$sheep | %$poult | %$othliv | %$crops | %$misc |
|---|---|---|---|---|---|---|---|---|
| %$milk | -0.149 | | | | | | | |
| %$catt | 0.180 | -0.026 | | | | | | |
| %$sheep | -0.192 | -0.244 | -0.814 | | | | | |
| %$poult | 0.119 | -0.014 | 0.099 | -0.189 | | | | |
| %$othliv | 0.015 | -0.029 | 0.158 | -0.105 | 0.139 | | | |
| %$crops | 0.145 | 0.015 | -0.082 | -0.448 | 0.161 | -0.100 | | |
| %$misc | -0.101 | 0.331 | -0.122 | -0.002 | 0.002 | -0.060 | -0.045 | |
| 1/cow | 0.019 | -0.158 | -0.126 | 0.166 | -0.053 | -0.160 | -0.019 | -0.094 |
| $mlk/cow | 0.081 | -0.106 | -0.177 | 0.176 | -0.071 | -0.104 | 0.023 | -0.094 |
| lamb/ewe | 0.650 | -0.034 | 0.056 | -0.195 | 0.129 | 0.034 | 0.294 | 0.004 |
| fatl/ewe | 0.312 | -0.025 | -0.023 | -0.100 | 0.030 | 0.020 | 0.245 | -0.035 |
| %return | 0.634 | 0.018 | 0.138 | -0.099 | -0.099 | -0.051 | -0.051 | 0.105 |
| SMDavail | 0.090 | 0.309 | 0.121 | -0.261 | 0.239 | 0.074 | 0.119 | 0.252 |
| SMDreq | 0.008 | 0.277 | -0.064 | 0.013 | -0.142 | -0.152 | -0.078 | 0.434 |
| $live/eh | 0.553 | 0.076 | 0.339 | -0.342 | 0.185 | 0.046 | 0.063 | -0.136 |
| $mech/eh | 0.274 | -0.025 | 0.162 | -0.290 | -0.020 | 0.106 | 0.296 | 0.006 |
| $crop/eh | 0.370 | -0.055 | 0.174 | -0.337 | 0.019 | 0.044 | 0.394 | -0.100 |
| $stor/eh | 0.247 | 0.085 | -0.005 | -0.147 | 0.167 | -0.081 | 0.251 | -0.005 |
| ehaCerl | 0.173 | 0.041 | -0.002 | -0.392 | 0.048 | -0.053 | 0.748 | -0.037 |
| ehaRoots | 0.013 | -0.033 | -0.029 | -0.163 | -0.033 | -0.033 | 0.391 | -0.078 |
| ehaHay | -0.109 | 0.470 | -0.065 | -0.125 | -0.012 | -0.085 | 0.114 | 0.200 |
| ehaSilag | 0.377 | -0.128 | 0.340 | -0.280 | 0.026 | -0.020 | 0.026 | 0.086 |
| ehaPast | -0.091 | 0.175 | -0.120 | 0.111 | -0.124 | -0.074 | -0.128 | 0.401 |
| ehaRough | -0.265 | -0.049 | 0.028 | 0.087 | -0.052 | -0.107 | -0.193 | 0.102 |
| ehaTotal | -0.165 | 0.132 | -0.008 | -0.011 | -0.113 | -0.157 | -0.053 | 0.386 |
| %Cerl | 0.193 | 0.007 | 0.017 | -0.438 | 0.158 | -0.038 | 0.818 | -0.065 |
| %Roots | -0.020 | -0.037 | -0.060 | -0.114 | -0.038 | -0.058 | 0.353 | -0.102 |
| %Hay | 0.043 | 0.202 | -0.031 | -0.085 | 0.055 | -0.056 | 0.124 | -0.014 |
| %Silag | 0.407 | -0.128 | 0.356 | -0.309 | 0.170 | 0.057 | 0.064 | -0.092 |
| %Past | 0.059 | 0.061 | -0.219 | 0.270 | -0.113 | 0.051 | -0.186 | 0.028 |
| %Rough | -0.374 | -0.070 | 0.031 | 0.128 | -0.064 | -0.036 | -0.269 | 0.067 |
| BSU | 0.119 | 0.295 | 0.057 | -0.239 | -0.097 | -0.152 | 0.204 | 0.353 |
| %$mlk>7% | -0.149 | 0.997 | -0.030 | -0.241 | -0.013 | -0.027 | 0.017 | 0.335 |
| 150ha+ | -0.247 | 0.242 | -0.105 | 0.007 | -0.052 | -0.105 | 0.024 | 0.314 |
| >3hRough | -0.323 | -0.113 | 0.016 | 0.090 | -0.096 | -0.010 | -0.145 | 0.013 |
| radius | -0.151 | 0.136 | 0.003 | -0.024 | -0.125 | -0.164 | -0.045 | 0.348 |
| Easting | -0.116 | 0.052 | -0.062 | 0.241 | -0.221 | 0.027 | -0.390 | 0.107 |
| Northing | 0.144 | 0.134 | 0.060 | -0.095 | 0.051 | -0.035 | 0.016 | 0.046 |
| Region | 0.284 | -0.087 | 0.029 | -0.211 | 0.152 | -0.094 | 0.391 | 0.095 |
| RegCat | 0.212 | -0.107 | 0.053 | -0.198 | 0.130 | -0.078 | 0.329 | 0.145 |
| Region1 | -0.219 | -0.041 | 0.013 | 0.062 | -0.041 | 0.145 | -0.119 | -0.130 |
| Region4 | -0.010 | -0.057 | 0.057 | 0.012 | -0.034 | -0.070 | -0.112 | 0.290 |
| milk%FR | -0.149 | 1.000 | -0.026 | -0.244 | -0.014 | -0.029 | 0.015 | 0.331 |
| catt%FR | 0.338 | -0.007 | 0.957 | -0.857 | 0.141 | 0.141 | 0.066 | -0.144 |
| shep%FR | 0.127 | -0.244 | -0.766 | 0.845 | -0.161 | -0.136 | -0.220 | -0.075 |
| polt%FR | 0.120 | -0.014 | 0.098 | -0.189 | 1.000 | 0.139 | 0.161 | -0.002 |
| oliv%FR | 0.043 | -0.030 | 0.170 | -0.135 | 0.174 | 0.995 | -0.066 | -0.056 |
| crop%FR | 0.150 | 0.011 | -0.074 | -0.451 | 0.169 | -0.074 | 0.993 | -0.045 |
| misc%FR | -0.074 | 0.392 | -0.116 | -0.040 | 0.008 | -0.055 | -0.010 | 0.990 |
| Fout%FR | 0.584 | 0.076 | 0.195 | -0.463 | 0.133 | -0.014 | 0.541 | -0.114 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| gCatt%FR | -0.150 | -0.083 | 0.508 | -0.316 | 0.040 | 0.126 | -0.205 | 0.001 |
| gShep%FR | -0.565 | -0.052 | -0.355 | 0.584 | -0.150 | -0.026 | -0.518 | 0.124 |
| gMisc%FR | -0.038 | -0.036 | -0.121 | 0.023 | -0.030 | 0.026 | 0.178 | -0.048 |
| gTotl%FR | -0.557 | -0.076 | -0.174 | 0.433 | -0.131 | 0.007 | -0.517 | 0.108 |
| milk%TO | -0.149 | 1.000 | -0.026 | -0.244 | -0.014 | -0.029 | 0.015 | 0.331 |
| catt%TO | 0.340 | -0.012 | 0.958 | -0.855 | 0.134 | 0.141 | 0.063 | -0.148 |
| shep%TO | 0.138 | -0.250 | -0.757 | 0.840 | -0.168 | -0.135 | -0.221 | -0.085 |
| polt%TO | 0.120 | -0.014 | 0.098 | -0.189 | 1.000 | 0.139 | 0.161 | -0.002 |
| oliv%TO | 0.043 | -0.030 | 0.170 | -0.134 | 0.170 | 0.995 | -0.066 | -0.056 |
| crop%TO | 0.150 | 0.010 | -0.076 | -0.449 | 0.165 | -0.074 | 0.993 | -0.046 |
| misc%TO | -0.071 | 0.387 | -0.114 | -0.040 | 0.008 | -0.055 | -0.010 | 0.990 |
| Fout%TO | 0.597 | 0.060 | 0.212 | -0.469 | 0.116 | -0.012 | 0.535 | -0.132 |
| gCatt%TO | -0.150 | -0.084 | 0.506 | -0.314 | 0.036 | 0.125 | -0.207 | -0.001 |
| gShep%TO | -0.564 | -0.055 | -0.349 | 0.581 | -0.152 | -0.025 | -0.521 | 0.117 |
| gMisc%TO | -0.039 | -0.036 | -0.122 | 0.024 | -0.030 | 0.026 | 0.179 | -0.048 |
| gTotl%TO | -0.554 | -0.079 | -0.166 | 0.427 | -0.133 | 0.008 | -0.518 | 0.100 |
| Frev%TO | 0.175 | -0.181 | 0.241 | -0.132 | -0.176 | 0.027 | -0.032 | -0.238 |
| nOut%TO | -0.175 | 0.181 | -0.241 | 0.132 | 0.176 | -0.027 | 0.032 | 0.238 |
| lnLive/h | 0.520 | 0.081 | 0.307 | -0.322 | 0.152 | 0.078 | 0.074 | -0.114 |
| %milk+.1 | -0.148 | 0.998 | -0.022 | -0.245 | -0.015 | -0.031 | 0.013 | 0.325 |
| %milk+1 | -0.149 | 1.000 | -0.025 | -0.244 | -0.014 | -0.029 | 0.014 | 0.330 |

| | 1/cow | $mlk/cow | lamb/ewe | fatl/ewe | %return | SMDavail | SMDreq | $live/eh |
|---|---|---|---|---|---|---|---|---|
| $mlk/cow | 0.836 | | | | | | | |
| lamb/ewe | 0.007 | 0.018 | | | | | | |
| fatl/ewe | 0.018 | 0.145 | 0.463 | | | | | |
| %return | 0.127 | 0.123 | 0.335 | 0.082 | | | | |
| SMDavail | 0.043 | -0.031 | 0.161 | -0.014 | 0.119 | | | |
| SMDreq | 0.107 | 0.037 | -0.033 | -0.068 | 0.470 | 0.517 | | |
| $live/eh | -0.125 | -0.019 | 0.344 | 0.174 | 0.293 | 0.187 | 0.117 | |
| $mech/eh | -0.054 | -0.050 | 0.247 | 0.215 | 0.064 | 0.072 | -0.033 | 0.494 |
| $crop/eh | -0.054 | -0.097 | 0.393 | 0.165 | 0.168 | 0.149 | -0.074 | 0.273 |
| $stor/eh | -0.092 | -0.120 | 0.224 | 0.057 | 0.130 | 0.186 | 0.038 | 0.197 |
| ehaCerl | 0.087 | 0.062 | 0.321 | 0.257 | 0.085 | 0.182 | 0.099 | 0.085 |
| ehaRoots | 0.124 | 0.082 | 0.066 | 0.064 | 0.049 | 0.062 | 0.127 | -0.055 |
| ehaHay | -0.086 | -0.088 | -0.079 | 0.034 | -0.025 | 0.199 | 0.198 | 0.027 |
| ehaSilag | 0.021 | -0.045 | 0.400 | 0.124 | 0.422 | 0.251 | 0.403 | 0.368 |
| ehaPast | 0.107 | 0.127 | -0.046 | -0.038 | 0.329 | 0.354 | 0.758 | -0.129 |
| ehaRough | 0.175 | -0.041 | -0.235 | -0.197 | -0.068 | -0.027 | 0.098 | -0.485 |
| ehaTotal | 0.211 | 0.053 | -0.075 | -0.090 | 0.276 | 0.338 | 0.729 | -0.350 |
| %Cerl | 0.041 | 0.027 | 0.306 | 0.287 | 0.017 | 0.154 | -0.029 | 0.128 |
| %Roots | 0.140 | 0.097 | -0.036 | 0.039 | -0.003 | -0.042 | 0.015 | -0.010 |
| %Hay | -0.128 | -0.061 | -0.051 | 0.070 | -0.106 | -0.070 | -0.209 | 0.124 |
| %Silag | -0.086 | -0.060 | 0.429 | 0.171 | 0.224 | 0.031 | -0.065 | 0.508 |
| %Past | -0.031 | 0.108 | -0.048 | -0.064 | 0.144 | 0.040 | 0.210 | 0.120 |
| %Rough | 0.102 | -0.070 | -0.285 | -0.178 | -0.227 | -0.082 | -0.073 | -0.500 |
| BSU | 0.083 | 0.005 | 0.094 | 0.066 | 0.419 | 0.502 | 0.895 | 0.265 |
| %$mlk>7% | -0.163 | -0.108 | -0.032 | -0.026 | 0.017 | 0.309 | 0.269 | 0.048 |
| 150ha+ | 0.262 | 0.085 | -0.095 | -0.079 | 0.029 | 0.201 | 0.452 | -0.400 |
| >3hRough | 0.147 | 0.033 | -0.194 | -0.093 | -0.103 | -0.112 | -0.077 | -0.460 |
| radius | 0.211 | 0.044 | -0.062 | -0.078 | 0.318 | 0.383 | 0.759 | -0.315 |
| Easting | 0.129 | 0.085 | -0.135 | -0.307 | 0.152 | -0.019 | 0.202 | -0.094 |
| Northing | -0.262 | -0.145 | 0.120 | 0.183 | 0.012 | 0.118 | 0.050 | 0.150 |
| Region | -0.126 | 0.023 | 0.266 | 0.245 | -0.057 | 0.029 | -0.066 | 0.266 |
| RegCat | -0.068 | 0.030 | 0.200 | 0.211 | -0.064 | 0.030 | -0.071 | 0.170 |
| Region1 | 0.065 | -0.110 | -0.196 | 0.027 | -0.153 | -0.062 | -0.135 | -0.273 |
| Region4 | 0.105 | 0.089 | -0.048 | -0.111 | 0.091 | 0.064 | 0.081 | -0.081 |
| milk%FR | -0.158 | -0.106 | -0.034 | -0.025 | 0.018 | 0.309 | 0.277 | 0.075 |
| catt%FR | -0.152 | -0.160 | 0.188 | 0.098 | 0.184 | 0.137 | -0.055 | 0.484 |
| shep%FR | 0.088 | 0.149 | 0.121 | 0.053 | -0.017 | -0.246 | -0.032 | -0.088 |
| polt%FR | -0.053 | -0.070 | 0.130 | 0.031 | -0.098 | 0.239 | -0.141 | 0.186 |
| oliv%FR | -0.166 | -0.106 | 0.065 | 0.044 | -0.046 | 0.077 | -0.161 | 0.067 |
| crop%FR | -0.021 | 0.018 | 0.293 | 0.265 | -0.059 | 0.131 | -0.081 | 0.069 |
| misc%FR | -0.107 | -0.104 | 0.049 | -0.014 | 0.120 | 0.305 | 0.443 | -0.102 |
| Fout%FR | -0.156 | -0.052 | 0.553 | 0.351 | 0.160 | 0.106 | -0.049 | 0.531 |
| gCatt%FR | 0.077 | -0.061 | -0.102 | -0.332 | 0.067 | 0.116 | -0.027 | -0.124 |
| gShep%FR | 0.136 | 0.073 | -0.548 | -0.268 | -0.188 | -0.151 | 0.065 | -0.519 |
| gMisc%FR | 0.044 | 0.012 | -0.017 | 0.026 | -0.012 | 0.048 | -0.068 | -0.015 |
| gTotl%FR | 0.166 | 0.053 | -0.538 | -0.352 | -0.156 | -0.105 | 0.034 | -0.472 |
| milk%TO | -0.158 | -0.106 | -0.034 | -0.025 | 0.018 | 0.309 | 0.277 | 0.075 |
| catt%TO | -0.150 | -0.159 | 0.190 | 0.098 | 0.188 | 0.138 | -0.051 | 0.486 |
| shep%TO | 0.089 | 0.150 | 0.131 | 0.054 | 0.005 | -0.236 | -0.017 | -0.077 |
| polt%TO | -0.053 | -0.070 | 0.130 | 0.031 | -0.098 | 0.239 | -0.141 | 0.186 |
| oliv%TO | -0.166 | -0.106 | 0.065 | 0.044 | -0.046 | 0.076 | -0.160 | 0.067 |
| crop%TO | -0.019 | 0.019 | 0.294 | 0.266 | -0.058 | 0.131 | -0.080 | 0.068 |
| misc%TO | -0.104 | -0.103 | 0.052 | -0.013 | 0.124 | 0.308 | 0.445 | -0.102 |
| Fout%TO | -0.151 | -0.051 | 0.564 | 0.351 | 0.188 | 0.120 | -0.029 | 0.543 |
| gCatt%TO | 0.079 | -0.060 | -0.102 | -0.332 | 0.068 | 0.118 | -0.024 | -0.124 |
| gShep%TO | 0.139 | 0.073 | -0.548 | -0.270 | -0.181 | -0.146 | 0.070 | -0.518 |
| gMisc%TO | 0.044 | 0.012 | -0.017 | 0.026 | -0.013 | 0.048 | -0.068 | -0.016 |
| gTotl%TO | 0.169 | 0.054 | -0.535 | -0.353 | -0.148 | -0.099 | 0.039 | -0.468 |
| Frev%TO | 0.065 | 0.011 | 0.156 | 0.005 | 0.356 | 0.185 | 0.244 | 0.171 |
| nOut%TO | -0.065 | -0.011 | -0.156 | -0.005 | -0.356 | -0.185 | -0.244 | -0.171 |
| lnLive/h | -0.172 | -0.029 | 0.323 | 0.164 | 0.297 | 0.174 | 0.108 | 0.956 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| %milk+.1 | -0.153 | -0.105 | -0.035 | -0.024 | 0.019 | 0.308 | 0.283 | 0.100 |
| %milk+1 | -0.158 | -0.106 | -0.034 | -0.025 | 0.018 | 0.309 | 0.278 | 0.078 |

| | $mech/eh | $crop/eh | $stor/eh | ehaCerl | ehaRoots | ehaHay | ehaSilag | ehaPast |
|---|---|---|---|---|---|---|---|---|
| $crop/eh | 0.331 | | | | | | | |
| $stor/eh | 0.178 | 0.384 | | | | | | |
| ehaCerl | 0.243 | 0.314 | 0.413 | | | | | |
| ehaRoots | 0.102 | -0.046 | 0.213 | 0.713 | | | | |
| ehaHay | -0.184 | -0.002 | -0.027 | -0.014 | -0.026 | | | |
| ehaSilag | 0.337 | 0.361 | 0.176 | 0.159 | 0.112 | -0.296 | | |
| ehaPast | -0.206 | -0.157 | -0.135 | -0.082 | -0.045 | 0.195 | 0.132 | |
| ehaRough | -0.291 | -0.203 | -0.143 | -0.155 | -0.056 | -0.106 | -0.072 | -0.075 |
| ehaTotal | -0.263 | -0.131 | -0.083 | 0.076 | 0.131 | 0.143 | 0.230 | 0.673 |
| %Cerl | 0.277 | 0.397 | 0.399 | 0.926 | 0.533 | -0.062 | 0.138 | -0.179 |
| %Roots | 0.114 | -0.088 | 0.158 | 0.570 | 0.907 | -0.015 | 0.017 | -0.154 |
| %Hay | -0.037 | -0.018 | -0.050 | -0.088 | -0.050 | 0.751 | -0.343 | -0.177 |
| %Silag | 0.510 | 0.429 | 0.209 | 0.082 | -0.026 | -0.294 | 0.797 | -0.289 |
| %Past | -0.080 | -0.101 | -0.141 | -0.245 | -0.243 | 0.043 | -0.189 | 0.588 |
| %Rough | -0.313 | -0.276 | -0.133 | -0.204 | -0.053 | -0.165 | -0.171 | -0.252 |
| BSU | 0.111 | 0.082 | 0.202 | 0.447 | 0.351 | 0.235 | 0.455 | 0.589 |
| %$mlk>7% | -0.032 | -0.053 | 0.089 | 0.039 | -0.031 | 0.470 | -0.133 | 0.175 |
| 150ha+ | -0.218 | -0.167 | -0.128 | 0.049 | 0.156 | 0.208 | 0.035 | 0.453 |
| >3hRough | -0.251 | -0.218 | -0.074 | -0.086 | -0.033 | -0.136 | -0.104 | -0.126 |
| radius | -0.271 | -0.111 | -0.067 | 0.099 | 0.138 | 0.158 | 0.247 | 0.698 |
| Easting | -0.111 | -0.296 | -0.343 | -0.348 | -0.052 | 0.070 | -0.059 | 0.279 |
| Northing | 0.044 | -0.049 | 0.068 | -0.035 | -0.187 | -0.136 | 0.125 | -0.036 |
| Region | 0.203 | 0.212 | 0.258 | 0.366 | 0.106 | 0.113 | 0.059 | -0.006 |
| RegCat | 0.141 | 0.170 | 0.216 | 0.341 | 0.129 | 0.085 | 0.053 | 0.004 |
| Region1 | -0.175 | -0.054 | -0.111 | -0.135 | -0.051 | -0.048 | -0.108 | -0.202 |
| Region4 | -0.052 | -0.090 | 0.028 | 0.044 | 0.130 | -0.050 | 0.031 | 0.187 |
| milk%FR | -0.025 | -0.055 | 0.085 | 0.041 | -0.033 | 0.470 | -0.128 | 0.175 |
| catt%FR | 0.269 | 0.277 | 0.059 | 0.119 | 0.014 | -0.044 | 0.398 | -0.121 |
| shep%FR | -0.088 | -0.167 | -0.030 | -0.211 | -0.069 | -0.110 | -0.134 | 0.042 |
| polt%FR | -0.019 | 0.021 | 0.166 | 0.048 | -0.033 | -0.012 | 0.028 | -0.124 |
| oliv%FR | 0.119 | 0.057 | -0.076 | -0.045 | -0.037 | -0.082 | -0.010 | -0.089 |
| crop%FR | 0.310 | 0.404 | 0.273 | 0.792 | 0.424 | 0.091 | 0.039 | -0.143 |
| misc%FR | 0.037 | -0.072 | 0.011 | -0.010 | -0.073 | 0.219 | 0.102 | 0.400 |
| Fout%FR | 0.427 | 0.399 | 0.258 | 0.475 | 0.222 | 0.054 | 0.302 | -0.119 |
| gCatt%FR | -0.031 | -0.092 | -0.099 | -0.241 | -0.072 | -0.069 | 0.099 | 0.042 |
| gShep%FR | -0.456 | -0.417 | -0.261 | -0.438 | -0.210 | -0.027 | -0.351 | 0.116 |
| gMisc%FR | 0.241 | 0.362 | 0.307 | 0.188 | -0.002 | -0.127 | 0.041 | -0.068 |
| gTotl%FR | -0.335 | -0.397 | -0.262 | -0.466 | -0.220 | -0.042 | -0.287 | 0.085 |
| milk%TO | -0.025 | -0.055 | 0.085 | 0.041 | -0.033 | 0.470 | -0.128 | 0.175 |
| catt%TO | 0.271 | 0.275 | 0.059 | 0.118 | 0.015 | -0.048 | 0.402 | -0.119 |
| shep%TO | -0.081 | -0.163 | -0.024 | -0.211 | -0.064 | -0.118 | -0.119 | 0.049 |
| polt%TO | -0.019 | 0.021 | 0.166 | 0.048 | -0.033 | -0.012 | 0.028 | -0.124 |
| oliv%TO | 0.119 | 0.057 | -0.076 | -0.045 | -0.037 | -0.082 | -0.010 | -0.089 |
| crop%TO | 0.311 | 0.404 | 0.275 | 0.794 | 0.426 | 0.089 | 0.039 | -0.142 |
| misc%TO | 0.038 | -0.071 | 0.011 | -0.009 | -0.072 | 0.214 | 0.106 | 0.402 |
| Fout%TO | 0.438 | 0.402 | 0.264 | 0.475 | 0.229 | 0.038 | 0.324 | -0.111 |
| gCatt%TO | -0.031 | -0.093 | -0.100 | -0.242 | -0.071 | -0.070 | 0.099 | 0.042 |
| gShep%TO | -0.455 | -0.417 | -0.261 | -0.441 | -0.210 | -0.032 | -0.346 | 0.118 |
| gMisc%TO | 0.240 | 0.361 | 0.308 | 0.188 | -0.002 | -0.127 | 0.040 | -0.068 |
| gTotl%TO | -0.331 | -0.395 | -0.260 | -0.466 | -0.219 | -0.046 | -0.281 | 0.086 |
| Frev%TO | 0.151 | 0.063 | 0.087 | 0.021 | 0.094 | -0.195 | 0.285 | 0.083 |
| nOut%TO | -0.151 | -0.063 | -0.087 | -0.021 | -0.094 | 0.195 | -0.285 | -0.083 |
| lnLive/h | 0.488 | 0.254 | 0.202 | 0.091 | -0.020 | 0.058 | 0.350 | -0.137 |
| %milk+.1 | -0.018 | -0.057 | 0.080 | 0.041 | -0.035 | 0.468 | -0.123 | 0.174 |
| %milk+1 | -0.024 | -0.056 | 0.084 | 0.041 | -0.033 | 0.470 | -0.127 | 0.175 |

| | ehaRough | ehaTotal | %Cerl | %Roots | %Hay | %Silag | %Past | %Rough |
|---|---|---|---|---|---|---|---|---|
| ehaTotal | 0.615 | | | | | | | |
| %Cerl | -0.177 | -0.042 | | | | | | |
| %Roots | -0.067 | 0.001 | 0.479 | | | | | |
| %Hay | -0.225 | -0.259 | -0.069 | 0.067 | | | | |
| %Silag | -0.262 | -0.261 | 0.152 | -0.043 | -0.138 | | | |
| %Past | -0.545 | -0.080 | -0.288 | -0.279 | -0.039 | -0.291 | | |
| %Rough | 0.851 | 0.347 | -0.225 | -0.047 | -0.282 | -0.266 | -0.654 | |
| BSU | -0.037 | 0.604 | 0.314 | 0.213 | -0.142 | 0.054 | 0.079 | -0.199 |
| %$mlk>7% | -0.046 | 0.133 | 0.005 | -0.035 | 0.202 | -0.133 | 0.059 | -0.065 |
| 150ha+ | 0.532 | 0.756 | -0.059 | 0.031 | -0.099 | -0.280 | -0.166 | 0.378 |
| >3hRough | 0.467 | 0.193 | -0.099 | -0.040 | -0.308 | -0.180 | -0.371 | 0.635 |
| radius | 0.555 | 0.983 | -0.023 | 0.002 | -0.292 | -0.253 | -0.054 | 0.324 |
| Easting | -0.045 | 0.096 | -0.486 | -0.076 | 0.016 | -0.228 | 0.352 | -0.026 |
| Northing | 0.041 | -0.008 | 0.013 | -0.230 | -0.135 | 0.121 | -0.089 | 0.100 |
| Region | -0.321 | -0.139 | 0.449 | 0.059 | 0.123 | 0.198 | 0.021 | -0.374 |
| RegCat | -0.254 | -0.092 | 0.399 | 0.056 | 0.087 | 0.164 | -0.027 | -0.272 |
| Region1 | 0.396 | 0.094 | -0.153 | -0.036 | -0.050 | -0.125 | -0.358 | 0.517 |
| Region4 | -0.108 | 0.062 | -0.028 | 0.017 | -0.063 | -0.043 | 0.137 | -0.077 |
| milk%FR | -0.049 | 0.132 | 0.007 | -0.037 | 0.202 | -0.128 | 0.061 | -0.070 |
| catt%FR | -0.109 | -0.068 | 0.152 | -0.017 | 0.002 | 0.437 | -0.171 | -0.133 |
| shep%FR | -0.122 | -0.141 | -0.237 | -0.007 | 0.019 | -0.107 | 0.290 | -0.139 |
| polt%FR | -0.051 | -0.111 | 0.159 | -0.037 | 0.055 | 0.173 | -0.115 | -0.063 |
| oliv%FR | -0.107 | -0.164 | -0.025 | -0.062 | -0.051 | 0.075 | 0.031 | -0.034 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| crop%FR | -0.197 | -0.057 | 0.860 | 0.379 | 0.103 | 0.077 | -0.205 | -0.269 |
| misc%FR | 0.066 | 0.370 | -0.037 | -0.100 | 0.000 | -0.065 | 0.039 | 0.026 |
| Fout%FR | -0.413 | -0.217 | 0.523 | 0.219 | 0.161 | 0.399 | -0.002 | -0.518 |
| gCatt%FR | 0.137 | 0.089 | -0.239 | -0.048 | 0.051 | 0.054 | -0.082 | 0.129 |
| gShep%FR | 0.397 | 0.206 | -0.497 | -0.216 | -0.174 | -0.443 | 0.031 | 0.510 |
| gMisc%FR | -0.081 | -0.085 | 0.289 | 0.010 | -0.153 | 0.112 | -0.036 | -0.077 |
| gTotl%FR | 0.384 | 0.179 | -0.513 | -0.218 | -0.110 | -0.344 | -0.017 | 0.482 |
| milk%TO | -0.049 | 0.132 | 0.007 | -0.037 | 0.202 | -0.128 | 0.061 | -0.070 |
| catt%TO | -0.106 | -0.065 | 0.148 | -0.016 | -0.001 | 0.437 | -0.171 | -0.130 |
| shep%TO | -0.117 | -0.131 | -0.238 | -0.002 | 0.013 | -0.100 | 0.286 | -0.137 |
| polt%TO | -0.051 | -0.112 | 0.159 | -0.037 | 0.055 | 0.172 | -0.115 | -0.063 |
| oliv%TO | -0.107 | -0.164 | -0.026 | -0.062 | -0.051 | 0.074 | 0.032 | -0.034 |
| crop%TO | -0.196 | -0.056 | 0.860 | 0.381 | 0.101 | 0.076 | -0.205 | -0.269 |
| misc%TO | 0.066 | 0.372 | -0.037 | -0.100 | -0.003 | -0.063 | 0.039 | 0.025 |
| Fout%TO | -0.402 | -0.202 | 0.519 | 0.226 | 0.148 | 0.406 | -0.010 | -0.509 |
| gCatt%TO | 0.139 | 0.091 | -0.240 | -0.047 | 0.050 | 0.052 | -0.083 | 0.132 |
| gShep%TO | 0.403 | 0.212 | -0.500 | -0.215 | -0.177 | -0.441 | 0.027 | 0.515 |
| gMisc%TO | -0.080 | -0.084 | 0.289 | 0.010 | -0.153 | 0.111 | -0.036 | -0.077 |
| gTotl%TO | 0.388 | 0.184 | -0.514 | -0.217 | -0.111 | -0.340 | -0.021 | 0.485 |
| Frev%TO | 0.125 | 0.185 | -0.022 | 0.097 | -0.129 | 0.121 | -0.107 | 0.087 |
| nOut%TO | -0.125 | -0.185 | 0.022 | -0.097 | 0.129 | -0.121 | 0.107 | -0.087 |
| lnLive/h | -0.609 | -0.443 | 0.124 | 0.031 | 0.173 | 0.509 | 0.165 | -0.568 |
| %milk+.1 | -0.052 | 0.130 | 0.008 | -0.039 | 0.201 | -0.123 | 0.063 | -0.075 |
| %milk+1 | -0.050 | 0.131 | 0.007 | -0.038 | 0.202 | -0.128 | 0.061 | -0.071 |

| | BSU | %$mlk>7% | 150ha+ | >3hRough | radius | Easting | Northing | Region |
|---|---|---|---|---|---|---|---|---|
| %$mlk>7% | 0.286 | | | | | | | |
| 150ha+ | 0.383 | 0.246 | | | | | | |
| >3hRough | -0.155 | -0.105 | 0.143 | | | | | |
| radius | 0.643 | 0.137 | 0.719 | 0.204 | | | | |
| Easting | 0.022 | 0.049 | 0.140 | -0.103 | 0.086 | | | |
| Northing | 0.028 | 0.125 | 0.007 | -0.040 | -0.013 | -0.307 | | |
| Region | 0.148 | -0.081 | -0.221 | -0.294 | -0.140 | -0.581 | 0.122 | |
| RegCat | 0.125 | -0.100 | -0.150 | -0.244 | -0.096 | -0.503 | 0.092 | 0.948 |
| Region1 | -0.188 | -0.038 | 0.258 | 0.286 | 0.099 | 0.022 | 0.093 | -0.496 |
| Region4 | 0.077 | -0.053 | 0.027 | -0.098 | 0.046 | 0.237 | -0.133 | 0.312 |
| milk%FR | 0.295 | 0.998 | 0.242 | -0.113 | 0.136 | 0.052 | 0.133 | -0.087 |
| catt%FR | 0.140 | -0.012 | -0.160 | -0.105 | -0.053 | -0.153 | 0.082 | 0.190 |
| shep%FR | -0.149 | -0.243 | -0.101 | -0.147 | -0.156 | 0.099 | -0.004 | 0.052 |
| polt%FR | -0.096 | -0.013 | -0.052 | -0.098 | -0.124 | -0.222 | 0.051 | 0.151 |
| oliv%FR | -0.153 | -0.028 | -0.108 | -0.006 | -0.171 | 0.003 | -0.019 | -0.076 |
| crop%FR | 0.222 | 0.014 | 0.007 | -0.150 | -0.051 | -0.417 | 0.016 | 0.417 |
| misc%FR | 0.379 | 0.397 | 0.315 | -0.024 | 0.336 | 0.116 | 0.062 | 0.096 |
| Fout%FR | 0.264 | 0.073 | -0.198 | -0.428 | -0.213 | -0.343 | 0.148 | 0.556 |
| gCatt%FR | -0.129 | -0.081 | 0.072 | 0.153 | 0.082 | 0.252 | -0.223 | -0.288 |
| gShep%FR | -0.235 | -0.050 | 0.194 | 0.404 | 0.203 | 0.299 | -0.086 | -0.514 |
| gMisc%FR | -0.046 | -0.033 | -0.121 | -0.040 | -0.069 | -0.218 | -0.006 | 0.160 |
| gTotl%FR | -0.264 | -0.073 | 0.178 | 0.384 | 0.169 | 0.361 | -0.181 | -0.514 |
| milk%TO | 0.295 | 0.997 | 0.242 | -0.113 | 0.136 | 0.052 | 0.134 | -0.087 |
| catt%TO | 0.142 | -0.016 | -0.159 | -0.102 | -0.050 | -0.150 | 0.081 | 0.186 |
| shep%TO | -0.138 | -0.249 | -0.099 | -0.150 | -0.144 | 0.103 | -0.007 | 0.041 |
| polt%TO | -0.096 | -0.013 | -0.052 | -0.098 | -0.124 | -0.222 | 0.051 | 0.151 |
| oliv%TO | -0.152 | -0.028 | -0.108 | -0.006 | -0.171 | 0.004 | -0.019 | -0.076 |
| crop%TO | 0.223 | 0.012 | 0.007 | -0.150 | -0.049 | -0.416 | 0.015 | 0.416 |
| misc%TO | 0.380 | 0.391 | 0.314 | -0.025 | 0.338 | 0.117 | 0.063 | 0.095 |
| Fout%TO | 0.277 | 0.056 | -0.195 | -0.424 | -0.193 | -0.335 | 0.142 | 0.538 |
| gCatt%TO | -0.127 | -0.083 | 0.073 | 0.156 | 0.084 | 0.253 | -0.224 | -0.289 |
| gShep%TO | -0.232 | -0.053 | 0.196 | 0.405 | 0.209 | 0.301 | -0.088 | -0.521 |
| gMisc%TO | -0.046 | -0.033 | -0.121 | -0.040 | -0.068 | -0.218 | -0.006 | 0.160 |
| gTotl%TO | -0.261 | -0.077 | 0.179 | 0.384 | 0.174 | 0.362 | -0.183 | -0.519 |
| Frev%TO | 0.174 | -0.187 | 0.037 | 0.020 | 0.224 | 0.078 | -0.063 | -0.215 |
| nOut%TO | -0.174 | 0.187 | -0.037 | -0.020 | -0.224 | -0.078 | 0.063 | 0.215 |
| lnLive/h | 0.260 | 0.064 | -0.487 | -0.465 | -0.400 | -0.045 | 0.083 | 0.277 |
| %milk+.1 | 0.303 | 0.991 | 0.237 | -0.119 | 0.135 | 0.055 | 0.141 | -0.092 |
| %milk+1 | 0.296 | 0.997 | 0.241 | -0.113 | 0.136 | 0.052 | 0.134 | -0.088 |

| | RegCat | Region1 | Region4 | milk%FR | catt%FR | shep%FR | polt%FR | oliv%FR |
|---|---|---|---|---|---|---|---|---|
| Region1 | -0.315 | | | | | | | |
| Region4 | 0.534 | -0.168 | | | | | | |
| milk%FR | -0.107 | -0.041 | -0.057 | | | | | |
| catt%FR | 0.175 | -0.100 | 0.022 | -0.007 | | | | |
| shep%FR | -0.003 | -0.141 | -0.043 | -0.244 | -0.689 | | | |
| polt%FR | 0.129 | -0.040 | -0.038 | -0.014 | 0.140 | -0.160 | | |
| oliv%FR | -0.060 | 0.149 | -0.076 | -0.030 | 0.162 | -0.148 | 0.174 | |
| crop%FR | 0.356 | -0.131 | -0.097 | 0.011 | 0.079 | -0.215 | 0.170 | -0.043 |
| misc%FR | 0.142 | -0.135 | 0.276 | 0.392 | -0.124 | -0.087 | 0.004 | -0.049 |
| Fout%FR | 0.429 | -0.384 | -0.099 | 0.076 | 0.443 | 0.063 | 0.134 | 0.018 |
| gCatt%FR | -0.189 | 0.119 | 0.241 | -0.083 | 0.338 | -0.457 | 0.037 | 0.114 |
| gShep%FR | -0.408 | 0.379 | 0.033 | -0.052 | -0.565 | 0.081 | -0.151 | -0.055 |
| gMisc%FR | 0.126 | -0.089 | -0.049 | -0.035 | -0.088 | -0.070 | -0.031 | 0.007 |
| gTotl%FR | -0.380 | 0.358 | 0.152 | -0.076 | -0.417 | -0.076 | -0.132 | -0.024 |
| milk%TO | -0.107 | -0.041 | -0.057 | 1.000 | -0.007 | -0.244 | -0.014 | -0.030 |
| catt%TO | 0.172 | -0.098 | 0.024 | -0.012 | 1.000 | -0.687 | 0.133 | 0.162 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| shep%TO | -0.015 | -0.137 | -0.049 | -0.250 | -0.681 | 0.998 | -0.166 | -0.148 |
| polt%TO | 0.129 | -0.041 | -0.038 | -0.014 | 0.140 | -0.160 | 1.000 | 0.174 |
| oliv%TO | -0.060 | 0.149 | -0.076 | -0.030 | 0.161 | -0.148 | 0.170 | 1.000 |
| crop%TO | 0.356 | -0.131 | -0.096 | 0.010 | 0.077 | -0.214 | 0.166 | -0.043 |
| misc%TO | 0.141 | -0.135 | 0.278 | 0.387 | -0.123 | -0.086 | 0.004 | -0.049 |
| Fout%TO | 0.412 | -0.375 | -0.102 | 0.059 | 0.456 | 0.057 | 0.117 | 0.020 |
| gCatt%TO | -0.189 | 0.120 | 0.242 | -0.084 | 0.336 | -0.454 | 0.033 | 0.114 |
| gShep%TO | -0.415 | 0.384 | 0.030 | -0.055 | -0.561 | 0.077 | -0.152 | -0.054 |
| gMisc%TO | 0.126 | -0.089 | -0.049 | -0.035 | -0.089 | -0.070 | -0.031 | 0.007 |
| gTotl%TO | -0.385 | 0.361 | 0.150 | -0.079 | -0.410 | -0.080 | -0.134 | -0.023 |
| Frev%TO | -0.203 | 0.114 | -0.047 | -0.182 | 0.201 | -0.090 | -0.177 | 0.025 |
| nOut%TO | 0.203 | -0.114 | 0.047 | 0.182 | -0.201 | 0.090 | 0.177 | -0.025 |
| lnLive/h | 0.184 | -0.304 | -0.048 | 0.080 | 0.454 | -0.060 | 0.153 | 0.097 |
| %milk+.1 | -0.113 | -0.043 | -0.060 | 0.998 | -0.003 | -0.244 | -0.014 | -0.032 |
| %milk+1 | -0.107 | -0.041 | -0.057 | 1.000 | -0.007 | -0.244 | -0.014 | -0.030 |

| | crop%FR | misc%FR | Fout%FR | gCatt%FR | gShep%FR | gMisc%FR | gTotl%FR | milk%TO |
|---|---|---|---|---|---|---|---|---|
| misc%FR | -0.009 | | | | | | | |
| Fout%FR | 0.565 | -0.059 | | | | | | |
| gCatt%FR | -0.225 | -0.003 | -0.295 | | | | | |
| gShep%FR | -0.538 | 0.067 | -0.956 | 0.009 | | | | |
| gMisc%FR | 0.180 | -0.045 | -0.065 | -0.130 | 0.040 | | | |
| gTotl%FR | -0.544 | 0.054 | -0.969 | 0.311 | 0.919 | 0.054 | | |
| milk%TO | 0.011 | 0.392 | 0.076 | -0.083 | -0.052 | -0.036 | -0.076 | |
| catt%TO | 0.075 | -0.129 | 0.441 | 0.342 | -0.564 | -0.089 | -0.414 | -0.012 |
| shep%TO | -0.217 | -0.096 | 0.067 | -0.443 | 0.073 | -0.068 | -0.080 | -0.250 |
| polt%TO | 0.169 | 0.004 | 0.134 | 0.037 | -0.151 | -0.031 | -0.132 | -0.014 |
| oliv%TO | -0.043 | -0.049 | 0.018 | 0.114 | -0.054 | 0.007 | -0.024 | -0.030 |
| crop%TO | 1.000 | -0.010 | 0.564 | -0.226 | -0.537 | 0.182 | -0.543 | 0.010 |
| misc%TO | -0.009 | 1.000 | -0.058 | 0.001 | 0.064 | -0.045 | 0.053 | 0.387 |
| Fout%TO | 0.559 | -0.076 | 0.997 | -0.269 | -0.961 | -0.061 | -0.965 | 0.060 |
| gCatt%TO | -0.227 | -0.004 | -0.296 | 1.000 | 0.010 | -0.129 | 0.312 | -0.084 |
| gShep%TO | -0.541 | 0.060 | -0.959 | 0.020 | 1.000 | 0.042 | 0.922 | -0.055 |
| gMisc%TO | 0.181 | -0.046 | -0.065 | -0.129 | 0.040 | 1.000 | 0.054 | -0.036 |
| gTotl%TO | -0.545 | 0.048 | -0.968 | 0.323 | 0.914 | 0.056 | 1.000 | -0.079 |
| Frev%TO | -0.039 | -0.228 | 0.027 | 0.340 | -0.137 | 0.051 | -0.021 | -0.181 |
| nOut%TO | 0.039 | 0.228 | -0.027 | -0.340 | 0.137 | -0.051 | 0.021 | 0.181 |
| lnLive/h | 0.081 | -0.076 | 0.539 | -0.098 | -0.536 | -0.017 | -0.484 | 0.081 |
| %milk+.1 | 0.009 | 0.386 | 0.078 | -0.083 | -0.054 | -0.037 | -0.078 | 0.998 |
| %milk+1 | 0.011 | 0.392 | 0.076 | -0.083 | -0.052 | -0.036 | -0.076 | 1.000 |

| | catt%TO | shep%TO | polt%TO | oliv%TO | crop%TO | misc%TO | Fout%TO | gCatt%TO |
|---|---|---|---|---|---|---|---|---|
| shep%TO | -0.679 | | | | | | | |
| polt%TO | 0.133 | -0.166 | | | | | | |
| oliv%TO | 0.161 | -0.147 | 0.170 | | | | | |
| crop%TO | 0.074 | -0.215 | 0.166 | -0.044 | | | | |
| misc%TO | -0.127 | -0.095 | 0.004 | -0.049 | -0.009 | | | |
| Fout%TO | 0.455 | 0.065 | 0.117 | 0.019 | 0.558 | -0.075 | | |
| gCatt%TO | 0.341 | -0.440 | 0.033 | 0.113 | -0.227 | -0.000 | -0.270 | |
| gShep%TO | -0.560 | 0.070 | -0.152 | -0.054 | -0.540 | 0.058 | -0.962 | 0.021 |
| gMisc%TO | -0.090 | -0.067 | -0.031 | 0.007 | 0.183 | -0.046 | -0.061 | -0.129 |
| gTotl%TO | -0.407 | -0.082 | -0.134 | -0.023 | -0.543 | 0.047 | -0.962 | 0.324 |
| Frev%TO | 0.216 | -0.037 | -0.177 | 0.026 | -0.036 | -0.221 | 0.106 | 0.347 |
| nOut%TO | -0.216 | 0.037 | 0.177 | -0.026 | 0.036 | 0.221 | -0.106 | -0.347 |
| lnLive/h | 0.454 | -0.050 | 0.153 | 0.096 | 0.080 | -0.076 | 0.549 | -0.097 |
| %milk+.1 | -0.007 | -0.250 | -0.014 | -0.032 | 0.008 | 0.381 | 0.062 | -0.085 |
| %milk+1 | -0.011 | -0.250 | -0.014 | -0.030 | 0.010 | 0.386 | 0.060 | -0.084 |

| | gShep%TO | gMisc%TO | gTotl%TO | Frev%TO | nOut%TO | lnLive/h | %milk+.1 |
|---|---|---|---|---|---|---|---|
| gMisc%TO | 0.041 | | | | | | |
| gTotl%TO | 0.918 | 0.056 | | | | | |
| Frev%TO | -0.111 | 0.052 | 0.006 | | | | |
| nOut%TO | 0.111 | -0.052 | -0.006 | -1.000 | | | |
| lnLive/h | -0.535 | -0.018 | -0.481 | 0.149 | -0.149 | | |
| %milk+.1 | -0.057 | -0.037 | -0.081 | -0.175 | 0.175 | 0.096 | |
| %milk+1 | -0.055 | -0.036 | -0.079 | -0.181 | 0.181 | 0.083 | 0.998 |

## A7.1.4: FBSW VARIABLES FOR MILK FARMS

This section contains information concerning cluster 2 (file clus2.mtw), the mainly milk farms. Contents are as per the previous section.

### A7.1.4.1: Descriptive statistics for FBSW variables

| | N | N* | MEAN | MEDIAN | TRMEAN | STDEV | SEMEAN |
|---|---|---|---|---|---|---|---|
| surp/ha | 104 | 0 | 703.8 | 655.6 | 692.9 | 306.0 | 30.0 |
| %$milk | 104 | 0 | 0.7919 | 0.8366 | 0.7997 | 0.1614 | 0.0158 |
| %$catt | 104 | 0 | 0.1136 | 0.0857 | 0.1082 | 0.1065 | 0.0104 |
| %$sheep | 104 | 0 | 0.06033 | 0.01849 | 0.05076 | 0.08456 | 0.00829 |
| %$poult | 103 | 1 | 0.00288 | 0.00000 | 0.00000 | 0.02558 | 0.00252 |
| %$othliv | 103 | 1 | 0.00016 | 0.00000 | 0.00003 | 0.00076 | 0.00007 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| %$crops | 103 | 1 | 0.02593 | 0.01373 | 0.02393 | 0.04628 | 0.00456 |
| %$misc | 103 | 1 | 0.00350 | 0.00001 | 0.00170 | 0.00978 | 0.00096 |
| l/cow | 104 | 0 | 4930.2 | 4946.0 | 4944.1 | 850.9 | 83.4 |
| $mlk/cow | 104 | 0 | 891.4 | 903.2 | 905.8 | 202.7 | 19.9 |
| lamb/ewe | 104 | 0 | 0.5837 | 0.0000 | 0.5561 | 0.6256 | 0.0613 |
| fatl/ewe | 104 | 0 | 1.1111 | 0.9900 | 1.0114 | 0.7635 | 0.0749 |
| %return | 104 | 0 | 15.13 | 17.03 | 15.23 | 14.78 | 1.45 |
| SMDavail | 104 | 0 | 733.9 | 636.5 | 695.7 | 367.0 | 36.0 |
| SMDreq | 104 | 0 | 1036.2 | 843.5 | 928.1 | 871.1 | 85.4 |
| $live/eh | 104 | 0 | 1036.0 | 989.0 | 1014.8 | 351.9 | 34.5 |
| $mech/eh | 104 | 0 | 648.1 | 612.5 | 629.6 | 288.2 | 28.3 |
| $crop/eh | 104 | 0 | 94.3 | 57.5 | 77.1 | 125.2 | 12.3 |
| $stor/eh | 104 | 0 | 23.64 | 11.00 | 20.13 | 30.91 | 3.03 |
| ehaCerl | 104 | 0 | 5.87 | 0.00 | 3.48 | 15.03 | 1.47 |
| ehaRoots | 104 | 0 | 0.750 | 0.000 | 0.234 | 2.617 | 0.257 |
| ehaHay | 104 | 0 | 3.192 | 2.000 | 2.798 | 3.695 | 0.362 |
| ehaSilag | 104 | 0 | 26.79 | 25.00 | 24.71 | 20.41 | 2.00 |
| ehaPast | 104 | 0 | 32.17 | 23.00 | 29.88 | 25.67 | 2.52 |
| ehaRough | 104 | 0 | 1.712 | 0.000 | 0.840 | 5.247 | 0.514 |
| ehaTotal | 104 | 0 | 70.86 | 58.16 | 64.41 | 55.46 | 5.44 |
| %Cerl | 104 | 0 | 0.05276 | 0.00000 | 0.04117 | 0.09021 | 0.00885 |
| %Roots | 104 | 0 | 0.00861 | 0.00000 | 0.00300 | 0.02906 | 0.00285 |
| %Hay | 104 | 0 | 0.06518 | 0.03517 | 0.05266 | 0.08952 | 0.00878 |
| %Silag | 104 | 0 | 0.3963 | 0.3742 | 0.3989 | 0.1584 | 0.0155 |
| %Past | 104 | 0 | 0.4505 | 0.4504 | 0.4509 | 0.1482 | 0.0145 |
| %Rough | 104 | 0 | 0.01896 | 0.00000 | 0.01174 | 0.04277 | 0.00419 |
| BSU | 103 | 1 | 33.83 | 25.56 | 29.56 | 31.50 | 3.10 |
| %$mlk>7% | 104 | 0 | 1.0000 | 1.0000 | 1.0000 | 0.0000 | 0.0000 |
| 150ha+ | 104 | 0 | 0.0673 | 0.0000 | 0.0213 | 0.2518 | 0.0247 |
| >3hRough | 104 | 0 | 0.1346 | 0.0000 | 0.0957 | 0.3430 | 0.0336 |
| radius | 104 | 0 | 4.486 | 4.300 | 4.385 | 1.571 | 0.154 |
| Easting | 104 | 0 | 2663.4 | 2550.0 | 2661.3 | 453.8 | 44.5 |
| Northing | 104 | 0 | 2880.3 | 2660.0 | 2881.6 | 640.8 | 62.8 |
| Region | 104 | 0 | 4.096 | 4.500 | 4.160 | 1.153 | 0.113 |
| RegCat | 104 | 0 | 0.7596 | 1.0000 | 0.7872 | 0.4294 | 0.0421 |
| Region1 | 104 | 0 | 0.00962 | 0.00000 | 0.00000 | 0.09806 | 0.00962 |
| Region4 | 104 | 0 | 0.2692 | 0.0000 | 0.2447 | 0.4457 | 0.0437 |
| milk%FR | 104 | 0 | 0.7807 | 0.8301 | 0.7887 | 0.1710 | 0.0168 |
| catt%FR | 104 | 0 | 0.1107 | 0.0848 | 0.1057 | 0.1029 | 0.0101 |
| shep%FR | 104 | 0 | 0.05712 | 0.01840 | 0.04885 | 0.07802 | 0.00765 |
| polt%FR | 103 | 1 | 0.00288 | 0.00000 | -0.00000 | 0.02558 | 0.00252 |
| oliv%FR | 103 | 1 | 0.00016 | 0.00000 | 0.00003 | 0.00072 | 0.00007 |
| crop%FR | 103 | 1 | 0.02571 | 0.01373 | 0.02372 | 0.04563 | 0.00450 |
| misc%FR | 103 | 1 | 0.00341 | 0.00001 | 0.00167 | 0.00945 | 0.00093 |
| Fout%FR | 104 | 0 | 0.98246 | 0.99582 | 0.98650 | 0.02933 | 0.00288 |
| gCatt%FR | 103 | 1 | 0.00148 | 0.00000 | 0.00091 | 0.00363 | 0.00036 |
| gShep%FR | 103 | 1 | 0.01526 | 0.00000 | 0.01105 | 0.02779 | 0.00274 |
| gMisc%FR | 103 | 1 | 0.00043 | 0.00000 | 0.00006 | 0.00231 | 0.00023 |
| gTotl%FR | 104 | 0 | 0.01754 | 0.00418 | 0.01350 | 0.02933 | 0.00288 |
| milk%TO | 104 | 0 | 0.7749 | 0.8257 | 0.7830 | 0.1697 | 0.0166 |
| catt%TO | 104 | 0 | 0.1099 | 0.0841 | 0.1049 | 0.1021 | 0.0100 |
| shep%TO | 104 | 0 | 0.05665 | 0.01831 | 0.04844 | 0.07737 | 0.00759 |
| polt%TO | 103 | 1 | 0.00286 | 0.00000 | -0.00000 | 0.02545 | 0.00251 |
| oliv%TO | 103 | 1 | 0.00016 | 0.00000 | 0.00003 | 0.00072 | 0.00007 |
| crop%TO | 103 | 1 | 0.02554 | 0.01363 | 0.02355 | 0.04530 | 0.00446 |
| misc%TO | 103 | 1 | 0.00339 | 0.00001 | 0.00166 | 0.00938 | 0.00092 |
| Fout%TO | 104 | 0 | 0.97512 | 0.98797 | 0.97892 | 0.03011 | 0.00295 |
| gCatt%TO | 103 | 1 | 0.00147 | 0.00000 | 0.00090 | 0.00358 | 0.00035 |
| gShep%TO | 103 | 1 | 0.01513 | 0.00000 | 0.01095 | 0.02755 | 0.00271 |
| gMisc%TO | 103 | 1 | 0.00043 | 0.00000 | 0.00006 | 0.00229 | 0.00023 |
| gTotl%TO | 104 | 0 | 0.01740 | 0.00417 | 0.01338 | 0.02907 | 0.00285 |
| Frev%TO | 104 | 0 | 0.99252 | 0.99359 | 0.99297 | 0.00516 | 0.00051 |
| nOut%TO | 104 | 0 | 0.00748 | 0.00641 | 0.00703 | 0.00516 | 0.00051 |
| lnLive/h | 104 | 0 | 6.8878 | 6.8966 | 6.8870 | 0.3354 | 0.0329 |
| %milk+.1 | 104 | 0 | -0.1483 | -0.0725 | -0.1325 | 0.2154 | 0.0211 |
| %milk+1 | 104 | 0 | 0.57222 | 0.60435 | 0.57810 | 0.09987 | 0.00979 |

| | MIN | MAX | Q1 | Q3 |
|---|---|---|---|---|
| surp/ha | 215.2 | 1442.4 | 440.4 | 905.2 |
| %$milk | 0.3657 | 1.0400 | 0.6688 | 0.9147 |
| %$catt | -0.0527 | 0.4333 | 0.0204 | 0.1993 |
| %$sheep | 0.00000 | 0.37511 | 0.00000 | 0.09990 |
| %$poult | 0.00000 | 0.25903 | 0.00000 | 0.00000 |
| %$othliv | -0.00138 | 0.00496 | 0.00000 | 0.00000 |
| %$crops | -0.13533 | 0.18683 | 0.00000 | 0.04520 |
| %$misc | 0.00000 | 0.05578 | 0.00000 | 0.00107 |
| l/cow | 2407.0 | 7270.0 | 4365.5 | 5488.0 |
| $mlk/cow | 157.9 | 1330.6 | 806.5 | 1038.2 |
| lamb/ewe | 0.0000 | 1.8300 | 0.0000 | 1.1925 |
| fatl/ewe | 0.0200 | 3.9200 | 0.6925 | 1.2650 |
| %return | -39.84 | 55.62 | 5.22 | 24.68 |
| SMDavail | 250.0 | 2240.0 | 500.0 | 889.7 |
| SMDreq | 111.0 | 6104.0 | 502.5 | 1305.3 |
| $live/eh | 461.0 | 2244.0 | 778.0 | 1241.0 |

| | | | | |
|---|---|---|---|---|
| $mech/eh | 218.0 | 1704.0 | 428.8 | 797.2 |
| $crop/eh | 0.0 | 898.0 | 20.3 | 115.0 |
| $stor/eh | 0.00 | 160.00 | 0.00 | 36.00 |
| ehaCerl | 0.00 | 122.00 | 0.00 | 6.00 |
| ehaRoots | 0.000 | 17.000 | 0.000 | 0.000 |
| ehaHay | 0.000 | 16.000 | 0.000 | 5.000 |
| ehaSilag | 0.00 | 142.00 | 13.00 | 36.00 |
| ehaPast | 0.00 | 107.00 | 14.25 | 44.00 |
| ehaRough | 0.000 | 46.000 | 0.000 | 1.000 |
| ehaTotal | 8.89 | 396.90 | 37.82 | 80.90 |
| %Cerl | 0.00000 | 0.39506 | 0.00000 | 0.09592 |
| %Roots | 0.00000 | 0.16505 | 0.00000 | 0.00000 |
| %Hay | 0.00000 | 0.50000 | 0.00000 | 0.08662 |
| %Silag | 0.0000 | 0.7568 | 0.2938 | 0.5000 |
| %Past | 0.0000 | 0.8461 | 0.3385 | 0.5506 |
| %Rough | 0.00000 | 0.24599 | 0.00000 | 0.01743 |
| BSU | 3.78 | 227.88 | 15.81 | 41.88 |
| %$mlk>7% | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 150ha+ | 0.0000 | 1.0000 | 0.0000 | 0.0000 |
| >3hRough | 0.0000 | 1.0000 | 0.0000 | 0.0000 |
| radius | 1.700 | 11.200 | 3.500 | 5.100 |
| Easting | 1870.0 | 3500.0 | 2302.5 | 3110.0 |
| Northing | 1690.0 | 3830.0 | 2297.5 | 3530.0 |
| Region | 1.000 | 6.000 | 4.000 | 5.000 |
| RegCat | 0.0000 | 1.0000 | 1.0000 | 1.0000 |
| Region1 | 0.00000 | 1.00000 | 0.00000 | 0.00000 |
| Region4 | 0.0000 | 1.0000 | 0.0000 | 1.0000 |
| milk%FR | 0.3524 | 1.0400 | 0.6337 | 0.9116 |
| catt%FR | -0.0521 | 0.4240 | 0.0204 | 0.1956 |
| shep%FR | 0.00000 | 0.32824 | 0.00000 | 0.09812 |
| polt%FR | 0.00000 | 0.25903 | 0.00000 | 0.00000 |
| oliv%FR | -0.00121 | 0.00453 | 0.00000 | 0.00000 |
| crop%FR | -0.12843 | 0.18503 | 0.00000 | 0.04332 |
| misc%FR | 0.00000 | 0.05524 | 0.00000 | 0.00106 |
| Fout%FR | 0.87506 | 1.00000 | 0.97831 | 1.00000 |
| gCatt%FR | 0.00000 | 0.02827 | 0.00000 | 0.00120 |
| gShep%FR | 0.00000 | 0.12494 | 0.00000 | 0.01867 |
| gMisc%FR | 0.00000 | 0.02179 | 0.00000 | 0.00000 |
| gTotl%FR | 0.00000 | 0.12494 | 0.00000 | 0.02170 |
| milk%TO | 0.3486 | 1.0255 | 0.6311 | 0.9067 |
| catt%TO | -0.0512 | 0.4231 | 0.0204 | 0.1935 |
| shep%TO | 0.00000 | 0.32645 | 0.00000 | 0.09707 |
| polt%TO | 0.00000 | 0.25766 | 0.00000 | 0.00000 |
| oliv%TO | -0.00120 | 0.00449 | 0.00000 | 0.00000 |
| crop%TO | -0.12708 | 0.18275 | 0.00000 | 0.04319 |
| misc%TO | 0.00000 | 0.05456 | 0.00000 | 0.00106 |
| Fout%TO | 0.87027 | 0.99930 | 0.96840 | 0.99380 |
| gCatt%TO | 0.00000 | 0.02784 | 0.00000 | 0.00119 |
| gShep%TO | 0.00000 | 0.12426 | 0.00000 | 0.01860 |
| gMisc%TO | 0.00000 | 0.02164 | 0.00000 | 0.00000 |
| gTotl%TO | 0.00000 | 0.12426 | 0.00000 | 0.02154 |
| Frev%TO | 0.96343 | 0.99930 | 0.99103 | 0.99592 |
| nOut%TO | 0.00070 | 0.03657 | 0.00408 | 0.00897 |
| lnLive/h | 6.1334 | 7.7160 | 6.6567 | 7.1237 |
| %milk+.1 | -0.7932 | 0.1310 | -0.3098 | 0.0115 |
| %milk+1 | 0.30186 | 0.71294 | 0.49083 | 0.64792 |

## A7.1.4.2: Pearson correlation matrix for FBSW variables

| | surp/ha | %$milk | %$catt | %$sheep | %$poult | %$othliv | %$crops | %$misc |
|---|---|---|---|---|---|---|---|---|
| %$milk | 0.432 | | | | | | | |
| %$catt | -0.272 | -0.813 | | | | | | |
| %$sheep | -0.514 | -0.651 | 0.258 | | | | | |
| %$poult | 0.042 | -0.105 | -0.065 | -0.073 | | | | |
| %$othliv | -0.143 | -0.171 | 0.121 | 0.103 | -0.024 | | | |
| %$crops | 0.042 | -0.331 | 0.116 | -0.107 | 0.027 | 0.122 | | |
| %$misc | -0.018 | -0.294 | 0.009 | 0.157 | 0.340 | -0.149 | 0.338 | |
| 1/cow | 0.320 | 0.028 | 0.063 | 0.012 | -0.131 | -0.140 | -0.174 | -0.029 |
| $mlk/cow | 0.289 | 0.135 | -0.044 | -0.135 | -0.086 | -0.106 | -0.067 | -0.031 |
| lamb/ewe | -0.398 | -0.574 | 0.370 | 0.677 | -0.092 | 0.119 | -0.009 | 0.009 |
| fatl/ewe | 0.158 | -0.146 | 0.146 | 0.002 | 0.000 | 0.051 | 0.187 | 0.016 |
| %return | 0.639 | 0.275 | -0.152 | -0.270 | -0.096 | -0.093 | -0.008 | -0.291 |
| SMDavail | 0.141 | 0.004 | -0.047 | -0.122 | -0.011 | 0.071 | 0.283 | 0.047 |
| SMDreq | 0.153 | -0.055 | 0.018 | -0.067 | -0.043 | 0.056 | 0.271 | -0.029 |
| $live/eh | 0.666 | 0.165 | 0.011 | -0.299 | -0.007 | -0.062 | -0.060 | 0.009 |
| $mech/eh | 0.451 | 0.232 | -0.179 | -0.279 | 0.248 | -0.140 | -0.039 | 0.184 |
| $crop/eh | 0.054 | 0.131 | -0.146 | -0.116 | -0.062 | 0.008 | 0.103 | 0.127 |
| $stor/eh | 0.339 | 0.025 | 0.016 | -0.171 | -0.083 | 0.020 | 0.226 | -0.024 |
| ehaCerl | 0.027 | -0.151 | 0.076 | -0.126 | -0.045 | 0.110 | 0.568 | 0.067 |
| ehaRoots | 0.157 | 0.013 | -0.101 | -0.032 | -0.033 | -0.030 | 0.259 | 0.076 |
| ehaHay | -0.165 | -0.325 | 0.287 | 0.134 | -0.081 | 0.052 | 0.294 | -0.000 |
| ehaSilag | 0.163 | 0.017 | -0.003 | -0.160 | -0.001 | 0.060 | 0.216 | -0.056 |
| ehaPast | -0.266 | -0.321 | 0.239 | 0.253 | -0.096 | 0.241 | 0.130 | -0.082 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ehaRough | -0.232 | -0.239 | 0.175 | 0.252 | -0.036 | -0.017 | 0.001 | 0.016 |
| ehaTotal | -0.079 | -0.222 | 0.155 | 0.053 | -0.066 | 0.162 | 0.323 | -0.034 |
| %Cerl | -0.017 | -0.136 | 0.065 | -0.189 | -0.067 | 0.133 | 0.663 | 0.153 |
| %Roots | 0.124 | 0.097 | -0.165 | -0.028 | -0.034 | -0.066 | 0.103 | 0.093 |
| %Hay | -0.096 | -0.165 | 0.144 | 0.015 | -0.042 | -0.049 | 0.223 | 0.197 |
| %Silag | 0.474 | 0.465 | -0.307 | -0.394 | 0.214 | -0.095 | -0.303 | -0.116 |
| %Past | -0.417 | -0.322 | 0.259 | 0.458 | -0.137 | 0.084 | -0.207 | -0.154 |
| %Rough | -0.327 | -0.229 | 0.097 | 0.370 | -0.049 | -0.057 | -0.067 | 0.068 |
| BSU | 0.209 | -0.002 | -0.004 | -0.170 | -0.046 | 0.039 | 0.316 | -0.035 |
| 150ha+ | -0.075 | -0.067 | 0.056 | -0.058 | -0.031 | 0.254 | 0.171 | -0.080 |
| >3hRough | -0.220 | -0.225 | 0.119 | 0.257 | -0.043 | 0.033 | 0.094 | 0.028 |
| radius | -0.120 | -0.223 | 0.151 | 0.093 | -0.072 | 0.174 | 0.267 | -0.047 |
| Easting | -0.065 | -0.011 | -0.095 | 0.141 | 0.102 | -0.112 | -0.136 | 0.176 |
| Northing | -0.038 | -0.176 | 0.141 | 0.059 | 0.108 | -0.046 | 0.064 | 0.084 |
| Region | 0.341 | 0.099 | 0.090 | -0.284 | -0.183 | 0.115 | 0.092 | -0.221 |
| RegCat | 0.402 | 0.209 | -0.051 | -0.350 | -0.178 | 0.079 | 0.121 | -0.154 |
| Region1 | -0.132 | -0.261 | 0.151 | 0.147 | -0.011 | -0.021 | 0.275 | 0.149 |
| Region4 | 0.183 | 0.269 | -0.286 | -0.189 | -0.057 | -0.038 | 0.040 | 0.034 |
| milk%FR | 0.462 | 0.996 | -0.788 | -0.703 | -0.092 | -0.160 | -0.292 | -0.282 |
| catt%FR | -0.254 | -0.801 | 0.999 | 0.232 | -0.064 | 0.117 | 0.127 | 0.008 |
| shep%FR | -0.512 | -0.656 | 0.266 | 0.999 | -0.074 | 0.107 | -0.100 | 0.149 |
| polt%FR | 0.042 | -0.105 | -0.065 | -0.073 | 1.000 | -0.024 | 0.027 | 0.340 |
| oliv%FR | -0.142 | -0.168 | 0.118 | 0.098 | -0.025 | 0.999 | 0.124 | -0.143 |
| crop%FR | 0.046 | -0.327 | 0.114 | -0.112 | 0.028 | 0.118 | 1.000 | 0.341 |
| misc%FR | -0.011 | -0.288 | 0.008 | 0.135 | 0.352 | -0.141 | 0.351 | 0.999 |
| Fout%FR | 0.540 | 0.592 | -0.288 | -0.878 | 0.063 | -0.037 | 0.165 | -0.101 |
| gCatt%FR | -0.258 | -0.432 | 0.475 | 0.209 | -0.043 | 0.048 | 0.074 | -0.040 |
| gShep%FR | -0.522 | -0.552 | 0.233 | 0.884 | -0.059 | 0.036 | -0.176 | 0.109 |
| gMisc%FR | -0.060 | -0.096 | 0.079 | 0.143 | -0.021 | -0.040 | -0.087 | 0.024 |
| gTotl%FR | -0.540 | -0.592 | 0.288 | 0.878 | -0.063 | 0.037 | -0.165 | 0.101 |
| milk%TO | 0.467 | 0.995 | -0.787 | -0.704 | -0.092 | -0.159 | -0.289 | -0.281 |
| catt%TO | -0.253 | -0.801 | 0.999 | 0.231 | -0.064 | 0.118 | 0.127 | 0.008 |
| shep%TO | -0.512 | -0.656 | 0.266 | 0.999 | -0.074 | 0.107 | -0.101 | 0.150 |
| polt%TO | 0.042 | -0.105 | -0.065 | -0.073 | 1.000 | -0.024 | 0.027 | 0.339 |
| oliv%TO | -0.142 | -0.168 | 0.118 | 0.098 | -0.025 | 0.999 | 0.124 | -0.143 |
| crop%TO | 0.046 | -0.327 | 0.114 | -0.113 | 0.028 | 0.118 | 1.000 | 0.339 |
| misc%TO | -0.011 | -0.288 | 0.008 | 0.135 | 0.353 | -0.142 | 0.350 | 0.999 |
| Fout%TO | 0.557 | 0.576 | -0.280 | -0.865 | 0.067 | -0.027 | 0.176 | -0.091 |
| gCatt%TO | -0.258 | -0.433 | 0.476 | 0.209 | -0.043 | 0.048 | 0.075 | -0.039 |
| gShep%TO | -0.522 | -0.552 | 0.232 | 0.884 | -0.059 | 0.035 | -0.176 | 0.110 |
| gMisc%TO | -0.060 | -0.096 | 0.079 | 0.142 | -0.021 | -0.040 | -0.087 | 0.024 |
| gTotl%TO | -0.540 | -0.592 | 0.288 | 0.878 | -0.063 | 0.037 | -0.165 | 0.102 |
| Frev%TO | 0.204 | 0.023 | -0.016 | -0.102 | 0.031 | 0.047 | 0.094 | 0.043 |
| nOut%TO | -0.204 | -0.023 | 0.016 | 0.102 | -0.031 | -0.047 | -0.094 | -0.043 |
| lnLive/h | 0.651 | 0.147 | 0.033 | -0.307 | 0.012 | -0.071 | -0.058 | 0.044 |
| %milk+.1 | 0.468 | 0.990 | -0.779 | -0.711 | -0.082 | -0.170 | -0.277 | -0.295 |
| %milk+1 | 0.466 | 0.995 | -0.785 | -0.708 | -0.089 | -0.165 | -0.285 | -0.289 |

| | 1/cow | $mlk/cow | lamb/ewe | fatl/ewe | %return | SMDavail | SMDreq | $live/eh |
|---|---|---|---|---|---|---|---|---|
| $mlk/cow | 0.554 | | | | | | | |
| lamb/ewe | 0.041 | -0.108 | | | | | | |
| fatl/ewe | 0.136 | 0.124 | 0.144 | | | | | |
| %return | 0.415 | 0.409 | -0.151 | 0.217 | | | | |
| SMDavail | 0.166 | 0.174 | -0.078 | 0.161 | 0.299 | | | |
| SMDreq | 0.143 | 0.143 | -0.002 | 0.222 | 0.405 | 0.856 | | |
| $live/eh | 0.318 | 0.184 | -0.187 | 0.211 | 0.353 | 0.249 | 0.293 | |
| $mech/eh | 0.161 | 0.103 | -0.293 | 0.011 | -0.014 | -0.025 | -0.086 | 0.322 |
| $crop/eh | 0.077 | 0.004 | -0.143 | -0.038 | -0.020 | 0.030 | 0.028 | -0.003 |
| $stor/eh | 0.200 | 0.206 | 0.015 | 0.175 | 0.255 | 0.427 | 0.364 | 0.404 |
| ehaCerl | -0.084 | -0.017 | 0.075 | 0.231 | 0.174 | 0.574 | 0.690 | -0.027 |
| ehaRoots | 0.115 | 0.074 | -0.073 | 0.052 | 0.242 | 0.264 | 0.345 | 0.045 |
| ehaHay | -0.115 | -0.011 | 0.175 | 0.119 | -0.015 | 0.102 | 0.143 | -0.207 |
| ehaSilag | 0.193 | 0.178 | -0.013 | 0.272 | 0.442 | 0.765 | 0.929 | 0.263 |
| ehaPast | 0.169 | 0.169 | 0.243 | 0.057 | 0.184 | 0.679 | 0.739 | -0.110 |
| ehaRough | -0.009 | 0.009 | 0.127 | -0.084 | -0.004 | 0.215 | 0.275 | -0.097 |
| ehaTotal | 0.126 | 0.143 | 0.146 | 0.192 | 0.307 | 0.791 | 0.920 | 0.020 |
| %Cerl | -0.110 | -0.052 | -0.061 | 0.089 | 0.093 | 0.367 | 0.362 | -0.075 |
| %Roots | 0.121 | 0.058 | -0.161 | -0.065 | 0.181 | 0.104 | 0.127 | 0.061 |
| %Hay | -0.251 | -0.176 | 0.055 | -0.045 | -0.411 | -0.248 | -0.320 | -0.166 |
| %Silag | 0.139 | 0.114 | -0.315 | 0.124 | 0.356 | -0.033 | 0.039 | 0.460 |
| %Past | 0.031 | -0.016 | 0.361 | -0.101 | -0.206 | -0.055 | -0.093 | -0.341 |
| %Rough | -0.004 | -0.009 | 0.179 | -0.072 | -0.125 | 0.049 | 0.072 | -0.141 |
| BSU | 0.118 | 0.137 | -0.052 | 0.238 | 0.423 | 0.853 | 0.991 | 0.311 |
| 150ha+ | -0.048 | 0.028 | 0.031 | 0.067 | 0.100 | 0.641 | 0.694 | 0.029 |
| >3hRough | 0.069 | 0.063 | 0.247 | 0.058 | -0.005 | 0.246 | 0.293 | -0.105 |
| radius | 0.192 | 0.186 | 0.158 | 0.162 | 0.353 | 0.789 | 0.880 | 0.016 |
| Easting | 0.007 | -0.084 | 0.044 | -0.111 | -0.098 | -0.157 | -0.200 | -0.010 |
| Northing | 0.079 | -0.035 | 0.115 | 0.055 | -0.046 | -0.048 | -0.083 | 0.066 |
| Region | 0.092 | 0.072 | -0.034 | 0.117 | 0.418 | 0.154 | 0.228 | 0.258 |
| RegCat | 0.096 | 0.078 | -0.133 | 0.080 | 0.424 | 0.125 | 0.173 | 0.267 |
| Region1 | -0.086 | -0.082 | 0.102 | 0.306 | -0.136 | -0.091 | -0.073 | 0.018 |
| Region4 | -0.064 | -0.070 | -0.216 | -0.155 | 0.090 | -0.090 | -0.101 | 0.033 |
| milk%FR | 0.033 | 0.138 | -0.593 | -0.129 | 0.288 | 0.018 | -0.044 | 0.187 |
| catt%FR | 0.067 | -0.039 | 0.359 | 0.153 | -0.144 | -0.045 | 0.020 | 0.024 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| shep%FR | 0.015 | -0.140 | 0.698 | 0.007 | -0.263 | -0.122 | -0.068 | -0.301 |
| polt%FR | -0.131 | -0.086 | -0.092 | 0.000 | -0.096 | -0.011 | -0.043 | -0.007 |
| oliv%FR | -0.136 | -0.099 | 0.119 | 0.050 | -0.093 | 0.074 | 0.055 | -0.055 |
| crop%FR | -0.173 | -0.066 | -0.013 | 0.185 | -0.007 | 0.288 | 0.275 | -0.058 |
| misc%FR | -0.035 | -0.036 | 0.001 | 0.016 | -0.291 | 0.048 | -0.030 | 0.008 |
| Fout%FR | 0.055 | 0.106 | -0.486 | 0.065 | 0.297 | 0.124 | 0.058 | 0.291 |
| gCatt%FR | 0.008 | 0.034 | 0.236 | 0.038 | -0.050 | -0.071 | -0.065 | -0.173 |
| gShep%FR | -0.084 | -0.135 | 0.468 | -0.068 | -0.302 | -0.132 | -0.057 | -0.265 |
| gMisc%FR | 0.022 | 0.003 | 0.096 | 0.009 | 0.044 | -0.101 | -0.063 | -0.151 |
| gTotl%FR | -0.055 | -0.106 | 0.486 | -0.065 | -0.297 | -0.124 | -0.058 | -0.291 |
| milk%TO | 0.040 | 0.142 | -0.593 | -0.127 | 0.297 | 0.026 | -0.035 | 0.194 |
| catt%TO | 0.069 | -0.039 | 0.359 | 0.153 | -0.143 | -0.044 | 0.022 | 0.025 |
| shep%TO | 0.017 | -0.140 | 0.698 | 0.007 | -0.263 | -0.122 | -0.067 | -0.300 |
| polt%TO | -0.131 | -0.086 | -0.092 | -0.000 | -0.096 | -0.011 | -0.043 | -0.007 |
| oliv%TO | -0.135 | -0.099 | 0.120 | 0.050 | -0.093 | 0.074 | 0.055 | -0.055 |
| crop%TO | -0.173 | -0.066 | -0.013 | 0.186 | -0.006 | 0.289 | 0.277 | -0.058 |
| misc%TO | -0.034 | -0.036 | 0.001 | 0.016 | -0.290 | 0.049 | -0.029 | 0.008 |
| Fout%TO | 0.103 | 0.127 | -0.477 | 0.073 | 0.348 | 0.178 | 0.123 | 0.331 |
| gCatt%TO | 0.008 | 0.034 | 0.236 | 0.038 | -0.050 | -0.071 | -0.064 | -0.173 |
| gShep%TO | -0.083 | -0.135 | 0.468 | -0.068 | -0.302 | -0.132 | -0.057 | -0.265 |
| gMisc%TO | 0.022 | 0.003 | 0.096 | 0.009 | 0.044 | -0.101 | -0.063 | -0.151 |
| gTotl%TO | -0.054 | -0.106 | 0.487 | -0.065 | -0.297 | -0.123 | -0.058 | -0.290 |
| Frev%TO | 0.295 | 0.145 | -0.040 | 0.058 | 0.356 | 0.340 | 0.395 | 0.294 |
| nOut%TO | -0.295 | -0.145 | 0.040 | -0.058 | -0.356 | -0.340 | -0.395 | -0.294 |
| lnLive/h | 0.353 | 0.205 | -0.182 | 0.194 | 0.341 | 0.248 | 0.273 | 0.977 |
| %milk+.1 | 0.032 | 0.151 | -0.580 | -0.139 | 0.304 | 0.031 | -0.032 | 0.191 |
| %milk+1 | 0.033 | 0.144 | -0.588 | -0.133 | 0.296 | 0.024 | -0.039 | 0.189 |

| | $mech/eh | $crop/eh | $stor/eh | ehaCerl | ehaRoots | ehaHay | ehaSilag | ehaPast |
|---|---|---|---|---|---|---|---|---|
| $crop/eh | 0.091 | | | | | | | |
| $stor/eh | 0.181 | -0.053 | | | | | | |
| ehaCerl | -0.060 | 0.016 | 0.319 | | | | | |
| ehaRoots | 0.014 | 0.043 | 0.303 | 0.413 | | | | |
| ehaHay | -0.230 | 0.013 | -0.171 | 0.293 | 0.024 | | | |
| ehaSilag | -0.073 | -0.009 | 0.289 | 0.673 | 0.250 | 0.104 | | |
| ehaPast | -0.309 | -0.087 | 0.136 | 0.431 | 0.141 | 0.146 | 0.649 | |
| ehaRough | -0.171 | -0.057 | -0.085 | 0.104 | 0.048 | 0.039 | 0.189 | 0.400 |
| ehaTotal | -0.215 | -0.039 | 0.247 | 0.762 | 0.319 | 0.252 | 0.888 | 0.867 |
| %Cerl | -0.024 | 0.080 | 0.274 | 0.740 | 0.299 | 0.167 | 0.334 | 0.188 |
| %Roots | 0.034 | 0.037 | 0.181 | 0.136 | 0.874 | -0.083 | 0.046 | -0.006 |
| %Hay | -0.085 | 0.086 | -0.240 | -0.120 | -0.130 | 0.622 | -0.392 | -0.290 |
| %Silag | 0.335 | -0.014 | 0.108 | -0.130 | -0.096 | -0.394 | 0.258 | -0.353 |
| %Past | -0.275 | -0.107 | -0.119 | -0.234 | -0.169 | -0.000 | -0.246 | 0.439 |
| %Rough | -0.178 | -0.095 | -0.121 | -0.041 | 0.042 | -0.004 | 0.010 | 0.183 |
| BSU | -0.060 | 0.041 | 0.385 | 0.741 | 0.350 | 0.156 | 0.932 | 0.679 |
| 150ha+ | -0.157 | -0.082 | 0.168 | 0.487 | 0.085 | 0.059 | 0.636 | 0.701 |
| >3hRough | -0.144 | -0.109 | -0.008 | 0.273 | 0.189 | 0.102 | 0.282 | 0.310 |
| radius | -0.240 | -0.022 | 0.219 | 0.656 | 0.293 | 0.219 | 0.858 | 0.889 |
| Easting | 0.102 | -0.040 | 0.051 | -0.159 | -0.226 | -0.223 | -0.162 | -0.163 |
| Northing | 0.056 | -0.078 | 0.124 | -0.082 | -0.161 | -0.045 | -0.088 | -0.012 |
| Region | -0.111 | -0.057 | 0.096 | 0.139 | 0.130 | 0.030 | 0.249 | 0.133 |
| RegCat | -0.119 | -0.019 | 0.101 | 0.146 | 0.110 | -0.056 | 0.206 | 0.016 |
| Region1 | -0.026 | 0.001 | -0.034 | -0.012 | -0.028 | 0.022 | -0.101 | -0.066 |
| Region4 | -0.086 | 0.038 | 0.032 | 0.038 | -0.075 | -0.108 | -0.067 | -0.213 |
| milk%FR | 0.245 | 0.137 | 0.041 | -0.129 | 0.018 | -0.310 | 0.032 | -0.325 |
| catt%FR | -0.169 | -0.144 | 0.028 | 0.084 | -0.101 | 0.292 | 0.002 | 0.229 |
| shep%FR | -0.285 | -0.116 | -0.173 | -0.124 | -0.040 | 0.140 | -0.159 | 0.256 |
| polt%FR | 0.248 | -0.062 | -0.083 | -0.045 | -0.033 | -0.081 | -0.001 | -0.096 |
| oliv%FR | -0.137 | 0.005 | 0.024 | 0.112 | -0.031 | 0.049 | 0.060 | 0.239 |
| crop%FR | -0.037 | 0.104 | 0.229 | 0.573 | 0.264 | 0.293 | 0.218 | 0.130 |
| misc%FR | 0.189 | 0.135 | -0.021 | 0.072 | 0.067 | -0.007 | -0.054 | -0.085 |
| Fout%FR | 0.258 | 0.130 | 0.169 | 0.127 | 0.028 | -0.063 | 0.152 | -0.243 |
| gCatt%FR | -0.248 | -0.082 | -0.069 | 0.009 | -0.087 | 0.135 | -0.047 | 0.157 |
| gShep%FR | -0.245 | -0.120 | -0.174 | -0.125 | -0.010 | 0.055 | -0.153 | 0.214 |
| gMisc%FR | 0.002 | 0.008 | -0.013 | -0.059 | -0.050 | -0.054 | -0.034 | 0.026 |
| gTotl%FR | -0.258 | -0.130 | -0.169 | -0.127 | -0.028 | 0.063 | -0.152 | 0.243 |
| milk%TO | 0.247 | 0.139 | 0.045 | -0.125 | 0.021 | -0.310 | 0.042 | -0.319 |
| catt%TO | -0.167 | -0.143 | 0.029 | 0.086 | -0.100 | 0.293 | 0.004 | 0.230 |
| shep%TO | -0.284 | -0.116 | -0.173 | -0.124 | -0.040 | 0.139 | -0.158 | 0.256 |
| polt%TO | 0.248 | -0.062 | -0.083 | -0.045 | -0.033 | -0.081 | -0.001 | -0.096 |
| oliv%TO | -0.137 | 0.005 | 0.024 | 0.113 | -0.032 | 0.049 | 0.060 | 0.239 |
| crop%TO | -0.037 | 0.104 | 0.230 | 0.575 | 0.266 | 0.294 | 0.221 | 0.131 |
| misc%TO | 0.189 | 0.135 | -0.021 | 0.072 | 0.068 | -0.007 | -0.053 | -0.085 |
| Fout%TO | 0.271 | 0.140 | 0.191 | 0.156 | 0.052 | -0.058 | 0.216 | -0.194 |
| gCatt%TO | -0.248 | -0.082 | -0.069 | 0.009 | -0.087 | 0.136 | -0.046 | 0.157 |
| gShep%TO | -0.244 | -0.120 | -0.173 | -0.125 | -0.010 | 0.055 | -0.153 | 0.215 |
| gMisc%TO | 0.003 | 0.008 | -0.013 | -0.059 | -0.050 | -0.054 | -0.034 | 0.026 |
| gTotl%TO | -0.257 | -0.130 | -0.168 | -0.127 | -0.027 | 0.063 | -0.152 | 0.243 |
| Frev%TO | 0.133 | 0.084 | 0.163 | 0.194 | 0.146 | 0.020 | 0.406 | 0.242 |
| nOut%TO | -0.133 | -0.084 | -0.163 | -0.194 | -0.146 | -0.020 | -0.406 | -0.242 |
| lnLive/h | 0.368 | 0.004 | 0.371 | -0.010 | 0.064 | -0.208 | 0.255 | -0.111 |
| %milk+.1 | 0.240 | 0.133 | 0.059 | -0.110 | 0.014 | -0.294 | 0.041 | -0.319 |
| %milk+1 | 0.242 | 0.135 | 0.049 | -0.121 | 0.017 | -0.303 | 0.036 | -0.323 |

| | ehaRough | ehaTotal | %Cerl | %Roots | %Hay | %Silag | %Past | %Rough |
|---|---|---|---|---|---|---|---|---|
| ehaTotal | 0.382 | | | | | | | |
| %Cerl | -0.011 | 0.429 | | | | | | |
| %Roots | 0.027 | 0.087 | 0.170 | | | | | |
| %Hay | -0.111 | -0.291 | -0.138 | -0.143 | | | | |
| %Silag | -0.197 | -0.145 | -0.182 | -0.022 | -0.483 | | | |
| %Past | 0.050 | 0.035 | -0.304 | -0.188 | 0.074 | -0.662 | | |
| %Rough | 0.818 | 0.157 | -0.113 | 0.046 | -0.083 | -0.176 | 0.012 | |
| BSU | 0.198 | 0.899 | 0.421 | 0.122 | -0.295 | 0.070 | -0.162 | 0.004 |
| 150ha+ | 0.448 | 0.739 | 0.194 | -0.043 | -0.151 | -0.118 | 0.063 | 0.203 |
| >3hRough | 0.648 | 0.398 | 0.048 | 0.102 | -0.126 | -0.124 | -0.054 | 0.763 |
| radius | 0.373 | 0.967 | 0.429 | 0.106 | -0.375 | -0.131 | 0.069 | 0.171 |
| Easting | -0.167 | -0.221 | 0.007 | -0.091 | -0.160 | 0.182 | -0.048 | -0.116 |
| Northing | 0.001 | -0.074 | 0.042 | -0.179 | 0.011 | 0.001 | 0.052 | -0.003 |
| Region | 0.019 | 0.205 | 0.077 | 0.088 | -0.104 | 0.082 | -0.067 | -0.136 |
| RegCat | -0.022 | 0.126 | 0.127 | 0.102 | -0.112 | 0.142 | -0.162 | -0.170 |
| Region1 | -0.032 | -0.075 | 0.093 | -0.029 | 0.080 | -0.118 | 0.045 | -0.044 |
| Region4 | -0.166 | -0.139 | 0.172 | 0.007 | -0.022 | 0.129 | -0.206 | -0.189 |
| milk%FR | -0.266 | -0.213 | -0.108 | 0.096 | -0.149 | 0.473 | -0.347 | -0.268 |
| catt%FR | 0.151 | 0.152 | 0.075 | -0.166 | 0.151 | -0.298 | 0.247 | 0.073 |
| shep%FR | 0.241 | 0.055 | -0.187 | -0.038 | 0.020 | -0.397 | 0.464 | 0.356 |
| polt%FR | -0.036 | -0.066 | -0.067 | -0.034 | -0.043 | 0.214 | -0.137 | -0.048 |
| oliv%FR | -0.014 | 0.162 | 0.136 | -0.065 | -0.050 | -0.095 | 0.080 | -0.051 |
| crop%FR | -0.001 | 0.325 | 0.667 | 0.106 | 0.222 | -0.303 | -0.209 | -0.070 |
| misc%FR | 0.003 | -0.036 | 0.162 | 0.081 | 0.199 | -0.110 | -0.159 | 0.047 |
| Fout%FR | -0.435 | -0.064 | 0.188 | 0.018 | 0.050 | 0.357 | -0.406 | -0.524 |
| gCatt%FR | 0.114 | 0.071 | 0.092 | -0.099 | -0.008 | -0.224 | 0.197 | 0.113 |
| gShep%FR | 0.426 | 0.049 | -0.196 | 0.002 | -0.040 | -0.334 | 0.382 | 0.509 |
| gMisc%FR | 0.125 | -0.013 | -0.087 | -0.048 | -0.080 | -0.044 | 0.088 | 0.280 |
| gTotl%FR | 0.435 | 0.064 | -0.188 | -0.018 | -0.050 | -0.357 | 0.406 | 0.524 |
| milk%TO | -0.266 | -0.205 | -0.106 | 0.097 | -0.156 | 0.475 | -0.347 | -0.267 |
| catt%TO | 0.151 | 0.154 | 0.076 | -0.166 | 0.151 | -0.297 | 0.246 | 0.072 |
| shep%TO | 0.241 | 0.055 | -0.187 | -0.038 | 0.019 | -0.396 | 0.464 | 0.356 |
| polt%TO | -0.036 | -0.066 | -0.067 | -0.034 | -0.043 | 0.214 | -0.137 | -0.048 |
| oliv%TO | -0.014 | 0.162 | 0.136 | -0.065 | -0.050 | -0.095 | 0.080 | -0.051 |
| crop%TO | -0.000 | 0.327 | 0.668 | 0.107 | 0.220 | -0.302 | -0.210 | -0.070 |
| misc%TO | 0.004 | -0.035 | 0.162 | 0.081 | 0.197 | -0.109 | -0.160 | 0.047 |
| Fout%TO | -0.420 | -0.006 | 0.200 | 0.027 | 0.004 | 0.365 | -0.403 | -0.510 |
| gCatt%TO | 0.114 | 0.072 | 0.092 | -0.099 | -0.008 | -0.224 | 0.197 | 0.112 |
| gShep%TO | 0.426 | 0.049 | -0.196 | 0.003 | -0.040 | -0.334 | 0.382 | 0.508 |
| gMisc%TO | 0.125 | -0.013 | -0.087 | -0.048 | -0.080 | -0.044 | 0.088 | 0.280 |
| gTotl%TO | 0.435 | 0.065 | -0.188 | -0.017 | -0.051 | -0.357 | 0.406 | 0.524 |
| Frev%TO | -0.002 | 0.326 | 0.107 | 0.061 | -0.263 | 0.120 | -0.063 | -0.022 |
| nOut%TO | 0.002 | -0.326 | -0.107 | -0.061 | 0.263 | -0.120 | 0.063 | 0.022 |
| lnLive/h | -0.083 | 0.025 | -0.064 | 0.082 | -0.183 | 0.471 | -0.361 | -0.132 |
| %milk+.1 | -0.271 | -0.202 | -0.085 | 0.086 | -0.145 | 0.466 | -0.347 | -0.271 |
| %milk+1 | -0.269 | -0.209 | -0.097 | 0.092 | -0.147 | 0.470 | -0.347 | -0.270 |

| | BSU | 150ha+ | >3hRough | radius | Easting | Northing | Region | RegCat |
|---|---|---|---|---|---|---|---|---|
| 150ha+ | 0.674 | | | | | | | |
| >3hRough | 0.256 | 0.344 | | | | | | |
| radius | 0.847 | 0.655 | 0.371 | | | | | |
| Easting | -0.209 | -0.152 | -0.194 | -0.185 | | | | |
| Northing | -0.102 | -0.060 | -0.082 | -0.053 | 0.491 | | | |
| Region | 0.251 | 0.078 | -0.058 | 0.215 | -0.362 | -0.040 | | |
| RegCat | 0.215 | 0.061 | -0.108 | 0.123 | -0.124 | -0.030 | 0.851 | |
| Region1 | -0.069 | -0.026 | -0.039 | -0.094 | 0.078 | 0.083 | -0.266 | -0.175 |
| Region4 | -0.059 | -0.077 | -0.239 | -0.158 | 0.603 | 0.120 | -0.051 | 0.341 |
| milk%FR | 0.015 | -0.063 | -0.243 | -0.218 | -0.024 | -0.174 | 0.127 | 0.231 |
| catt%FR | 0.002 | 0.053 | 0.101 | 0.146 | -0.100 | 0.140 | 0.100 | -0.042 |
| shep%FR | -0.170 | -0.060 | 0.254 | 0.095 | 0.140 | 0.065 | -0.275 | -0.347 |
| polt%FR | -0.046 | -0.031 | -0.043 | -0.072 | 0.102 | 0.108 | -0.183 | -0.178 |
| oliv%FR | 0.040 | 0.263 | 0.040 | 0.174 | -0.113 | -0.049 | 0.111 | 0.075 |
| crop%FR | 0.321 | 0.171 | 0.093 | 0.269 | -0.136 | 0.064 | 0.091 | 0.120 |
| misc%FR | -0.034 | -0.080 | 0.013 | -0.050 | 0.178 | 0.094 | -0.213 | -0.145 |
| Fout%FR | 0.156 | -0.012 | -0.333 | -0.098 | -0.119 | -0.064 | 0.306 | 0.321 |
| gCatt%FR | -0.077 | 0.005 | 0.204 | 0.104 | 0.023 | 0.175 | 0.097 | 0.044 |
| gShep%FR | -0.148 | 0.020 | 0.285 | 0.078 | 0.108 | 0.039 | -0.298 | -0.309 |
| gMisc%FR | -0.073 | -0.050 | 0.207 | 0.000 | 0.003 | -0.011 | -0.229 | -0.218 |
| gTotl%FR | -0.156 | 0.012 | 0.333 | 0.098 | 0.119 | 0.064 | -0.306 | -0.321 |
| milk%TO | 0.025 | -0.060 | -0.241 | -0.208 | -0.030 | -0.176 | 0.131 | 0.234 |
| catt%TO | 0.004 | 0.053 | 0.101 | 0.148 | -0.100 | 0.139 | 0.100 | -0.043 |
| shep%TO | -0.170 | -0.059 | 0.254 | 0.095 | 0.139 | 0.065 | -0.276 | -0.348 |
| polt%TO | -0.046 | -0.031 | -0.043 | -0.072 | 0.102 | 0.107 | -0.183 | -0.178 |
| oliv%TO | 0.040 | 0.264 | 0.041 | 0.174 | -0.114 | -0.049 | 0.112 | 0.075 |
| crop%TO | 0.323 | 0.173 | 0.093 | 0.271 | -0.137 | 0.064 | 0.092 | 0.121 |
| misc%TO | -0.033 | -0.080 | 0.013 | -0.049 | 0.178 | 0.093 | -0.213 | -0.145 |
| Fout%TO | 0.217 | 0.015 | -0.312 | -0.029 | -0.153 | -0.076 | 0.318 | 0.323 |
| gCatt%TO | -0.076 | 0.006 | 0.204 | 0.105 | 0.023 | 0.175 | 0.097 | 0.044 |
| gShep%TO | -0.147 | 0.020 | 0.285 | 0.078 | 0.108 | 0.039 | -0.299 | -0.310 |
| gMisc%TO | -0.073 | -0.050 | 0.207 | 0.000 | 0.003 | -0.011 | -0.229 | -0.218 |
| gTotl%TO | -0.155 | 0.012 | 0.333 | 0.099 | 0.118 | 0.063 | -0.307 | -0.322 |
| Frev%TO | 0.391 | 0.157 | 0.059 | 0.385 | -0.225 | -0.088 | 0.127 | 0.071 |
| nOut%TO | -0.391 | -0.157 | -0.059 | -0.385 | 0.225 | 0.088 | -0.127 | -0.071 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| lnLive/h | 0.290 | 0.022 | -0.086 | 0.022 | 0.005 | 0.112 | 0.254 | 0.250 |
| %milk+.1 | 0.029 | -0.058 | -0.249 | -0.205 | -0.031 | -0.164 | 0.145 | 0.244 |
| %milk+1 | 0.022 | -0.061 | -0.246 | -0.213 | -0.027 | -0.170 | 0.135 | 0.238 |

| | Region1 | Region4 | milk%FR | catt%FR | shep%FR | polt%FR | oliv%FR | crop%FR |
|---|---|---|---|---|---|---|---|---|
| Region4 | -0.060 | | | | | | | |
| milk%FR | -0.248 | 0.268 | | | | | | |
| catt%FR | 0.149 | -0.284 | -0.773 | | | | | |
| shep%FR | 0.155 | -0.194 | -0.706 | 0.240 | | | | |
| polt%FR | -0.011 | -0.057 | -0.092 | -0.064 | -0.074 | | | |
| oliv%FR | -0.022 | -0.037 | -0.157 | 0.115 | 0.102 | -0.025 | | |
| crop%FR | 0.268 | 0.042 | -0.288 | 0.125 | -0.105 | 0.027 | 0.120 | |
| misc%FR | 0.149 | 0.041 | -0.274 | 0.007 | 0.128 | 0.352 | -0.136 | 0.353 |
| Fout%FR | -0.064 | 0.165 | 0.660 | -0.253 | -0.859 | 0.063 | -0.033 | 0.169 |
| gCatt%FR | -0.041 | -0.076 | -0.430 | 0.454 | 0.209 | -0.043 | 0.047 | 0.072 |
| gShep%FR | 0.076 | -0.151 | -0.622 | 0.200 | 0.865 | -0.059 | 0.032 | -0.180 |
| gMisc%FR | -0.018 | -0.074 | -0.116 | 0.068 | 0.139 | -0.021 | -0.041 | -0.088 |
| gTotl%FR | 0.064 | -0.165 | -0.660 | 0.253 | 0.859 | -0.063 | 0.033 | -0.169 |
| milk%TO | -0.249 | 0.262 | 1.000 | -0.773 | -0.708 | -0.092 | -0.156 | -0.285 |
| catt%TO | 0.149 | -0.284 | -0.773 | 1.000 | 0.240 | -0.064 | 0.115 | 0.125 |
| shep%TO | 0.155 | -0.195 | -0.706 | 0.240 | 1.000 | -0.074 | 0.103 | -0.106 |
| polt%TO | -0.011 | -0.057 | -0.092 | -0.064 | -0.074 | 1.000 | -0.025 | 0.027 |
| oliv%TO | -0.022 | -0.037 | -0.157 | 0.115 | 0.102 | -0.025 | 1.000 | 0.120 |
| crop%TO | 0.266 | 0.042 | -0.287 | 0.125 | -0.106 | 0.027 | 0.120 | 1.000 |
| misc%TO | 0.148 | 0.041 | -0.274 | 0.007 | 0.128 | 0.353 | -0.136 | 0.352 |
| Fout%TO | -0.072 | 0.121 | 0.643 | -0.245 | -0.848 | 0.067 | -0.023 | 0.180 |
| gCatt%TO | -0.041 | -0.076 | -0.431 | 0.455 | 0.209 | -0.043 | 0.048 | 0.073 |
| gShep%TO | 0.075 | -0.152 | -0.622 | 0.199 | 0.865 | -0.059 | 0.032 | -0.180 |
| gMisc%TO | -0.018 | -0.074 | -0.117 | 0.068 | 0.139 | -0.021 | -0.041 | -0.088 |
| gTotl%TO | 0.063 | -0.166 | -0.660 | 0.253 | 0.860 | -0.063 | 0.033 | -0.169 |
| Frev%TO | -0.062 | -0.231 | 0.033 | -0.008 | -0.103 | 0.031 | 0.050 | 0.098 |
| nOut%TO | 0.062 | 0.231 | -0.033 | 0.008 | 0.103 | -0.031 | -0.050 | -0.098 |
| lnLive/h | 0.034 | 0.010 | 0.171 | 0.046 | -0.309 | 0.012 | -0.063 | -0.056 |
| %milk+.1 | -0.296 | 0.271 | 0.993 | -0.762 | -0.713 | -0.082 | -0.166 | -0.273 |
| %milk+1 | -0.268 | 0.270 | 0.999 | -0.770 | -0.711 | -0.088 | -0.161 | -0.281 |

| | misc%FR | Fout%FR | gCatt%FR | gShep%FR | gMisc%FR | gTotl%FR | milk%TO | catt%TO |
|---|---|---|---|---|---|---|---|---|
| Fout%FR | -0.079 | | | | | | | |
| gCatt%FR | -0.040 | -0.317 | | | | | | |
| gShep%FR | 0.087 | -0.990 | 0.206 | | | | | |
| gMisc%FR | 0.021 | -0.239 | -0.034 | 0.172 | | | | |
| gTotl%FR | 0.079 | -1.000 | 0.317 | 0.990 | 0.239 | | | |
| milk%TO | -0.273 | 0.662 | -0.433 | -0.624 | -0.115 | -0.662 | | |
| catt%TO | 0.008 | -0.252 | 0.451 | 0.198 | 0.068 | 0.252 | -0.772 | |
| shep%TO | 0.129 | -0.859 | 0.208 | 0.865 | 0.140 | 0.859 | -0.707 | 0.240 |
| polt%TO | 0.352 | 0.063 | -0.043 | -0.059 | -0.021 | -0.063 | -0.092 | -0.064 |
| oliv%TO | -0.136 | -0.032 | 0.047 | 0.031 | -0.041 | 0.032 | -0.155 | 0.115 |
| crop%TO | 0.352 | 0.169 | 0.072 | -0.180 | -0.088 | -0.169 | -0.284 | 0.125 |
| misc%TO | 1.000 | -0.080 | -0.040 | 0.087 | 0.021 | 0.080 | -0.273 | 0.008 |
| Fout%TO | -0.070 | 0.986 | -0.335 | -0.974 | -0.222 | -0.986 | 0.649 | -0.243 |
| gCatt%TO | -0.040 | -0.317 | 1.000 | 0.206 | -0.034 | 0.317 | -0.434 | 0.452 |
| gShep%TO | 0.088 | -0.990 | 0.205 | 1.000 | 0.173 | 0.990 | -0.624 | 0.198 |
| gMisc%TO | 0.021 | -0.239 | -0.034 | 0.172 | 1.000 | 0.239 | -0.115 | 0.068 |
| gTotl%TO | 0.080 | -1.000 | 0.316 | 0.990 | 0.240 | 1.000 | -0.662 | 0.251 |
| Frev%TO | 0.042 | 0.117 | -0.180 | -0.113 | 0.052 | -0.117 | 0.058 | -0.003 |
| nOut%TO | -0.042 | -0.117 | 0.180 | 0.113 | -0.052 | 0.117 | -0.058 | 0.003 |
| lnLive/h | 0.043 | 0.298 | -0.171 | -0.273 | -0.167 | -0.298 | 0.179 | 0.047 |
| %milk+.1 | -0.286 | 0.669 | -0.452 | -0.630 | -0.115 | -0.669 | 0.993 | -0.762 |
| %milk+1 | -0.280 | 0.666 | -0.440 | -0.627 | -0.117 | -0.666 | 0.998 | -0.769 |

| | shep%TO | polt%TO | oliv%TO | crop%TO | misc%TO | Fout%TO | gCatt%TO | gShep%TO |
|---|---|---|---|---|---|---|---|---|
| polt%TO | -0.074 | | | | | | | |
| oliv%TO | 0.102 | -0.025 | | | | | | |
| crop%TO | -0.107 | 0.027 | 0.120 | | | | | |
| misc%TO | 0.129 | 0.353 | -0.136 | 0.351 | | | | |
| Fout%TO | -0.847 | 0.067 | -0.022 | 0.181 | -0.070 | | | |
| gCatt%TO | 0.208 | -0.043 | 0.048 | 0.072 | -0.040 | -0.335 | | |
| gShep%TO | 0.865 | -0.059 | 0.031 | -0.180 | 0.088 | -0.974 | 0.205 | |
| gMisc%TO | 0.140 | -0.021 | -0.041 | -0.088 | 0.022 | -0.222 | -0.034 | 0.173 |
| gTotl%TO | 0.859 | -0.063 | 0.032 | -0.170 | 0.080 | -0.985 | 0.316 | 0.990 |
| Frev%TO | -0.100 | 0.031 | 0.051 | 0.099 | 0.043 | 0.283 | -0.178 | -0.111 |
| nOut%TO | 0.100 | -0.031 | -0.051 | -0.099 | -0.043 | -0.283 | 0.178 | 0.111 |
| lnLive/h | -0.308 | 0.012 | -0.062 | -0.055 | 0.043 | 0.337 | -0.171 | -0.272 |
| %milk+.1 | -0.713 | -0.082 | -0.166 | -0.272 | -0.286 | 0.654 | -0.453 | -0.630 |
| %milk+1 | -0.711 | -0.088 | -0.161 | -0.280 | -0.280 | 0.649 | -0.441 | -0.627 |

| | gMisc%TO | gTotl%TO | Frev%TO | nOut%TO | lnLive/h | %milk+.1 |
|---|---|---|---|---|---|---|
| gTotl%TO | 0.240 | | | | | |
| Frev%TO | 0.053 | -0.115 | | | | |
| nOut%TO | -0.053 | 0.115 | -1.000 | | | |
| lnLive/h | -0.167 | -0.297 | 0.294 | -0.294 | | |
| %milk+.1 | -0.115 | -0.669 | 0.046 | -0.046 | 0.174 | |
| %milk+1 | -0.117 | -0.666 | 0.039 | -0.039 | 0.173 | 0.998 |

# APPENDIX 7.2: DEFINING FARM GATE INCOME (FGI) AND THE SOCIAL VALUE OF AGRICULTURE (SV)

## A7.2.1: DEFINING FARM GATE INCOME (FGI)

As explained in the main text analysis showed that positive correlations between the subsidies and grants element of net farm income and environmental adversity meant the negative impact of the latter upon farm income became obscured. Here we analyze the value adjustment between surplus/ha (which omits subsidies and grants) and the farmers perceived net income (the farm gate income; FGI). This is calculated in line with conversations with Tim Jenkins, (Director, FBSW, Aberystwyth) in Summer 1995 concerning the definition of farms perceived income. FGI per hectare is constructed as per equation (A7.2.1):

$$FGI = \text{surp/ha} + \{\text{grants and subsidies/ha} - \text{rent and rates/ha} - \text{depreciation/ha}\} \quad (A7.2.1)$$

where {.} = ADJFGI; the adjustment between surp/ha and FGI.

The variable ADJFGI was calculated for both the sheep and milk sectors producing variables ADJFGIS and ADJFGIM respectively. Given our rationale for this adjustment it was interesting to examine the nature of the link between this adjustment factor (which contained the grants and subsidies element) and the environment.

### A7.2.1.1: Sheep farms

*Estimating ADJFGIS*

A stepwise regression over 79 potential predictors was then run to see if ADJFGIS could be predicted from environmental variables. The final model obtained is given in Model A7.2.1.

Model A7.2.1: Estimating ADJFGIS from environmental variables.

| Predictor | Coef | Stdev | t-ratio | p |
|---|---|---|---|---|
| Constant | -720.0 | 128.2 | -5.62 | 0.000 |
| Easting | 0.08428 | 0.01502 | 5.61 | 0.000 |
| lnFCdays | 95.71 | 23.80 | 4.02 | 0.000 |

s = 41.03    R-sq = 43.5%    R-sq(adj) = 42.1%
n = 84 (one missing observation)

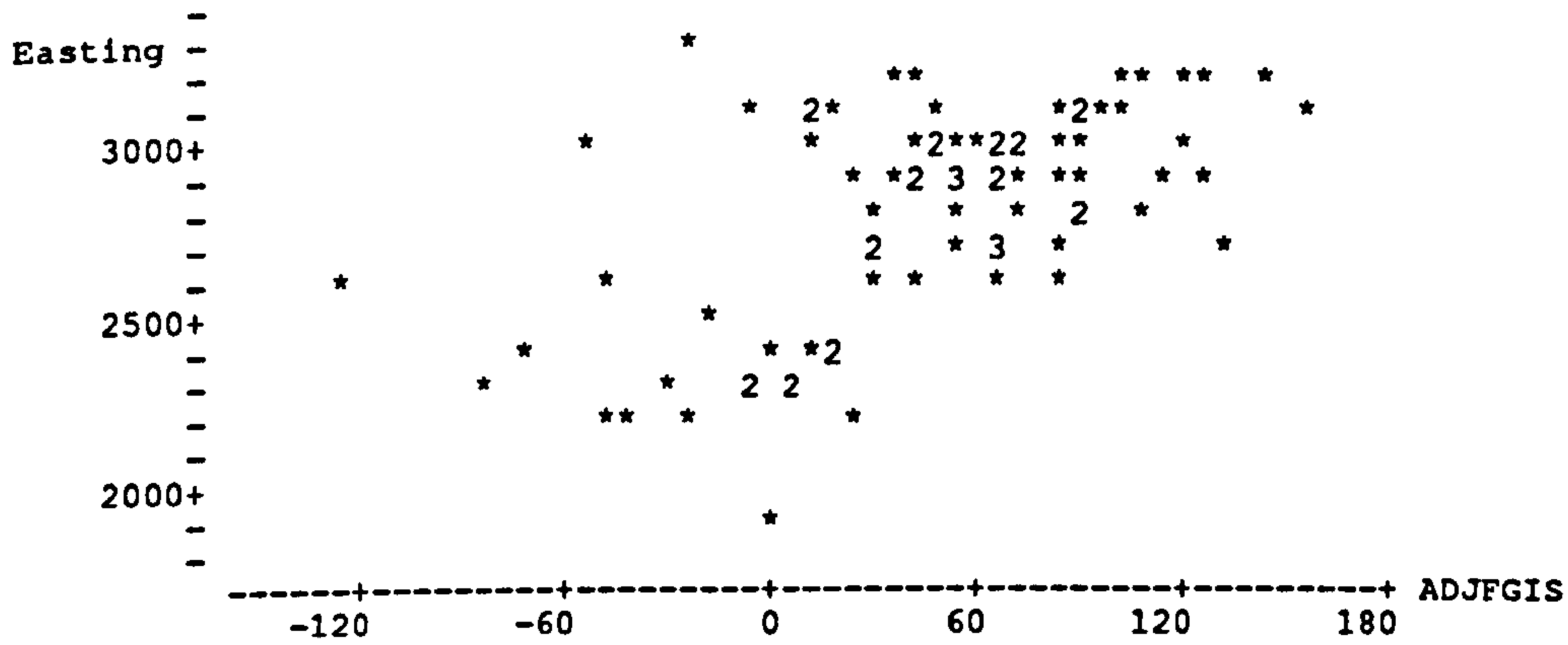
Analysis of Variance

| SOURCE | DF | SS | MS | F | p |
|---|---|---|---|---|---|
| Regression | 2 | 104979 | 52489 | 31.18 | 0.000 |
| Error | 81 | 136364 | 1684 | | |
| Total | 83 | 241342 | | | |

| SOURCE | DF | SEQ SS |
|---|---|---|
| Easting | 1 | 77760 |
| lnFCdays | 1 | 27219 |

Tests suggested that this model was robust and provided a good fit of ADJFGIS. Figure A7.3 illustrates the relationship between ADJFGIS and the Easting predictor.

Figure A7.3: Relationship between ADJFGIS and the Easting predictor




Consequently the adjustment between Farm Surplus and FGI was, for sheep farms, estimated using model A7.2.1 (i.e. predicted $FGI_s$ = predicted Farm Surplus + predicted ADJFGIS). Table A7.2.1 details descriptive statistics for the variables in that model as well as Farm Surplus and FGI.

Table A7.2.1: Descriptive statistics for selected variables: sheep farms (£/ha)

| | N | MEAN | MEDIAN | TRMEAN | STDEV | SEMEAN |
|---|---|---|---|---|---|---|
| Farm surplus | 85 | 110.9 | 108.3 | 109.2 | 115.7 | 12.6 |
| ADJFGIS | 85 | 48.4 | 53.4 | 48.7 | 58.9 | 6.4 |
| FGI | 85 | 159.3 | 160.0 | 162.7 | 122.0 | 13.2 |
| Easting | 85 | 2803.6 | 2900.0 | 2817.4 | 307.3 | 33.3 |
| lnFCdays | 85 | 5.5338 | 5.4931 | 5.5311 | 0.1951 | 0.0212 |

| | MIN | MAX | Q1 | Q3 |
|---|---|---|---|---|
| Farm surplus | -177.3 | 403.5 | 28.0 | 192.6 |
| ADJFGIS | -127.0 | 271.7 | 14.1 | 85.9 |
| FGI | -175.4 | 422.6 | 85.3 | 263.5 |
| Easting | 1910.0 | 3260.0 | 2615.0 | 3025.0 |
| lnFCdays | 5.1705 | 5.8999 | 5.3822 | 5.6454 |

### A7.2.1.2: Milk farms

The variable ADJFGIM was calculated as defined above. A series of statistical tests were undertaken which failed to identify any substantial relationship between ADJFGIM and farm level environmental variables. However, it was noted that ADJFGIM was normally distributed with a relatively small range compared to the Farm Surplus variable for this sector. Table A7.2.1 details distributions for these variables and FGI.

Table A7.2.1: Descriptive statistics for selected variables: milk farms (£/ha)

| | N | MEAN | MEDIAN | TRMEAN | STDEV | SEMEAN |
|---|---|---|---|---|---|---|
| Farm Surplus | 104 | 703.8 | 655.6 | 692.9 | 306.0 | 30.0 |
| ADJFGIM | 104 | -95.3 | -95.8 | -93.3 | 64.5 | 6.3 |
| FGI | 104 | 608.4 | 558.9 | 599.9 | 283.4 | 27.8 |

| | MIN | MAX | Q1 | Q3 |
|---|---|---|---|---|
| surp/ha | 215.2 | 1442.4 | 440.4 | 905.2 |
| ADJFGIM | -261.5 | 27.4 | -132.6 | -49.6 |
| EARN/h | 81.8 | 1258.4 | 377.8 | 811.2 |

Given the findings of table A7.2.1 we feel justified in holding ADJFGIM at its mean value when converting between Farm Surplus and FGI (i.e. predicted $FGI_m$ = predicted Farm Surplus - 95.34).

## A7.2.2 DEFINING THE SOCIAL VALUE OF AGRICULTURE (SV)

This section details product specific shadow pricing calculations and their amalgamation within the social valuation adjustment factors for the sheep and milk sectors ($SVadj_s$ and $SVadj_m$ respectively). All figures are for 1990, for further explanation see chapter 9.

### A7.2.2.1: Product specific shadow pricing calculations

This section presents the necessary data to calculate shadow prices for the various major and minor outputs produced by our sample farms (milk, cattle, sheepmeat, pigmeat, poultry, crops). Roman numeral superscript notes can be found at the end of this section.

1. Milk

Producer price 1990[i] (ECU/t) 292.6188148
Green exchange rate (milk) in 1989/90[ii,v] (£/ECU) 0.7077283
∴ Producer price (£/t) 207.09461

Value of production[i] (ECUm) 34177.58495
Market price support[i] (ECUm) 22318.38414

∴ Ratio 1 = $\frac{\text{Market Price Support}}{\text{Value of Production}} = \frac{22318.38414}{34177.58495} = 0.6530123$

Reduction of input costs[ii] (ECUm) 3250.84226

∴ Ratio 2 = $\frac{\text{Reduction of input costs}}{\text{Value of Production}} = \frac{3250.84226}{34177.58495} = 0.0951162$

Direct payments[i] (ECUm) 562.1

∴ Ratio 3 = $\frac{\text{Direct Payments}}{\text{Value of Production}} = \frac{562.1}{34177.58495} = 0.0164464$

Levies[i] -348.5

∴ Ratio 4 = $\frac{\text{Levies}}{\text{Value of Production}} = \frac{-348.5}{34177.58495} = 0.0101967$

The world price uplift factor resulting from a multinational liberalisation of agricultural policy is estimated[iv] for dairy products as being 65.3%.

Example: Milk output on farm number AAAAA[1]

[1] Direct subsidies and grants subtracted on a farm by farm basis

i. Adjusting for market price support and levies

Output value * [1-(Price support ratio - Levies ratio)]
= £ 39407 * [1-(0.6530123 - 0.0101967)]
= £ 39407 * 0.3571844
= £ 14075.57

ii. Adjusting for World trade liberalisation effects[2]

World trade liberalisation factor = 65.3%. Milk output is therefore adjusted as follows:
£ 14075.57 * 1.653 = £ 23266.91

## 2. Cattle

| | | |
|---|---|---|
| Producer price 1990[i] (ECU/t) | 3212.030745 | |
| Green exchange rate (sheep) in 1989/90[ii,vi] (£/ECU) | 0.730897 | |
| ∴ Producer price (£/t) | 2347.6636 | |
| Value of production[i] (ECUm) | 26659.85518 | |
| Market price support[i] (ECUm) | 12637.2941 | |
| ∴ Ratio 1 = Market Price Support / Value of Production = | 12637.2941 / 26659.85518 | = 0.4740196 |
| Reduction of input costs[ii] (ECUm) | 2291.546871 | |
| ∴ Ratio 2 = Reduction of input costs / Value of Production = | 2291.546871 / 26659.85518 | = 0.0859549 |
| Direct payments[i] (ECUm) | 725.6 | |
| ∴ Ratio 3 = Direct Payments / Value of Production = | 725.6 / 26659.85518 | = 0.0272169 |
| Levies[i] | 0.0 | |
| ∴ Ratio 4 = Levies / Value of Production = | 0.0 / 26659.85518 | = 0.0 |

The world price uplift factor resulting from a multinational liberalisation of agricultural policy is estimated[iv] for ruminant meats (beef, mutton and lamb) as being 21.0%.

Example: Cattle output on farm number BBBBB[3]

i. Adjusting for market price support and levies

Output value * [1-(Price support ratio + Levies ratio)]
= £ 15162 * [1-(0.4740196 - 0.0)]
= £ 15162 * 0.5259804
= £ 7974.91

ii. Adjusting for World trade liberalisation effects[4]

World trade liberalisation factor = 21.0%. Cattle output is therefore adjusted as follows:
£ 7974.91 * 1.210 = £ 9649.64

---

[2] Conversion factor for items i and ii = 0.3571844 * 1.653 = 0.5904258

[3] Direct subsidies and grants subtracted on a farm by farm basis

[4] Conversion factor for items i and ii = 0.5259804 * 1.210 = 0.6364362

## 3. Sheepmeat

| | |
|---|---|
| Producer price 1990[i] (ECU/t) | 3415.860147 |
| Green exchange rate (sheep) in 1989/90[ii,iii] (£/ECU) | 0.7003186 |
| ∴ Producer price (£/t) | 2392.1904 |
| Value of production[i] (ECUm) | 3976.061211 |
| Market price support[i] (ECUm) | 2407.439889 |

∴ Ratio 1 = $\frac{\text{Market Price Support}}{\text{Value of Production}} = \frac{2407.439889}{3976.061211} = 0.6054835$

Reduction of input costs[ii] (ECUm) 289.021090

∴ Ratio 2 = $\frac{\text{Reduction of input costs}}{\text{Value of Production}} = \frac{289.021090}{3976.061211} = 0.0726903$

Direct payments[i] (ECUm) 1452.3

∴ Ratio 3 = $\frac{\text{Direct Payments}}{\text{Value of Production}} = \frac{1452.3}{3976.061211} = 0.3652609$

Levies[i] 0.0

∴ Ratio 4 = $\frac{\text{Levies}}{\text{Value of Production}} = \frac{0.0}{3976.061211} = 0.0$

The world price uplift factor resulting from a multinational liberalisation of agricultural policy is estimated[iv] for ruminant meats (beef, mutton and lamb) as being 21.0%.

Example: Sheep output on farm number CCCCC[5]

i. Adjusting for market price support and levies

Output value * [1-(Price support ratio + Levies ratio)]
= £ 12044 * [1-(0.6054835 - 0.0)]
= £ 12044 * 0.3945165
= £ 4751.56

ii. Adjusting for World trade liberalisation effects[6]

World trade liberalisation factor = 21.0%. Sheep output is therefore adjusted as follows:
= £ 4751.56 * 1.210 = £ 5749.38

## 4. Pigmeat

| | |
|---|---|
| Producer price 1990[i] (ECU/t) | 1441.370616 |
| Green exchange rate (pigmeat) in 1989/90[ii,vii] (£/ECU) | 0.749191 |
| ∴ Producer price (£/t) | 1079.8619 |
| Value of production[i] (ECUm) | 21189.58942 |
| Market price support[i] (ECUm) | 4219.055062 |

∴ Ratio 1 = $\frac{\text{Market Price Support}}{\text{Value of Production}} = \frac{4219.055062}{21189.58942} = 0.1991098$

---

[5] Direct subsidies and grants subtracted on a farm by farm basis

[6] Conversion factor for items i and ii = 0.3945165 * 1.210 = 0.4773649

Reduction of input costs[ii] (ECUm) 1926.921615

∴ Ratio 2 = $\frac{\text{Reduction of input costs}}{\text{Value of Production}} = \frac{1926.921615}{21189.58942} = 0.0909371$

Direct payments[i] (ECUm) 0.0

∴ Ratio 3 = $\frac{\text{Direct Payments}}{\text{Value of Production}} = \frac{0.0}{21189.58942} = 0.0$

Levies[i] 0.0

∴ Ratio 4 = $\frac{\text{Levies}}{\text{Value of Production}} = \frac{0.0}{21189.58942} = 0.0$

The world price uplift factor resulting from a multinational liberalisation of agricultural policy is estimated[iv] for non-ruminant meats (pork, poultry meat and eggs) as being 12.4%.

Example: Pigmeat output on farm number DDDDD[7]

i. Adjusting for market price support and levies

Output value * [1-(Price support ratio + Levies ratio)]
= £ 580 * [1-(0.1991098 - 0.0)]
= £ 580 * 0.8008902
= £ 464.51

ii. Adjusting for World trade liberalisation effects[8]

World trade liberalisation factor = 12.4%. Pigmeat output is therefore adjusted as follows:
= £ 464.51 * 1.124 = £ 522.12

## 5. Poultry

| | |
|---|---|
| Producer price 1990[i] (ECU/t) | 1183.237341 |
| Green exchange rate (poultry) in 1989/90[ii,viii] (£/ECU) | 0.7077283 |
| ∴ Producer price (£/t) | 837.41052 |
| Value of production[i] (ECUm) | 7670.927682 |
| Market price support[i] (ECUm) | 2816.042246 |

∴ Ratio 1 = $\frac{\text{Market Price Support}}{\text{Value of Production}} = \frac{2816.042246}{7670.927682} = 0.3671058$

Reduction of input costs[ii] (ECUm) 638.4610266

∴ Ratio 2 = $\frac{\text{Reduction of input costs}}{\text{Value of Production}} = \frac{638.4610266}{7670.927682} = 0.0832312$

Direct payments[i] (ECUm) 0.0

∴ Ratio 3 = $\frac{\text{Direct Payments}}{\text{Value of Production}} = \frac{0.0}{7670.927682} = 0.0$

Levies[i] 0.0

[7] Direct subsidies and grants subtracted on a farm by farm basis
[8] Conversion factor for items i and ii = 0.8008902 * 1.124 = 0.9002005

∴ Ratio 4 = $\frac{\text{Levies}}{\text{Value of Production}}$ = $\frac{0.0}{7670.927682}$ = 0.0

The world price uplift factor resulting from a multinational liberalisation of agricultural policy is estimated[iv] for non-ruminant meats (pork, poultry meat and eggs) as being 12.4%.

Example: Poultry output on farm number EEEEE[9]

i. Adjusting for market price support and levies

Output value * [1-(Price support ratio + Levies ratio)]
= £ 4347 * [1-(0.3671058 - 0.0)]
= £ 4347 * 0.6328942
= £ 2751.19

ii. Adjusting for World trade liberalisation effects[10]

World trade liberalisation factor = 12.4%. Poultry output is therefore adjusted as follows:
= £ 2751.19 * 1.124 = £ 3092.34

## 6. Common wheat

Producer price 1990[i] (ECU/t) 162.3089101
Green exchange rate (crop products) in 1989/90[ii,ix] (£/ECU) 0.701383
∴ Producer price (£/t) 113.84071

Value of production[i] (ECUm) 12568.22814
Market price support[i] (ECUm) 4275.046742

∴ Ratio 1 = $\frac{\text{Market Price Support}}{\text{Value of Production}}$ = $\frac{4275.046742}{12568.22814}$ = 0.3401471

Reduction of input costs[i] (ECUm) 887.397369

∴ Ratio 2 = $\frac{\text{Reduction of input costs}}{\text{Value of Production}}$ = $\frac{887.397369}{12568.22814}$ = 0.0706064

Direct payments[i] (ECUm) 15.63818182

∴ Ratio 3 = $\frac{\text{Direct Payments}}{\text{Value of Production}}$ = $\frac{15.638182}{12568.22814}$ = 0.00124426

Levies[i] -301.0

∴ Ratio 4 = $\frac{\text{Levies}}{\text{Value of Production}}$ = $\frac{-301.0}{12568.22814}$ = 0.0239492

The world price uplift factor resulting from a multinational liberalisation of agricultural policy is estimated[iv] for wheat as 36.7%.

Example: Crops output on farm number FFFFF[11]

i. Adjusting for market price support and levies

Output value * [1-(Price support ratio + Levies ratio)]
= £ 982 * [1-(0.3401471 - 0.0239492)]

---

[9] Direct subsidies and grants subtracted on a farm by farm basis
[10] Conversion factor for items i & ii = 0.6328942 * 1.124 = 0.711373
[11] Direct subsidies and grants subtracted on a farm by farm basis

= £ 982 * 0.6838021
= £ 671.49

ii. Adjusting for World trade liberalisation effects[12]

World trade liberalisation factor = 36.7%. Crops output is therefore adjusted as follows:
= £ 671.49 * 1.367 = £ 917.93

Notes

i. OECD (1992) "Tables of producer subsidy equivalents and consumer subsidy equivalents 1978-1991", OECD, Paris.

ii. European Community (1992) "CAP monitor : 24.6.92", EC, Brussels.

iii. EC (1992) (reference 2 above) gives the green exchange rate for sheepmeat as being £1=0.699340 ECU on 1st May 1989 (which is identified as the start of the 1989/90 marketing year), changing to £1=0.702276 on 11th January 1990. This latter price stayed in force until the end of marketing year 1989/90 (the 1st May 1990 when the rate jumped to £1=0.779553). A weighted average was constructed from the two 1989/90 rates (weights based upon the length of time they were valid) being £1=0.7003186.

iv. Roningen, V O and Dixit, P M (1989) "Economics Implications of Agricultural Policy Reforms in Industrial Market Economics", Staff Report No. AGES 89-36, Agriculture and Trade Analysis Division, Economics Research Service, United States Department of Agriculture. Figures taken from Table 5 (p.16).

v. EC (1992) gives the green exchange rate for milk as £1=0.70678 on 1st May 1989 and £1=0.709729 on 11th January 1990. This gives a weighted (see note 3) mean of £1=0.707283 for 1989/90.

vi. EC (1992) gives the green exchange rate for beef and veal as £1=0.729831 on 1st May 1989 and £1=0.733029 on 11th January 1990. This gives a weighted (see note 3) mean of £1=0.730897.

vii. EC (1992) gives the green exchange rate for pigmeat as £1=0.726750 on 1st May 1989; £1=0.731431 on 12th June 1989; £1=0.747127 on 1st July 1989; £1=0.749992 on 9th October 1989; £1=0.756267 on 12th October 1989; and £1=0.756267 on 11th January 1990 which was valid until the end of the 1989/90 marketing year (14th May 1990 at which point the exchange rate jumped to £1=0.838723). A weighted average for 1989/90 is £1=0.749191.

viii. EC (1992) gives the green exchange rate for poultry as £1=0.706728 on 1st May 1989 and £1=0.709729 on 11th January 1990. This gives a weighted (see note 3) mean of £1=0.7077283.

ix. EC (1992) gives the green exchange rate for crop products as £1=0.701383 on 1st May 1989. This rate stayed in force throughout 1989/90 (changing to £1=0.779553 on 14th May 1990).

## A7.2.2.2: Summary shadow pricing conversion factors

1. Price effect conversion factors

The conversion factors given in table A7.2.2 below take into account three impacts upon output prices:

1. Market price support;
2. Levies;
3. World trade liberalisation effects.

2. Direct payments

Information regarding direct support payments is held for each individual farm and is therefore accounted for at the farm level.

[12] Conversion factor for items i & ii = 0.6838021 * 1.367 = 0.9347574

3. Input subsidy conversion factors

Input subsidies are accounted for separately by increasing input costs accordingly. Input subsidy conversion factors are given in table A7.2.3.

The conversion factors given in table A7.2.3 refer to the rate of input subsidy pertaining to each type of output. These are then weighted by the mix of outputs on the individual farm and the resultant weighted input subsidy factor is then applied to the cost side.

Table A7.2.2: Price effect conversion factors

| Output | Conversion factor |
|---|---|
| Milk | 0.5904258 |
| Cattle | 0.6364362 |
| Sheep | 0.4773649 |
| Pigs | 0.9002005 |
| Poultry | 0.7113730 |
| Other livestock[1] | n/a |
| Crops[2] | 0.9347574 |
| Misc | n/a |

Notes: 1. The "Other livestock" category consists mainly of non-riding horses, goats and deer.
2. The "Crops" category consists mainly of winter barley and wheat. The conversion factor given is that for common wheat. However, big values usually signify potatoes.

Table A7.2.3: Input subsidy conversion factors

| Output | Conversion factor |
|---|---|
| Milk | 0.0951162 |
| Cattle | 0.0859549 |
| Sheep | 0.0726903 |
| Pigs | 0.0909371 |
| Poultry | 0.0832312 |
| Other livestock | n/a |
| Crops | 0.0706064 |
| Misc | n/a |

**A7.2.2.3: Social value calculation example: farm number BBBBB**

Intervention occurs both with respect to farm output values (market price support, levies, direct subsidies and world price effects) and farm input costs (input subsidies).

*1. The shadow value of outputs*

Farm BBBBB has no production of milk, pigs or poultry. Its main outputs are beef cattle and sheep with relatively minor outputs of other livestock[13], crops[14] and miscellaneous items. Table A7.2.4 adjusts market prices using the previously derived output conversion factors. Direct subsidies and grants are also removed at this stage. They are of course included in the unadjusted financial value calculations.

Table A7.2.4: Market and shadow output value: Farm BBBBB

| **Farm Number BBBBB** | | **Market Output Value (£)** | **Output Conversion Factor** | **Shadow Output Value (£)** |
|---|---|---|---|---|
| **Output** | Milk | 0 | 0.5904258 | 0 |
| | Cattle | 15162 | 0.6364362 | 9649.64 |
| | Sheep | 12044 | 0.4773649 | 5749.38 |
| | Pigs | 0 | 0.9002005 | 0 |
| | Poultry | 0 | 0.7113730 | 0 |
| | Other livestock | 67 | 1 | 67 |
| | Crops | -1385 | 0.9347574 | -1294.64 |
| | Misc | 104 | 1 | 104 |
| **FARM OUTPUT** | | 25992 | | 14275.38 |
| **Direct grants and subsidy** | Cattle | 2888 | 0 | 0 |
| | Sheep | 8494 | 0 | 0 |
| | Misc | 114 | 0 | 0 |
| **FARM REVENUE** | | 37488 | | 14275.38 |
| **Notional outputs** | Benefit value of farm houses | 334 | 1 | 334 |
| **TOTAL OUTPUT** | | 37822 | | 14609.38 |

[13] This is typically horses, goats, etc. Generally there is no intervention in these products and shadow values are taken as being market values.

[14] Crops are recorded either as "main crops" or as "by-products, forage and cults". Low value main crops usually correspond to winter wheat or barley (for which shadow pricing is necessary) whilst higher crop values are usually associated with potatoes (FBSW, pers comm). Here all crop production (-£1,385 i.e. a loss) is recorded as "by-products, forage and cults" and so no shadow pricing adjustment is made.

*2. The shadow value of inputs*

The total value of input subsidies is calculated using the previously derived conversion factors. Results are given in table A7.2.5.

Table A7.2.5: Total value of input subsidies: Farm BBBBB

| **Farm Number BBBBB** | | **Market Output Value (£)** | **Input Subsidy Conversion Factor** | **Input Subsidy Value (£)** |
|---|---|---|---|---|
| **Output** | Milk | 0 | 0.0951162 | 0 |
| | Cattle | 15162 | 0.0859549 | 1303.25 |
| | Sheep | 12044 | 0.0726903 | 875.48 |
| | Pigs | 0 | 0.0909371 | 0 |
| | Poultry | 0 | 0.0832312 | 0 |
| | Other livestock | 67 | 0 | 0 |
| | Crops | -1385 | 0.0706064 | -97.79 |
| | Misc | 104 | 0 | 0 |
| **Total Input Subsidy Value** | | | | 2080.94 |

The total input subsidy value can now be allowed for within the shadow farm account.

3. Calculating farm gate income and social value

Table A7.2.6 brings together results from the previous two tables to calculate the market and shadow net farm income.

## A7.2.2.4: Calculating a general social value adjustment factor

*1. Sheep farms* ($SVadj_s$)

The social value conversion process was generalised within each sector by the calculation of a sectoral social value adjustment factor (see text of Chapter 9 for further details). This is in effect a mean liberalisation price effect weighted by the mix of outputs characterising each sector. Price, input and direct payment subsidies are accounted for as detailed in previous sections. Table A7.2.7 gives descriptive statistics for the proportional weights of each output value stream and the resultant social value adjustment factor ($SVadj_s$) for the sheep sector.

Table A7.2.6: Farm gate income and social value

| Farm Number BBBBB | | Market Value (£) | Shadow Value (£) |
|---|---|---|---|
| **REVENUE** | **Farm Output** | 25992 | 14275 |
| | Direct grants and subsidies | 11496 | 0 |
| | **Farm Revenue** | 37488 | 14275 |
| | Notional outputs | 334 | 334 |
| | **Total Output** | 37822 | 14609 |
| **COST** | Inputs | 14743 | 14743 |
| | Input subsidy | n/a | 2081 |
| | **Farm Input** | 14743 | 16824 |
| | Rent and rates | 1795 | 1795 |
| | **Farm Expenses** | 16538 | 18619 |
| | Notional inputs | 14880 | 14880 |
| | Depreciation | 4051 | 4051 |
| | **Total Inputs** | 35469 | 37550 |
| **PROFIT** | **Net Farm Income** | 2353 | -22941 |
| | **Net Farm Income per Effective Hectare**[15] | 12.47 | -121.55 |

Note: For further clarification of terms see table 9.1 (Chapter 9).

Table A7.2.7: Descriptive statistics for sheep farms: Proportion of total output value derived from each output type and social value adjustment factor

| | N | MEAN | MEDIAN | TRMEAN | STDEV | SEMEAN |
|---|---|---|---|---|---|---|
| milk | 85 | 0.00459 | 0.00000 | 0.00000 | 0.03949 | 0.00428 |
| cattle | 85 | 0.32520 | 0.36740 | 0.32890 | 0.14060 | 0.01530 |
| sheep | 85 | 0.62590 | 0.61270 | 0.62380 | 0.16300 | 0.01770 |
| pigs | 85 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| poultry | 85 | 0.00038 | 0.00000 | 0.00000 | 0.00324 | 0.00035 |
| other | 85 | 0.00117 | 0.00000 | 0.00050 | 0.00468 | 0.00051 |
| crops | 85 | 0.03872 | 0.02155 | 0.03325 | 0.08432 | 0.00915 |
| misc | 85 | 0.00403 | 0.00000 | 0.00268 | 0.00853 | 0.00093 |
| SVadj. | 85 | 0.55014 | 0.54404 | 0.54927 | 0.04331 | 0.00470 |

| | MIN | MAX | Q1 | Q3 |
|---|---|---|---|---|
| milk | 0.00000 | 0.36342 | 0.00000 | 0.00000 |
| cattle | 0.00000 | 0.58770 | 0.20170 | 0.43470 |
| sheep | 0.26790 | 1.00000 | 0.51480 | 0.73720 |
| pigs | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| poultry | 0.00000 | 0.02976 | 0.00000 | 0.00000 |

[15] Farm size = 188.73 effective hectares

| | | | | |
|---|---|---|---|---|
| other | -0.00877 | 0.03445 | 0.00000 | 0.00000 |
| crops | -0.15073 | 0.32929 | -0.00179 | 0.06941 |
| misc | -0.00199 | 0.04815 | 0.00000 | 0.00421 |
| $SVadj_s$ | 0.44839 | 0.65184 | 0.52220 | 0.57241 |

Note: Other = other livestock

Analysis failed to identify any significant environmental predictors of $SVadj_s$. This is as expected, while the adjustment factor for FGI is related to the environment because of the positive correlation between the subsidies and grants element and environmental adversity, the latter transfer element is excluded from the social value of agriculture. Given this we use the mean value of $SVadj_s$ (which is normally distributed) when converting from predicted Farm Surplus to social value (i.e. predicted $SV_s$ = predicted Farm Surplus * 0.55014).

*2. Milk farms ($SVadj_m$)*

The social value adjustment factor for the milk sector ($SVadj_m$) was calculated as per that for the sheep sector. Table A7.2.8 details descriptive statistics for $SVadj_m$ and the proportional weights of each output value stream in the milk sector.

Table A7.2.8: Descriptive statistics for milk farms: Proportion of total output value derived from each output type and social value adjustment factor

| OUTPUT | N | MEAN | MEDIAN | TRMEAN | STDEV | SEMEAN |
|---|---|---|---|---|---|---|
| milk | 104 | 0.79190 | 0.83660 | 0.79970 | 0.16140 | 0.01580 |
| cattle | 104 | 0.11360 | 0.08570 | 0.10820 | 0.10650 | 0.01040 |
| sheep | 104 | 0.06033 | 0.01849 | 0.05076 | 0.08456 | 0.00829 |
| pigs | 103 | 0.00203 | 0.00000 | 0.00000 | 0.01215 | 0.00120 |
| poultry | 103 | 0.00288 | 0.00000 | 0.00000 | 0.02558 | 0.00252 |
| other | 103 | 0.00016 | 0.00000 | 0.00003 | 0.00076 | 0.00007 |
| crops | 103 | 0.02593 | 0.01373 | 0.02393 | 0.04628 | 0.00456 |
| misc | 103 | 0.00350 | 0.00001 | 0.00170 | 0.00978 | 0.00096 |
| $SVadj_m$ | 103 | 0.60043 | 0.59753 | 0.59982 | 0.02178 | 0.00215 |

| | MIN | MAX | Q1 | Q3 |
|---|---|---|---|---|
| milk | 0.36570 | 1.04000 | 0.66880 | 0.91470 |
| cattle | -0.05270 | 0.43330 | 0.02040 | 0.19930 |
| sheep | 0.00000 | 0.37511 | 0.00000 | 0.09990 |
| pigs | 0.00000 | 0.09695 | 0.00000 | 0.00000 |
| poultry | 0.00000 | 0.25903 | 0.00000 | 0.00000 |
| other | -0.00138 | 0.00496 | 0.00000 | 0.00000 |
| crops | -0.13533 | 0.18683 | 0.00000 | 0.04520 |
| misc | 0.00000 | 0.05578 | 0.00000 | 0.00107 |
| $SVadj_m$ | 0.53588 | 0.67598 | 0.58718 | 0.61268 |

Notes: 1 missing record for minor outputs (pigs, poultry, other, crops, misc): omitted from calculation of $SVadj_m$
Other = other livestock.

As before and as expected, analysis failed to identify any significant environmental predictors of $SVadj_m$. Given this and the variable again being normally distributed, we use the mean value of $SVadj_m$ when converting from predicted Farm Surplus to social value, i.e. we set $SVadj_m$ = 0.60043 (i.e. predicted $SV_m$ = predicted Farm Surplus * 0.60043).

# APPENDIX 7.3: PRINCIPAL COMPONENTS ANALYSIS OF FARM-LEVEL ENVIRONMENTAL VARIABLES

## A7.3.1: PCA FOR ENVIRONMENTAL VARIABLES ON SHEEP FARMS

The PCA was carried out in SPSS-X, the relevant executable file (SHEEP.SPS) being reproduced in the notes to this appendix. The principles of PCA and interpretation of results are explained in the PCA of environmental variables conducted as part of our analysis of timber output. Consequently in this appendix we merely list results with only minimal commentary. Table A7.3.1 details the anti-image covariance matrix while table A7.3.2 details the anti-image correlation matrix. Factor eigenvalues were calculated (table A7.3.3), four of which had values in excess of 1 (i.e. more significant than the initial input variables) and were extracted for further analysis. The factor matrix detailed in table A7.3.4 details the component loadings (the correlation between each input variable and each of the four extracted factors). Factors were then varimax rotated (convergence after 6 iterations) and communality (table A7.3.5) and component loadings (table A7.3.6) recalculated (a factor transformation matrix, correlating pre and post rotation factors is detailed in table A7.3.7). The final factor score coefficient matrix is given in table A7.3.8. This uses the factors as weights to calculate factor scores for each farm. Inspection of this matrix allows us to interpret the factors for sheep farms as follows:

| *Factor No.* | *Interpretation*[1] |
|---|---|
| 1 | High rainfall / low temperature |
| 2 | High elevation / high slope |
| 3 | High water availability / high workability score |
| 4 | High machinery working days / Westerly aspect |

Note: 1. See Chapter 7 and Appendix 5 for definition of these terms

## Table A7.3.1: Anti-image covariance matrix

| | ACCTEMP | RAINFALL | ENDMED | FCAPDAYS | MDEFGRA | AVWATGRA | WORKABIL | SPRMWD | WSELVGR2 |
|---|---|---|---|---|---|---|---|---|---|
| ACCTEMP | .36116 | | | | | | | | |
| RAINFALL | -.03729 | .03045 | | | | | | | |
| ENDMED | .02854 | -.01933 | .02817 | | | | | | |
| FCAPDAYS | -.00375 | -.01077 | -.01484 | .04119 | | | | | |
| MDEFGRA | -.13181 | .01492 | -.00614 | .01579 | .14180 | | | | |
| AVWATGRA | -.02130 | .04629 | .00255 | -.06053 | .02760 | .23889 | | | |
| WORKABIL | .03036 | -.04160 | -.00817 | .05493 | -.04919 | -.20019 | .25082 | | |
| SPRMWD | .04071 | -.04115 | .00672 | .04322 | -.05992 | -.11161 | .12725 | .66016 | |
| WSELVGR2 | .02983 | -.01402 | .01825 | -.00750 | .02511 | .01584 | -.02667 | .02115 | .55059 |
| DSL2 | .00467 | .00601 | -.01360 | .01181 | .00995 | -.06031 | .06827 | -.00403 | -.30098 |
| COSASP | .06188 | -.04792 | .01203 | .04652 | -.02592 | -.09838 | .13135 | .05716 | -.10894 |
| SINASP | .10600 | -.00742 | .00049 | -.00600 | -.06772 | .01353 | .04800 | .20767 | -.05976 |

| | DSL2 | COSASP | SINASP |
|---|---|---|---|
| DSL2 | .56673 | | |
| COSASP | -.01122 | .78612 | |
| SINASP | .13434 | .00172 | .76045 |

KAISER-MEYER-OLKIN MEASURE OF SAMPLING ADEQUACY = .65293 ; BARTLETT TEST OF SPHERICITY = 833.66363, SIGNIFICANCE = .00000
THERE ARE 22 (16.7%) OFF-DIAGONAL ELEMENTS OF AIC MATRIX > 0.09

## Table A7.3.2: Anti-image correlation matrix

| | ACCTEMP | RAINFALL | ENDMED | FCAPDAYS | MDEFGRA | AVWATGRA | WORKABIL | SPRMWD | WSELVGR2 | DSL2 | COSASP | SINASP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ACCTEMP | .72767 | | | | | | | | | | | |
| RAINFALL | -.35557 | .66814 | | | | | | | | | | |
| ENDMED | .28300 | -.65992 | .80290 | | | | | | | | | |
| FCAPDAYS | -.03078 | -.30399 | -.43570 | .73870 | | | | | | | | |
| MDEFGRA | -.58247 | .22697 | -.09711 | .20660 | .82490 | | | | | | | |
| AVWATGRA | -.07253 | .54267 | .03108 | -.61018 | .14995 | .26665 | | | | | | |
| WORKABIL | .10086 | -.47594 | -.09715 | .54044 | -.26083 | -.81781 | .28690 | | | | | |
| SPRMWD | .08338 | -.29024 | .04927 | .26208 | -.19584 | -.28105 | .31272 | .61166 | | | | |
| WSELVGR2 | .06690 | -.10825 | .14654 | -.04981 | .08987 | .04367 | -.07178 | .03509 | .71589 | | | |
| DSL2 | .01032 | .04572 | -.10767 | .07730 | .03510 | -.16390 | .18108 | -.00660 | -.53881 | .61732 | | |
| COSASP | .11613 | -.30970 | .08087 | .25851 | -.07764 | -.22701 | .29580 | .07934 | -.16559 | -.01681 | .28177 | |
| SINASP | .20227 | -.04878 | .00337 | -.03387 | -.20622 | .03174 | .10991 | .29310 | -.09236 | .20463 | .00223 | .57457 |

MEASURES OF SAMPLING ADEQUACY (MSA) ARE PRINTED ON THE DIAGONAL.

Table A7.3.3: Initial statistics: factor eigenvalues

| VARIABLE | COMMUNALITY | * | FACTOR | EIGENVALUE | PCT OF VAR | CUM PCT |
|---|---|---|---|---|---|---|
| ACCTEMP | 1.00000 | * | 1 | 4.60480 | 38.4 | 38.4 |
| RAINFALL | 1.00000 | * | 2 | 1.78948 | 14.9 | 53.3 |
| ENDMED | 1.00000 | * | 3 | 1.60648 | 13.4 | 66.7 |
| FCAPDAYS | 1.00000 | * | 4 | 1.01221 | 8.4 | 75.1 |
| MDEFGRA | 1.00000 | * | 5 | .86897 | 7.2 | 82.3 |
| AVWATGRA | 1.00000 | * | 6 | .67479 | 5.6 | 88.0 |
| WORKABIL | 1.00000 | * | 7 | .60503 | 5.0 | 93.0 |
| SPRMWD | 1.00000 | * | 8 | .39027 | 3.3 | 96.3 |
| WSELVGR2 | 1.00000 | * | 9 | .29680 | 2.5 | 98.7 |
| DSL2 | 1.00000 | * | 10 | .10780 | .9 | 99.6 |
| COSASP | 1.00000 | * | 11 | .02622 | .2 | 99.9 |
| SINASP | 1.00000 | * | 12 | .01716 | .1 | 100.0 |

Table A7.3.4: Factor matrix: component loadings

| | FACTOR 1 | FACTOR 2 | FACTOR 3 | FACTOR 4 |
|---|---|---|---|---|
| ACCTEMP | -.71185 | .15999 | -.03046 | .15758 |
| RAINFALL | .89306 | .06999 | -.15217 | .31135 |
| ENDMED | .93176 | .10460 | -.13702 | .24570 |
| FCAPDAYS | .94786 | .09684 | -.09743 | .16783 |
| MDEFGRA | -.91946 | .08648 | .00189 | -.08941 |
| AVWATGRA | .20327 | .67097 | .48378 | -.31203 |
| WORKABIL | .20759 | .81459 | .19919 | -.14867 |
| SPRMWD | -.47135 | -.00151 | .32483 | .58930 |
| WSELVGR2 | .47574 | -.40916 | .51582 | -.23326 |
| DSL2 | .33058 | -.35583 | .70100 | -.13542 |
| COSASP | .00796 | -.52281 | .23263 | .01210 |
| SINASP | .21501 | -.22375 | -.60274 | -.50426 |

Table A7.3.5: Post rotation factor statistics

| VARIABLE | COMMUNALITY | * | FACTOR | EIGENVALUE | PCT OF VAR | CUM PCT |
|---|---|---|---|---|---|---|
| ACCTEMP | .55809 | * | 1 | 4.60480 | 38.4 | 38.4 |
| RAINFALL | .92255 | * | 2 | 1.78948 | 14.9 | 53.3 |
| ENDMED | .95827 | * | 3 | 1.60648 | 13.4 | 66.7 |
| FCAPDAYS | .94547 | * | 4 | 1.01221 | 8.4 | 75.1 |
| MDEFGRA | .86088 | * | | | | |
| AVWATGRA | .82292 | * | | | | |
| WORKABIL | .76843 | * | | | | |
| SPRMWD | .67496 | * | | | | |
| WSELVGR2 | .71422 | * | | | | |
| DSL2 | .74564 | * | | | | |
| COSASP | .32766 | * | | | | |
| SINASP | .71387 | * | | | | |

Table A7.3.6: Rotated factor matrix

| | FACTOR 1 | FACTOR 2 | FACTOR 3 | FACTOR 4 |
|---|---|---|---|---|
| ACCTEMP | -.57644 | -.35182 | -.04249 | .31658 |
| RAINFALL | .95880 | .00572 | .03254 | -.04657 |
| ENDMED | .96891 | .02946 | .09605 | -.09693 |
| FCAPDAYS | .94778 | .09093 | .13410 | -.14466 |
| MDEFGRA | -.86787 | -.27348 | -.03960 | .17700 |
| AVWATGRA | .03080 | .16322 | .89104 | .03723 |
| WORKABIL | .14729 | -.17246 | .84573 | .04177 |
| SPRMWD | -.25679 | -.06321 | -.15010 | .76321 |
| WSELVGR2 | .24551 | .80209 | .01103 | -.10236 |
| DSL2 | .12490 | .84341 | .07181 | .11634 |
| COSASP | -.05180 | .44518 | -.35185 | .05471 |
| SINASP | .08496 | -.12476 | -.21666 | -.80259 |

Table A7.3.7: Factor transformation matrix

| | FACTOR 1 | FACTOR 2 | FACTOR 3 | FACTOR 4 |
|---|---|---|---|---|
| FACTOR 1 | .91199 | .27904 | .15622 | -.25690 |
| FACTOR 2 | .05430 | -.52062 | .84072 | .13851 |
| FACTOR 3 | -.15146 | .74961 | .38941 | .51332 |
| FACTOR 4 | .37733 | -.29861 | -.34225 | .80704 |

Table A7.3.8: Factor score coefficient matrix

| | FACTOR 1 | FACTOR 2 | FACTOR 3 | FACTOR 4 |
|---|---|---|---|---|
| ACCTEMP | -.07451 | -.15038 | -.00965 | .16801 |
| RAINFALL | .30941 | -.12910 | -.07898 | .15521 |
| ENDMED | .29222 | -.11039 | -.03554 | .10823 |
| FCAPDAYS | .26242 | -.06571 | -.00271 | .05730 |
| MDEFGRA | -.21299 | -.05362 | .04012 | -.01269 |
| AVWATGRA | -.10131 | .13490 | .54490 | -.05360 |
| WORKABIL | -.00837 | -.08761 | .48830 | -.00341 |
| SPRMWD | .09565 | -.05040 | -.13722 | .59982 |
| WSELVGR2 | -.05378 | .45737 | .02782 | -.07937 |
| DSL2 | -.06190 | .49060 | .05975 | .07004 |
| COSASP | -.03171 | .25757 | -.19306 | .04307 |
| SINASP | -.09536 | -.05436 | -.07343 | -.62396 |

## A7.3.2: PCA FOR ENVIRONMENTAL VARIABLES ON MILK FARMS

The SPSS executable and outfiles are similar to those used in the PCA of sheep farms and are accordingly not reproduced in the notes to this Appendix. The analysis is similar to that for sheep farms and so commentary is as for the previous section with tables being listed below. As before four PCA factors were extracted and rotated, their interpretation being as follows:

| *Factor No.* | *Interpretation*[1] |
|---|---|
| 1 | High rainfall |
| 2 | High workability score / high water availability |
| 3 | High elevation / high slope |
| 4 | High temperature / Southerly aspect |

Note: 1. See Chapter 7 and Appendix 5 for definition of these terms

Table A7.3.11: Initial statistics: factor eigenvectors

| VARIABLE | COMMUNALITY | * | FACTOR | EIGENVALUE | PCT OF VAR | CUM PCT |
|---|---|---|---|---|---|---|
| ACCTEMP | 1.00000 | * | 1 | 4.43101 | 36.9 | 36.9 |
| RAINFALL | 1.00000 | * | 2 | 1.94067 | 16.2 | 53.1 |
| ENDMED | 1.00000 | * | 3 | 1.34368 | 11.2 | 64.3 |
| FCAPDAYS | 1.00000 | * | 4 | 1.02747 | 8.6 | 72.9 |
| MDEFGRA | 1.00000 | * | 5 | .94918 | 7.9 | 80.8 |
| AVWATGRA | 1.00000 | * | 6 | .90451 | 7.5 | 88.3 |
| WORKABIL | 1.00000 | * | 7 | .58525 | 4.9 | 93.2 |
| SPRMWD | 1.00000 | * | 8 | .35072 | 2.9 | 96.1 |
| WSELVGR2 | 1.00000 | * | 9 | .26234 | 2.2 | 98.3 |
| DSL2 | 1.00000 | * | 10 | .18240 | 1.5 | 99.8 |
| COSASP | 1.00000 | * | 11 | .01701 | .1 | 100.0 |
| SINASP | 1.00000 | * | 12 | .00576 | .0 | 100.0 |

## Table A7.3.9: Anti-image covariance matrix

| | ACCTEMP | RAINFALL | ENDMED | FCAPDAYS | MDEFGRA | AVWATGRA | WORKABIL | SPRMWD | WSELVGR2 |
|---|---|---|---|---|---|---|---|---|---|
| ACCTEMP | .45453 | | | | | | | | |
| RAINFALL | -.04469 | .01484 | | | | | | | |
| ENDMED | .03312 | .00021 | .02130 | | | | | | |
| FCAPDAYS | .00877 | -.00796 | -.00935 | .00862 | | | | | |
| MDEFGRA | -.14457 | .01762 | -.02293 | .00501 | .15248 | | | | |
| AVWATGRA | -.04558 | .00386 | -.01771 | .00102 | -.00395 | .49755 | | | |
| WORKABIL | .07162 | -.00290 | .00836 | .00051 | -.03212 | -.31093 | .50485 | | |
| SPRMWD | .07612 | .00789 | .01476 | -.00770 | -.06414 | -.14529 | .20273 | .56595 | |
| WSELVGR2 | .04740 | -.00642 | -.00308 | .00470 | .02878 | -.04820 | .00376 | -.02371 | .53998 |
| DSL2 | -.09300 | .01927 | -.00396 | -.01005 | -.00119 | .07292 | .04247 | .04138 | -.31791 |
| COSASP | .07489 | -.00725 | -.00508 | .00975 | .00452 | .04148 | -.02615 | .07516 | -.10505 |
| SINASP | -.05104 | .01465 | -.01955 | .00113 | .01811 | -.00942 | -.04548 | .06531 | .01024 |

| | DSL2 | COSASP | SINASP |
|---|---|---|---|
| DSL2 | .53960 | | |
| COSASP | -.02638 | .83594 | |
| SINASP | .03755 | .06516 | .91351 |

KAISER-MEYER-OLKIN MEASURE OF SAMPLING ADEQUACY = .70366 ; BARTLETT TEST OF SPHERICITY = 1132.0926, SIGNIFICANCE = .00000
THERE ARE 14 (10.6%) OFF-DIAGONAL ELEMENTS OF AIC MATRIX > 0.09

## Table A7.3.10: Anti-image correlation matrix

| | ACCTEMP | RAINFALL | ENDMED | FCAPDAYS | MDEFGRA | AVWATGRA | WORKABIL | SPRMWD | WSELVGR2 | DSL2 | COSASP | SINASP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ACCTEMP | .30905 | | | | | | | | | | | |
| RAINFALL | -.54414 | .75789 | | | | | | | | | | |
| ENDMED | .33667 | .01196 | .78971 | | | | | | | | | |
| FCAPDAYS | .14015 | -.70379 | -.69037 | .75187 | | | | | | | | |
| MDEFGRA | -.54915 | .37037 | -.40241 | .13824 | .79556 | | | | | | | |
| AVWATGRA | -.09584 | .04489 | -.17209 | .01555 | -.01435 | .50845 | | | | | | |
| WORKABIL | .14952 | -.03350 | .08064 | .00772 | -.11576 | -.62039 | .46336 | | | | | |
| SPRMWD | .15008 | .08611 | .13446 | -.11018 | -.21835 | -.27380 | .37927 | .75554 | | | | |
| WSELVGR2 | .09567 | -.07172 | -.02875 | .06891 | .10029 | -.09299 | .00720 | -.04290 | .67311 | | | |
| DSL2 | -.18778 | .21533 | -.03696 | -.14738 | -.00415 | .14074 | .08138 | .07488 | -.58895 | .56707 | | |
| COSASP | .12149 | -.06507 | -.03810 | .11488 | .01265 | .06431 | -.04025 | .10927 | -.15636 | -.03928 | .74096 | |
| SINASP | -.07920 | .12579 | -.14016 | .01270 | .04852 | -.01397 | -.06697 | .09083 | .01458 | .05348 | .07457 | .58046 |

MEASURES OF SAMPLING ADEQUACY (MSA) ARE PRINTED ON THE DIAGONAL.

Table A7.3.12: Factor matrix: component loadings

| | FACTOR 1 | FACTOR 2 | FACTOR 3 | FACTOR 4 |
|---|---|---|---|---|
| ACCTEMP | -.33554 | -.06902 | -.32435 | .69623 |
| RAINFALL | .96202 | .07651 | -.15360 | .03639 |
| ENDMED | .95744 | .11337 | -.07821 | -.00345 |
| FCAPDAYS | .97050 | .08396 | -.12103 | .00465 |
| MDEFGRA | -.90487 | .02313 | .06423 | .16289 |
| AVWATGRA | .18653 | .71637 | .36806 | .09532 |
| WORKABIL | -.10306 | .70604 | .53463 | .09141 |
| SPRMWD | -.59279 | -.09019 | -.10826 | -.20749 |
| WSELVGR2 | .42970 | -.50105 | .53122 | .19405 |
| DSL2 | .29665 | -.65221 | .35564 | .38349 |
| COSASP | -.19030 | -.32313 | .57719 | -.30549 |
| SINASP | -.09966 | .33008 | .12309 | .41990 |

Table A7.3.13: Post rotation factor statistics

| VARIABLE | COMMUNALITY | * | FACTOR | EIGENVALUE | PCT OF VAR | CUM PCT |
|---|---|---|---|---|---|---|
| ACCTEMP | .70729 | * | 1 | 4.43101 | 36.9 | 36.9 |
| RAINFALL | .95625 | * | 2 | 1.94067 | 16.2 | 53.1 |
| ENDMED | .93567 | * | 3 | 1.34368 | 11.2 | 64.3 |
| FCAPDAYS | .96358 | * | 4 | 1.02747 | 8.6 | 72.9 |
| MDEFGRA | .84999 | * | | | | |
| AVWATGRA | .69254 | * | | | | |
| WORKABIL | .80330 | * | | | | |
| SPRMWD | .41431 | * | | | | |
| WSELVGR2 | .75554 | * | | | | |
| DSL2 | .78693 | * | | | | |
| COSASP | .56710 | * | | | | |
| SINASP | .31036 | * | | | | |

Table A7.3.14: Rotated factor matrix

| | FACTOR 1 | FACTOR 2 | FACTOR 3 | FACTOR 4 |
|---|---|---|---|---|
| ACCTEMP | -.25673 | -.07306 | .04166 | .79643 |
| RAINFALL | .97521 | -.02610 | .06673 | -.00909 |
| ENDMED | .96070 | .03709 | .07537 | -.07521 |
| FCAPDAYS | .97753 | -.00891 | .07215 | -.05228 |
| MDEFGRA | -.88360 | .09833 | -.09543 | .22464 |
| AVWATGRA | .21560 | .79033 | -.13435 | -.05821 |
| WORKABIL | -.09880 | .88107 | -.08237 | -.10231 |
| SPRMWD | -.57319 | -.18291 | -.21778 | -.06989 |
| WSELVGR2 | .25015 | -.02195 | .81879 | -.14853 |
| DSL2 | .13748 | -.19498 | .84805 | .10402 |
| COSASP | -.34790 | .02027 | .41140 | -.52575 |
| SINASP | -.06269 | .42964 | .01897 | .34853 |

Note: converged after 7 iterations

Table A7.3.15: Factor transformation matrix

| | FACTOR 1 | FACTOR 2 | FACTOR 3 | FACTOR 4 |
|---|---|---|---|---|
| FACTOR 1 | .97117 | -.00262 | .20639 | -.11928 |
| FACTOR 2 | .14222 | .76620 | -.62359 | .06209 |
| FACTOR 3 | -.18968 | .59354 | .64146 | -.44751 |
| FACTOR 4 | .02503 | .24627 | .39633 | .88411 |

Table A7.3.16: Factor score coefficient matrix

| | FACTOR 1 | FACTOR 2 | FACTOR 3 | FACTOR 4 |
|---|---|---|---|---|
| ACCTEMP | -.01586 | -.00345 | .12026 | .71393 |
| RAINFALL | .23903 | -.02949 | -.03907 | .05902 |
| ENDMED | .22911 | .00882 | -.03050 | .00093 |

| | | | | |
|---|---|---|---|---|
| FCAPDAYS | .23606 | -.01977 | -.03776 | .02087 |
| MDEFGRA | -.20173 | .07708 | .04391 | .14387 |
| AVWATGRA | .04374 | .46815 | -.00902 | -.02267 |
| WORKABIL | -.04409 | .53688 | .05882 | -.07404 |
| SPRMWD | -.12631 | -.13281 | -.13035 | -.12941 |
| WSELVGR2 | -.01280 | .08309 | .50946 | -.03755 |
| DSL2 | -.02364 | -.00867 | .54109 | .18269 |
| COSASP | -.15431 | .05427 | .25268 | -.46031 |
| SINASP | -.00480 | .28540 | .11003 | .33356 |

**Notes:**

*1. SPSS executable file 'SHEEP.SPS':*

```
TITLE 'PCA ON ENV DATA FOR SHEEP FARMS'
SET LENGTH=NONE
FILE HANDLE SHEEP /NAME='SHEEP.DAT'
DATA LIST FILE=SHEEP RECORDS=3
  / FARMID ACCTEMP GROWSEAS GRAZSEAS RAINFALL RETWET RETMED RETDRY
    ENDWET ENDMED ENDDRY FCAPDAYS MDEFGRA MDEFCER MDEFSBPT AVWATGRA
    AVWATCER AVWATPOT WORKABIL AUTMWD SPRMWD WSELVGR2 DSL2 WSASPGR2
    (F6.0/12F5.0/9F5.0,F5.1,F5.0)
COMPUTE COSASP=COS(WSASPGR2*0.0174532)
COMPUTE SINASP=SIN(WSASPGR2*0.0174532)
DESCRIPTIVES VARIABLES = ALL
FACTOR VARIABLES=ACCTEMP RAINFALL ENDMED FCAPDAYS MDEFGRA AVWATGRA
    WORKABIL SPRMWD TO DSL2 COSASP SINASP
  / CRITERIA=DEFAULT
  / PRINT=KMO AIC DEFAULT FSCORE
  / EXTRACTION=PC
  / ROTATION=VARIMAX
  / SAVE REG (ALL FSC)
PRINT OUTFILE='SHFACSCR.DAT'
  / FARMID FSC1 TO FSC4 (F6.0,4F8.3)
EXECUTE
FINISH
```

*2. PCA output files*
The PCA log file is 'SHEEPPCA.LOG'. Data is stored in 'SHFACSCR.DAT'

# APPENDIX 7.4: DESCRIPTIVE STATISTICS FOR STAGE 2 MODIFICATION VARIABLES

## A7.4.1: SHEEP FARM MODELS

Three environmental modification variables are included in our stage 2 models for sheep farms:

| | | |
|---|---|---|
| $crop/h | = | Value of crops per effective hectare |
| Silag% | = | Proportion of farm put to silage |
| <140eh | = | 1 for farms of less than 140 ha.; = 0 otherwise |

For predictive purposes all the above were held at their median values. Table A7.4.1 provides descriptive statistics for these variables.

Table A7.4.1: Descriptive statistics for stage 2 modification variables: sheep farms

| Variable | MEAN | MEDIAN | TRMEAN | STDEV | SEMEAN | MIN | MAX | Q1 | Q3 |
|---|---|---|---|---|---|---|---|---|---|
| $crop/h | 42.45 | 19.50 | 36.38 | 53.96 | 5.89 | 0.00 | 255.00 | 4.00 | 65.25 |
| Silag% | 0.1458 | 0.1444 | 0.1380 | 0.1215 | 0.0133 | 0.0000 | 0.4868 | 0.0290 | 0.2020 |
| <140eh | 0.8214 | 1.0000 | 0.8553 | 0.3853 | 0.0420 | 0.0000 | 1.0000 | 1.0000 | 1.0000 |

## A7.4.2: MILK FARM MODELS

Four environmental modification variables are included in our stage 2 models for milk farms:

| | | |
|---|---|---|
| pConc/h | = | Value of purchased concentrates per hectare |
| Fert/h | = | Value of fertiliser per hectare |
| f&sLab/h | = | Notional value of farmer and spouse labour input per hectare |
| ehaHay | = | Absolute area (ha.) of farm put to hay |

For predictive purposes all the above were held at their median values. Table A7.4.2 provides descriptive statistics for these variables.

Table A7.4.2: Descriptive statistics for stage 2 modification variables: milk farms

| Variable | MEAN | MEDIAN | TRMEAN | STDEV | SEMEAN | MIN | MAX | Q1 | Q3 |
|---|---|---|---|---|---|---|---|---|---|
| pConc/h | 296.5 | 241.2 | 283.0 | 182.6 | 17.9 | 40.8 | 1069.7 | 171.4 | 403.8 |
| Fert/h | 92.72 | 88.36 | 90.91 | 47.16 | 4.62 | 12.72 | 232.23 | 60.51 | 114.57 |
| f&sLab/h | 188.0 | 135.6 | 165.3 | 182.9 | 17.9 | 0.4 | 1274.8 | 79.1 | 226.9 |
| ehaHay | 3.192 | 2.000 | 2.798 | 3.695 | 0.362 | 0.000 | 16.000 | 0.000 | 5.000 |

# APPENDIX 7.5: BATCH FILES USED TO GENERATE FARM SURPLUS SURFACES

Below we list the batch files custom written to generate the Farm Surplus surfaces for both sheep (SHEEP.BAT) and milk (MILK.BAT) farms. Note that we use the truncated environmental variable surfaces. These are prefixed by the letter 't'. For example, in SHEEP.BAT the truncated log of field capacity days is labelled 'tslfcap'.

**SHEEP.BAT**

```
scalar x tslfcap xt1 3 -0.452
scalar x xt1 xt2 1 3.6169
overlay x 3 xt2 wales1km lambewe

scalar x tslfcap xt1 3 -410
scalar x tsspmwd2 xt2 3 1.42
overlay x 1 xt1 xt2 xt21
scalar x xt21 xt31 1 2862.2
overlay x 3 xt31 wales1km sliveeh

scalar x tsewet1 xt1 3 37.9
scalar x tsspmwd1 xt2 3 -710
scalar x tsspmwd2 xt3 3 78.6
overlay x 1 x xt1 xt2 xt21
scalay x xt3 xt22 1 1400
overlay x 1 xt21 xt22 xt31
overlay x 3 xt31 wales1km fslab

scalar x tslfcap xt1 3 0.272
scalar x tslndsl xt2 3 0.032
overlay x 1 xt1 xt2 xt21
scalar x xt21 xt31 1 -1.292
overlay x 3 xt31 wales1km grants

scalar x lambewe xt1 3 180.87
scalar x sliveeh xt2 3 0.151
scalar x fslab xt3 3 0.00984
scalar x grants xt4 3 -210.43
overlay x 1 xt1 xt2 xt21
overlay x 1 xt3 xt4 xt22
overlay x 1 xt21 xt22 xt31
scalar x xt31 xt41 2 207.77
overlay x 3 xt41 wales1km ssurpha
```

**MILK.BAT**

```
scalar x tmlendw1 xt1 3 -737
scalar x wales1km xt2 3 3775.6                    (1)
scalar x relief46 xt3 3 140
overlay x 1 xt1 xt2 xt21
scalar x xt3 xt22 1 850.44
overlay x 1 xt21 xt22 xt31
overlay x 3 xt31 wales1km liveeh
```

```
scalar x tmedry1 xt1 3 -0.00256
scalar x tmedry21 xt2 3 0.000014
overlay x 1 xt1 xt2 xt21
scalar x xt21 xt31 1 0.128
overlay x 3 xt31 wales1km gsheep

scalar x soilt23 xt1 3 152
scalar x tmavwc21 xt2 3 0.0160
scalar x tmspmwd1 xt3 3 -11.1
scalar x relief46 xt4 3 84.1
overlay x 1 xt1 xt2 xt21
overlay x 1 xt3 xt4 xt22
overlay x 1 xt21 xt22 xt31
scalar x xt31 xt41 1 511.058
overlay x 3 xt41 wales1km milkcow

scalar x tmrain21 xt1 3 -0.000322
scalar x tmmdefc xt2 3 -4.80
scalar x tmgrazs xt3 3 1.04
scalar x tmedry21 xt4 3 0.032
scalar x tmelev21 xt5 3 -0.000602
overlay x 1 xt1 xt2 xt21
overlay x 1 xt3 xt4 xt22
scalar x xt5 xt23 1 207.07
overlay x 1 xt21 xt22 xt31
overlay x 1 xt23 xt31 xt41
overlay x 3 xt41 wales1km plabh

scalar x liveeh xt1 3 0.46656
scalar x gsheep xt2 3 -3543.2
scalar x wales1km xt3 3 144.7                    (2)
scalar x milkcow xt4 3 0.24095
scalar x plabh xt5 3 -0.5101
scalar x wales1km xt6 3 -50.9884                 (3)
overlay x 1 xt1 xt2 xt21
overlay x 1 xt3 xt4 xt22
overlay x 1 xt5 xt6 xt23
overlay x 1 xt21 xt22 xt31
scalar x xt23 xt32 1 4.8
overlay x 1 xt31 xt32 xt41
overlay x 3 xt41 wales1km msurpha
```

Notes:

(1) lnavwpt set to estimated slope coefficient from regression multiplied by mean lnavwpt value for Wales = 3775.6

(2) genfch set to estimated slope coefficient from regression multiplied by mean value for dairy farms = 144.7

(3) cattfr set to estimated slope coefficient from regression multiplied by mean value for dairy farms = -50.9884

# APPENDIX 7.6: A NOTE ON SOFTWARE AND HARDWARE

This research has utilised a variety of software and hardware. Two GIS packages were used as appropriate. The majority of the spatial analysis involved in our study of recreation was conducted using Arc/Info while most of the timber yield, carbon sequestration and agricultural modelling relied upon Idrisi for integration and manipulation of spatial data[16]. In all cases the statistical analysis facilities included in both GIS packages proved inadequate[17] and so transformed data was read out[18] into a number of statistical packages including Minitab for VAX/VMS (Versions 7 to 9); Minitab for Windows (Versions 9 and 10); SPSS for Windows and MLn[19]. Data was also transferred to and directly entered into the Quattro Pro for Windows and Excel spreadsheet packages. Finally use was also made of the FC's Forestry Investment Appraisal Package (FIAP) running on mainframe computers[20] at both the FC headquarters in Edinburgh and at UEA.

A variety of hardware was also employed with the workload being fairly evenly distributed between PC and mainframe computers. The Idrisi GIS work and some of the statistical modelling was conducted on two Viglen PC's[21]. The Arc/Info GIS work and the remaining statistical modelling was conducted using a mixture of DEC Alpha and VAX mainframe computers.

---

[16]This division of tasks reflects both the type of data employed (the Idrisi GIS being raster based and therefore inherently less suitable for vector data) and the sophistication of the analyses (Arc/Info being the more flexible if less user friendly of the two systems).

[17]A situation which has recently been partly addressed through the release of Arc/Info - S Plus interface software.

[18]Early transfers were made using the Kermit package. This cumbersome process was significantly improved following the release of the WS_FTP software.

[19]Available from the Multi Level Models Project, Institute of Education, London.

[20]The FC has recently announced the impending launch of a PC based version of FIAP to be based upon the Excel spreadsheet package.

[21]The first being a 486 processor, 8Mb RAM machine with a 700Mb hard disc. This proved very slow for some of the more intensive GIS calculations (for example, many of the Idrisi interpolation routines took over 8 hours to run) and so later work was completed on a Pentium processor, 32Mb machine with a 1Gb hard disc.

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