Fiscal Policy in Models of Economic Growth: Theory and Evidence

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Abstract

Growth models contain strong predictions regarding the effect of fiscal policy on the steady state growth path. Fiscal policies have no effect on the steady state growth rate in the neoclassical model whereas fiscal policy does feature in the steady state of endogenous growth models. The number of alternative policies which have been found to effect growth in the endogenous growth models is large as one of the few restrictions placed upon policy in the models is which sector of the model is affected, demand or supply. Only policies that are included in the supply side of the model affect the growth rate.

Despite the strength of the growth predictions regarding fiscal policy in growth models the empirical relationship between the two has proved more difficult establish. Even when comparisons are made between studies that purport to correct for many of the statistical biases present in the data, non-robustness still abounds. We believe that this non-robustness can in part be explained by a failure to adequately account for the predictions from the theoretical models. We use four conclusions from our review of the theoretical literature (the method of financing changes in policy, differences between the transition and the steady state, the assumption of homogeneity of expenditures, and the direct versus indirect effects of policy) to provide the shape for new empirical tests. We find that once done, the strength of the empirical relationship is increased and matches the predictions from the basic public policy endogenous growth model of Barro (1990).

Acknowledgments

My reaching this has point has come from the influence of a large number of people. I have decided to string them as a long list of names (except a few at the end). Adam M, Adrian K, Alvaro P, Amanda G, Andy E, AnneMarie K (formerly P), Caroline S, Chris J, Chris J, Elaine K, Ian G, Ian J, Ian K, Jag B, James E, Jason L, Jill B, Jimmy K, John D, Justin, Kevin M, Kim K, Louise H, Marjory M, Matt A, Matt C, Max L, Michael M, Michelle P, Nick McN, Nicky C, Paul C, Paul H, Paul McS, Pete C, Pete T, Pete W, Ramesh D, Rich B, Rob E, Rob S, Sarah K, Sean K, Sharon T, Steve T, Sue B, Sue M, Suzzanah F, Tim B, Tim L, Vic S, Wyn M,

Having done all of that I would like to give special thanks to my mum and dad and to Helen. You have contributed more than you should have, as always, and are aware of.

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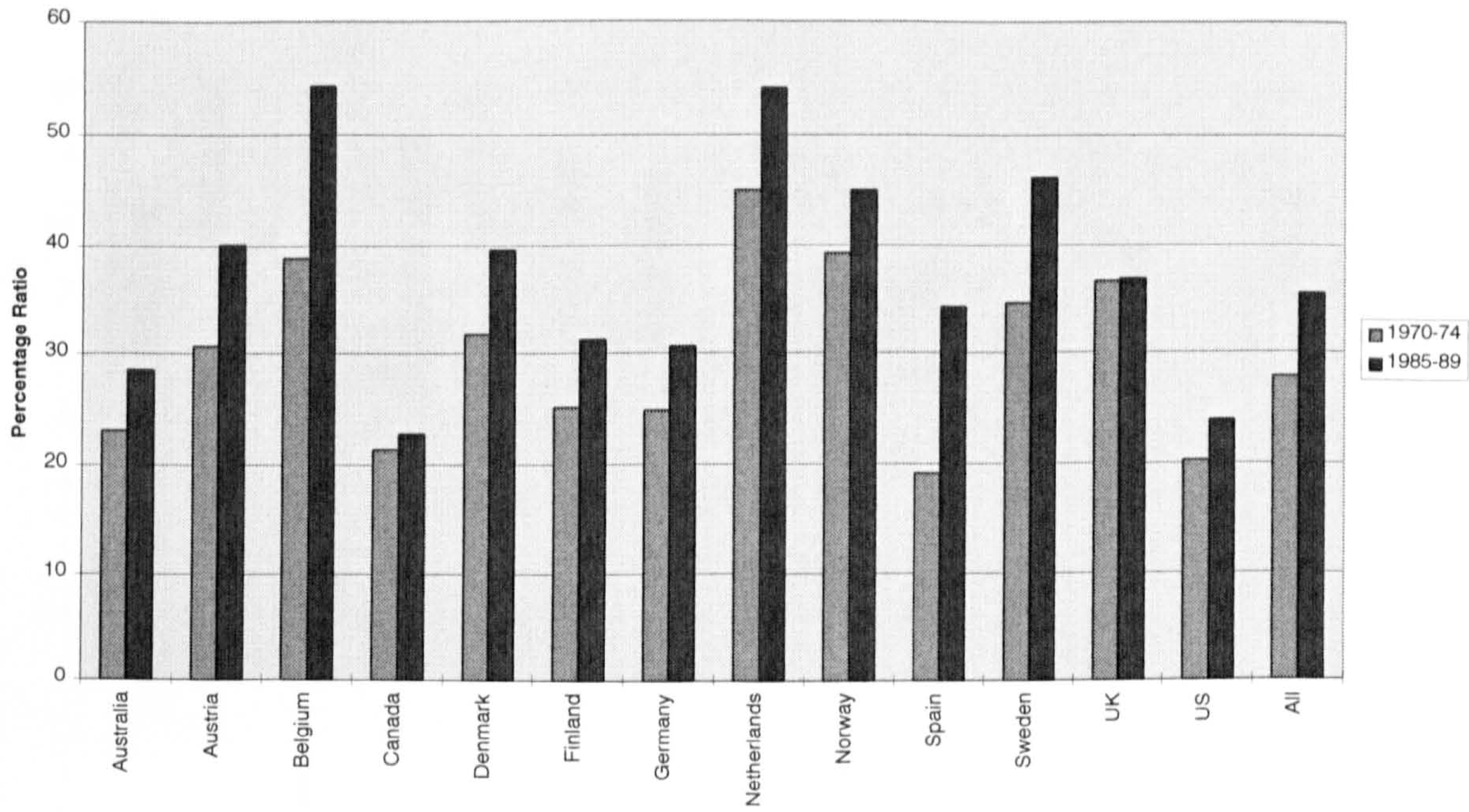
Chapter 1

Introduction

"The conduct of government is the testing ground of social ethics and civilised living. Intelligent conduct of government requires an understanding of the economic relations involved; and the economist, by aiding in this understanding, may hope to contribute to a better society"
Musgrave (1959) pp.iii-iv

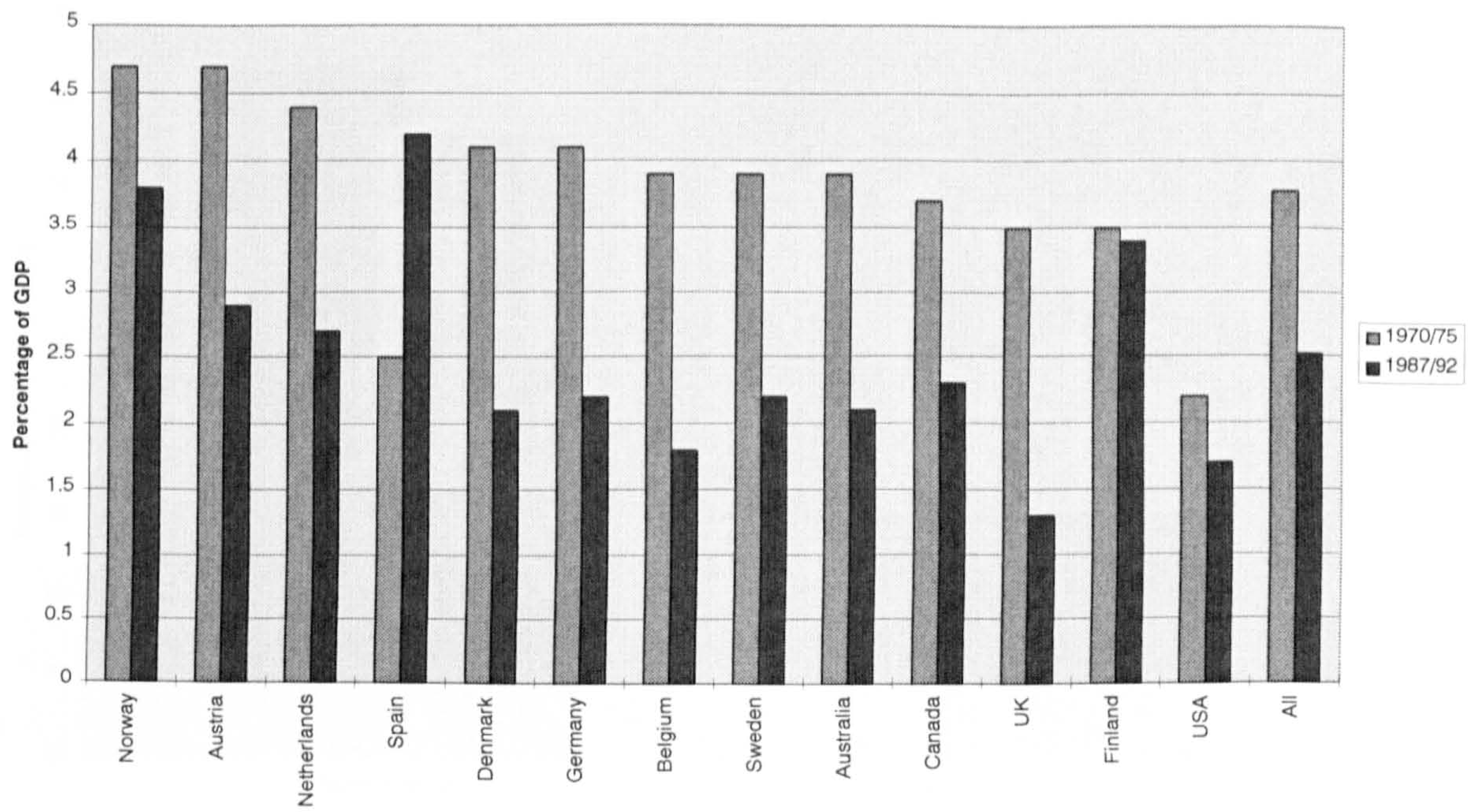
Two features which may be said to have characterised the economies of developed nations over the last 30 years are: the slowdown in the growth rate of output, and that governments have on average appropriated an increasing proportion of GDP. Figure 1.1 displays evidence of the second of these. The average level of government expenditure in the 13 OECD countries expressed as a percentage ratio to GDP increased from 27.8% in 1970/74 to 35.6% in 1985/89, while the average growth rate of the 13 OECD countries included in Figure 1.1 fell from 4.21% in the period 1970/74 to 1.14% per annum in 1985/89. Unsurprisingly it has been argued that the increased intrusion of government into the workings of the economy is crucial for explaining the slowdown in growth and has caused living standards to be below those which could have been achieved. The aim of this thesis is to investigate and extend the theoretical and empirical links between the mix of fiscal policies and growth.

Figure 1.1: Government Expenditure as a Percentage Ratio of GDP



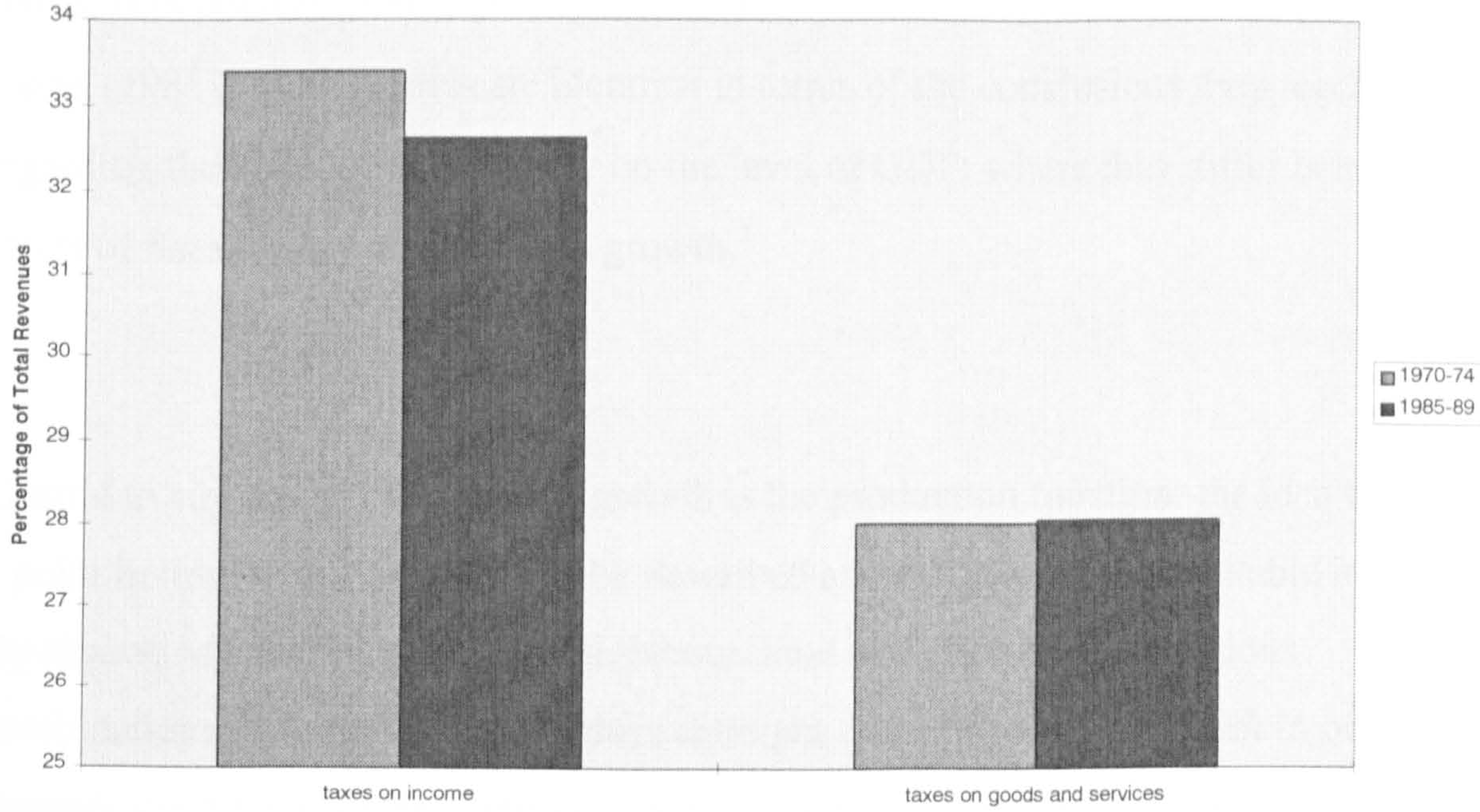
The expansion of government expenditure has been criticised principally on the grounds that it has been directed towards consumption expenditures. The political sensitivity of social security expenditure and the need to finance increasing national debt has meant that public investment has been targeted as the easy political option (Oxley & Martin (1991)). This can be seen in Figure 1.2 below: despite the increased appropriation of GDP evident in Figure 1.1 the 13 OECD countries included in the sample have cut back on government capital expenditure as a percentage of GDP (Spain is the exception) from an average of 3.77% in 1970/75 down to just over 2.5% in 1987/92. It can also be seen from this sample that the UK currently spends the lowest proportion of its GDP on government capital (1.3% in 1987/92), although in turn, it can also be argued that the lower growth rate justifies a lower stock of public capital.

Figure 1.2: Public Investment (% GDP) in OECD Countrires, 1970/75 - 1987/92



Simply considering the changing expenditure pattern of countries over the period provides an incomplete perspective on the changing role of government. Attention has, therefore, also been attracted to the method of financing as an explanation for the slowdown in growth. Within the average country expenditures are mostly funded out of income tax, social security tax and goods and services tax revenues. From Figure 1.3 it would appear the relative importance of these tax revenues has changed very little over the period. These aggregate figures hide substantial differences however, in both the revenue breakdown between countries and the changes in the revenue mix within countries over the period. Some countries, for example Belgium, have collected an increasing share of revenue from income taxes rather then taxes on goods and services while others, such as the UK, has adopted the opposite strategy. Germany and the US have collected a decreasing proportion of revenues from taxes on income and goods and services taxation over the period in favour of increased revenues from social security taxation, while Finland has not changed the makeup of its tax revenues over the period.

Figure 1.3: Tax revenues by Type, Percentage Ratio of Total Revenues



The maximisation of the growth rate is not the only objective of governments but examining this objective has the advantage over alternatives, such as improvements in social welfare, that there is a readily available supply of data through which to test the models of government behaviour. Given that in theory the maximisation of welfare is the principal aim of government we must assume in the thesis that the rate of improvement in social welfare and the growth of output are positively correlated.[1] The failure to find growth effects from a particular type of policy is not then an indication that this policy should be replaced. Indeed, assuming that its stated objective is being met, then the failure to find growth effects from a particular policy may in fact justify this policy over the range of possible alternatives.

1.2: Theoretical Literature

The theoretical relationship between fiscal policy and the growth of output is reviewed using a class of model known as economic growth models. These models investigate the underlying causes of growth over long periods of time (rather than short run fluctuations due to the business cycle). Growth models come in two main forms, neoclassical (Solow (1956), Swan (1956)) and endogenous (Romer (1986), Lucas (1988)). Both models are identical in terms of the conclusions they reach regarding the effect of fiscal policy on the level of GDP; where they differ is in the effect of fiscal policy on economic growth.[2]

Central to any model of economic growth is the production function: the idea that at a point in time a firm's output can be described as a function of the available inputs. By mixing together physical capital, labour, land and technology in various combinations firms are able to produce different types of output.[3] *Growth* in output depends upon the economy finding more, or improving the quality, of these inputs over time. However, increasing the amount of any one input very quickly does not lead to fast growth in output in the long run because of diminishing returns in the accumulation of inputs (adding an additional unit of an input increases output but by less than the previous unit of input).

The accumulation of physical capital is determined in such models by the firm's investment decision, whereas growth in the size of the labour force and to the level of technology are determined by nature (they increase at an independent exogenous rate over time).[4] Diminishing returns to investment imply that firms find it profitable to invest only when new labour becomes available to use new machines (growth in the labour force); and as the productivity of workers using the existing stock of machines

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[1] This assumption lets us over come problems such as; revealing households true preferences; or determining whether the new allocation of resources is efficient (Musgrave (1959)).

[2] There are many ways in which endogenous growth can be introduced into the model we concentrate only on public investments as the source of endogenous growth. For a more complete review of the literature see Aghion & Howitt (1998).

[3] We abstract from the idea of human capital as an input in the production function in order to simplify the discussion. An extension to include human capital is relatively easy to make (Rebelo (1991)) and this is done later in the chapter. This abstraction changes none of the basic results.

[4] A branch of the literature has looked at the reason firms choose to invest in product design and R&D (for example Romer (1990)). The implications of government policy for growth are in many ways identical to those when technical progress is exogenous and so we do not consider them in detail. A simple model where government policy determines the growth in the efficiency of labour (Krichel & Levine (1995)) is given in Chapter 2 Section 2.4.1.

improves (technological progress).[5] Assuming the size of the labour force is constant then new investment in capital and the growth of output will only be as fast as the rate of technical progress allows.[6]

From this description of growth models it appears that, if governments are to have a positive effect on the long run growth rate of a country then they are constrained to chose policies that facilitate technical change. The interactions of economic agents in this model yield an allocation of resources which is *optimal* (because of the assumption of a full and perfectly competitive set of markets). Any intervention by the government into these markets can serve only to distort the optimal resource-mix and reduce the growth rate. Additional roles may, therefore, only be found if there are imperfections in the functioning of markets within the model.

According to Musgrave (1959) government intervention can be justified when: (*i*) the allocation of resources is sub-optimal; (*ii*) the distribution of income is unethical; and (*iii*) the macroeconomy requires stabilisation. The growth literature has tended to concentrate on the first of these roles, the allocation of resources.[7]

Market failure may take several forms but the most common example given in the literature is the divergence between the private and social returns to investment.[8] If there are benefits that accrue to society as a whole from the investment decision of firms, and these firms are not compensated for the positive externalities of their investment, then the amount of investment in this input will be below that which

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[5] Technological change is limited in the model to improvements in the efficiency of labour.

[6] Technical progress offsets the diminishing returns to capital investment that would otherwise limit growth.

[7] We discuss briefly some of the literature relating to the other objectives of government further below along with the potential interrelationship with the allocation of resources.

[8] We do not look at models where divergence between private and social returns exists for a whole class of capital goods, such as the externality to capital accumulation (learning-by-doing) in Romer (1986) or the externalities to human capital accumulation in Lucas (1988). These models advocate subsidies rather than the public provision of capital described here.

society would optimally choose. Co-ordination of firms to invest together will not be possible, as the incentive not to bear the costs and only reap the benefits will be too strong. This is usually described as the public good nature of capital, and transport infrastructure, street lighting and policing are the examples usually given, but this could also be extended to include education and health care.[9]

Government correction of this market failure through the public provision of this input raises the marginal product of capital and encourages faster investment and growth. In the neoclassical model the effect of this policy is only temporary, as private capital and public capital are not close enough substitutes. Good policies shift the path of output upwards but do not permanently affect the slope of this path (Agell et al. (1997)). In contrast, in the endogenous growth model the effect on the returns to investment are so large that the diminishing marginal returns to capital which otherwise limit growth are *permanently* offset. More investment leads to faster output growth, which in turn means that more public investments can be afforded which encourages yet more investment. A virtuous circle is formed. Technological change is no longer the key to economic growth and instead it is the accumulation of resources.[10] Therefore, government policies that encourage the accumulation of reproducible factors of production raise the long run rate of growth of a country.[11]

The improved allocation of resources through the correction of market failure by the government may be undone if the taxes used to finance the provision of the necessary goods and services reduce the incentives to accumulate factor inputs. Taxes on the reproducible inputs lowers their return discouraging investment lowering the growth

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[9] The model justifies government provision of productive expenditures not their production. This distinction is made in order to ignore the possibility that the efficiency of the public sector in producing these inputs is below that of the private sector. We briefly review such a model in Section 2.4.2 in Chapter 2.

[10] In most of the endogenous growth models we describe we hold the level of technology constant.

[11] Given the scope for intervention provided by the government in growth models it is common to approach this relationship through a discussion of the relationship between the *level* of government spending and taxation and the *growth* of GDP. For an introductory discussion of the relationship between, the *level* of fiscal variables and, the *level* of income and the *growth* of fiscal variables and the *growth* of income see Sundrum (1990).

rate and the steady state level of the capital stock. [12] There is an excess burden from government intervention on the optimal allocation of resources.[13] If the negative distortionary effects of taxation outweigh the positive benefits to public investment (as may happen when the level of expenditure becomes too large) then the level and growth of output will be lowered by this combination of policies (Barro (1990)).

Immediately the differences between the new and old growth theories offer alternative explanations for the slowdown in growth. The neoclassical model suggests that the level and the mix of fiscal policy has no power as an explanatory variable of growth rates. Any correlation between the two is instead due to changes in the perceived role of government in, for example, social welfare provision (Wagner's law). Increases in the level of national income have led to increased expenditures on social welfare. Only in the endogenous growth model is the mix of fiscal policies consistent with the view that governments have caused the slowdown in growth.

Public policy endogenous growth models can themselves be separated into two main types. The first strand encompasses those models in which fiscal policy helps to endogenise the rate of growth of the model (for example Barro (1990), Devarajan et al. (1996), Capolupo (1996)). Examples of these models tend to be concentrated, and better developed, in one-sector models and require taxation and government expenditure to be included together. For this reason this type of model is not encountered until Chapter 4. The second strand concerns those models in which fiscal policy is effective in the presence of endogenous growth.[14] This sort of model tends to be used when the characteristics of the fiscal instrument are such that it is not capable of endogenising the rate of growth, for example in two-sector tax models

[12] It should be obvious from these descriptions that we do not consider the possibility of market failure due to non-perfectly competitive markets. Indeed we retain the assumption of perfect competition throughout in order to simplify the analysis. As a point of note in models in which monopoly power is required to provide the incentives for R&D investment (see Aghion & Howitt (1998) for an excellent description of these models) then under certain conditions its removal would in fact lower the growth rate.

[13] If there is more than one reproducible factor accumulated by economic agents then the relative taxation of these inputs becomes important. Such issues are taken up in Chapter 3.

[14] Endogenous growth being achieved by some means other than fiscal policy such as constant returns to capital.

(Rebelo (1991), Lucas (1990), Mendoza et al. (1997)), and where public goods are subject to congestion in one-sector models (Barro & Sala-i-Martin (1992)). The models can be found throughout Chapters 2 to 4. We use both types of endogenous growth model because the conditions under which fiscal policy is the *source* of endogenous growth are fairly limited and a concentration on only one strand of the literature would severely restrict the way in which we could capture the effects of fiscal policy in a growth model framework.[15]

It should be noted that when using these models throughout the thesis we make the strong assumption that all changes in fiscal policy are permanent. That is we do not allow any forward looking behaviour from agents in the model. Relaxation of this assumption would have implications for both the theory and empirical testing.

1.3: Empirical Literature

The clarity of the relationship between fiscal policy and the growth of GDP present in the theoretical model does not translate itself across to the empirical literature. Indeed, the empirical literature has produced results which can only be described as diverse and, therefore, of little value when trying to explain the role of government in the growth slowdown. As an example of this diversity the relationship between transfer payments and growth has been estimated as positive (and significant), negative (and significant) and insignificant by various authors despite using similar data sets and similarly specified regressions (for details see Chapter 5). Variability in the estimates such as this has led to the suggestion that the use of fiscal variables in growth regressions be abandoned as they are more likely to represent underlying 'symptoms' of growth performance rather than have any direct relationship themselves (Sala-i-Martin (1997)).

A number of recent, more careful, studies have attempted to alter this conjecture (Fuente (1997), Mendoza et al. (1997)). These studies account for many of the statistical problems typically encountered when estimating growth regressions but, as

[15] Examples of this sort of switching can be found in the literature, for example Barro & Sala-i-Martin

further demonstrated in Chapter 5, a comparison of their results serves only to make the empirical relationship appear even weaker. It is possible the lack of a consistent methodology combined with the continued presence of statistical biases which infect the results could explain some of the diversity but not all. However, there are a number of theoretical issues which need to be addressed and which have not yet, or have only incompletely, been incorporated into empirical tests. The empirical section of this thesis develops the theoretical issues we raise in Chapters 2 to 4 into a series of tests.

1.4: Some Qualifications

There is a limit to the number of different government interventions we can explore in the thesis and by concentrating on the direct effects of policy on growth we have chosen to ignore some important, closely related issues (some of these have already been highlighted in the text).

1.4.1: Budget Deficit

One element of fiscal policy that we ignore in our theoretical discussion is that of the government budget deficit. In the simple models that we consider government budget deficits behave as if they were lump-sum taxes and have no effect on the rate of growth (Ricardian Equivalence holds). As we do not consider household preference functions where Ricardian Equivalence is violated (such as in overlapping generations models) from a theoretical perspective this omission does not appear to be serious. In addition the empirical section of the thesis uses the deficit term to collect statistical error and although included in the regressions this is not discussed explicitly. Instead we refer the reader to Tanzi & Zee(1997) for an extensive discussion of the possible relationship between budget deficits and growth and to Levine & Krichel (1996) for an example of an endogenous growth model which allows budget deficits.

(1992).

1.4.2: Macroeconomic Stability

Growth models abstract from the idea of the management of the macroeconomy by assuming as essentially classical short-run structure of the model. There is no unemployment and it is relative rather than absolute prices on which agents' decisions are based. That is, the classical dichotomy between nominal and real sectors of the economy holds. The long run aggregate supply curve (LRAS) is vertical around the full employment output level and the economy is on the maximum of the production possibility frontier. This therefore provides no scope for the use of Keynesian demand management policies. The assumption of perfect foresight rules out the possibility that expectations can systematically be incorrect and all regime shifts (such as changes in government) are fully anticipated. From this perspective the role of government is limited to implementing policies which shift the supply curve.

Attempts have been made in the literature to incorporate some long run effects from instability in the macroeconomy (see Barro (1995, 1996) and Bruno & Easterly (1996, 1998) as an introduction to the topic) where the most likely effect of this uncertainty is on investment decision of firms. The empirical relationships between macro-instability and growth are non-robust. As Temple (1998) writes, "a common conclusion from this literature is that although 'policy matters' we do not yet have any clear idea which elements of policy are crucial."[16]

1.4.3: Income Inequality

In the standard model all households are identical and therefore the re-distribution of wealth between them is irrelevant. However, it is possible to extend the endogenous growth model to consider the likely growth effects of inequality in income between households (Alesina & Rodrik (1994), Persson & Tabellini (1994)). The link with fiscal policy is generated by the political economy literature and by the consistent finding in the empirical literature of a negative relationship between inequality and

[16] Temple (1998) pp.41

growth. For example in Perotti (1996) we find that economies with an uneven distribution may actually have slower growth rates.

1.5: Outline of the Thesis

We use the remainder of this chapter to discuss the basic form of the growth models we use throughout the thesis. This allows us to conserve space elsewhere in the thesis but also to highlight how fiscal policy might be introduced into growth models and the mechanisms by which it is effective in the endogenous growth model but not in the neoclassical model. We begin with a description of the neoclassical model, then move to the 'AK' and Romer-type one-sector endogenous growth models before finally discussing the two-sector endogenous growth models. We do not provide a full description of the dynamics of the models, preferring instead to concentrate on the derivation of the steady state and to understand the conditions under which endogenous growth occurs in the models. Detailed references where full descriptions of the models can be found are made throughout.

Public policy is introduced into growth models in Chapters 2 and 3. These discuss respectively expenditure and taxation policies. We begin in both of these chapters with a discussion of policy irrelevance in the neoclassical model before describing a simple one-sector growth model (which we develop as a neoclassical model when certain assumptions hold). Once we have explored some of the developments of this basic one sector model we move to public policy in two-sector endogenous growth models. Chapter 4 integrates these two halves of the government budget firstly into a neoclassical model, then into a one-sector model and finally a two-sector model. The two halves of the government budget constraint are brought together in order to highlight their interdependence.

The empirical half of the thesis begins in Chapter 5 with a review of the literature. We also use this chapter to draw out some of the failings of this literature both in terms of (*i*) the statistical bias which might be present, and (*ii*) the limitations of the models it claims to test. Chapters 6 to 9 conduct the empirical tests and Chapter 10 concludes.

1.6 Assumptions of the model

1.6.1 The Neoclassical Model

This section offers a general description of the assumptions underlying the growth models used throughout this thesis and to which we can later add fiscal policy. We describe the consumption and production sectors of the economy and solve for the equilibrium time paths of consumption and capital. The description of the models borrows extensively from Barro & Sala-i-Martin (1995) and the reader is referred to this text for a more complete description.[17]

We assume a decentralised economy, closed to international trade, which has an equal number of identical households and identical firms. The rate of labour augmenting technological progress, $(\frac{\dot{A}}{A})$ and the rate of growth of population, $(\frac{\dot{L}}{L})$ are exogenous and constant $(\frac{\dot{A}}{A} = x,\ \frac{\dot{L}}{L} = n)$.[18] A continuum of perfectly competitive households and firms are assumed to have the following properties.

Behaviour of Households

The representative household is infinitely-lived and chooses consumption and saving to maximise its dynastic utility. That is, we assume throughout that the Ramsey (1928) preference function, first introduced into the growth literature by

[17] We do not extend the neoclassical model to include human capital accumulation (Mankiw, Romer & Weil (1992)). If human capital is a reproducible factor of production then the speed of transition to the steady state and the effect of policy on the steady state is faster (De Long (1996)) but the effect on the long run growth rate of output is still zero.

[18] We normalise the number of adults at time 0 to unity, so that the labour force at time t is given by $L(t)=e^{nt}$. Likewise we normalise the available technology at time 0 to unity, so that the level of technology at time t is given by $A(t)=e^{xt}$.

Cass (1965) and Koopmans (1965), holds. The preferences of the representative household are given by the following function,

Equation 1. 1
$$u = \int_0^\infty e^{-\rho t} u(c) \delta t$$

where c_t is consumption per person (C/L), ρ is the constant rate of time preference, $(\rho > 0)$, and $u(c)$ is given by the following CIES utility function,

Equation 1. 2
$$u(c) = \frac{c^{1-\sigma} - 1}{1 - \sigma}$$

which has a constant rate of intertemporal substitution σ.[19] Household utility is maximised subject to a budget constraint, equation (1.3). The assets of the household, a, rise with income, $w + ra$, and fall with consumption, c. The flow of income is made up of the return from capital, r[20], and the returns from labour, w[21].

Equation 1. 3
$$\dot{a} = ra + w - c$$

In order to rule out the possibility of chain letter debt finance the net present value of assets is constrained to being asymptotically nonnegative.[22] If we also assume that agents do not leave assets at the end of time, then the transversality condition is given by,

Equation 1. 4
$$\lim_{t \to \infty} \{a(t) \exp[-\int_0^t [r(v) - n] dv]\} = 0$$

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[19] The felicity function $u(c)$ has the usual properties regarding the returns to consumption $u'(c)>0$, $u''(c)<0$ as well as satisfying the Inada conditions $u(c) \to \infty$ as $c \to 0$, and $u'(c) \to 0$ as $c \to \infty$.

[20] Interest income can be either positive or negative depending whether the household at that point in time is a debtor or creditor to other households. The representative household must hold a net zero position in equilibrium.

[21] Each agent supplies inelastically one unit of labour per unit of time for which they receive a wage which clears the competitive labour market.

[22] This constraint limits the amount of borrowing each household is able to undertake in order to prevent households from rolling over their debt into future periods indefinitely and effectively gaining the first unit of consumption for free. That is, we prevent households from consuming more than the value of their initial wealth plus lifetime earnings.

Household utility (equation (1.2) is substituted into equation (1.1) for *u(c)*) and maximised subject to the household budget constraint (equation (1.3)). From this maximisation the growth path of consumption (known as the Euler equation) can be derived,

Equation 1. 5 $$\gamma_C = \frac{\dot{c}}{c} = \frac{1}{\sigma}(r - \rho).$$

The growth of consumption is given by the return to saving, r, less the rate of time preference, ρ, divided by the rate at which households are willing to substitute consumption across time, σ.

Behaviour of Firms

Each firm has access to a constant returns to scale production function in which capital, K, labour, L, and a labour augmenting technology term, A, are inputs (equation (1.6)).

Equation 1. 6 $$Y = F(K, AL).$$

If we re-write capital as a ratio to effective labour, $k = \frac{K}{AL}$, then the production function becomes,

Equation 1. 7 $$y = f(k),$$

The production function is assumed to satisfy the Inada conditions, most notably that each input is subject to positive but diminishing marginal returns.[23] The technology used to produce consumption or capital goods is identical such that a unit of output can be used either for consumption or investment in the capital stock. The evolution of the capital stock is determined by investment net of depreciation.[24] Equation (1.8) also represents the resource constraint of the economy.

Equation 1. 8 $$\dot{k} = f(k) - c - (x + n + \delta)k$$

The competitive firms' flow of profits is given by the value of its output less its costs for capital and labour (equation (1.9)),

Equation 1. 9 $$. = F(K,AL) - (r + .)K - wL$$

The cost of capital is set by perfect competition at the rate r, which is equal to the net marginal product of capital, $\frac{.F}{\delta K}$ - δ, (where δ is the constant depreciation rate of capital). Capital and loans are equivalent stores of value for households and therefore the net marginal product of capital equals the returns households receive from making loans. This assumption links the production and consumption sides of the model. The competitive wage rate is equal to the marginal product of labour, $\frac{\delta F}{\delta L}$.

The equilibrium profit the firm receives is zero (factor payments exactly offset total output) through the assumption of perfect competition and constant returns technology.

Steady State

Steady state occurs in this model when consumption and capital grow at a constant rate. The growth path of consumption can be found by substituting the net marginal product of capital, $\frac{\delta F}{\delta K}$ - δ, into the Euler equation (equation 1.5) for the interest rate.

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[23] The Inada conditions $\lim_{K \to 0}(F_K) = \lim_{L \to 0}(F_L) = \infty$, $\lim_{K \to \infty}(F_K) = \lim_{L \to \infty}(F_L) = 0$ hold for equation (1.6) and equivalently $\lim_{k \to 0}(f_k) = \infty$, $\lim_{k \to \infty}(f_k) = 0$ for equation (1.7).

[24] An implication of this assumption is that the prices of consumption or new capital are identical and set at unity.

Equation 1.10 $$\gamma_C = \frac{\dot{c}}{c} = \frac{1}{\sigma}[f'(k) - \delta - x - n - \rho].$$

The growth path for capital is given by equation (1.8). Equations (1.8) and (1.10) along with the initial capital stock and the transversality condition, $\lim_{t\to\infty}\{k\exp(-\int_0^t [f'(k) - \delta - x - n]dv)\} = 0$, provide a system of equations which describe the time paths of consumption and capital. The steady state can be shown graphically in Figure 1.4 as combinations of c and k in which the growth of the consumption and physical capital effective labour ratios are constant, $\dot{c} = \dot{k} = 0$.[25] The steady state is then given at the intersection point A where the capital stock/ effective labour ratio is constant at k^*. The capital/effective labour ratio is constant when the growth of the capital stock is exactly equal to the growth rate of labour and technology. Differentiating $k = \frac{K}{AL}$ with respect to time to yield $\frac{\dot{k}}{k} = (\frac{\dot{K}}{K}) - (\frac{\dot{L}}{L}) - (\frac{\dot{A}}{A}) = 0$ and then substituting for the growth rates of labour and technology, $\frac{\dot{L}}{L} = n, \frac{\dot{A}}{A} = x$, implies the capital stock grows at the rate $\frac{\dot{K}}{K} = x + n$. If we assume Cobb-Douglas technology then the growth rate of output can be found by differentiating the production function with respect to time, $\frac{\dot{Y}}{Y} = \alpha\frac{\dot{K}}{K} + (1-\alpha)(\frac{\dot{L}}{L} + \frac{\dot{A}}{A})$, and substituting for the growth of capital, technology and labour. The growth of output is therefore also equal to, $\frac{\dot{Y}}{Y} = x + n$.

[25] The $\hat{c}(\hat{k})$ line provides the stable path for the transitional dynamics of the model, the details of which can be found in Barro & Sala-i-Martin (1995).

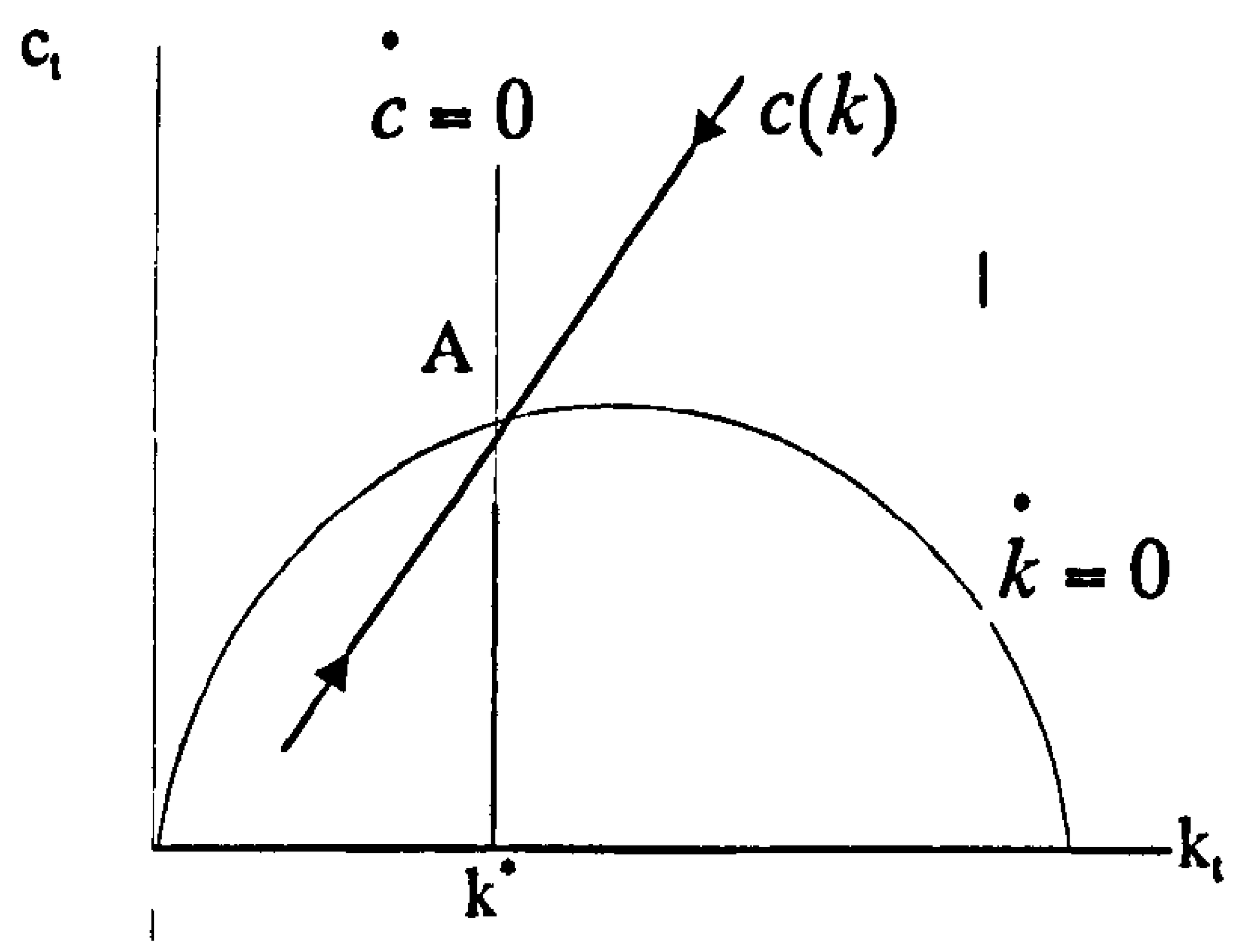

Figure 1.4 : Phase Plane Diagram of the Steady State in the Neoclassical Growth Model

If there is no growth in technology or the labour force, $\frac{\dot{L}}{L} = \frac{\dot{A}}{A} = 0$, then the growth rate of capital and output are both equal to zero because of diminishing marginal returns to capital. This result implies that if fiscal policy helps to determine the growth of technological progress or population growth, then it also affects the growth rate of output in the neoclassical model (Peacock & Shaw (1971)). Under such circumstances we prefer to describe the source of growth in these models as endogenous rather than exogenous, and provide an example of such a model in section 2.4.1 (Levine & Krichel (1996)).

In the public policy endogenous growth models that we describe in the following chapters, a constant positive rate of steady state growth is possible in the *absence* of labour or technology growth. In the one-sector models this occurs by preventing the private returns to capital from declining towards zero over time, i.e. the Inada condition $\lim_{K \to \infty}(F_K) = 0$ does not hold; while in the two-sector models this is achieved through the separate endogenous accumulation of human capital. Growth is then a product of capital accumulation (and human capital accumulation in the two-sector models), not of technological change or labour force growth as in the neoclassical model. The endogenous growth literature uses two main forms of one-sector model. The first is the constant returns to capital, or 'AK', model (Jones & Manuelli (1990)); and the second is the externalities, or Romer-type, model (Romer (1986)). Despite the fact that these models are essentially both 'AK' models we highlight the distinction because the Romer-type model allows fiscal policy to provide the engine for growth. We discuss a two-sector endogenous growth model in Section 1.2.4

1.6.2 AK Endogenous Growth Models

In the 'AK' model (Jones & Manuelli (1990)) a constant positive steady state growth rate of output is an assumption rather than a result of the model. There are constant returns to capital, which implies that the marginal product of capital, and therefore the rate of interest and the growth rate, is constant in the steady state. The violation of the Inada condition of diminishing marginal returns to capital is crucial for these results. We assume for simplicity that the supply of labour is constant and therefore remove it from the production function. The capital term is then generally interpreted as encompassing both physical and human capital as a means of justifying the assumption of constant returns. The firms' production function described in equation (1.6) above now reads as,

Equation 1. 11

$$Y = F(K) = AK.$$

The net marginal product of capital $\frac{Y}{\delta K} = A - \delta$ can be substituted for the interest rate in the consumption growth equation to yield the consumption growth equation,

Equation 1. 12

$$\gamma_C = \frac{1}{\sigma}[A - \delta - \rho]$$

The steady state growth rate is then a positive constant value if $A > \delta + \rho$.[26] The growth rate of consumption is therefore independent of the capital stock in this model, which results in permanent differences in growth rates across countries.

---

[26] We impose the condition that $A > \delta + \rho > \frac{1-\sigma}{\sigma}(A - \delta - \rho)$ so that utility is bounded and the transversality $\lim_{t \to \infty}\{k(t)e^{-(A-\delta)t}\} = 0$ condition holds.

Fiscal policies affect the steady state growth rate in these 'AK' model because they amount to shifts of the technology parameter A. Changes in fiscal policy therefore lead to permanent differences in growth rates across countries. Endogenous growth is not caused by fiscal policy in the 'AK' models as this has been made one of the assumptions through constant returns to capital. We use these models extensively in Chapters 2 and 3 when we limit the available choice of policy variables to consider only one half of the government budget, and again in Chapter 4 when public goods are subject to congestion.

1.6.3 Romer-type Endogenous Growth Models

The Barro (1990) public policy endogenous growth model we discuss in Chapter 4 works on a identical principle to that of Romer (1986). There is some form of 'externality' to the accumulation of capital, which leads to constant returns to capital at the aggregate level. In Romer the accumulation of capital increases the stock of generally available knowledge, so there is learning-by-doing. Aggregate knowledge is a non-rival, non-excludable input into each firm's production function, available to all at zero cost. Knowledge accumulation and therefore growth is endogenous to the economy but is assumed by each individual firm to be exogenously determined because the effect of its own investment is small and non-appropriable. This assumption is important because it allows us to retain the assumption of perfect competition at the firm level. The production function for the individual firm (using a Cobb-Douglas functional form) is given by,[27]

Equation 1. 13 $$Y_i = AK_i^{\alpha} K^{1-\alpha}$$

There are diminishing marginal returns to physical capital but constant returns across physical capital and knowledge. This assumption of constant returns to scale across capital and knowledge is crucial, for when we aggregate across all firms we arrive back at an 'AK' type of production function.

Equation 1. 14 $$Y = AK$$

The marginal product of capital is constant and the economy has again a sustainable positive constant growth rate in the steady state. In the Barro-type endogenous growth model expenditure policy acts upon the production function in a manner similar to that of learning-by-doing in the Romer model. In this way certain fiscal policies become the engine for growth. This result rests heavily on the use of a particular mix of policy variables.

1.6.4 Two-sector Endogenous Growth Models

Diminishing returns to capital are prevented in the two-sector models by the separate endogenous accumulation of human capital. The amount of human capital investment is determined endogenously by utility-maximising households and is produced using alternative technology to that of consumption goods. Equation (1.15) describes the production of consumption goods and physical capital investment, and equation (1.16) the production of human capital.

Equation 1. 15

$$Y = C + \dot{K} + \delta K = A(\phi G)^{\beta_1}(vK)^{\alpha}(uH)^{1-\alpha}$$

Equation 1. 16

$$\dot{H} + \delta H = B[(1-\theta)G]^{\beta_2}[(1-v)K]^{\eta}[(1-u)H]^{1-\eta}$$

The terms *v*, *u*, *(1-v)* and *(1-u)* describe the fraction of human and physical capital used in the production of capital goods and human capital. We assume, as do Barro and Sala-i-Martin (1995), that the production of human capital is relatively intensive in human capital and that the technologies are different ($\alpha \neq \eta$). Both sectors are described by Cobb-Douglas production functions and for this reason the model will display constant steady state rates of growth (indeed in the steady state *C*, *K*, *H* and *Y* all grow at a common rate).[28]

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[27] We assume no growth in the stock of available labour and so remove it from the production function for simplicity.

[28] It is not necessary for sustainable growth for both sectors of the economy to exhibit constant returns to scale in *K* and *H* and the reader is referred to Barro & Sala-i-Martin (1995 Ch.-5 pp. 198) for a description of the conditions necessary for endogenous steady state growth.

If we maximise the utility function in the usual way we get a time path of consumption that does not look unusual in comparison to those described above,

Equation 1. 17
$$\gamma_C = \frac{1}{\sigma}[A(\frac{uH}{vK})^{(1-\alpha)} - \delta - \rho]$$

Since H and K grow at identical rates in the steady state then the marginal product of physical capital is constant and the economy exhibits a sustainable rate of growth. The derivation of the growth rates of human and physical capital is more complex than the equivalent one-sector case and instead the reader is referred to Barro & Sala-i-Martin (1995) for details.

The inclusion of fiscal policy is not necessary to endogenise the growth rate in these two-sector models.[29] Indeed if fiscal policy performs the same function as in the Romer externality type model then there are problems of how to model increasing returns to scale in a dynamic optimisation framework and retain the assumption of perfect competition. One possible means of overcoming this problem is to model fiscal policy as affecting the accumulation of human capital only (Capolupo (1996)). A second possible method is to restrict the form of government expenditures such that they amount to one-off shifts in the level of technology through the parameters A and B.[30] Fiscal policy then behaves in the same way as in the one-sector 'AK' models.

1.7 Conclusions

Diminishing returns to capital investment in the neoclassical growth model, means firms only find it profitable to invest as the technology in the economy improves. In contrast, in the endogenous growth model output growth is not limited by diminishing returns and instead grows as fast as firms investment in the factors of

[29] In the case of the two-sector models with government expenditure this appears to be a major source of their lack of development in the literature.
[30] A third possible means is to remove the assumption of perfect competition altogether. There are currently no examples of fiscal policy in a growth model with imperfect competition.

production. These different descriptions of the causes of growth have in turn differing implications for government policy. Under the neoclassical growth model governments are restricted to adopting policies which encourage technological change if they wish to permanently raise the growth rate, whereas in the endogenous growth model policies which encourage factor input accumulation induce faster growth. The endogenous growth models therefore offer governments a much broader range of effective policies to choose from, and it is the scope of this choice that we focus on in the next three chapters. Chapter 2 considers government expenditures, Chapter 3 taxation and Chapter 4 brings both halves of the budget constraint together. Only in the last of these three chapters does government policy actually provide the 'engine for growth'.

Chapter 2

Government Expenditures in Models of Economic Growth

2.1 Introduction

In the previous chapter we noted that the government can increase the growth rate of the economy if it supplies the goods and services to the private sector in which there would be sub-optimal investment in the absence of intervention (i.e. there is some form of market failure). In the neoclassical model the returns to these public investments are not sufficiently large to prevent the diminishing returns to capital investment which limit growth, whereas in the endogenous growth model they are. Within this chapter we must depart from this general description of the differences between the neoclassical and endogenous growth models because in order to concentrate solely on government expenditures we assume they are financed using lump-sum taxes. Lump-sum taxes have the advantage that they have no effect on the decisions of households or firms and so do not 'pollute' the effects of expenditures on growth,[1] but the disadvantage that, unlike distortionary taxes, they are incapable of providing one of the necessary mechanisms for fiscal policy to endogenise the growth rate. Policy enters both models in an identical manner, so the differences in the results rest not on the behaviour of fiscal policy, but instead, on the treatment of capital in the production function. The endogenous growth models we discuss in this chapter are therefore, of an 'AK' form where endogenous growth is an *assumption* of the model (see Section 1.6.2 for a review). This represents a departure from the original Barro (1990) model, but is necessary if expenditures are to be considered alone.[2]

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[1] This result is robust to changes in the household preference function and the firms' production function.
[2] We are forced to make a similar assumption in the next chapter.

Although the categorisation of expenditures between those which affect private production (which we label productive expenditures) and those which do not (which we label non-productive expenditures) is sufficient to determine the effect a particular expenditure policy has on growth, productive expenditures display a range of other characteristics which we are unlikely to capture through the use of a homogeneous productive expenditure term.[3] For example, education is dominated by public sector inputs in its production whereas transport infrastructure is often produced using private sector inputs/contractors. Additionally, education expenditure affects the accumulation of human capital in the economy whereas transport infrastructure raises private sector productivity directly. Differences in the combination of characteristics of this sort alter the way in which we choose to model productive expenditure, and in certain cases can remove the long run relationship between policy and the growth rate. We review the characteristics of expenditures in Section 2.1.1 and model various combinations of these characteristics in section 2.4.

In the neoclassical growth model the distinction between productive and non-productive types of expenditure is valueless (as is a discussion of their characteristics) as no type of expenditure determines the steady state growth rate.[4] We can however, show that distinguishing between different types of expenditure may be important in determining their effect on income *levels*. We review the results for the neoclassical model in Section 2.2 and demonstrate that changes in government expenditure affect only the level of output of the economy.

Finally, Section 2.5 adds government expenditure to a two-sector endogenous growth model where growth is endogenised through the separate accumulation of human capital. Unlike the tax models of the next chapter expenditures play exactly the same role as in the one-sector model and so very few new results are added.

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[3] We assume in our modelling of productive expenditures that the marginal social benefit of the fiscal instrument is positive (the social benefits to production are greater than the cost of the absorption of output). The model could readily be extended to cases where the social benefit is negative.

[4] As we demonstrate below we may still wish to distinguish between some of the characteristics of expenditure policies even in the neoclassical growth model, as government expenditure is still an effective determinant of the *level* of output.

2.1.1 Characteristics of Government Expenditure

The principal issue concerning public expenditures in endogenous growth models is whether the policy fits into either the production or consumption sectors of the model. Only those expenditures that are included in the production sector affect the growth rate. Non-productive expenditures are assumed to be perfect substitutes for private consumption and are therefore modelled as additional inputs to the household utility function. Non-productive expenditures have no effect on the saving/investment decision because of the assumed nature of the preference function. We define all types of non-productive expenditure in this way so their attributes require little discussion.

Productive Government Expenditures

A large number of public expenditures could be thought of as enhancing (or retarding) the production of output in the economy, and it is likely that few of these forms of expenditure affect output growth in a homogeneous manner. We use the variations of the Barro (1990) model to discuss the scope for public expenditures to affect the growth of output. These can broadly be thought of as being of two types; *i*) changes to the characteristics of the productive expenditure term; and *iii*) changes in the manner by which expenditures affect the production of output (expenditures that encourage the accumulation of additional reproducible factors). We consider this second question first.

Reproducible Factors of Production

Barro (1990) assumes that all productive expenditures are complementary to private production and can therefore be modelled as additional inputs to the firms' production function (they directly affect the marginal product of capital). Government expenditures promote growth by correcting the market failure (re-allocating the stock of available resources) caused by the public good nature of some types of capital. This assumption clearly limits the role of expenditure policy, and ignores expenditures such as those on policing, public sector R&D or health expenditures which have an indirect effect on production via investment or human capital accumulation (i.e. expenditures which encourage the accumulation of additional factors of production). Capolupo (1996) models public goods as inputs in the production of human capital (education expenditure) in both one-sector and two-sector models. In comparison Levine & Krichel (1996) allow expenditures to determine the rate of labour-augmenting technological change. Barro & Sala-i-Martin (1995) develop the idea of productive expenditures and model them as increasing the likelihood of maintaining ownership of output, as in the protection of property rights, and hence the investment decision. The underlying transmission mechanism is altered in these models, but it has no consequence for the way public goods behave in the steady state (the equations for the steady state all look identical).

Characteristics of Productive Expenditure

The second strand of the literature develops the set of characteristics which productive expenditure display. Models of economic growth limit the role of government to correction for market failure. In addition the model assumes that the technology the government has available to produce the goods and services to correct for market failure is identical, or at least not less efficient, that of the private sector. There is private production but public provision (Barro (1990)). If the government exceeds this albeit limited role and intervenes where market failures are not present, and/or the productivity of the public sector is below that of the private sector, then the growth potential of government expenditures may be unrealised. Government intervention acts like a tax and private sector investment is 'crowded-out'. Despite the ease with which examples may be found which do not satisfy either assumption, this is not an issue we choose to explore in any great depth (although we do develop a very simple model in Section 2.4.2 as an example). The addition of a separate production function for public goods requires the addition of a government objective function in order to determine the choice of the level of expenditure. This in turn requires a discussion of social welfare, which is well beyond the scope of the thesis.

Barro assumes that all government expenditures are productive as flows of goods into the production function. Such a characterisation of expenditures is unlikely to be true in all cases, as some forms of productive expenditures, transport infrastructure for example, may be better thought of as a stock of public capital. The distinction between flows (Barro (1990)) or stocks of public goods (Glomm & Ravikumar (1994, 1997), Futagami et al. (1993)) adds, somewhat surprisingly, very little to the model though. The equation for the steady state is identical in both cases and the addition to the model comes instead from transitional dynamics not present in the Barro model. Given that the interest of the thesis is in the behaviour of the steady state rather than transitional dynamics this is not a model we explore in any great depth.

Barro assumes that productive expenditures are homogeneous in their effect on production. That is, the marginal benefit of different expenditure categories is identical, and therefore they can be aggregated into a single term. In practice it seems doubtful that the effect of a unit increase in education expenditure on the rate of growth is identical to that of health expenditure and this is supported by empirical evidence (Devarajan et al. (1996)). Removing this assumption and allowing multiple forms of productive goods within the same production function adds to the set of results through the possibility of growth effects from the *mix* as well as the *level* of expenditure.

The final characteristic of productive expenditure we consider is the degree to which the public good or service is subject to rivalry and excludability (Barro & Sala-i-Martin (1992)). Excludability refers to the technical ability to prevent or limit the use of the public good or service by private producers (a quantity constraint), whereas rivalry impinges the quality of the public good through its use by other producers. Three alternative combinations of rivalry and excludability are developed by Barro & Sala-i-Martin (1992): *(i)* rival and excludable public goods; *(ii)* non-rival and non-excludable public goods; and *(iii)* rival but non-excludable (and therefore subject to congestion)[5] public goods. The first two are generally seen as useful extreme representations for capturing certain characteristics of expenditures, such as those on health and education (Atkinson & Stiglitz (1980), Barro (1990), Barro & Sala-i-Martin (1992)). We use these first two definitions of public goods interchangeably throughout the text as they have no real impact on the results. We cannot do the same for congested public goods as the congestion of public expenditures over time renders the results for fiscal policy from the endogenous growth model redundant. This has interesting implications as it suggests that even if we make endogenous growth an assumption of the model, if public goods are subject to congestion then, under certain conditions, productive expenditures may not help to determine the steady state growth rate.

Excludability of public goods suggests that an individual firm has excludable ownership over a certain quantity of publicly provided input. The fact that public goods are rival is irrelevant in this setting as each individual can prevent other firms from trespassing or congesting the quantity or quality of public goods. This form of productive expenditure is commonly known as a private public good because of the complete property rights that exist for each producer over their proportion of government expenditure. For example the production function of firm i is given by:

Equation 2. 1 $$Y_i = f(K_i, G_{Yi})$$

where Y_i is output of firm i, K_i is the capital input used by firm i, and G_{Yi} is government expenditure available to the individual firm i (i = 1 to n), where n is the number of producers

Aggregating across all producers produces the following production function:

Equation 2. 2 $$Y = f(K, g_Y)$$

[5] Congestion is the impingement upon the quality of the publicly provided good or service received by each individual producer through its use by other producers.

Where g_Y is the equal proportion of productive government expenditure received by each producer ($g_Y = G_Y/n$).

If productive expenditures can be described as non-rival and non-excludable in nature then consideration as to the amount each individual firm receives is unwarranted. Each individual producer does not affect the quantity or quality of service any other producer receives. This is commonly known as a pure-public good (Samuelson (1954)) as there are no enforceable property rights over part of government expenditure by individuals. The firms' production function includes total productive expenditure as input, G_Y, rather than the share per capita.

Equation 2. 3 $$Y_i = f(K_i, G_Y)$$

which, aggregating across all firms, can be written as:

Equation 2. 4 $$Y = f(K, G_Y).$$

Barro & Sala-i-Martin argue that a third alternative specification is the most likely description of most government expenditures (transport and communication infrastructure being obvious examples). Productive expenditures are included as inputs into the production function of firm *i* as the ratio of total government expenditure, G_Y, to private output, Y (Barro & Sala-i-Martin (1995)).[6] As aggregate output increases there is a decrease in the ratio G_Y/Y, and congestion of public expenditures. The value to the productive process of government expenditure diminishes because of the congestion created by the increase in the output of all producers, *Y*. This negative externality is ignored when the firm decides its output and investment decisions as its own effect on congestion is infinitesimally small. The production function of the individual firm can be written as:

[6] In Barro & Sala-i-Martin (1992) the private production suffers congestion through the aggregate capital stock term not aggregate output. Barro & Sala-i-Martin (1995) note that this change in assumption does not change the nature of the results.

Equation 2. 5

$$Y_i = f(K_i, \frac{G_Y}{Y}).$$

Alternative formulations of congestion are available in the literature, and these offer a more satisfying description of congestion than the normalisation of public goods to the size of the economy described above. For example Fisher & Turnovsky (1998) develop a specification of congestion based on the median voter model of Edwards (1990). Congested public goods are given by:

Equation 2. 6

$$G_{SYi} = G_Y(\frac{K_i}{K})^{1-\omega}$$

where $0 \leq \omega \leq 1$ and G_{SYi} is the stock of productive expenditures available to firm *i.*

K_i represents the capital stock of the individual firm, K the aggregate capital stock, G_Y aggregate public capital and ω the congestion parameter. The congestion of public goods increases with increases in the total private capital stock and decreases with increases in the public capital stock. If $\omega=1$, then public goods are non-rivalrous (there is no congestion) and if $\omega=0$, congestion increases in direct proportion to increases in the capital stock (as in Barro & Sala-i-Martin (1992)). If $0<\omega<1$ then there is a degree of congestion and the results lie between the formulation of congested goods in (2.5) and the non-congested public goods case.[7] By using these extreme descriptions of congestion we are able to capture the limits of this more general formulation of congestion.

Alternatively Glomm & Ravikumar (1994) write their formulation of congested goods as:

[7] When public goods are subject to any degree of congestion, $0<\omega<1$, public expenditures have no effect on the steady state growth rate. The measure of congestion does, however, affect the speed of transition to the steady state growth rate. The lower the rivalrous nature of public goods, the less congested it is (ω is close to 1) the slower the speed of transition to the steady state from a change in public expenditure.

Equation 2. 7

$$G_{SYi} = \frac{G_Y}{K^{\omega} L^{\xi}}$$

where $0 \leq \omega, \xi$.

This can be seen to be a similar formulation to Fisher & Turnovsky in that congestion increases with increases in the private capital stock and decreases with increases in public expenditures, but it now also depends on the size of the labour force. If the growth of the labour force is zero (and hence labour term can be suppressed from equation (2.7)) and ω=1 then we are back to the Barro & Sala-i-Martin (1992) formulation where the congestion of public goods is proportional to the size of the aggregate capital stock. Once again we describe the extreme cases to provide the limits of this more generalised formulation.

2.2 *The Neoclassical Model - Policy Ineffectiveness*

Discussion of the defining characteristics of public expenditures in the context of a neoclassical growth model is relevant only if there is interest in the relationship between the level of expenditures and the level of output. There are no growth effects from fiscal policy in the neoclassical model. To demonstrate the differences between the neoclassical and endogenous growth models clearly we include fiscal policy in an identical manner to the Barro (1990) endogenous growth model. We assume that the rate of growth of the labour force and labour-augmenting technological change are zero (allowing for either does not alter the results).

For simplicity we write the production function in a Cobb-Douglas form with constant returns to scale in capital and labour. To this we add the term G_Y which we use to represent productive government expenditures. We describe productive expenditures as non-rival, non-excludable public goods that are productive as a flow of goods and services. G_Y is assumed to be produced under an identical technology to that of private goods; to affect production directly; and for all productive goods have a homogeneous effect on output. The elasticity of output with respect to government expenditures is given by β, and we assume that $0<\beta<1$ so that public goods, like all inputs in (2.8) are subject to diminishing marginal returns.[8]

Equation 2. 8 $$Y = AK^{\alpha}L^{1-\alpha}G_Y^{\beta}$$

Government expenditures are financed by a lump-sum tax at the rate τ.[9] The government budget constraint (constrained to balance at every moment in time) is given by:[10]

Equation 2. 9 $$G = \tau .$$

where $G = G_Y + G_C$ and G_C is government consumption expenditure (see below).

The resource constraint of the economy is given as:

Equation 2. 10 $$Y = C + I + G$$

where C is consumption, I investment and G total government expenditures.

Using $I = \dot{K} + \delta K$ and $G = \tau$ (2.10) can be re-written as (2.11), the growth equation of capital:

Equation 2. 11 $$\dot{K} = Y - C - \delta K - \tau .$$

As in the previous chapter household utility is assumed to be a function of private consumption and government consumption expenditure, G_C. We further assume that government consumption expenditure and private consumption are perfect substitutes. For this reason the provision of consumption by the government has no effect on the choice of consumption by households. Equation (1.9) from chapter 1 now reads:

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[8] The value of β has only a small part to play in this model but the assumption we make regarding its value when we add distortionary taxation to the model (Chapter 4) is crucial for the results.

[9] We choose lump-sum taxes because they are non-distortionary and therefore have no effect on any part of the models that we consider.

[10] We assume that taxation is time invariant, although as Chamley (1986) demonstrates the *optimal* tax schedule may be time variant. Such issues are outside the scope of this thesis.

Equation 2. 12
$$u(c,G_C) = \int_0^{\infty} e^{-\rho t} (\frac{(c^{1-\zeta} G_C^{\zeta})^{1-\sigma}}{1-\sigma}) \delta t$$

where $0<\zeta<1$

The basic set-up of the model is identical to that in Chapter 1 except the felicity function, $u(c,G_C)$ replaces $u(c)$. Household utility is maximised subject to the economy's resource constraint to yield the growth path for consumption (equation (2.13)). The level of government expenditures is taken as given because each firm assumes that their increase in output does not affect the available amount of productive expenditures. In the context of this model this assumption would appear to be obvious, as the steady state level of productive expenditure is constant anyhow. This assumption has greater importance when we consider the congested public good model in Section 2.3 below and the models of Chapter 4.

Equation 2. 13
$$\gamma_C = \frac{1}{1-(1-\sigma)(1-\xi)} [\alpha A K^{\alpha-1} L^{1-\alpha} G_Y^{\beta} - \delta - \rho].$$

Equations (2.11) and (2.13) combined with the transversality condition in footnote 26 of Chapter 1 provide the solution to the time paths of consumption and capital, and mirror equations (1.8) and (1.10) in Chapter 1. The interest rate is constant, $\dot{r} = 0$, when the growth of the capital stock is equal to the growth of the labour force plus technology and when the growth in government expenditures is constant. This can be seen in equation (2.13) where the growth rate of consumption is constant when the capital-labour ratio is constant and the level of government expenditure is constant.

By assumption the growth of population and technology is zero, $\frac{\dot{A}}{A} = \frac{\dot{L}}{L} = 0$. Differentiating the government budget constraint in (2.9) with respect to time demonstrates that the growth of government expenditure is also zero, $\frac{\dot{G}}{G} = \frac{\dot{\tau}}{\tau} = 0$. If we differentiate the production function with respect to time and substitute for the growth of technology, population and government expenditures, then we can show that the growth rate of output is also zero, $\frac{\dot{Y}}{Y} = \frac{\dot{A}}{A} + \alpha\frac{\dot{K}}{K} + (1-\alpha)\frac{\dot{L}}{L} + \beta\frac{\dot{G}_Y}{G_Y} = 0$.

Adding public goods to aid private production or provide utility to households has no affect on the steady state growth rate in this model.[11] Firms find it optimal to invest only to the point at which the capital stock depreciates. Hence, there is no growth in the inputs and therefore output. These results are robust to all changes in the characteristics of productive expenditures.

Fiscal policy may not affect the growth rate but it does affect the position of the steady state (and hence the level of income). This can be seen through the use of a phase diagram of the dynamic equations of the model (Figure 2.1). Increases (decreases) in productive expenditures have two effects on the economy; they raise (lower) the marginal product of capital by the term $(G_Y)^\beta$ increasing output; but reduce (increase) the resources available to the rest of the economy through the resource constraint. From equation (2.13) it is clear that the first of these effects causes the $\dot{C} = 0$ line to move unambiguously to the right, while both combine in the movement of the line $\dot{K} = 0$. The movement of $\dot{K} = 0$ depends whether the effect on the marginal product of capital, $(G_Y)^\beta$, is greater than the effect of a reduction in available resources. Figure 2.1 demonstrates this for the phase planes of *C* and *K*, assuming the total effect on *K* is positive. The steady state levels of *C* and *K* at point B are greater than those at point A. Expansionary fiscal policy has increased the level of income in the economy. Fiscal policy also affects the transition between these equilibria (and hence the growth rate in the transition).

[11] It follows therefore that if we alter the mix of government expenditures between productive and non-productive types we have no affect on the steady state growth rate.

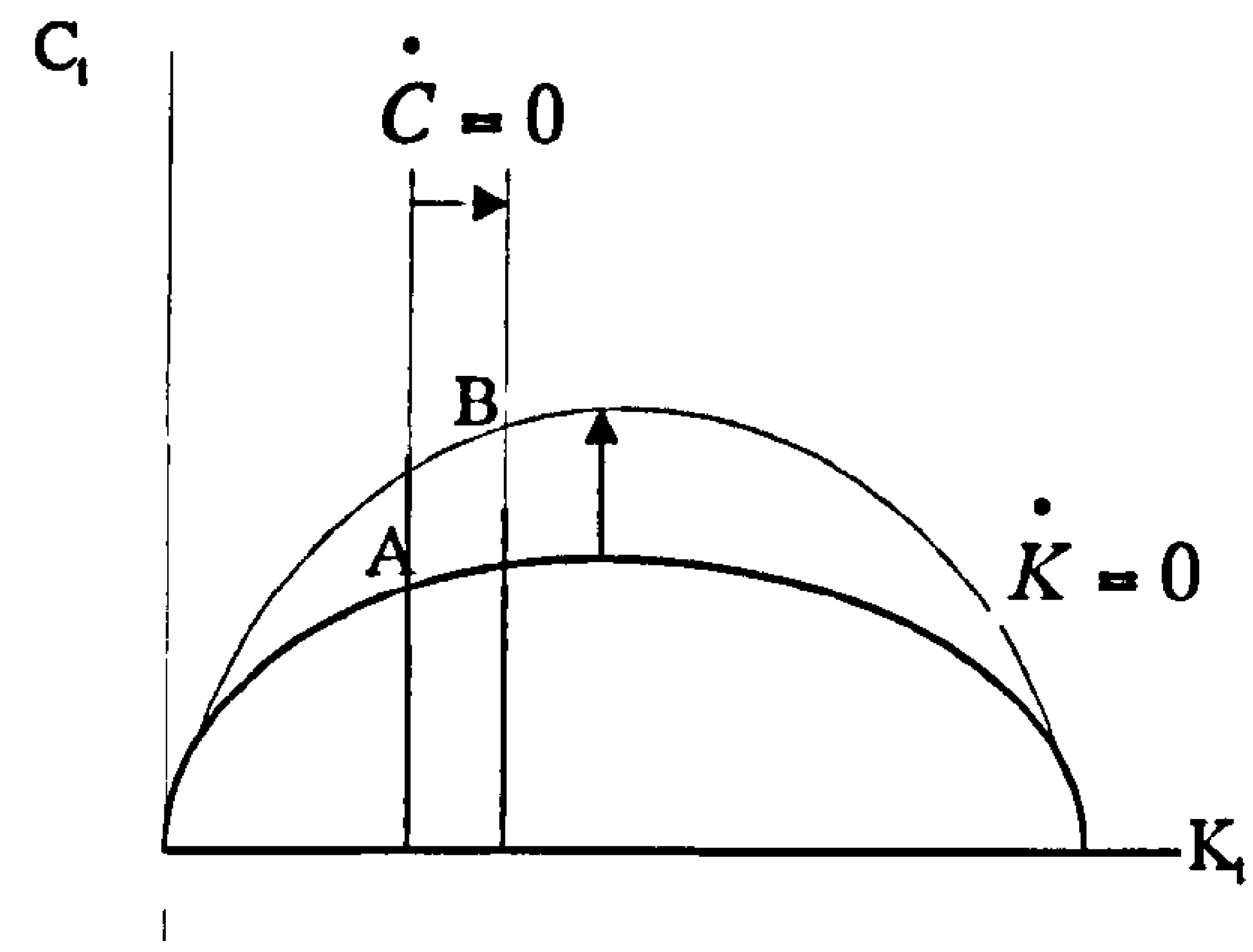

Figure 2. 1: Level Effects of Increases in Productive Government Expenditures in the Neoclassical Growth Model

In contrast to an increase in productive expenditures the effect of an increase in government consumption expenditure comes only through the reduction in the resources available to the rest of the economy. The more goods consumed by the government, obviously the fewer can be consumed by the private sector if *K* is to be held constant. The private sector becomes 'crowded-out'. In Figure 2.2 this leads to a reduction in the $\dot{K} = 0$ line and the steady state values of *C* and *K* move from point A to point B'. The equilibrium levels of *C* and *K* and therefore income are below those in the absence of government intervention.

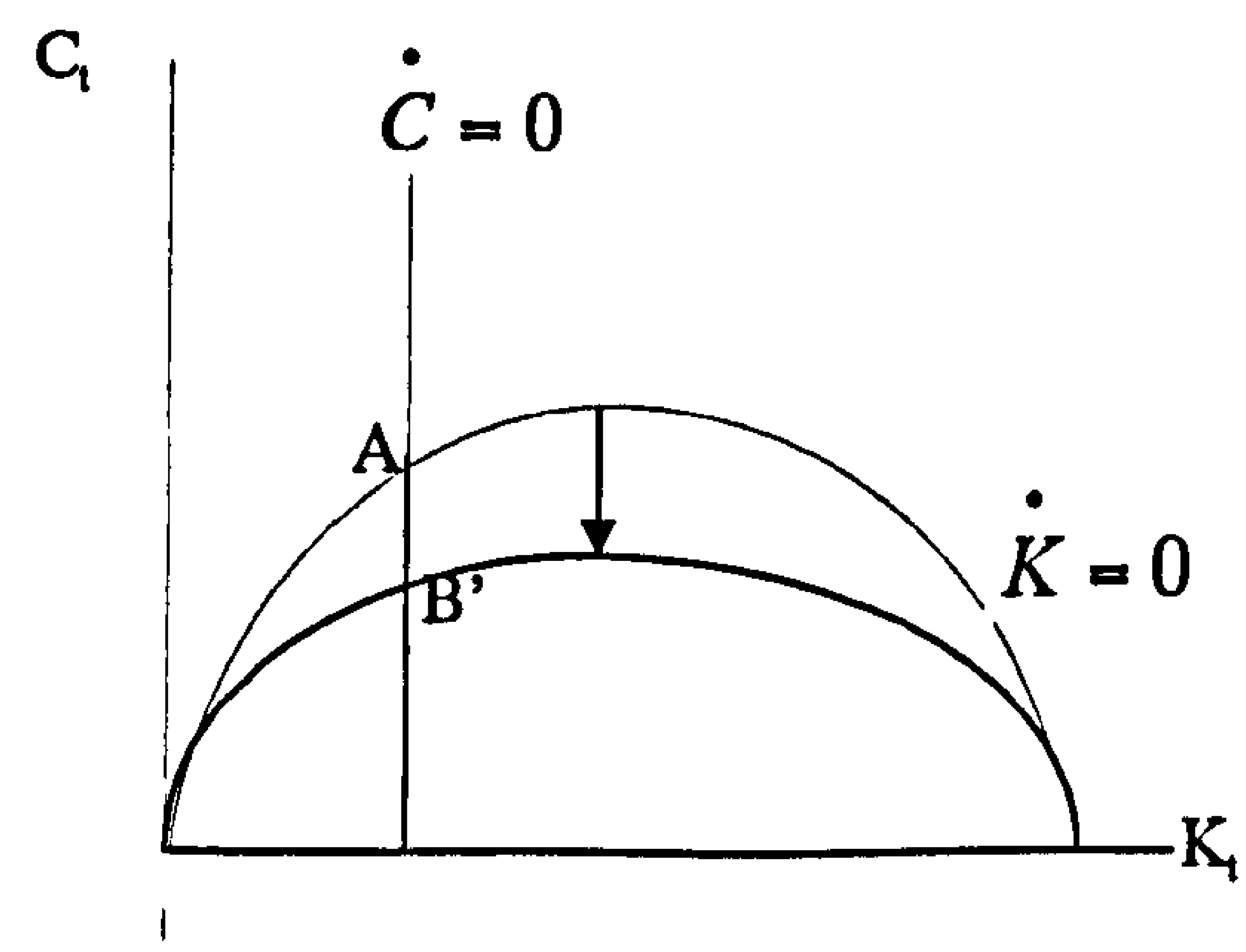

Figure 2. 2 Level Effects of Increases in Non-productive Government Expenditures in the Neoclassical Growth Model

The role of fiscal policy in the neoclassical model has been well researched despite the fact that it is ineffective in determining the growth rate. Examples of fiscal policies that affect the position of the steady state (such as those discussed by Feldstein (1973)) are provided in Atkinson & Stiglitz (1980); Peacock & Shaw

(1971) discuss ways in which fiscal policy may affect the growth of technical progress or the labour force; and Cornwall (1963), R. Sato (1963) and K. Sato (1967) discuss how fiscal policy helps to determine the speed of adjustment to the steady state.

2.3 Endogenous Growth Models (Barro) - Effective Fiscal Policy

The Barro (1990) model represents the first, and perhaps the simplest, example of public policy endogenous growth models in the literature. The model uses an identical set of assumptions to the neoclassical model bar one. Production is assumed to be linearly homogeneous in capital. Fiscal policy is *effective* in the Barro model *because* of this assumption. The addition of productive government expenditures to a growth model is not sufficient in itself to endogenise the growth rate, hence endogenise growth is required as an assumption of the model. The difference between the results for the neoclassical and endogenous models (in this chapter) are therefore based solely on a mathematical restriction on the assumed nature of production technology. The importance of this mathematical restriction for the results from the models is well understood (Barro & Sala-i-Martin (1995)), although the economic implications of it are not (see Solow (1994), Romer (1994) and Mankiw (1995) for a discussion of the assumptions and implications of 'AK' endogenous growth models versus neoclassical growth models).

Production technology is given by the 'AK' functional form described in Chapter 1 Section 1.2.2, to which we now add government expenditures as an input into this process (in non-rival, non-excludable form).[12] There are constant returns to capital but increases in public goods are subject to diminishing marginal returns.

Equation 2. 14 $$Y = AKG_Y^{\beta}$$

where $0<\beta<1$.

[12] It follows naturally from this that the production function for rival, excludable public goods could be written as $Y = AKg_Y^{\beta}$ and as $Y = AK(\frac{G_Y}{Y})^{\beta}$ for rival, non-excludable public goods.

Utility (which includes government consumption expenditure) is maximised in the usual way and the steady-state growth rate of consumption is as equation (2.15).

Equation 2. 15
$$\gamma_C = \frac{1}{1-(1-\sigma)(1-\xi)}[AG_Y^{\beta} - \delta - \rho]$$

The growth rate of consumption is a positive constant because the determinants of the steady state are all constant (there is no growth in technology and no growth in the level of government expenditures).[13] In equilibrium productive expenditures have a positive effect on the marginal product of capital and hence on the growth rate.

The steady state growth rate is an increasing function at all sizes of government (shown in Figure 2.3) but subject to diminishing returns (the slope of the function is given by the elasticity parameter β).

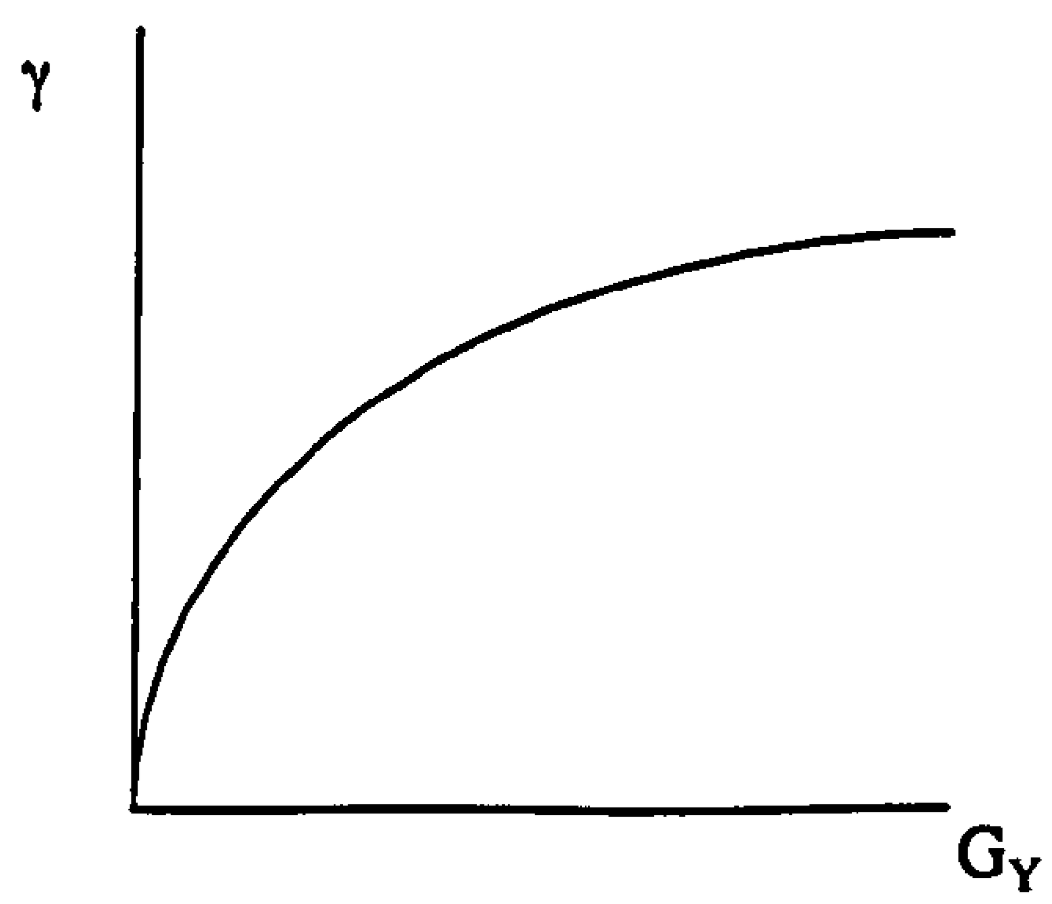

Figure 2. 3 Growth Effects of Increases in Productive Government Expenditures in an 'AK' Endogenous Growth Model

Government consumption expenditure has a benign effect on the steady state rate of consumption, because it does not distort the Euler equation.[14] This holds because

[13] Because there is no growth of government expenditures the economy is always in its steady state, that is there are no transitional dynamics in the model.
[14] Cashin (1995) argues that some forms of government consumption expenditure have a positive effect on the rate of growth and models them as such without altering the household utility function

government consumption expenditure and private consumption are perfect substitutes and therefore yield an identical level of utility.[15] It follows from this discussion that if we alter the mix of total government expenditure, G, towards productive government expenditure, G_Y, and away from non-productive expenditure, G_C, there would be an increase in the steady state growth rate.

Congested Public Goods

Changing the characteristics of public goods to ones where they now display rivalry and excludability adds nothing to the model. The growth rate of consumption would then be given by:

Equation 2. 16

$$\gamma_C = \frac{1}{1-(1-\sigma)(1-\xi)}[Ag_Y^{\beta} - \delta - \rho]$$

The congested public goods case is interesting because it resembles the endogenous growth model in that the steady state rate of growth is a positive constant value, but the neoclassical model in that at the limit (of time) productive goods are irrelevant for determining the steady state growth rate. Equation (2.17) gives the growth rate of consumption.

Equation 2. 17

$$\gamma_C = \frac{1}{1-(1-\sigma)(1-\xi)}[A(\frac{G_Y}{Y})^{\beta} - \delta - \rho]$$

The ratio G/Y declines towards zero as output tends to infinity, $\lim_{Y \to \infty} \frac{G_Y}{Y} \to 0$, because $\frac{\dot{G}_Y}{G_Y} = 0$, that is as public goods become congested. The steady state growth rate in this model is equal to the technology parameter, A (the marginal product of

from the Ramsey (1928) form. Cashin achieves this by instead modelling government consumption expenditures as inputs into the production function. Consumption expenditure therefore becomes equivalent to productive expenditure.

capital). Only if public goods expand at the same rate as output can public goods permanently affect the steady state (although public policy will still not have caused endogenous growth). There is no such mechanism at present for this to occur in this chapter but there is in Chapter 4 when productive expenditures are modelled simultaneously with distortionary taxes.

Public policy affects the transition to the steady state, as in the neoclassical model, the speed of this adjustment depending on the value of the parameter β. The lower the value of β the slower the adjustment to the steady state.[16] If, as Barro & Sala-i-Martin (1992) suggest, a large number of productive expenditures are subject to congestion, then even in the presence of sustainable growth public policy may not permanently affect the long run growth rate of the economy.

2.4 *Extensions to the Barro Model*

Productive expenditure in the Barro (1990) model are assumed to directly affect the production function as a flow of goods and services; to be produced under identical technology to private output; and the magnitude of the effect of productive expenditures on growth is assumed to be homogeneous.[17] Many of the extensions to the Barro model made in the literature reflect different combinations of characteristics discussed in Section 2.1.1. We use this section to assess the impact on the model of this work.

[15] We could extend the non-productive expenditure model to consider multiple forms of government consumption expenditure but given these results there is little value to this.
[16] Estimates of the elasticity of government expenditures in production function regression equations vary considerably. For example Aschauer (1989) estimate the elasticity of public goods as being in the range 0.34-0.73 using a Cobb-Douglas approach; Bajo-Rubio & Sosvilla-Rivero (1993) and Otto & Vos (1996) estimate a parameter in the range of 0.17-0.19 using a cointegration approach and; Merriman (1990) an elasticity in the range 0.43-0.58 using a translog production function.
[17] We choose to omit from the model non-productive government expenditures. There inclusion has no substantive change on the results.

2.4.1 Indirect Productive Expenditures

Barro assumes that all productive government expenditures have public good characteristics and therefore directly affect private sector production. It is however, simple to think of examples of expenditure where this is not the case. Education or health expenditure affects the quantity or quality of human capital; whereas policing affects the expected returns from investment. We draw upon three models developed in the literature to assess the impact of allowing expenditures to encourage the accumulation of other reproducible factors. The first is an education model based on Capolupo (1996), and the second is labour-augmenting technological change (Levine & Krichel (1996)). Both work on a similar basis because of the need to retain the one-sector framework and provide the necessary conditions for endogenous growth. The third is slightly different from these two although the results are qualitatively very similar. This third model increases the probability of retaining ownership over capital encouraging further investment (Barro & Sala-i-Martin (1992)).[18]

Labour-Augmenting Technological Change

In the model used so far output is a function of the composite capital term 'AK' which includes both physical capital and human capital. Both the Levine & Krichel (1996) and the Capolupo (1996) models disaggregate this composite term and assume human capital is produced under an alternative technology to physical capital. Government expenditures are then restricted to affect the production of human capital only.

Aggregate output is a function of human and physical capital with constant returns to scale at the aggregate level and diminishing marginal returns to each individual input. We remove public goods from the production of aggregate output in order to concentrate on the indirect effects of fiscal policy. Using a C-D form, the production function of firm *i* is given by,

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[18] Technically this model does not encourage the accumulation of additional reproducible factors but of capital investment. It could however be argued that this form of expenditure is different from the re-allocation of the given stock of capital goods.

Equation 2. 18 $$Y_i = AK_i^{1-\alpha} H_i^{\alpha}$$

Levine & Krichel (1996) assume human capital in firm i is produced using a combination of raw labour, L_i, and an efficiency parameter unique to firm i, ε_i. The growth rate of labour is assumed to be constant so that changes in human capital can occur only through changes to the efficiency of the use of raw labour.

Equation 2. 19 $$H_i = \varepsilon_i L_i$$

The efficiency of labour of firm i is a function of aggregate labour, private capital and public expenditure. Efficiency is assumed to accumulate linearly in K.[19]

Equation 2. 20 $$\varepsilon_i = B_i \frac{G_Y^{\gamma} K_i}{L_i}$$

Assuming all firms are identical allows us to substitute the efficiency production function (equation (2.20)) into the human capital function (equation (2.19)) and then into the production function for output (equation (2.18)). The resulting equation is:

Equation 2. 21 $$Y = AB^{\alpha} K^{(1-\alpha)+\alpha} G_Y^{\alpha\gamma}$$

or

Equation 2. 22 $$Y = JKG_Y^{\beta}$$

where $J = AB^{\alpha}$ and $\beta = \gamma\alpha$

Maximising consumer utility subject to the usual constraints leads to the following growth rate of consumption:

Equation 2. 23 $$\gamma_C = \frac{1}{1-(1-\sigma)(1-\xi)}[JG_Y^{\beta} - \delta - \rho]$$

[19] We require this restriction on the production function in order to produce a constant rate of growth in the model. This is a simplification of the Krichel & Levine (1995) model and is required because

There is no growth of expenditures and so the steady state rate of growth is constant. Government expenditures affect the steady state through the marginal product of capital, however, the relationship is indirect through the increasing efficiency of labour. Public goods in this model perform exactly the same function as labour augmenting technological change in the neoclassical model of Chapter 1. Unlike in the original paper there is no growth in the efficiency of human capital in this model because we assume only lump-sum taxes are used to finance government expenditures.

Education Expenditure

A similar model to this is developed by Capolupo (1996) except that the Capolupo model works by assuming that human capital production uses only public goods as inputs. The absence of physical capital in the human capital production function requires aggregate output to be linear in physical capital, *K*, for endogenous growth.[20] The production of aggregate output is given by:

Equation 2. 24 $$Y = AKH^{\alpha}$$

and the production of human capital by:

Equation 2. 25 $$H = G_Y^{\beta}$$

Substituting for *H* in equation (2.24) yields an aggregate production function which is of identical form to that used in the Barro model. The effect of public goods on the steady state is therefore also identical.

Returns to Investment

Barro & Sala-i-Martin (1995-Ch.4) develop a model in which the marginal productivity of capital in production is increased indirectly through the perceived

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we do not use distortionary taxation to fund government expenditure. Under such circumstances we cannot endogenise the rate of growth and require an 'AK' model.

returns to investment. Public expenditures, such as national defence, policing or the judiciary, influence the likelihood of maintaining ownership, and hence affect the decision to invest. The probability of maintaining ownership is assumed to be an increasing function of government expenditures subject to diminishing returns:

Equation 2. 26 $$p = p\,(G_Y)$$

where [$p'(.)>0$ and $p''(.)<0$].

If output is produced using 'AK' technology then the steady state growth rate is given by:

Equation 2. 27 $$\gamma = \frac{1}{1-(1-\sigma)(1-\xi)}[Ap(G_Y) - \delta - \rho]$$

The growth rate is increasing in government expenditures, $p'(G_Y)>0$, but is subject to diminishing marginal returns, $p''(G_Y)<0$. Barro & Sala-i-Martin (1995) assume that the level of protection (for a given level of government expenditure) is a decreasing function with respect to the volume of output it is required to protect (there is congestion). If this holds then public goods are no longer determinants of the long run growth rate.

2.4.2 Characteristics of Productive Expenditures

Relative Technology

One of the assumptions characterising public goods in the Barro model is that the public and private sectors enjoy identical technology. Given that the policy of competitive tendering employed in the UK throughout the 1980-90s was based on the assumption that the technology of the public sector was less efficient than the private sector, then it is perhaps surprising that this issue has so far received so little attention in the literature. We develop a very simple model to demonstrate the

[20] We simplify Capolupo by assuming human capital is a flow rather than a stock.

possible means by which relative efficiency could be introduced into a one-sector model. The results from this model rest crucially on the assumption that capital is linear in the production of public goods and that the proportion of the capital stock used in the production of public goods is set by some exogenous factor. The development of the model would require a description of the government's objective function and associated social welfare costs. The choice over the level of private capital used in the production of public goods could then become endogenous to the model but the results would depend on the form of the objective function chosen. Considerations such as these lie well outside the scope of this thesis and we choose to simplify the analysis by ignoring them altogether.

Assuming constant returns to scale in the production of private output and diminishing marginal returns to each input results in the following production function:

Equation 2. 28 $$Y = AK^{1-\alpha}G_Y^{\alpha}$$

Relative efficiency is introduced by assuming public goods are produced under an alternative technology to private goods (consumption and investment).[21] Public goods use 'AK' technology in their production given below, where the marginal product of capital in the public goods sector by the technological parameter B.

Equation 2. 29 $$G_Y = BK$$

A simple substitution of (2.29) into the production function for aggregate output, equation (2.28), for G_Y yields an alternative aggregate production function,

Equation 2. 30 $$Y = AK^{1-\alpha}[BK]^{\alpha}$$

or

Equation 2. 31 $$Y = AB^{\alpha}K$$

[21] The substitution on which the results are based was inspired by a similar one in Capolupo (1996). Capolupo overcome the problem as to the choice over the level of private capital used in the education sector by assuming human capital is produced only using public goods.

This substitution, and hence the results, rely heavily on the assumption that public goods production is linear in capital.

The growth rate is now given by the available technology in both sectors of the economy. The relative technology of the public sector is weighted by the term α which corresponds to the elasticity of output with respect to public goods.[22] The steady state rate of growth is given by,

Equation 2. 32
$$\gamma_C = \frac{1}{1-(1-\sigma)(1-\xi)}[AB^{\alpha} - \delta - \rho]$$

The steady state rate of growth is independent of the size of government but public goods still affect the growth rate through the marginal product of capital. If the relative efficiency of the public sector is below that of the public sector ($A>B^{\alpha}$), then the steady state rate of growth will be lower than when both sectors share identical technology. In this sense the relative productivity acts like a tax on the steady state as private investment is 'crowded-out'.

The Stock of Productive Government Expenditures

Government expenditures in the Barro (1990) model are flow inputs in the private production function. Glomm & Ravikumar (1994, 1997) and Futagami et al. (1993) alter this assumption to model public goods as stocks of capital (such as transport infrastructure). Although the use of public capital has many appealing features it has no effect on the behaviour of the steady state equation and the additions from the model are in the transitional dynamics not present in Barro (1990).[23]

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[22] The efficiency term, B, would appear to be similar to the eternality term which appears in Fuente (1997). However, the externality term in Fuente is not derived from an underlying production function of public goods, indeed public and private goods are assumed to be produced using identical technology.
[23] The transitional dynamic described in Glomm & Ravikumar (1994, 1997) and Futagami et al. (1993) papers would be more complicated than those in this much simpler model.

The description of public inputs as; rival and excludable; non-rival and non-excludable: and rival, non-excludable goods, is not complicated by changing the nature of expenditures from a flow to a stock. The three cases make as much intuitive sense as a stock as they do as a flow (in fact for the congestion case perhaps more so). The production function is given by:

Equation 2. 33 $$Y = AKG_{YS}^{\beta}$$

where G_{YS} is the stock of public capital.

The stock of productive government capital is assumed to evolve with investment in public capital, I_G, and decreases with depreciation.[24]

Equation 2. 34 $$\dot{G}_{YS} = I_G - \delta G_{YS}$$

The resource constraint of the economy changes so that it includes government investment, I_G, rather than the flow of government expenditures G_Y.

Equation 2. 35 $$Y = C + I_K + I_G$$

The receipts from taxation fund investment in the stock of public goods and the government budget constraint must be altered to account for this.

Equation 2. 36 $$I_G = \tau .$$

Utility is maximised in the usual manner and the balanced growth rate of consumption is given as:

Equation 2. 37 $$\gamma_C = \frac{1}{1-(1-\sigma)(1-\xi)}[A G_{YS}{}^{\beta} - \delta - \rho].$$

The steady state growth equation is of an identical form to that when expenditures are modelled as a flow into the production function.[25] Increases in the stock of

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[24] We assume for simplicity that the rate of depreciation of the public capital stock is equal to the rate of depreciation of private capital. Changing this assumption would have no consequential impact on the results.

public goods have a positive but diminishing effect on the steady state rate of growth as in Figure 2.2. The new element of the model from the stock of public capital goods reads in the transitional dynamics. The empirical tests contained within this thesis rely on being able to distinguish between the steady state predictions of the neoclassical and endogenous growth models rather than the transitional dynamics and hence these are felt to lie outside the remit of this thesis and are omitted.[26]

Multiple Forms of Productive Government Expenditures

Devarajan, Swaroop & Zou (1996) develop the Barro (1990) model to allow multiple forms of productive goods to enter the aggregate production function. The single productive expenditure term used by Barro (1990) assumes that a £1 increase in any category of government expenditure has an identical effect on the rate of growth. Empirical evidence against such an assumption can be found in Devarajan et al. (1996).

Output is produced using C-D production technology[27] and for simplicity there are only two differentiated forms of public goods G_{Y1} and G_{Y2} (still in non-rival, non-excludable form):

Equation 2. 38
$$Y = AKG_{Y1}^{\beta}G_{Y2}^{\lambda}$$

This formulation of productive government expenditure allows for a richer description of the relationship between the rate of growth and government expenditure as the elasticity parameters on government expenditure are no longer constrained to be identical, $\beta \neq \lambda$. The government is assumed to fully finance expenditure on G_{Y1} and G_{Y2} through lump-sum taxation, and to be balanced at every moment in time.

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[25] This does not mean that the steady state rate of growth is identical as this depends on the value of G_Y and G_S, and the value of the elasticity parameter, β, in each model.

[26] See Glomm & Ravikumar (1994, 1997) and Futagami et al. (1993) for details.

[27] Devarajan, Swaroop & Zou (1996) use a constant elasticity of substitution (CES) production function.

Equation 2.39 $$\tau = G = G_{Y1} + G_{Y2}$$

Using $G_{Y1}=\phi G_Y$ and $G_{Y2}=(1-\phi)G_Y$ in equation (2.38) (where ϕ equals the proportion of each expenditure in the budget) and maximising household utility leads to the following equation for the steady state growth rate of consumption:

Equation 2.40 $$\gamma_C = \frac{1}{1-(1-\sigma)(1-\xi)}[A[\phi G_Y]^{\beta}[(1-\phi)G_Y]^{\gamma} - \delta - \rho]$$

Both forms of government expenditure affect the rate of growth through the marginal product of capital, but their *relative* effect depends upon the *relative* productivity of G_{Y1} and G_{Y2} (given by the elasticity parameters β and γ) and their *relative* budget shares, ϕ and $(1-\phi)$.[28] G_{Y1} can be thought of as having a greater relative productivity than G_{Y2} if the change in the rate of growth from a change in G_{Y1}, $\delta\gamma/\delta G_{Y1}$, is greater than the change in the rate of growth from a change in G_{Y2}, $\delta\gamma/\delta G_{Y2}$ (holding total government expenditure constant). Given that $G_{Y1}=\phi G_Y$ and $G_{Y2}=(1-\phi)G_Y$, G_{Y1} is said to be relatively more productive than G_{Y2} if $\delta\gamma/\delta\phi > 0$. For a Cobb-Douglas production function this can be shown to be the case when:

Equation 2.41 $$\frac{\gamma}{1-\phi} < \frac{\beta}{\phi}.$$

If G_{Y1} has a greater elasticity value than G_{Y2} ($\beta > \gamma$) then the rate of growth may still not be increased if the expenditure share of G_{Y1} to G_{Y2} is currently too high. This suggests that changing the mix of expenditures is as important for the growth rate as changes to the level of expenditure. Equation (2.42) gives the condition for the mix of productive expenditures to be at its optimum:[29]

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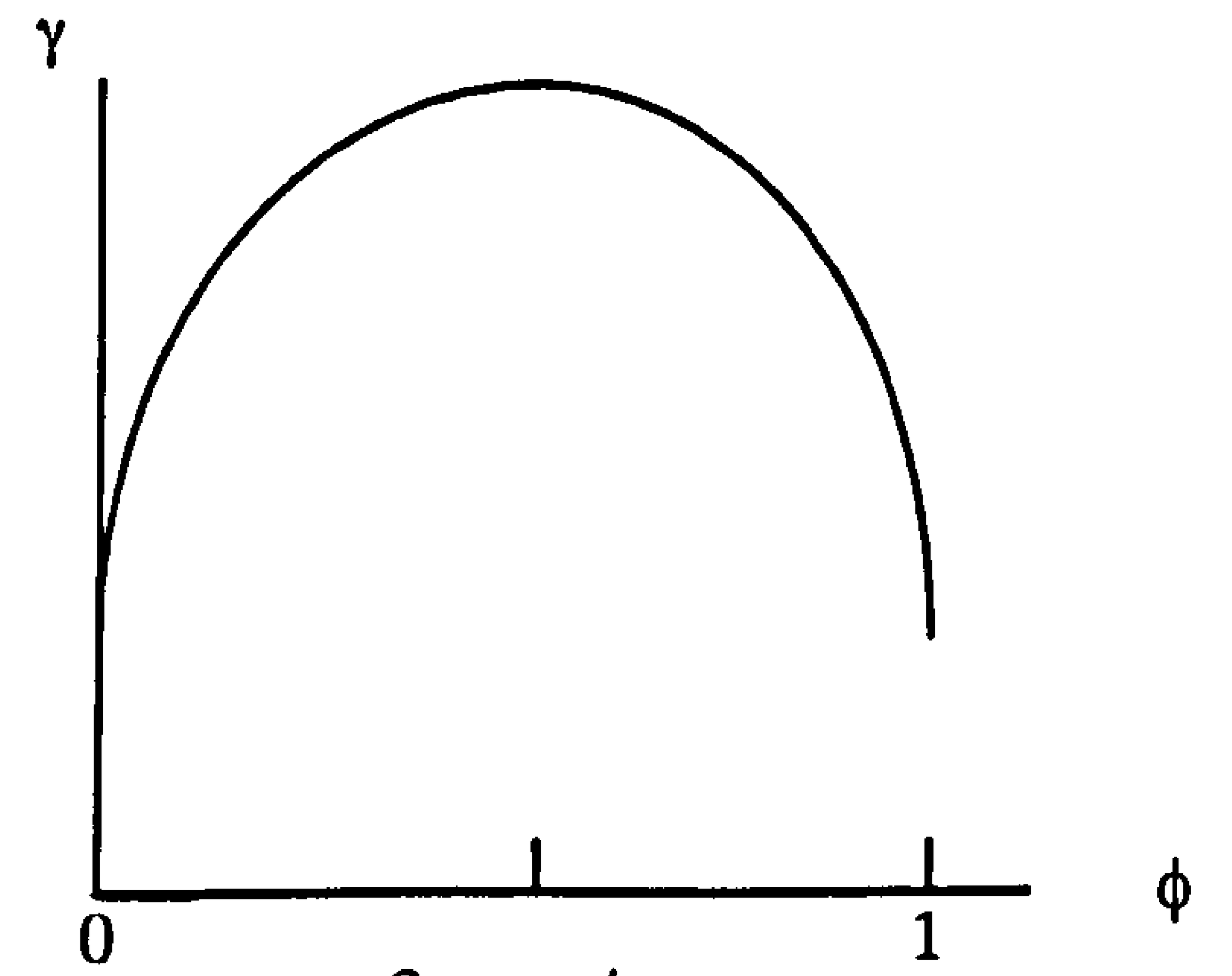
[28] Devarajan, Swaroop & Zou (1996) describe G_1 and G_2 as either productive or un-productive expenditure depending whether the effect on growth from changing the mix of expenditure (holding total expenditure constant) is either positive or negative. This definition contrasts with the distinction between productive and non-productive expenditure used here. Under the definition of productive expenditures used here both expenditures are described as being productive because they are both used as inputs in private production. They therefore differ in terms of their *relative* productivity only.

[29] Devarajan et al. (1996) provide a general condition from the N productive expenditure good case. An increase in expenditure *i* financed by a decrease in expenditure *j* is positive if the following

Equation 2.42 $$\frac{\phi}{1-\phi}=\frac{\beta}{\gamma}.$$

If this is not met then the growth rate may be increased by adjusting the components of expenditure and without having to increase *total* expenditure. Figure 2.4 demonstrates this graphically. The maximum of the line corresponds to the point where $\frac{\phi}{1-\phi}=\frac{\beta}{\gamma}$.[30]



$$\frac{\beta}{\gamma}=\frac{\phi}{1-\phi}$$

Figure 2.4 Growth Effects of Changes in the Mix of Productive Government Expenditures in an 'AK' Endogenous Growth Model

2.5 *Two-sector Models with Government Expenditure*

The inclusion of productive government expenditure in a two-sector endogenous growth is no more complex than the equivalent one-sector case.[31] The models behave

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condition is met $\frac{\beta_i}{\phi_i}>\frac{\beta_j}{\phi_j}$, where β is the elasticity parameter in a C-D production function and ϕ is the budget share.

[30] We note, as in Devarajan et al. (1996), the problem with using the Cobb-Douglas production function to describe the case of multiple productive expenditures. The budgetary share of either form of expenditure, ϕ, cannot be allowed to be equal to zero or one because of the effect that this has on total output. While this is obviously a restriction on the use of the Cobb-Douglas production function we retain its for the purposes of demonstration as it provides useful insights into the workings of the model and we suggest the reader consults the original text for a more alternative treatment of multiple productive goods.

[31] The results for non-productive government expenditures do not change when we develop the analysis to the two-sector model and so we omit them for ease.

in the steady state in a similar fashion to the one-sector 'AK' models.[32] The use of lump-sum taxation results in a constant level of government expenditure in the steady state and therefore it cannot provide the engine for growth. These models are not simply an extension of the one-sector education model described above because the accumulation of human capital is now a decision of households rather than government policy.[33] The two-sector framework has the appealing feature of enabling us to model the accumulation of human capital under an alternative technology to private output and therefore to differentiate between expenditures which affect human capital accumulation (education and health being obvious examples) from those which aid private production (such as transport and communication). The main determinant of the behaviour of the steady state is the accumulation of physical and human capital changes in government expenditures, which are equivalent to changes in the level of technology (a change in the value of the technology parameters A and B).

The two-sector model we describe simply adds government expenditures to the model of Chapter 1 (Section 1.2.4) where the production of aggregate output and human capital sector are given by the following equations:

Equation 2. 43
$$Y = C + \dot{K} + \delta K + G = A(\phi G_Y)^{\beta_1}(vK)^{\alpha}(uH)^{1-\alpha}$$

Equation 2. 44
$$\dot{H} + \delta H = B[(1-\theta)G_Y]^{\beta_2}[(1-v)K]^{\eta}[(1-u)H]^{1-\eta}$$

β_1 and β_2 are the elasticity parameters of output with respect to public goods and ϕ and $1\text{-}\phi$ the budget shares allocated to each public good. Both sectors display

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[32] The lack of examples of this type of model within the literature have more to do with the problems of endogenising the rate of growth in the two-sector sector models if we allow for distortionary taxed financed increases in productive expenditure. More of this issue is made in Chapter 4.

[33] The 'mathematical tricks' used by Krichel & Levine (1995), or Capolupo (1996) to retain the one-sector framework do not work here because the accumulation of human capital is made part of the household decision.

constant returns to human and physical capital in production, and for this reason K and H grow at identical constant rates in the steady state.[34]

Utility is maximised in the usual manner (taking government expenditure as given) and the time path of consumption does not look unusual in comparison to those described above:

Equation 2. 45
$$\gamma_C = \frac{1}{1-(1-\sigma)(1-\xi)}[A(\phi G_Y)^{\beta_1}[\frac{uH}{vK}]^{(1-\alpha)} - \delta - \rho].$$

If, as happens, H and K grow at identical rates in the steady state then the marginal product of physical capital is constant and the economy exhibits a sustainable rate of growth.[35] The transmission mechanism by which public goods affect the steady state is identical to the one-sector case. An increase in public goods in the production sector (a change in G_{Y1}) acts like a once and for all increase in the technology parameter in the private goods sector, A; whereas an increase expenditures on public goods in the human capital accumulation sector, G_{Y2}, acts like a once and for all increase in the technology parameter B. These results can be seen in the equations describing the growth of human and physical capital (equations (2.46) and (2.47)).

Equation 2. 46
$$\gamma_K = A(\phi G)^{\beta_1} v(\frac{uH}{vK})^{1-\alpha} - \frac{C}{K} - \frac{G}{K} - \delta$$

Equation 2. 47
$$\gamma_H = B[(1-\theta)G]^{\beta_2}(1-v)[\frac{(1-u)H}{(1-v)K}]^{1-\eta} - \delta$$

There are therefore, both direct and indirect effects from changes in expenditure on public goods. The optimal provision of public goods to each sector occurs when the

[34] Because productive expenditure acts like a once for all increase in technology productive expenditure still to help to determine the steady state growth even when we use extreme forms of the production of human capital, such as Lucas (1988). In Lucas (1988) the production of human capital depends linearly on H, the rate of growth of human capital (without productive goods) is given by $\dot{H} + \delta H = B(1-u)H$. The effect of public goods in this model is independent of the technology of the human capital sector.

[35] ϕG is constant because we use lump-sum taxation and do not allow any adjustment to τ.

marginal product of public goods is equated across both sectors of the economy, shown by equation (2.48):

Equation 2. 48

$$MP_{GY_1} = MP_{GY_2} = \beta_1 A(\phi G_Y)^{\beta_1 - 1}(vK)^{\alpha}(uH)^{1-\alpha} = \beta_2 B[(1-\phi)G_Y]^{\beta_2 - 1}[(1-v)K]^{\eta}[(1-u)H]^{\eta - 1}$$

Congested Public Goods

The basic result from the congested good case is the same result as that for the one-sector model, namely that the steady state growth rate is independent of public goods. The steady state rate of consumption in the economy is given by:

Equation 2. 49

$$\gamma_C = \frac{1}{1-(1-\sigma)(1-\xi)}[A(\frac{G_Y}{Y})^{\beta_1}[\frac{uH}{vK}]^{(1-\alpha)} - \delta - \rho]$$

An increase in government expenditure still acts like a one-off gain in technology but affects the steady state rate of growth only temporarily. As the level of output grows in the economy the congestion of the available stock of public goods (the ratio G_Y/Y falls) and the steady state rate of growth is given by $A[\frac{uH}{vK}]^{(1-\alpha)} - \delta - \rho$ which is independent of the congestion of public goods.

2.6 Conclusions

The principal difference between the effects of government policy in the neoclassical and endogenous growth models is that only in the endogenous growth models do government expenditures affect the growth rate. However, not all categories of government expenditure are predicted to affect the steady state in endogenous growth models. Growth effects occur only if the expenditures affect the supply side of the model and are not subject to congestion.

Figure 2.5 lists the necessary assumptions which need to be made for government expenditures to affect the growth rate, the symbol '√' indicating where the expenditure variable has a significant effect on the growth rate, 'x' where the effect is insignificant and '-' where the expenditure is not relevant to that part of the model. For example, government consumption expenditure is non-effective in both the neoclassical and endogenous growth models and as it does not affect private sector production it is not relevant to that part of the model.

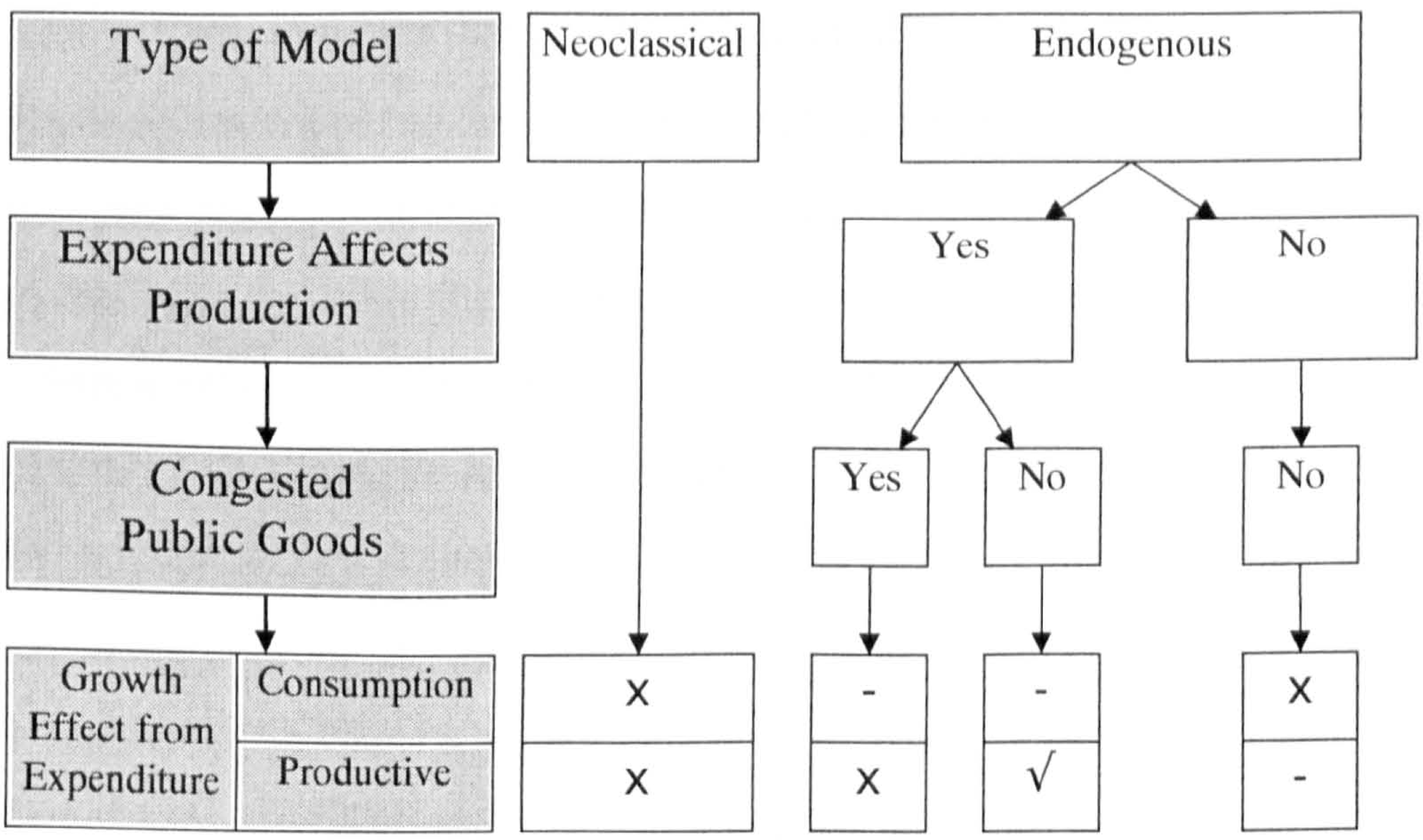

Figure 2. 5: Summary of the Assumptions Necessary for Government Expenditures to Affect the Steady State Growth Rate in Models of Economic Growth

The government's expenditures are constrained to be financed solely by lump-sum taxation in this chapter and by implication the level of government expenditure is constant in the steady state. Public expenditures are then not sufficient to provide the engine to growth and endogenous growth must be made an assumption through constant returns to capital. Lump-sum taxes are used because they do not distort the decisions of private agents in the model (this result is robust to changes in the household preference function or firms' production functions) which allows the growth effects of expenditure to be decoupled from those of taxation.

At an initial level we can classify expenditures as either affecting the production or consumption sectors of the model. In both the neoclassical and endogenous growth models changes in the level of productive government expenditure are equivalent changes in the level of technology. In the neoclassical model the effect on growth is temporary whereas in the endogenous growth model it is permanent. The relationship between the level of productive expenditures and the rate of growth is positive but non-linear because of diminishing marginal returns. Expenditures which are included on the consumption side of the model (non-productive expenditure) do not affect the form of the equation describing the growth of consumption (the Euler equation) nor the steady state rate of interest.

Barro (1990) assumes that productive goods directly affect production as a flow of goods and services; are produced using identical technology to the private sector; and that each category of expenditure has an equivalent effect on output. Developments of the Barro model in the literature have concentrated on changing the set of characteristics of expenditures.[36] However, the requirement of constant returns to capital at the aggregate level (to endogenise the growth rate) means that much of this work relies on fairly specific assumptions about the nature of public goods or the technology used in the production of either public goods or human capital. As Sala-i-Martin (1997) writes "a good theorist could make almost any variable affect the level of technology….as a result, he could make almost any variable look like an important theoretical determinant of the rate of economic growth."[37] The same appears to apply here. The behaviour of the steady state growth rate is therefore virtually identical under all different combinations of characteristics because of this need.

The one caveat to the result from the endogenous growth model is when productive expenditures suffer from congestion. Even in the presence of endogenous growth, public expenditures will not affect the steady state if public goods are congested (and financed by lump-sum taxes). As time (and therefore output) tends to infinity the benefit of public goods to firms' production approaches zero and the steady state growth rate is independent of public expenditures. The transition to the steady state would still be affected by public expenditures (as in the neoclassical model), the speed depending on the elasticity of output parameter with respect to public goods

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[36] These additions concentrate on productive forms of expenditure. We could perform the same exercise for non-productive expenditures but given that they have no effect on the steady state growth rate such a description is valueless.

[37] Sala-i-Martin (1997) pp. 2-3

(in Glomm & Ravikumar (1994, 1997) and Turnovsky & Fisher (1997) also on the degree of congestion).

The behaviour of public expenditures in the growth models discussed provide several hypothesis with which to test in the empirical section of the thesis. The first is whether a significant relationship exists between the long run rate of growth and government expenditures.[38] If government expenditures are found to have a significant effect on the long run rate of growth of a country then this would provide evidence in favour of the endogenous growth models over neoclassical models.[39]

The second would be that the estimated coefficients on forms of expenditure thought of as affecting household utility are insignificantly different from zero; whereas those expenditures which affect production have statistically significant positive coefficients.[40] Estimated coefficients displaying these properties would provide evidence that the separation of expenditures into consumption and production affecting is sufficient to describe their effect on the rate of growth. If all categories of expenditure are estimated as having positive coefficients then it could be argued that the endogenous growth model is not a complete representation of the growth process and the production and consumption sectors have a greater inter-relationship than that described presently. It also follows from these results that for a given level of expenditure changing the mix of expenditures will have an effect on the rate of growth. Increased (decreased) expenditure on productive government goods and services financed through decreased (increased) expenditure on non-productive

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[38] Whether the estimated coefficient on a expenditure variable is statistically significantly different from zero.

[39] We assumed for simplicity that the rate of growth of technological progress and the labour force was constant. If government expenditures help to determine either of these growth rates then the predicted insignificant relationship between government expenditures and the rate of growth in the neoclassical model would no longer exist. We overcome this problem in the text by describing this case as an endogenous growth model (because public policy is an endogenous variable). In an empirical setting we could overcome this problem if we could find evidence of a significant relationship between growth and public expenditures in the presence of technological change or the growth of the labour force.

[40] Evidence of statistically significant negative coefficients would provide evidence that not all forms of government expenditure which affect production have the positive effect assumed in the text. The possible negative external effects of governments on production have not been discussed in the text.

goods and services should lead to an increase (decrease) in the long run rate of growth of the economy.

The final testable hypothesis refers to the model with multiple forms of productive expenditure (Devarajan et al. (1996))). An increase (decrease) in the productive expenditure which has the greater *relative* productivity (based on the elasticity parameters and the expenditure shares) leads to an increase (decrease) in the long run growth rate. A-priori categorising of actual government expenditures into those having greater and lesser relative productivity is likely to prove difficult.

Although the characteristics of public goods have been fairly well described in the literature there are areas which perhaps require further development. The one highlighted in the text is that of the relative technology of the private and public sector. Most models in the literature make the simplifying assumption that the public and private sectors share identical technology. We develop one model but the technology is described in such a way that a simple substitution allows us to remain within the one-sector model.[41] Such an analysis should also develop the use of a government objective function in the endogenous growth model (see attempts by Barro (1990), Davoodi et al. (1995)) and the social welfare considerations which follow from this.

A second possibility would be to endogenise technological progress and for government policy to help to determine this growth rate. Endogenous technological progress would take the analysis beyond the simple one-sector model of Levine & Krichel (1996) described above and would require the use of a imperfectly competitive framework (Aghion & Howitt (1998)). One possibility would be for governments to provide or help to administer the pool of generally available knowledge through university research and hence increase the speed or size of each innovation.

[41] This result does not rely on public goods being described as a flow of goods as one could extend the Capolupo (1996) model to allow for public goods rather than human capital (human capital is a stock in the Capolupo model).

Chapter 3

Taxation in Models of Economic Growth

3.1 Introduction

Of the 13 tax measures that Easterly & Rebelo (1993) calculates only one, the marginal rate of taxation calculated from a time series regression on GDP, has a consistently significant negative correlation with growth. Similarly Mendoza et al. (1997), using measures of taxation which closely match their theoretical counterparts, find no direct relationship between growth and taxation. Such findings, typical of those found in the empirical literature, suggest that differences in tax policy cannot be used to explain differences in output growth across time and space; and in turn, imply that the endogenous growth model, in which taxation is a determinant of the steady state growth rate, is misspecified. The neoclassical model therefore better represents the growth process and government tax policies have a neutral long run effect on growth. This Chapter considers the theoretical relationship between the incidence of taxation and the growth rate.

The techniques, and hence the results, used to introduce taxation into growth models are in many ways analogous to those used for government expenditure in the previous chapter. Government taxation, like expenditures, is not sufficient to endogenise the rate of growth in the model and once again the results for government policy rest crucially on the assumptions underlying the production function.

Once the conditions for endogenous growth have been established ('AK' technology) the growth effects of taxes can be separated into those taxes which affect the returns from investment and those which do not.[1] Investment-distorting taxes reduce the returns to capital (the interest rate) and hence the growth rate of output.[2] We discuss three different forms of distortionary taxation in an endogenous growth model (income, capital and investment taxation) but only use one (income taxation) to illustrate policy ineffectiveness in the neoclassical model. Taxes which distort the consumption decision of households (consumption taxation) along with taxes which create no distortions (lump-sum and human capital taxation in the one-sector model) are discussed only in reference to the endogenous growth models.

The description of taxation is fairly limited and therefore un-interesting. Once beyond the basic results we therefore move to the much richer two-sector models very quickly (Section 3.4). The non-distorting effect of human capital taxation in the one-sector endogenous growth model can be contrasted with the results for the same tax variable in the two-sector model. The two-sector model, by allowing human capital to be accumulated, means its taxation affects the interest rate and hence the growth rate. The exact effect of human capital taxation depends on the relative tax rates on the factors of production in each sector. This offers an interesting extension to the results but has led to some considerable debate in the literature as to the best way to model the technology of the human capital sector; the taxation of the human capital sector and the elasticity of labour supply all impact on the results.

The taxes we use in the Chapter are all proportional (ad-valorem or flat-rate) taxes. These taxes have the convenient properties that the marginal and average tax rates are constant and equal over the range of taxation. Such taxes create distortions (tax wedges) to the decision of economic agents but do so in a linear manner. This

[1] This classification of taxation is slightly different from that of government expenditures, because the inclusion of a tax on the production side of the model is not sufficient for it to have an effect on the rate of growth.

enables us to simplify the analysis greatly but implies that the *mix* as well as the *level* of taxation must be discussed in relation to the effects of taxation on growth. The tax policies discussed in the text are stylised in their description of tax policy and ignore many related issues which include: other types of taxation; non-linear taxation: or the equity effects of tax policies.[3] These issues are not researched because we are interested in the possibility that taxation affects the growth rate of a country and the results can simply be extended to capture these more complex cases; and secondly this is a review of the literature rather than a development of it, hence, the tax policies used merely reflect those already discussed in the literature.

3.2 The Neoclassical Model - Policy Ineffectiveness

The basic model we use remains identical to that of Chapter 1. We have a decentralised, competitive, closed economy where all households share identical utility functions and all firms identical production functions. Firms maximise their profits and households their utility taking the interest rate, r, and the wage rate, w, as given. We allow for no growth of the labour force or of technology in this model.

Income is taxed at a constant proportional rate, τ_Y, in order to finance government expenditures, which are returned to households as non-distortionary, lump-sum rebates. Government expenditures are assumed to be of this form because they do not affect the utility of households or the production possibilities of the private sector. This is a common method of allowing the singular analysis of the effects of taxation, and to avoid the complications of productive government expenditure.[4] We

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[2] In the text taxes that affect investment are labelled 'distortionary taxes' and those that do not are labelled 'non-distortionary'.

[3] In addition to this Ireland (1994) considers the dynamic 'Laffer curve' effects of changes in tax policy; Easterly (1993) the effect tax policy has on the price of investment goods in developing countries with large black-market sectors; Devereux & Love (1995) the growth and welfare effects of permanent against temporary changes in tax policy; and Hendricks (1996) use a life-cycle rather than a infinite horizon framework.

[4] We note, as do Futagami et al. (1993), that the rationale for levying distortionary taxes on the economy without any corresponding benefit from expenditures is unclear.

assume that the size of the government is constant and the government's budget constraint can be written as:

Equation 3. 1 $$\mathrm{G} = \tau_{\mathrm{Y}}\mathrm{Y}$$

where G is non-productive government expenditures and τ_Y is the rate of taxation on income, Y. Unlike in the previous chapter the level of government expenditures grows in the steady state at the same rate as output, $\frac{\dot{G}}{G} = \frac{\dot{Y}}{Y}$. It should perhaps be obvious from this that the addition of distortionary taxation to the model provides the mechanisms for fiscal policy to endogenise the growth rate, although this will not occur here because expenditures do not affect production. The steady state growth rates of capital and consumption are given by the following equations:

Equation 3. 2 $$\gamma_K = (1-\tau_Y)\alpha A(\frac{K}{L})^{-(1-\alpha)} - \delta - \frac{C}{K}$$

Equation 3. 3 $$\gamma_C = \frac{1}{1-(1-\sigma)(1-\xi)}[(1-\tau_Y)\alpha A(\frac{K}{L})^{-(1-\alpha)} - \delta - \rho]$$

With no labour force growth or technological change the growth in the capital stock is zero, $\gamma_K = 0$, and therefore if we differentiate the production function with respect to time to find the growth path of output it follows that this is zero also, $\gamma_Y = 0$. The form of the steady state growth equations for C and K are identical to those in Chapters 1 & 2, as in those models the growth rate is zero in the absence of technological change or population growth. Changes in tax policy have no effect on the steady state growth rate of output. As with expenditure policy taxation acts like a once-and-for-all change in the level of technology.[5]

[5] If taxation affects the growth of technology or labour then the government policy would become effective in the neoclassical model. We overcome this problem by assuming technology and the size of the labour force are constant.

3.3 Endogenous Growth Models - Effective Fiscal Policy

3.3.1 *Distortionary Taxation*

In order to generate endogenous growth in the model we assume that the technology used in the production of output is such that there are constant returns to capital. This assumption is required because government expenditures are assumed to be non-productive and hence do not appear in the equation for the steady state. Under such conditions government policy cannot be used to prevent the marginal product of capital from declining towards zero over time.[6] Increases (decreases) in the rate of taxation then behave like decreases (increases) in the level of technology. The aggregate production function is given by the following equation,

Equation 3. 4
$$Y = AK.$$

Given the production function in (3.4) and the assumption that income is taxed at a constant proportional rate (equation (3.1)) then the growth rate of capital is,

Equation 3. 5
$$\gamma_K = (1-\tau_Y)A - \frac{C}{K} - \delta.$$

The rate of interest is set equal to the after-tax marginal product of capital, $r = (1-\tau_Y)\frac{\delta Y}{\delta K}$ which after substitution into the Euler equation gives the following growth path for consumption,

Equation 3. 6
$$\gamma_C = \frac{1}{1-(1-\sigma)(1-\xi)}[(1-\tau_Y)A - \delta - \rho].$$

[6] Therefore the only way to endogenise growth is to remove this assumption.

It follows from the 'AK' production function that the steady state rate of growth is constant and therefore increases in the rate of income tax rate have a negative effect on the growth rate. The steady state growth rate declines at the linear rate ($1-\tau_Y$), as shown in Figure 3.1. The rate of growth varies between

$\frac{1}{1-(1-\sigma)(1-\xi)}[A-\delta-\rho]$, when the rate of taxation is zero, $\tau_Y = 0$, and zero

when taxation consumes all of output, $\tau_Y = 1$.

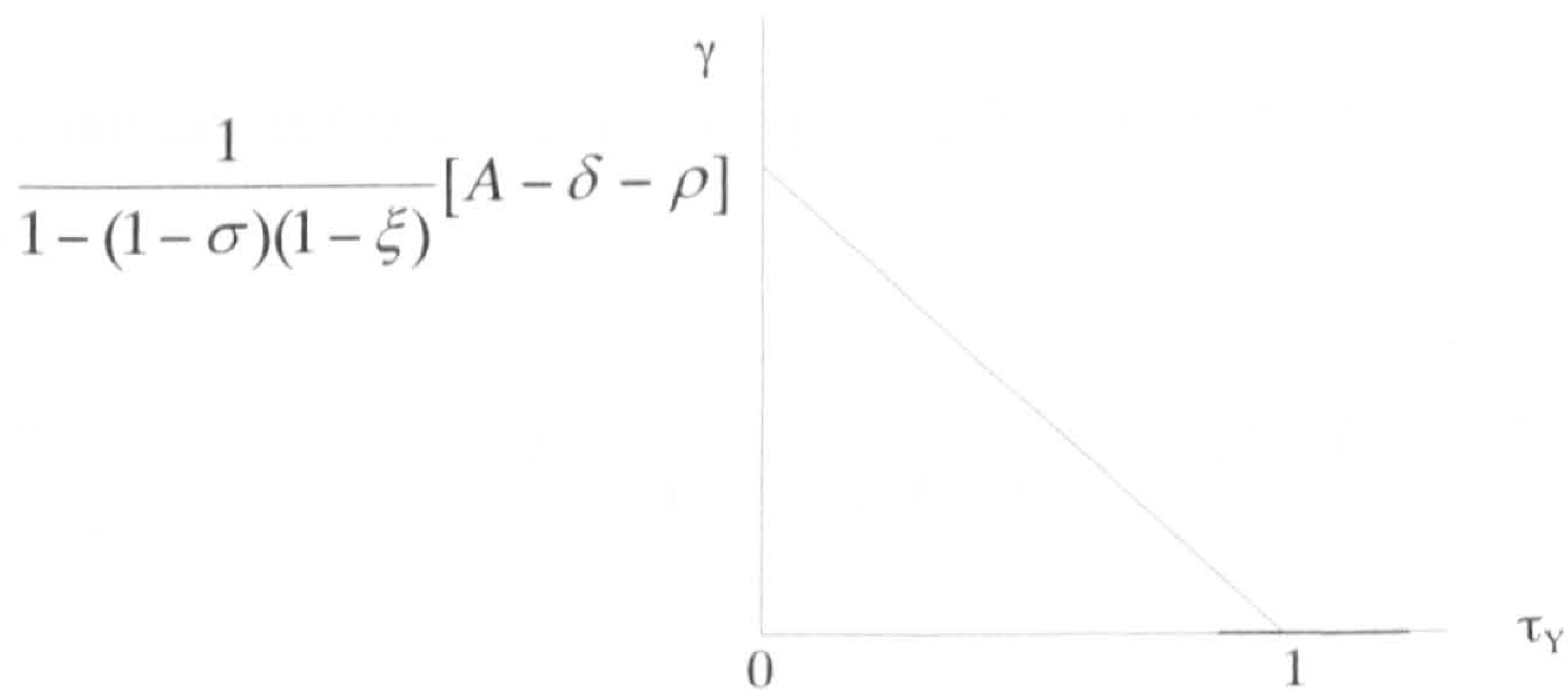

Figure 3. 1: The Effect of Income Taxation on the Steady State Growth Rate in a 'AK' Endogenous Growth Model.

In both endogenous and the neoclassical models the equilibrium steady state value of capital, k^*, is lower because of taxation. Taxation lowers the after tax returns to investment and with it the equilibrium capital-labour ratio.

Capital Taxation

In Capolupo (1996) government expenditures are funded through a tax on capital. The form of capital taxation used by Capolupo (1996) is such that it distorts the steady state in a slightly different way to income taxation and it behaves like an additional depreciation factor of the capital stock, δ. Capital taxation lowers the growth rate by reducing the net after-tax return on capital, that is, the marginal product of capital less the rate of depreciation, $r = f'(K) - \delta$. Capital taxation acts on the quantity of available capital rather than on the returns to capital. Changing the government budget constraint so that non-distorting government expenditures are financed by capital taxation can be written as:

Equation 3. 7
$$G = \tau_K K$$

The growth rate of capital can then be given as:

Equation 3. 8
$$\gamma_K = A - \frac{C}{K} - (\delta + \tau_K),$$

and if we maximise in the usual way we get the following growth path for consumption,

Equation 3. 9
$$\gamma_C = \frac{1}{1-(1-\sigma)(1-\xi)}[A - (\delta + \tau_K) - \rho]$$

The decline in the growth rate from increases in capital taxation is again linear but is slower than that for income taxation. The growth rate now varies between

$\frac{1}{1-(1-\sigma)(1-\xi)}[A - \delta - \rho]$ when the tax rate is zero, $\tau_K = 0$, and

$\frac{1}{1-(1-\sigma)(1-\xi)}[A - \delta - \rho - 1]$ when the tax rate is one, $\tau_K = 1$, as shown in Figure 3.2.

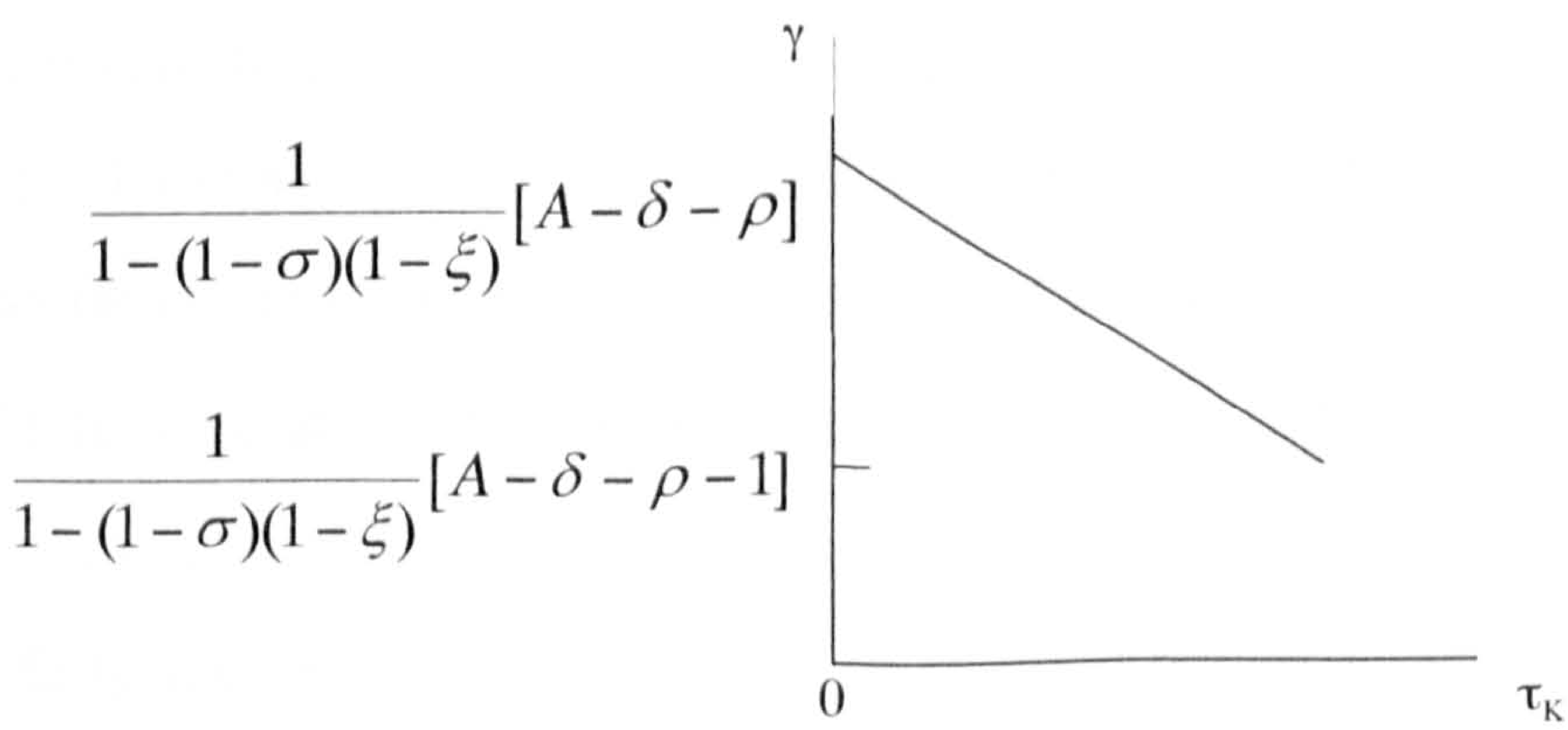

Figure 3. 2: The Growth Effects of Capital Taxation in a 'AK' Endogenous Growth Model

Investment Taxation

Rebelo (1991) models the financing of non-distorting government cash transfers through a tax on investment. The government budget constraint is then written as:

Equation 3. 10 $G = \tau_I I.$

Equation (3.10) is substituted into the resource constraint of the economy for G and then rewritten as a growth of capital equation using $I = \dot{K} + \delta K$:

Equation 3. 11 $\dot{K} = (\frac{Y - C}{1 + \tau_I}) - \delta K$.

Investment taxation affects the after tax return on capital in much the way that income taxation does, except the tax effect is described by $\frac{1}{(1 + \tau_I)}$. Maximising in the usual way leads to the following growth path for consumption,

Equation 3. 12 $\gamma_C = \frac{1}{1 - (1 - \sigma)(1 - \xi)}[\frac{A}{(1 + \tau_I)} - \delta - \rho]$

An increase in investment taxation lowers the growth rate by reducing the after tax return on capital and hence investment. Like the other types of distortionary taxation a tax on investment acts like a once and for all reduction in technology. For an identical rate of taxation of income and investment, $\tau_I = \tau_Y$, the effect of investment taxation on the rate of growth is lower than that for income taxation (the term $(1- \tau_Y)$ falls towards zero at a faster rate than the term $1/(1+ \tau_I)$), as shown in Figure 3.3.

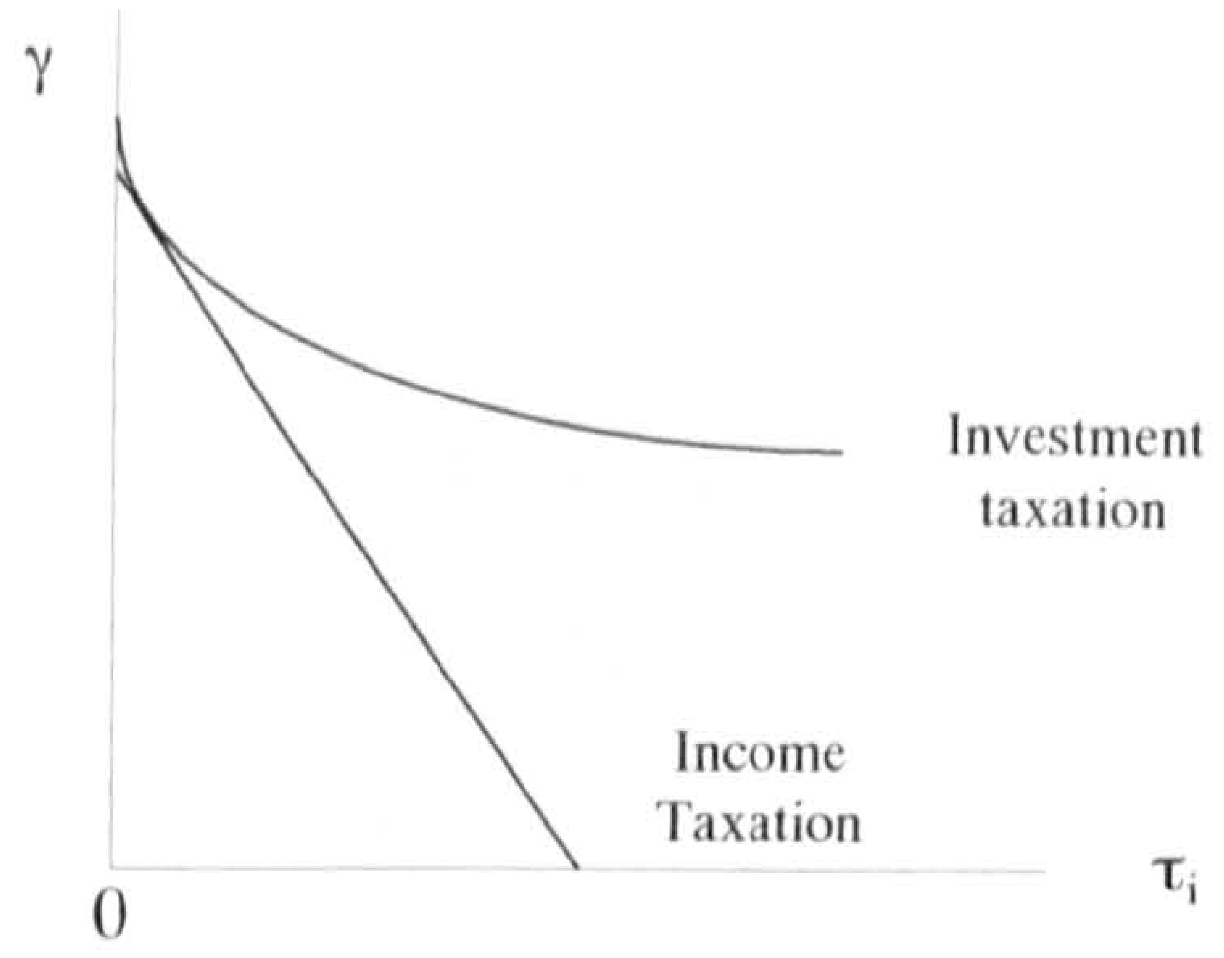

Figure 3. 3: A Comparison of the Growth Effects of Income and Investment Taxation in a 'AK' Endogenous Growth Model

3.3.2 *Non-Distortionary Taxation*

Non-distortionary taxes are fairly simple to introduce in to the endogenous growth framework as they have no effect on the steady state growth rate. In each of the examples we give the constant growth rate of consumption is therefore, given by:

Equation 3. 13
$$\gamma_C = \frac{1}{1-(1-\sigma)(1-\xi)}[A-\delta-\rho].$$

The marginal product of capital is equal to the constant technology parameter A from the 'AK' production function which is independent of non-distortionary taxes. As with any change in government policy private investment is 'crowded-out' by the change in non-distortionary taxation through the resource constraint of the economy, but the steady state rate of growth remains unchanged.

The limited way in which non-distortionary taxes impact on the economy makes them fairly un-interesting to discuss. Therefore, we review only their salient characteristics and move quickly on to the much richer two-sector models. Slightly longer is spent with the human capital taxes that are non-distortionary in some versions of the one-sector model but not all.

Lump-Sum Taxation

As discussed in the previous chapter lump-sum taxes are useful when describing the effect on growth of government expenditure because they do not distort the investment or the consumption decision of firms and households respectively. The results for lump-sum taxes are robust to all changes in the assumptions about production technology or household preferences, and are therefore, useful for providing a benchmark against which the behaviour of other taxes can be compared. Under lump-sum taxation equation (3.10), the government budget constraint, would instead be given by (3.14).

Equation 3. 14 $$G = \tau$$

Consumption Taxation

Consumption taxation behaves like lump-sum taxation in the simple endogenous growth models because it does not alter the investment decision of the representative firm. Consumption is assumed to be taxed at a constant proportional rate, τ_C, so that the government budget constraint would read:

Equation 3. 15 $$G = \tau_C C.$$

As we shall see later the result that consumption taxation has benign effect on growth is non-robust to changes in the model.

Human Capital Taxation

If we decompose the composite capital term in the 'AK' production function into physical and human capital and then tax human capital, we find results that are the same for lump-sum and consumption taxation. This result holds because there are no returns to human capital and therefore it would not be accumulated. Its taxation would then obviously have no effect on the investment choice of firms.[7] If human capital were taxed at a constant proportional rate τ_H then the government budget constraint would be given by:

Equation 3. 16 $$G = \tau_W H.$$

It is possible to make human capital taxation distortionary in the simple model if we allow investment to be in either human capital or physical capital (and assume that these are produced under identical technology). Barro & Sala-i-Martin (1995) write the production function in the standard C-D form in K and H, given in equation (3.17), and demonstrate that this model collapses to that of a 'AK' production function with composite capital. The taxation of human capital would then be the same as the taxation of capital already described above. This point is similar to that expressed in footnote 5 except that here the separate accumulation of human and physical capital is explicitly expressed:

Equation 3. 17 $$Y = AK^{\alpha} H^{1-\alpha}$$

3.4 *Two-sector Models of Taxation*

The existing literature modelling the effect of taxation in two-sector endogenous growth models is large, and the implications for growth have been researched to a much deeper level than the equivalent one-sector models. The manner in which taxation affects the steady state is identical to the one-sector models, but the results are less robust to changes in the underlying assumptions of the model. The mechanism by which taxes affect the steady state in the two-sector models is still by distorting the returns to accumulation of either physical or human capital. The *relative* taxation of physical and human capital in each sector of the economy is vital for determining the effect on growth. Only if all inputs are taxed at identical rates,

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[7] We have what appears an inconsistency in the results here because if we leave human capital as a component of aggregate capital then its taxation has an effect on the steady state yet when we disaggregate human capital out of the composite capital term its taxation has no effect on the steady state.

which is equivalent to an income tax in the one-sector model, does the growth rate unambiguously fall (Rebelo (1991)). Changes in the assumptions regarding the production of human capital, the tax treatment of the human capital sector, and the underlying structure of the preference function lead to differences in how the reproducible factors are affected (Stokey & Rebelo (1995)).

The two-sector model we describe can be seen as a direct extension to that described in Chapter 1, but allowing for taxation.[8] The analysis uses the same tools as the one-sector model except now capital and human capital are produced using non-identical technology (which also allows the factors of production to be taxed at different rates).

3.4.1 Distortionary Taxation

The underlying assumptions of the household utility function and firm's production are identical to that described in Chapter 1. The production functions are the most important determinants of the growth effects of taxation and are given in equations (3.18) and (3.19) below as a reminder.

Equation 3. 18
$$Y = C + \dot{K} + \delta K + G = A(vK)^{\alpha}(uH)^{1-\alpha}$$

Equation 3. 19
$$\dot{H} + \delta H = B[(1-v)K]^{\eta}[(1-u)H]^{1-\eta}$$

The government can now tax either human or physical capital in either sector of the economy and at differing rates. The government budget constraint (again assuming non-distorting lump-sum government transfers) can then be written as:

Equation 3. 20
$$G = \tau_{K1}r_{K1}vK + \tau_{K2}r_{K2}(1-v)K + \tau_{W1}r_{w1}uH + \tau_{W2}r_{W2}(1-u)H$$

[8] King & Rebelo (1990), Kim (1992), Stokey & Rebelo (1995) all assume technology and taxation are of the form described here. Jones et al. (1993) use an almost identical set-up except they do not allow the taxation of the human capital input in the human capital sector, τ_{H2}=0.

Where τ_{K1} is the taxation of physical capital in the production of aggregate output, τ_{K2} the taxation of physical capital in the production of human capital, τ_{W1} the taxation of human capital in the production of aggregate output and, τ_{H2} the taxation of human capital in the production of human capital. Equation (3.20) allows the tax rates of physical and human capital all to differ from each other *within* sectors and *across* sectors (if the tax rates in an individual sector were equal then the tax could be described as sector-specific income tax).

If we maximise the utility function in the usual way we get a time path of consumption that does not look unusual in comparison to those described above,

Equation 3. 21
$$\gamma_C = \frac{1}{1-(1-\sigma)(1-\xi)}[(1-\tau_{K1})\alpha A[\frac{uH}{vK}]^{(1-\alpha)} - \delta - \rho]$$

H and *K* grow at identical rates in the steady state so that the marginal product of physical capital is constant and the economy exhibits a sustainable rate of growth. The steady state interest rate is set equal to the rate of return to physical capital in the output sector, which must also equal the rate of return to physical in the production of human capital (expressed in terms of physical capital goods) - equations (3.22) & (3.23). Equation (3.24) states that the return to the factors of production in all sectors of the economy must be equated in the steady state.[9]

Equation 3. 22
$$r = (1-\tau_{K1})\alpha A(\frac{vK}{uH})^{\alpha-1} - \delta$$

Equation 3. 23
$$r^{*} = (1-\tau_{H2})(1-\eta)B(\frac{(1-v)K}{(1-u)H})^{\eta} - \delta + \frac{\dot{q}}{q}$$

Equation 3. 24
$$(\frac{1-\alpha}{\alpha})(\frac{1-u}{u})(\frac{1-\tau_{W1}}{1-\tau_{K1}}) = (\frac{1-\eta}{\eta})(\frac{1-v}{v})(\frac{1-\tau_{W2}}{1-\tau_{K2}})$$

The taxation of the factors of production at non-identical rates will lead, through equation (3.24), to an adjustment in the factor intensities, *v*, *u*, *(1-v)* and *(1-u)*, so that the rates of return are equated across all sectors. The taxation of any one individual factor income has a negative effect on the growth rate, the transmission mechanism of which is identical to the one-sector models. That is, factor income taxes affect the steady state by reducing the returns to investment.

Complications to the results are added when the factor inputs are not taxed at identical rates and when changes are made to the assumption regarding the technology of human capital production and the tax treatment of the human capital sector. Such changes lead to different sized relative distortions from physical and human capital taxation.[10] If all factor incomes are taxed at identical rates within an individual sector then the tax term drops out of equation (3.24) and taxation does not alter the factor inputs, but it can be seen to still affect the steady state interest rate, equations (3.22) & (3.23). The return to investment in either the output sector and the human capital sector is reduced by the factor $1-\tau_{Yi}$ (i = 1,2).[11] There is an unambiguous fall in the growth rate because of this change in the interest rate (Rebelo (1991)). The results are open to debate in these models when factor incomes are not taxed at identical rates and we attempt to alter the *mix* of these factor income taxes.

The growth paths for capital and human capital are given by equations (3.25) and (3.26) below. We include these for completeness but choose not to discuss their properties or to produce the full dynamics of the model. For a fuller analysis of the dynamic structure of the model the reader is referred to Barro & Sala-i-Martin (1995 Ch.-5).

Equation 3. 25

$$\gamma_K = (1-\tau_{K1}-\tau_{w1})Av^{\alpha}K^{\alpha-1}(uH)^{1-\alpha} - \frac{C}{K} - \frac{G}{K} - \delta$$

Equation 3. 26

$$\gamma_H = B[(1-v)K]^{\eta}(1-u)^{1-\eta}H^{-\eta} - \delta$$

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[9] See Stokey & Rebelo (1995) for a version of this equation with three different types of reproducible inputs all taxed at non-identical rates.

[10] The reader is referred to Stokey & Rebelo (1995) for an excellent treatment of the important parameters of the model.

As mentioned above the technology under which human capital is produced and the tax treatment of human capital are important determinants of the growth effects of factor income taxation. An extreme example of a model illustrating this point is a model developed by Lucas (1990). Lucas assumes that the education sector is a non-market activity and therefore not subject to taxation, and that human capital is accumulated linearly using only human capital as an input, $\dot{H} = B(1-u)H$. The rate of return on human capital is equal to the constant technology parameter B. This rate of return is independent of the taxation in the other sector of the economy. In the steady state all factor income must be equalised (equations (3.22) & (3.23)). In the Lucas model the interest rate is therefore equal to the technology parameter B. The growth rate of the economy is then independent of taxation (assuming that labour is supplied inelastically). We can modify this result slightly if we allow the human capital sector to be taxed. The rate of interest is then equal to the after-tax marginal product of human capital in the human capital sector $r^* = (1-\tau_{H2})B - \delta + \frac{\dot{q}}{q}$. Only the tax on human capital affects the growth rate, not all taxes (Stokey & Rebelo (1995)). Following Tanzi & Zee (1997) we can discern the following policy rule. "The lighter the tax burden on the production of human capital relative to the tax burden on sectors that are human capital intensive, the smaller will be the adverse impact on growth of taxing physical capital."[12] Stokey & Rebelo (1995) provide a series of simulation exercises to demonstrate the sensitivity of the results to changes in the underlying assumptions of the model.

3.4.2 *Non-Distortionary Taxation*

The description of the two-sector model above means the results for the non-distortionary taxes of consumption and lump-sum taxation are identical to the examples of consumption and lump-sum taxation in the one-sector model. The

[11] This is independent of the production technology in each sector as there are no changes to the input ratios from the introduction of taxation.

[12] Tanzi & Zee (1997) pp. 184.

household sector of the model has not changed so that there remains no channel by which non-distortionary taxation can affect the rate of growth (in the absence of productive expenditures that is). Given that the results and the intuition behind the results are identical in these two cases we choose not to repeat their results. By changing the underlying structure of the model we can change the results for consumption taxation quite easily. This is made the subject of the next section.

3.5 *Extensions to the Two-Sector Model*

Labour Leisure Choice

Households are now assumed to maximise their utility by making choices as to how they allocate their time between leisure, education and working (Mendoza et al. (1997)). Leisure is therefore included as an additional argument in the utility function:

Equation 3. 27
$$U = \int_0^\infty e^{-\rho t} u(C_t, l_t) dt$$

(where l_t is leisure time). The felicity function is still of the CIES[13] form but now includes leisure as an input,[14]

Equation 3. 28
$$u(C_t, l_t) = \frac{(C_t l_t^\theta)^{1-\sigma}}{1-\sigma} - 1.$$

$\theta \neq 1$.

Assume the remainder of the model is equivalent to that described above.[15] Each individual's time is either allocated between leisure, work (the production of output) or education (the accumulation of human capital). This is then normalised to one

[13] Constant intertemporal elasticity of substitution.
[14] Stokey & Rebelo (1995) demonstrate that if leisure time is adjusted for quality then these results no longer hold.
[15] We assume that the rate of taxation on all factor inputs is equal to zero so that all government expenditures (of a non-distorting lump-sum type) are financed by taxes on consumption. The government budget constraint is then given by, $G = \tau_C C$.

(equation (3.29)). The term z_t now replaces $(1\text{-}u)_t$ in the human capital production function.

Equation 3.29 $$l_t + u_t + z_t = 1$$

Maximising in the normal way has little effect on the steady state behaviour of the model but it does provide us with a new equation describing the consumption-education decision. The ratio of consumption to human capital is given by the marginal rate of substitution between consumption and leisure, $\eta^{-1}(1\text{-}u\text{-}z)$, and the real rate of return on human capital:

Equation 3.30 $$\frac{C}{H} = \frac{1}{(1+\tau_C)}\eta^{-1}(1-u-z)(1-\alpha)A[\frac{vK}{uH}]^{\alpha}$$

Consumption taxation affects the leisure, work, and education decision in equation (3.30), which in turn indirectly affects the rate of growth. An increase in consumption taxation causes a reduction in household consumption, which results in an increase in time spent in work/education. This in turn leads to a fall in the rate of return on these activities and therefore a fall in the steady state rate of growth.[16] The magnitude of the effect of consumption taxation on the steady state rate of growth depends on the elasticity of labour supply parameter η (as identified by Stokey & Rebelo (1995)). If the supply of labour is inelastic, η =0 (as assumed by Lucas (1990), and King & Rebelo (1990)), then an increase in consumption taxation does not lead to an adjustment in time spent in work/education and leisure and hence not affect on the rate of growth. If the value of the elasticity of labour supply parameter is large (as assumed by Jones et al. (1993)) then the effects of factor income taxation are also large.[17]

[16] The introduction of a labour-leisure choice in the model creates additional affects from factor income taxation on the rate of growth, the details of which can be found in Mendoza et al. (1997). These too are dependent upon the assumption regarding the elasticity of the supply of labour and the way that this affects the interest rate.

[17] Jones et al. (1993) estimate that the removal of all distortionary taxes in the model would increase the rate of growth by a massive eight percentage points.

The labour-leisure choice extends the results for the factor income taxes. Factor income taxation distorts the labour-leisure choice in much the same way as consumption taxation. Given that these effects are negative, and therefore augment the existing effects of factor income taxation on growth (rather than alter the results) we do not report them and refer the reader to the large number of tax studies that have included a labour-leisure choice (Jones et al. (1993), Stokey & Rebelo (1995), Mendoza et al. (1997)).

3.6 Conclusions

Government tax policy is not sufficient in itself to provide the engine for growth, hence the conditions for endogenous growth must already be present if taxation is to have an affect on the growth rate. The critical assumption which distinguishes between the results for the neoclassical and endogenous growth models is that of constant returns to capital in the one-sector model, and constant returns to scale technology in both capital and human capital production in the two-sector model.[18] If these conditions are satisfied then endogenous growth is an assumption of the model and tax policy can have an effect (although not necessarily so) on the growth rate. These types of model are commonly used in the literature when considering tax policy in isolation and government expenditures are returned to households as non-distorting, lump-sum rebates. The use of this type of expenditure has the additional advantage in that it allows the expenditure effects of fiscal policy to be decoupled from the tax effects.

As noted above endogenous growth models, are however, only necessary, not sufficient, conditions for tax policy to have a permanent effect on the growth rate of a country. For tax policy to have a permanent effect it must affect the returns to investment and in the case of the two-sector model this requires the education sector to be a market sector where human capital production is not linear in human capital. In both the one-sector and two-sector models we define distortionary taxation through whether it distorts the returns to the factors of production which can be accumulated. This is because the growth effects of taxation are via investment (they reduce the returns to investment) although they act on the steady state in an equivalent manner to a one-off change in the level of technology. This leads to an interesting distinction between the one and two-sector models regarding the growth effect of human capital taxation. In the one-sector model unless we explicitly allow the accumulation of human capital then its taxation has a benign effect on the steady state growth rate (see Section 3.3.2).

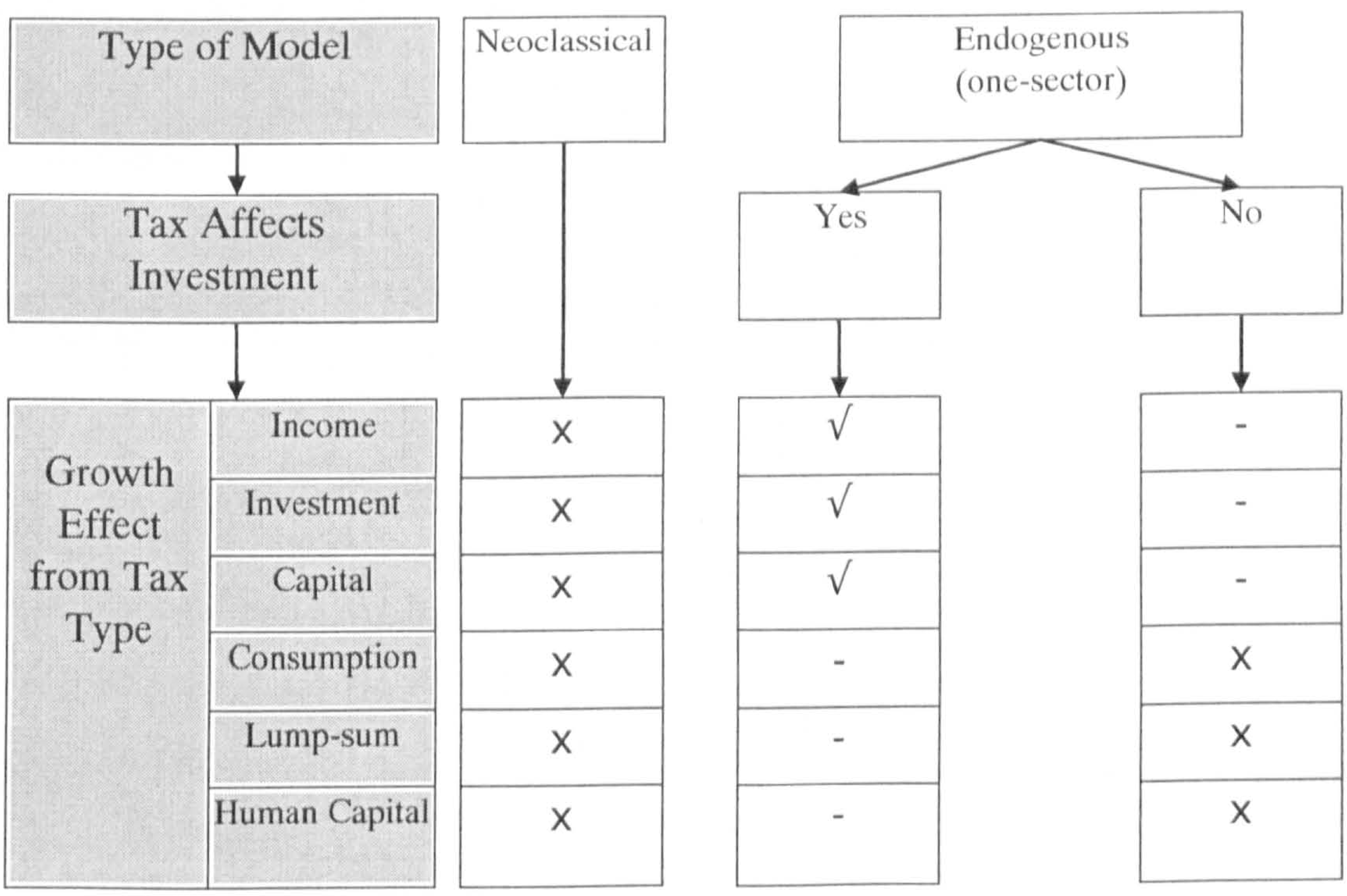
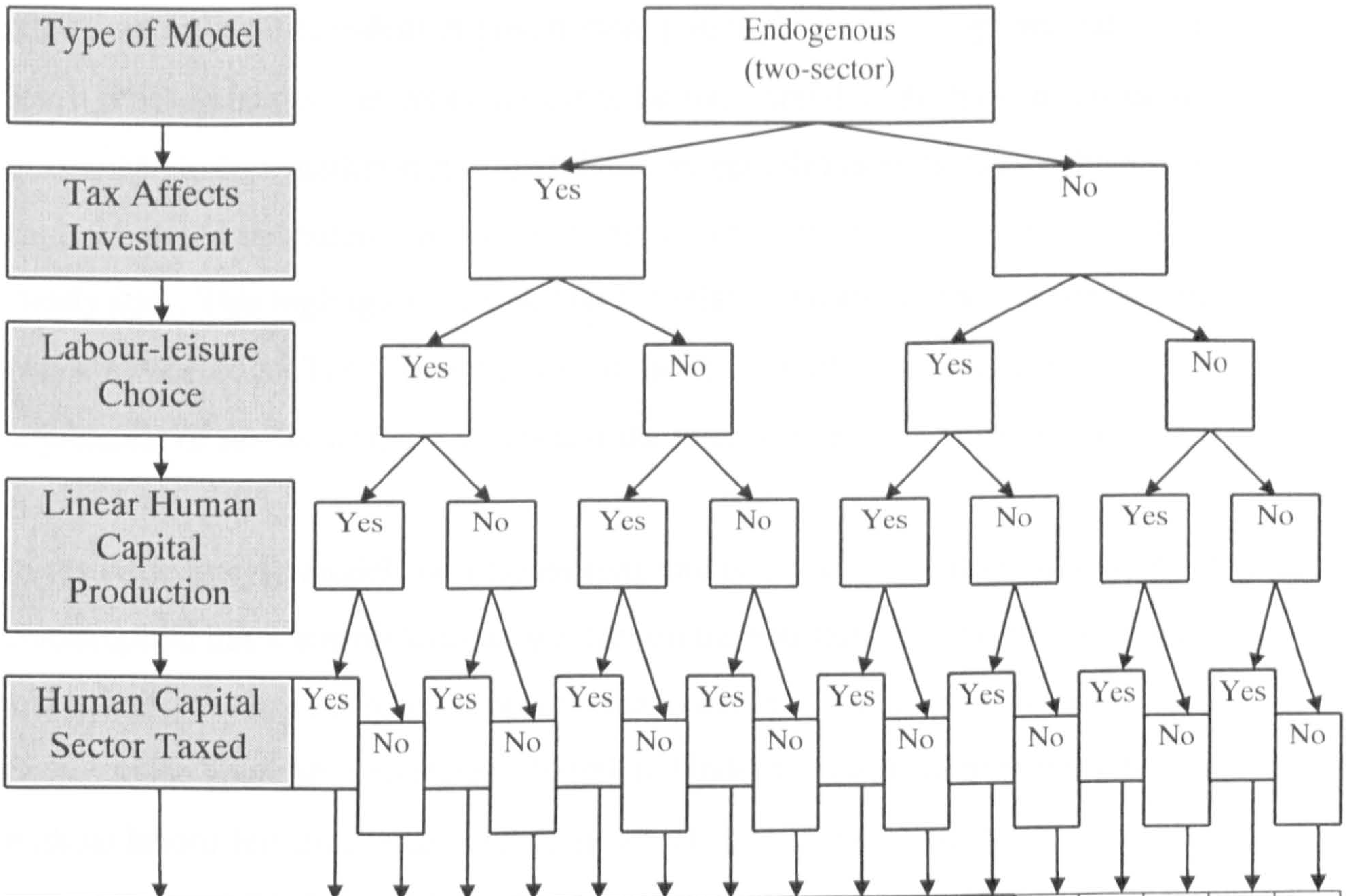


Figure 3. 4: Summary of the Necessary Assumptions for Government Tax Policy to Affect the Steady State Growth Rate in One-sector Models of Economic Growth

Figure 3.4 represents a summary of the necessary assumptions in the neoclassical and one-sector endogenous growth model; whereas Figure 3.5 is an attempt to summarise the results from the two-sector model. The symbol '√' indicates where the tax has a distortionary effect on the steady state; 'x' where the tax has no effect on the steady state; and '-' where the tax is not relevant for that section of the diagram. For example consumption taxation is not effective in either the neoclassical or endogenous growth model and does not affect the returns to investment in the endogenous growth model.

[18] This is necessary for K and H to grow at identical rates, see Barro & Sala-i-Martin (1995) Chapter 5 for a more general set of conditions.



Tax Type	Income	τ_{K1}	X	X	√	√	X	X	√	√	-	-	-	-	-	-	-	-
		τ_{K2}	-	-	√	-	-	-	√	-	-	-	-	-	-	-	-	-
		τ_{H1}	X	X	√	√	X	X	√	√	-	-	-	-	-	-	-	-
		τ_{H2}	√	-	√	-	√	-	√	-	-	-	-	-	-	-	-	-
	Consumption		-	-	-	-	-	-	-	-	X	X	√	√	X	X	X	X

Figure 3. 5: Summary of the Necessary Assumptions for Government Tax Policy to Affect the Steady State Growth Rate in Two-sector Models of Economic Growth

In addition to the conditions for effective tax policy in the one-sector model the growth-retarding effects of tax policy in the two-sector model are dependent as to the technology of the human capital sector. Indeed, it is possible to completely remove all growth effects of taxation in the two-sector model (Lucas (1990)) if it is assumed that: the human capital sector is a non-market sector and is not taxed; that human capital production uses only human capital as an input; and that the accumulation of human capital is linear in this input. The steady state interest rate in the human capital sector will then be equal to the technology parameter in that sector, B, (a constant). Standard arbitrage conditions then ensure that this is equal to the interest rate in the production goods sector and therefore, the growth rate is endogenously determined by the interest rate in the human capital sector, B. Given the human capital sector is independent of government policy then so is the growth rate. This result relies in part on the tax treatment of human capital. If the human capital sector is assumed to be a market sector (and therefore taxable) then the tax on the human capital input in the human capital production sector affects the growth rate in the steady state. This highlights the role that the relative taxation of the factor income plays in the results. The taxation of factor incomes at different rates leads to an adjustment of the factor input shares and the interest rate (equations (3.22)-(3.23)).

In the basic growth models we discuss (one and two-sector) taxation of households' consumption has a non distortionary effect on the equilibrium returns to investment and hence growth. This result is non-robust to the introduction of a labour-leisure choice to the household preference function. Under the Ramsey-preference function with no labour-leisure choice the household labour supply function is assumed to be perfectly inelastic. The addition of a labour-leisure choice removes this assumption and requires the returns to leisure and education to be equated. Consumption taxation decreases the returns to leisure hence encouraging investment in education, which lowers their returns, and through the interest rate the steady state growth rate.[19] The size of the distortion from the labour-leisure choice depends on the assumptions regarding the elasticity of labour supply. Jones et al. (1993) assume labour supply is elastic, while Lucas (1990) assumes that labour supply is inelastic. The growth effects of the same change in tax policy are therefore, much larger in the Jones et al. (1993) model than the Lucas model (Stokey & Rebelo (1995)).

The conditions under which tax policy affects the steady state growth rate provides us with a series of testable hypothese for the empirical section of the thesis. Tax policy affects the long run growth rate only if the model displays the properties of endogenous growth. We would therefore expect the estimated coefficients on tax variables in a growth regression to be statistically significantly different from zero

[19] There are also additional effects to factor income taxation, which we do not develop in the text.

only if the growth process was best described by an endogenous growth model.[20] The one-sector endogenous growth model further divides taxation into those, which distort the returns to investment, and those, which do not. Only those measures of taxation that distort investment would be expected to have a statistically significant, negative relationship with growth. This result suggests a third potential hypothesis relating to the mix of taxes in the one-sector model. An increase (decrease) in non-distortionary taxation financed by a decrease (increase) in distortionary taxation so as to leave the total size of government constant would be expected to have a significant positive (negative) effect on the long run growth rate.

If the three distortionary taxes which we describe in the one-sector model (income, investment and capital taxation) were taxed at an identical rate then we would expect that the magnitude of the estimated coefficient would be larger (and negative) for income over investment over capital taxation. Figure 3.6 provides a summary of this result. If information is not available as to the tax rate, or indeed if taxes are not of the linear proportional kind described in the theory (as is likely to be the case), then this may be a much more difficult hypothesis to test in practice.

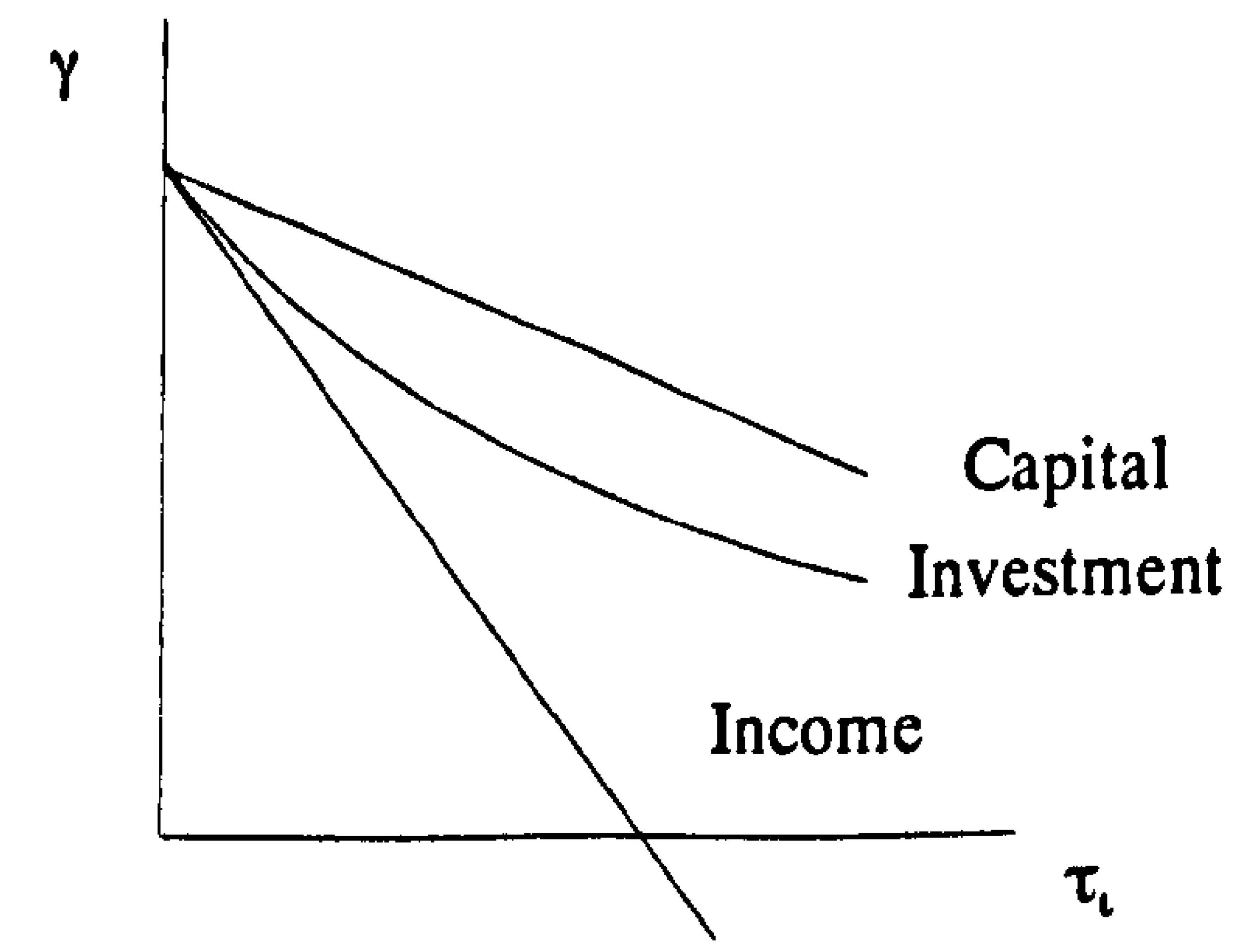


Figure 3. 6: A Comparison of the Growth Effects of Income, Capital and Investment Taxation when Taxed at Identical Rates in a 'AK' Endogenous Growth Model

The simplicity of the results from the one-sector model does not carry over to the two-sector models and distortionary taxes can no longer be described simply as to whether they distort the returns to investment. This is turn affects our ability to

[20] We discuss the problems of the measurement of tax variables elsewhere in the thesis

describe testable hypotheses for empirical testing. For example, consumption taxation and human capital taxation are examples of non-distortionary taxation in the one-sector model but may or may not be distorting in the two-sector model. Human capital taxes are distortionary in the two-sector model if human capital can be accumulated under a household decision; but non-distortionary if human capital sector is non-taxable and human capital technology is linear in human capital. Similarly, consumption taxation becomes distortionary if households are allowed to make a choice about their consumption based in part on their allocation of time between work, leisure and education; in this case consumption taxation has a negative distortionary effect on the growth rate. The hypotheses derived from the one-sector model about the *mix* between distortionary and non-distortionary are, therefore, not so clear in the two-sector model. Unless there is information about the true nature of taxation in each country and accessible information about the rate of taxation then it may prove to be very difficult to make a-priori predictions regarding the growth effects of changes to the *mix* of taxes. Empirical testing is required to distinguish between these competing hypotheses.

A final problem from the two-sector model for distinguishing between assumptions of the model is if the human capital sector is a non-market sector and human capital is accumulated linearly in human capital. Tax policy cannot then be used to distinguish between the neoclassical growth model and endogenous growth model as they are in this respect observationally equivalent.

Chapter 4

Fiscal Policy in Models of Economic Growth

4.1 Introduction

According to the public-policy endogenous growth model government expenditures affect the long run growth rate of an economy if they affect the supply side of the economy and are not subject to congestion; whereas tax policies affect the long run growth rate if they distort the returns to the reproducible factors of production or labour supply. In reaching these conclusions Chapters 2 and 3 make the simplifying assumption that one half of the government budget has benign growth effects (by assuming that either taxation is non-distorting - Chapter 2 - or expenditure is non-productive - Chapter 3). Such assumptions are useful in allowing the singular analysis of one direction of fiscal policy (the negative effect of taxation or the positive effect of expenditure) but are in practice a gross simplification of reality.

The use of both halves of the budget constraint together modifies the results from Chapters 2 & 3 by highlighting the method of financing changes in expenditure. For example distortionary tax financed changes in productive expenditures have quite different effects on the growth rate from equivalent non-distortionary tax financed changes. The growth effects of certain combinations of fiscal policy now also vary with the size of government, being positive when the government is small, but negative when the size of the government is too large.

The inclusion of distortions from both halves of the budget also alters the behaviour of fiscal policy in the steady state and in turn modifies the assumptions necessary for endogenous growth. The level of productive expenditures now grows at a constant rate because of the use of distortionary taxation and therefore the assumption of 'AK' technology, used in chapters 2 & 3, can no longer be sustained in the one-sector model. Instead diminishing returns to capital are assumed and the neoclassical and endogenous growth models are distinguished through the steady state growth rates of productive expenditures and capital.[1] The appealing feature of these one-sector endogenous growth models is that fiscal policy provides the engine for growth. This is robust across a large range of characteristics of expenditures.[2]

The steady state growth of productive expenditures is more problematic in the two-sector model. As a consequence only one example of a two-sector model with productive government expenditures and distortionary taxation together exists currently in the literature. The problems arise when we have three reproducible factors of production (physical capital, human capital and public capital) yet require constant returns to scale to remain within a perfectly competitive framework. One solution is to assume that only two reproducible factors are used in any one production function (Capolupo (1996)); and a second yet untried method is to assume that productive expenditures are subject to congestion.

Section 4.2 describes fiscal policy in the one-sector model. The neoclassical and endogenous models share a common set up and are described together. The differences between the neoclassical and endogenous growth models can then be seen to again rest on fairly specific assumptions but this is now the elasticity parameter with respect to productive expenditures rather than that on physical capital. Section 4.3 describes the equivalent two-sector models highlighting the problems of endogenising the growth rate when fiscal policy is added to the model. Finally section 4.4 concludes.

[1] In Chapters 2 & 3 the neoclassical and endogenous growth models were distinguished by the assumption on the returns to capital.
[2] These two results perhaps also go a long way to explaining their popularity in the literature.

4.2 One-sector Public Policy Growth Models

4.2.1 The Barro Model

Examples of one-sector endogenous growth models that include both productive expenditures and distortionary taxation are relatively abundant in the literature because they have the appealing feature that fiscal policy provides the engine for growth. The model developed here therefore displays a close resemblance to much that already exists (Barro (1990), Barro & Sala-i-Martin (1992, 1995), Devarajan et al. (1996)). We add to it solely in our attempt to integrate several different examples of fiscal policy into a single model.

The general form of the model follows that of Romer (1986) (see Chapter 1), but where productive expenditures replace aggregate knowledge in the production function. The assumption of constant returns to capital ('AK' production) is no longer required for endogenous growth[3] but *constant returns scale* in capital and public goods are.[4] The endogenous and neoclassical growth models are differentiated in their results in part by this second assumption. There are no growth effects from fiscal policy in the neoclassical model because fiscal policy is incapable of providing the mechanism by which the marginal product of capital declines towards over time (the Inada conditions hold in full). The difference between fiscal policy in the neoclassical and endogenous growth models rests upon a 'knife-edge'.

The Model

The representative household maximises a CIES utility function identical to that discussed in Section 2.2 and repeated below as a reminder. The utility function includes both public and private consumption which are assumed to be perfect substitutes.[5]

[3] Indeed if it exists then the growth rate explodes towards infinity over time.
[4] Then is the steady growth rate of public goods is identical to that of capital.
[5] We do not allow a labour-leisure choice at this juncture.

Equation 4. 1
$$u = \int_0^\infty e^{-\rho t} \left(\frac{(c^{1-\zeta} G_C{}^{\zeta})^{1-\sigma}}{1-\sigma}\right) \delta t$$

Private production is a function of capital and two forms of productive government inputs, all of which are subject to diminishing marginal returns. Productive expenditures are assumed to directly affect private production as a flow of non-rival, non-excludable goods and to be produced under identical technology to the private sector. Barro (1990) describes this as the appropriation of a flow of private sector output by the government. The private production function is given by:

Equation 4. 2
$$Y = AK^{1-\alpha} G_{Y1}^{\beta} G_{Y2}^{\lambda}$$

The government budget is constrained to balance at every moment in time through the sum of taxation on consumption and income. The second crucial assumption is that in the steady state productive government expenditures are maintained as a constant ratio to output, equation (4.4). This implies that all increased tax revenues from a growing economy are used to finance further increases in productive expenditures.

Equation 4. 3
$$G_{Y1} + G_{Y2} + G_C = \tau_C C + \tau_Y Y$$

and,

Equation 4. 4
$$\frac{\dot{G}_{Y1}}{G_{Y1}} + \frac{\dot{G}_{Y2}}{G_{Y2}} = \frac{\dot{Y}}{Y}$$

Maximising in the usual way yields a growth path of consumption that bears most of the characteristics described in the previous chapters. Productive government expenditure have a positive effect on the growth rate through the marginal product of capital; while government consumption expenditures have no effect on the steady state growth rate. Income taxation reduces the returns to investment and therefore the steady state growth rate; whereas consumption taxation has no effect on the steady state path of consumption.

Equation 4. 5 $$\gamma_C = \frac{1}{\sigma}[(1-\alpha)(1-\tau_Y)A(\frac{1}{K})^{\alpha}(G_{Y1})^{\beta}(G_{Y2})^{\gamma} - \delta - \rho]$$

The steady state interest rate (and therefore the growth rate) is constant in equation (4.5) if the ratio of productive expenditures to capital, $[G_{Y1}, G_{Y2}]/K$, is constant[6] (that is if G and K grow at identical rates) and if the sum of the exponents on the two productive government expenditure equals α, that is $\beta + \gamma = \alpha$. Differentiating the production function with respect to time, $\frac{\dot{Y}}{Y} = (1-\alpha)\frac{\dot{K}}{K} + \beta\frac{\dot{G}_{Y1}}{G_{Y1}} + \gamma\frac{\dot{G}_{Y2}}{G_{Y2}}$, and using equation (4.4) implies that if $\beta + \gamma = \alpha$ then by simple substitution the steady state growth rate of output is equal to the growth of capital input, $\frac{\dot{Y}}{Y} = \frac{\dot{K}}{K}$. Output increases proportionally to increases in the capital stock and continual economies of scale lead to an ever-growing economy. The economy has no transitional dynamics and the growth rate equals that in equation (4.5).

In the neoclassical model equation (4.4) does not hold *and/or* $\beta + \gamma < \alpha$ (there are decreasing returns to scale) and the growth of capital is faster than the growth of public goods. Fiscal policy then has no effect on the long-run growth rate as public expenditures cannot prevent diminishing returns to capital.[7] Barro (1990) also demonstrates the importance of this 'knife-edge' assumption.

The steady state growth path in equation (4.5) and the government budget constraint, equation (4.3), generate a series of hypothese concerning government expenditures and the method by which they are financed (the results of which are summarised in Table 4.1). The rows indicate the fiscal variable that is increased and the column the compensating fiscal variable. For example *row 3/ column 2* (and *row 2/column 3*) indicates the effect on growth of changes to the tax mix of distortionary taxation and non-distortionary taxation; whereas *row2 / column 6* (and *row 6/column 2*) indicates

[6] Barro (1990) implicitly assumes the second by restricting the available policies to an income tax and a single form of productive expenditure.

the growth effects of distortionary tax financed increases in non-productive expenditure.

Table 4. 1: Summary of the Growth Effects from Combinations of Fiscal Policy in the Barro Endogenous Growth Model

	Distortionary taxation	**Non-distortionary taxation**	**Productive expenditure G_{Y1}**	**Productive expenditure G_{Y2}**	**Non-productive expenditure**
Distortionary taxation		-	+/0/-	+/0/-	-
Non-distortionary taxation	+		+	+	0
Productive expenditure G_{Y1}	+/0/-	+		+/0/-	+
Productive expenditure G_{Y2}	+/0/-	+	+/0/-		+
Non-productive expenditure	-	0	-	-	

The most obvious relationships from Table 4.1 concern those elements of fiscal policy which have benign growth effects (non-distortionary taxation and non-productive expenditure) as the results are the same when we ignored one half of the government budget in Chapter 2 & 3. For example an increase (decrease) of consumption expenditure financed by an increase (decrease) in non-distortionary taxation (consumption taxation) has no effect on the steady state growth rate. Alternatively, an increase (decrease) in government consumption expenditure financed by an increase (decrease) in income taxation then the steady state growth rate decreases (increases) relative to the growth rate with no change to fiscal policy. Finally non-distortionary tax financed increases (decreases) in productive government expenditures (*row 3 / column 4 or 5*) have positive growth effects.

Holding the revenues from taxation constant we can still affect the rate of growth in the model if we alter the mix of government expenditures. It can be clearly seen from equation (4.5) that an increase in either form of productive government expenditure compensated by a decrease in non-productive government expenditure (but leaving the size of government constant) has a positive effect on the rate of growth. The effect of the mix of productive government expenditure on the rate of growth

[7] This is not necessarily the same neoclassical model with public policy discussed by the likes of Peacock & Shaw (1971) and Musgrave (1959) but follows from that discussed in Chapter 2 & 3.

depends upon the *relative* productivity and the *relative* size of the productive expenditures (Devarajan et al. (1996)).

Changes to the growth rate can also be achieved through changes to the mix of taxation. The increased use of consumption taxation and decreased use of distortionary taxation (keeping total revenues constant) has a positive effect on the steady state rate of growth. Only income tax reduces the returns to investment in the model and therefore any shift away from income tax will increase the of growth.

Interesting growth effects result from changes to the level of productive government expenditures financed by distortionary taxation as the effect on growth now varies over the level of expenditure. The positive effects of increases in the level of productive expenditures on the growth rate are non-linear because of the assumption of diminishing marginal returns to productive expenditures. In contrast the effect of increases in the revenues from distortionary taxation are linear in their effect. Figure 4.1 (based on Barro (1990 - Fig.1)) demonstrates that at small sizes of government the positive effect is greater than the negative effects, but beyond the optimum point, at which $\alpha = \tau_Y = (G/Y)$, the negative effects of taxation outweigh the positive effects of expenditure.

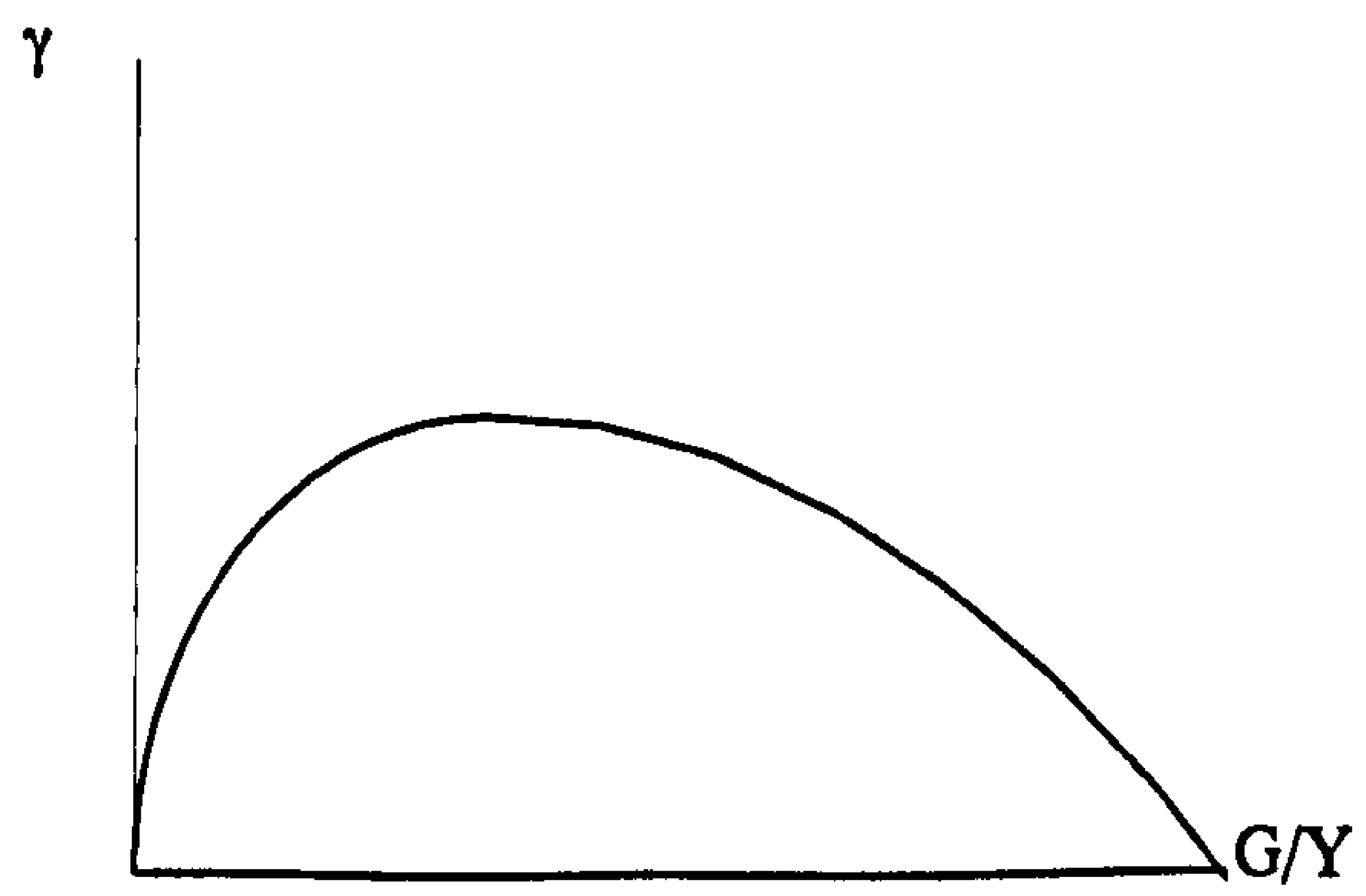


Figure 4.1: The Growth Effects of Distortionary Tax Financing of Productive Government Expenditures in the Barro Growth Model

4.2.2 *Congested Public Goods*

If public goods are subject to congestion then the above results are made redundant because equation (4.4) can no longer be made to hold. Instead the steady state behaviour of productive expenditures is given by (4.6). Fiscal policy can no longer be used to prevent diminishing marginal returns to capital driving the growth rate to zero. The congested public goods model is observationally equivalent to the neoclassical model and the steady state is independent of fiscal policy.

Equation 4. 6
$$\frac{\dot{G}_{Y1}}{G_{Y1}}+\frac{\dot{G}_{Y2}}{G_{Y2}}=\frac{\dot{\tau}}{\tau}=0$$

This result is however, sensitive to the assumptions made about technology. The congestion of public goods implies expenditures can no longer be used to prevent diminishing returns to capital over time. Therefore the only way to endogenise the growth rate is to remove the assumption of diminishing marginal returns. That is we assume there are constant returns to capital in the production function (Barro & Sala-i-Martin (1992)).[8] The results differ from the congested goods model discussed in Chapter 2 because the use of distortionary taxation results in a constant level of congestion in the steady state (as shown in equation (4.6)).

The set of conditions required for endogenous growth in the congested goods model changes to: i) there must be constant returns to capital in production *and*; *ii)* increased tax revenues from a growing economy are used to solely finance productive expenditures.[9]

Consumption growth in this model is given by:

Equation 4. 7
$$\gamma_C=\frac{1}{\sigma}[(1-\tau_Y)A(\tau_Y)^{\beta}-\delta-\rho]$$

The dual effect of fiscal policy is well demonstrated in equation (4.7) through the two tax terms. Increases in expenditure have a positive but diminishing marginal effect,

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[8] If the Barro (1990) model rests on the 'knife-edge' assumption that $\beta+\gamma=\alpha$ then the results for the congested goods model (Barro & Sala-i-Martin (1992)) rest on the 'knife-edge' that the exponent on the capital term equals one, $(1-\alpha)=1$. If $1-\alpha<1$ then there are no growth effects from fiscal policy, while if $1-\alpha>1$ then the growth rate explodes towards infinity over time. The results in the congested good case are independent of the exponent on the government expenditure term. That is we no longer require constant returns across physical capital and government expenditures.

[9] The parameter value on the expenditure term in the production function has no effect on the results.

$(\tau_Y)^{\beta} > 0$, and a linear negative effect, $(1 - \tau_Y) < 0$. If the condition of constant returns to capital is met then the same set of results for the non-congested public good case applies here (Table 4.1).

Changes to the characteristics of expenditure or the choice of distortionary taxation have no substantive impact on the results because the mathematical requirements for endogenous growth remain the same. Such modifications of the model are abundant in the literature and rather than report the results for various combinations of fiscal policy we refer the reader to the relevant sections of Chapters 2 & 3.

4.3 Two-sector Public Policy Growth Models

Only one example of a two-sector endogenous growth model that includes both productive government expenditures and distortionary taxation exists in the literature. This stems from the problem of constant returns to scale technology when three factors of production (physical capital, human capital and public capital) grow in the steady state.[10] One solution is to assume that only two of these three factors are used within the production function of any one-sector. For example in the Capolupo (1996) education model aggregate output is a function of physical and human capital, whereas the education sector uses human and public capital as inputs. This has the appealing feature that government policies provide the engine for growth but limits the types of expenditures that the model can be reasonably thought to reflect. Expenditures which affect the production of output, and which empirical work by the likes of Aschauer (1989) suggest are important, cannot then be modelled in a two-sector model.

A second possible solution (and one not yet discussed in the literature) is to assume that government expenditures are subject to congestion. If the level of congestion remains constant in the steady state then the growth rate is endogenised, but public

[10] The problem is how to achieve a constant steady state growth rate i.e. one that does not explode away over time.

policy does not provide the engine for growth.[11] This follows a similar approach to that adopted when public goods are congested in a one-sector model (Barro & Sala-i-Martin (1992)). The congested good model is discussed in Section 4.3.1 followed by the Capolupo model in Section 4.3.2.

4.3.1 Congested Public Goods

The production technology employed in the two-sectors of the economy is identical to that described in Chapter 2 (and repeated as equations (4.8) & (4.9) below). Both sectors of the economy exhibit constant returns to scale in physical and human capital inputs. For this reason physical and human capital grow at identical rates in the steady state. We assume that $\alpha \neq \eta$ so that physical and human capital are produced under different technologies. Expenditures are assumed to be productive as a flow of goods in each sector and for all public goods within any one sector to have equal marginal productivity. Public goods are subject to congestion and enter the production functions as a ratio to output, G_i/Y (i = 1,2).[12]

Equation 4. 8
$$Y = C + \dot{K} + \delta K = A\left(\frac{G_{Y1}}{Y}\right)^{\beta_1}(vK)^{\alpha}(uH)^{1-\alpha}$$

Equation 4. 9
$$\dot{H} + \delta H = B\left(\frac{G_{Y2}}{Y}\right)^{\beta_2}[(1-v)K]^{\eta}[(1-u)H]^{1-\eta}$$

Household utility is of an identical form to that described in equation (4.1) above.

Productive public goods, G_{Y1}/Y and G_{Y2}/Y, and consumption expenditure, G_C, are financed by taxing the output of the capital sector, the human capital sector or consumption.

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[11] The lack of discussion of public expenditures in two-sector endogenous growth models has much to do with this problem of using public goods as the engine for growth. In some ways this is surprising given that the two-sector tax models such as Rebelo (1990), Stokey & Rebelo (1995) etc. (discussed in Chapter 3) make exactly the same assumption as that used here, production technology is two-sector 'AK'.

[12] We do not discuss alternative measures of congestion (Glomm & Ravikumar (1994), Fisher & Turnovsky (1998)) although given that the measure we discuss is a representation of complete congestion the results should hold when the rate of congestion is only partial. The disadvantage of this assumption is that both sectors become congested at an identical rate.

Equation 4. 10

$$\frac{G_{Y11}}{Y}+\frac{G_{Y2}}{Y}+G_C=[\tau_{K1}r_{K1}vK+\tau_{W1}r_{w1}uH]+[\tau_{K2}r_{K2}(1-v)K+\tau_{W2}r_{W2}(1-u)H]+\tau_C C$$

We assume for simplicity that the rate of taxation on physical and human capital is identical in each sector, that is $\tau_{Ki}=\tau_{Hi}$ (i = 1,2) but $\tau_{Ki}\neq\tau_{Kj}$ (i ≠ j) and $\tau_{Hi}\neq\tau_{Hj}$ (i ≠ j). This is equivalent to a different income tax rate on each sector of the economy. Further to this we assume that in the steady state increases in tax revenues resulting from a growing economy fund further increases in productive expenditure.[13] The level of congestion of public goods then remains constant in the steady state. Taxation does not affect the optimal input ratios but it does affect the rate of return in the physical and human sectors. These conditions (equivalent in forms to equations (3.23)-(3.25) of Chapter 3) are given as:

Equation 4. 11
$$r=(1-\tau_{Y1})\alpha A\left(\frac{G_{1Y}}{Y}\right)^{\beta_1}\left(\frac{vK}{uH}\right)^{\alpha-1}-\delta$$

Equation 4. 12
$$r^{*}=(1-\tau_{Y2})(1-\eta)B\left(\frac{G_{Y2}}{Y}\right)^{\beta_2}\left(\frac{(1-v)K}{(1-u)H}\right)^{\eta}-\delta+\frac{\dot{q}}{q}$$

Equation 4. 13
$$\left(\frac{1-\alpha}{\alpha}\right)\left(\frac{1-u}{u}\right)=\left(\frac{1-\eta}{\eta}\right)\left(\frac{1-v}{v}\right)$$

In the steady state the ratio $[\frac{uH}{vK}]$ is constant because capital and human capital grow at identical rates and by assumption the congestion of public goods is constant. The interest rate in equations (4.11)-(4.12), and therefore the growth path of consumption (equation (4.14)), is also constant in the steady state. The model therefore behaves in much the same way as the two-sector tax models of Chapter 3 but there are now also positive effects on growth from public good expenditures as well as the negative effects from taxation. Both types of policy are equivalent to one-off shifts in the level of technology (parameters A and B).

[13] As in the one-sector model this assumption is crucial for the results.

Equation 4. 14
$$\gamma_C = \frac{1}{\sigma}[(1-\tau_{Y1})(\frac{G_{Y1}}{Y})^{\beta_1} A[\frac{uH}{vK}]^{1-\alpha} - \delta - \rho]$$

The results from the two-sector model (summarised in Table 4.2) remain much the same as those from the one-sector for the reason that government expenditures and taxation affect the private production process by identical means. The greater realism of the two-sector model comes at the price of a loss of clarity of the results. The greater the number of distortionary taxes and productive expenditures the more difficult it becomes to predict the effect on growth of changes in the mix of policy variables. However a number of the results carry through, if only in general. Most noticeable of these is the importance of the method of financing expenditures. The effect on growth of increases in non-productive expenditure financed by distortionary taxation (of either sector) is negative if distortionary tax financed but zero if non-distortionary financed. A change in the level of productive expenditures financed by distortionary taxation varies across the size of government, being positive when small and negative when large.

Table 4. 2: Summary of the Growth Effects from Combinations of Fiscal Policy in a Two-Sector Endogenous Growth Model

	Production sector taxation	Human capital sector taxation	Non-distortionary taxation	Productive expenditure G_{Y1}	Productive expenditure G_{Y2}	Non-productive expenditure
production sector taxation		+/0/-	-	+/0/-	+/0/-	-
Human capital sector taxation	+/0/-		-	+/0/-	+/0/-	-
Non-distortionary taxation	+	+		+	+	0
Productive expenditure G_{Y1}	+/0/-	+/0/-	+		+/0/-	+
Productive expenditure G_{Y2}	+/0/-	+/0/-	+	+/0/-		+
Non-productive expenditure	-	-	0	-	-	

The two-sector model provides much scope to extend the role of fiscal policy in the determination of the growth rate but the results are in general non-robust to changes in the assumptions. The effects on the results are mostly confined to the tax variables (discussed in Chapter 3) although there are spillover effects on expenditures through the budget constraint. Changes to the assumptions regarding the technology of the human capital sector and the tax treatment of the human capital sector result in either no forms of taxation having an effect on the growth rate (the results of the model are then identical to the expenditure two-sector model of Chapter 2) or only human capital taxation having negative growth effects (see Chapter 3 for the details), whereas allowing elastic labour supply (elasticity values greater than zero) will introduce distortionary growth effects from consumption taxation. The predictions made about the growth effects of changes in the tax mix as well as changes in policy across the budget constraint will then be altered. The results from such a model are summarised in Table 4.3. The effect on growth of consumption tax financed increases in non-productive expenditures would be negative, but increases in productive expenditures vary across the range of government size. The growth effects of the tax mix will then depend in part on a number of parameters in the model, one of which is the rate of taxation. Mendoza et al. (1997) argue that consumption taxation is likely to be less distortionary than factor income taxation although this is in part based on the empirical results in that paper. On the expenditure side alternative measures of congestion (Glomm & Ravikumar (1994), Fisher & Turnovsky (1998)) can be incorporated into the model, as long as the assumption that the degree of congestion remains constant in the steady state holds, although this change has no real effect on the results.

Table 4. 3: Summary of the Growth Effects from Combinations of Fiscal Policy in the Mendoza et al. (1997) Two-sector Tax Model

	Production sector taxation	Human capital sector taxation	Consumption taxation	Productive expenditure G_{Y1}	Productive expenditure G_{Y2}	Non-productive expenditure
Production sector taxation		+/0/-	+/0/-	+/0/-	+/0/-	-
Human capital sector taxation	+/0/-		+/0/-	+/0/-	+/0/-	-
Consumption taxation	+/0/-	+/0/-		+/0/-	+/0/-	-
Productive expenditure G_{Y1}	+/0/-	+/0/-	+/0/-		+/0/-	+
Productive expenditure G_{Y2}	+/0/-	+/0/-	+/0/-	+/0/-		+
Non-productive expenditure	-	-	-	-	-	

4.3.2 Education Model

Capolupo (1996) limits the role of public policy to the accumulation of human capital. The production of private goods uses physical and human capital as inputs, whereas human capital production uses human capital and public goods as inputs. The production functions are given by:

Equation 4. 15 $$Y = AK^{\alpha}(uH)^{1-\alpha}$$

Equation 4. 16 $$\dot{H} = BG_{Y2}{}^{\beta}[(1-u)H]^{1-\beta}$$

We assume government expenditures (of which there is only the one type) are funded by a tax on capital (that is on the quantity of capital rather than on the returns to capital). This change has no effect on the basic results and is done in order to stay true to the original paper.

Equation 4. 17 $$G_{Y2} = \tau K$$

The household side of the model is equivalent to that in equation (4.1) above, and maximising in the usual way yields the following growth path for consumption,

Equation 4. 18 $$\gamma_C = \frac{1}{\sigma}[A[\frac{uH}{K}]^{1-\alpha} - \delta - \tau - \rho].$$

Despite the difference between this and the two-sector described above in general the results remain the same except for the fact that productive expenditures provide the engine for growth in the model. In the steady state the growth rate of human capital depends positively on increases in government expenditure (because of the increased productivity of the human capital input),[14] whereas the accumulation of physical

[14] Equation (20) is constant in the steady state because the ratio of G/H is constant. Differentiating (17) with respect to time yields $\frac{\dot{G}_{Y2}}{G_{Y2}} = \frac{\dot{K}}{K}$, demonstrates that equation (4.18) is constant if the ratio of K/H is constant which it is in the steady state.

capital depends negatively on increases in government expenditure because of the need to finance expenditures through a distortionary tax on the quantity of capital.

4.4 Conclusions

The presence of distortions from both halves of the government budget alters both the results and the structure of endogenous growth models. The growth effects of expenditure policy depend on the method of financing as well as the direction of expenditure (towards either the consumption or production sectors). Increases in non-productive expenditure have a negative effect on growth when distortionary tax financed yet no effect when non-distortionary tax financed. In contrast increases in productive expenditure have positive effects on growth when non-distortionary tax financed but their effect varies with the size of government when distortionary tax financed.

On the modelling side, increases in the steady state level of productive expenditure, because of their financing by distortionary taxation, imply that the assumption of constant returns to capital, used in Chapters 2 & 3, is then no longer sustainable. Instead diminishing marginal returns to capital (as in the neoclassical model of Chapter 1) are assumed. The returns to capital no longer distinguish between the results for the endogenous and neoclassical growth models and instead the models are characterised by *i)* a restriction on the substitutability of capital and public goods in the production function; and *ii)* that increases in the revenues from distortionary taxation are used to finance increases in productive forms of expenditure in the steady state. Public goods provide the engine for growth in these models which helps to explain their popularity in the literature. The exception is once again when public goods are subject to congestion. If the level of congestion remains constant in the steady state then the growth rate can be endogenised if we return to the use of 'AK' technology.[15]

[15] The growth rate is then endogenised only through the second assumption that increased tax revenues finance increases in productive expenditures.

The simplicity of the one-sector model does not however carry over to the two-sector model. Problems of three reproducible factors in constant returns to scale production functions require that either: one factor of production is removed from each production function (Capolupo (1996)); or public goods is subject to congestion (Section 4.3.1). The second model can be seen to be an extension of the one-sector congested public good model and public goods no longer provide the engine for growth. The general results for fiscal policy do carry over to both of these models if either of the above assumptions hold, but are non-robust to changes in the assumptions of the model.

Figure 4.2 highlights the necessary assumptions for growth effects from fiscal policy in the one and two-sector models (indicated by the symbol '√'). Figure 4.2 does not provide information as to which fiscal variables actually have an effect on growth; a summary of these can be found in Figure 2.5 in Chapter 2 and Figures 3.4 and 3.5 in Chapter 3. A 'X' symbol indicates under what assumptions fiscal policy is ineffective.

By implicitly ignoring the budget constraint from the analysis in Chapters 2 and 3 by assuming that one half of the budget has a benign effect on growth greatly simplifies the way in which the models can be tested. The results from chapter 2 carry across to this chapter if funded solely non-distorting (consumption) taxation; and the results for taxation from Chapter 3 follow if funded solely by non-productive expenditures. Distortionary tax financed increases in productive expenditure are positive when the size of government is small, but beyond some optimal point further increases in productive expenditure are negative (Barro (1990)). This may prove to be a problem when forming hypotheses to test in the empirical section of this thesis.

The tractability of the results from the one-sector model is lost we allow for multiple forms of productive expenditures and taxation in the two-sector model. This is not aided by the sensitivity of the results to changes in the assumptions of production technology and the elasticity of labour supply. Chapters 2 and 3 provide examples of the different results that can be achieved through varying the assumptions of the model but also highlight the difficulty these more detailed models have in providing a set of testable hypotheses.

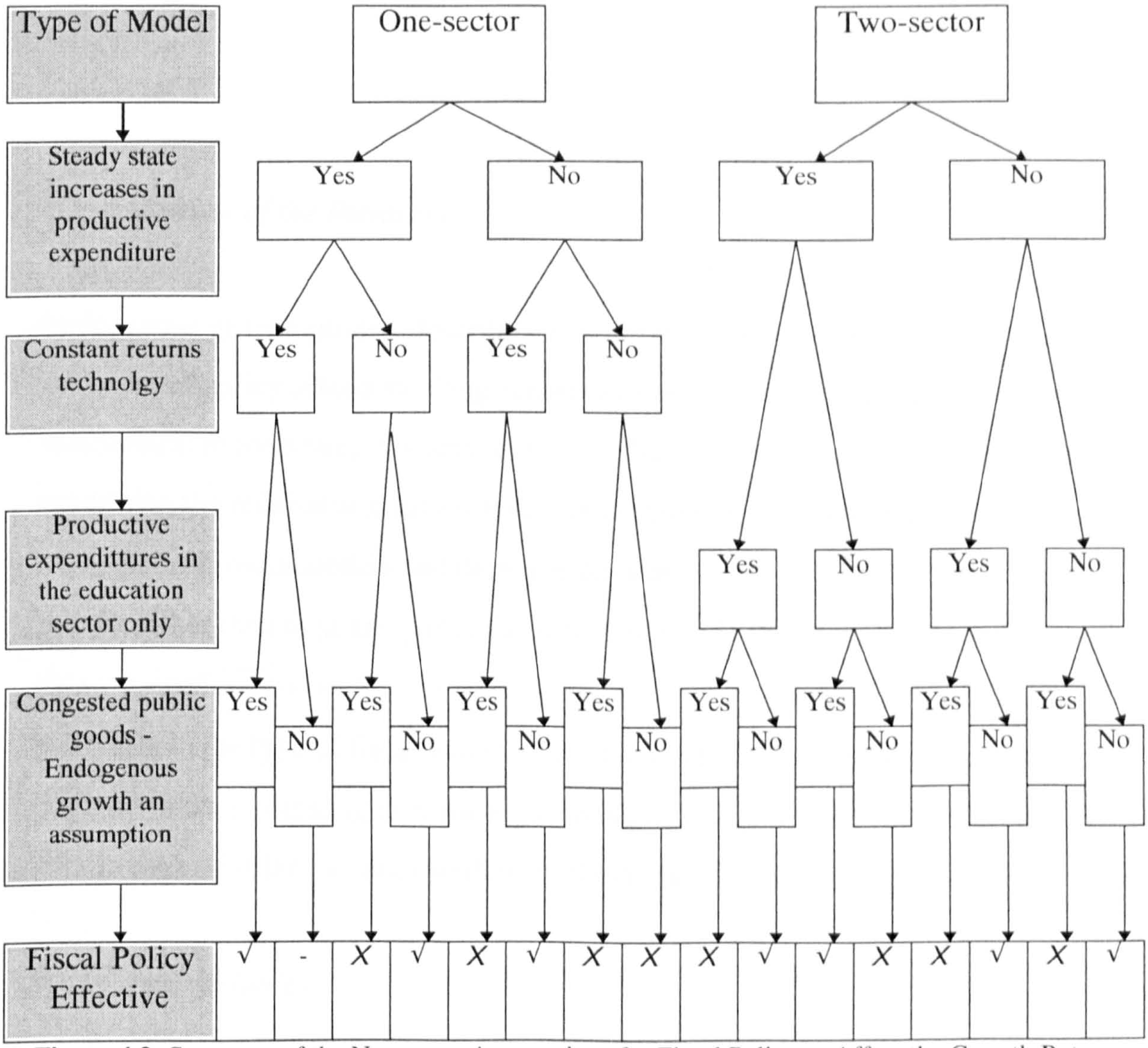

Figure 4.2: Summary of the Necessary Assumptions for Fiscal Policy to Affect the Growth Rate

Chapter 5

Review of the Empirical Literature

5.1 Review of the literature

Endogenous growth models describe a number of possible channels by which government policy affects the long run growth rate of a country; whereas the neoclassical models suggests only short run effects. Much of the empirical literature examining the relationship between economic growth and fiscal policy pre-dates the endogenous growth models and therefore tests are of the general determinants of growth rather then with any particular model in mind. These studies vary in terms of data set, econometric technique and quality and so we organise them initially according to the type of fiscal variables included within the regression equation. This is useful in demonstrating how the sign and significance of the estimated coefficients alter even on similar variables within similarly specified regressions.

5.1.1 Tax Variables

Table 5.1 below displays the findings from previous works that have included tax variables within a growth regression. These studies are not strictly comparable in terms of measurement of the tax variables (some measures can be thought of as reflecting average rather than marginal tax rates) but despite this, one strong conclusion which emerges is the consistent estimation of strong negative growth effects surrounding income taxation. This result appears to be robust across data set and econometric method. Of the other forms of taxation the results are mixed and if anything the weight of the evidence appears to suggest that these forms of taxation do not have significant effects on the growth rate.

Author	Countries	years	econometric method	length of average	main results
Marsden (1983)	10 pairs of matched GDP	1970s	pair comparisons		low tax countries grew quicker than high tax countries
Koester, Kormendi (1987)	63	1970-79	cross-section	10-years	marginal tax and average tax rates have no significant negative effect
Skinner (1987)	African countries		cross-section		income, corporation and import taxes are significant and negative. Export and sales taxes insignificant
Engen, Skinner (1992)	107	1970-85	cross-section	16 years	taxes have significant and negative effects in short and long-run
Dowrick (1993)	OECD	1960-85	cross-section	26 years	income taxes significant negative. Corporation taxes not significant
Easterly, Rebelo (1993)	100	1970-88	cross-section	19 years	income taxes significant and negative, others types of taxation non-robust
Cashin (1995)	23 OECD	1971-88	panel	5-years	total taxation significant negative
Mendoza, Milesi-Ferretti, Asea (1997)	18 OECD	1965-91	panel	annual, 5-year	effective capital, consumption and labour tax rates are insignificant in 5-year averages, non-robustly significant in annual data regressions
Kocherlakota & Yi (1997)	US, UK	US 1891-1991, UK 1831-1991	time-series	annual (10 lags)	tax measures insignificant individually, significant when put with public capital term
Agell, Lindh & Ohlsson (1997)	22 OECD	1970-90	cross-section	21 years	total tax revenue insignificant
Folster & Henrekson (1997)	22 OECD	1970-95	panel	5-years	total tax revenue significant negative
Fuente (1997)	21 OECD	1965-95	panel	5-years	total tax revenue significant negative

Table 5. 1:Review of the Empirical Relationship Between Taxation and Growth

5.1.2 Government Expenditures

Consumption Expenditure

Our review of the literature for expenditure variables proceeds by separating expenditures into three different types; total and government consumption expenditure; social welfare expenditure; and public investment expenditure (in both aggregated and disaggregated forms). Tables summarising the findings of these three classifications of expenditure can be found below.

The results for government consumption expenditure are symptomatic of the general findings from the growth literature. In some studies, Ram (1986) and Romer (1989a, b, 1990), *positive* coefficients are estimated; in others, Kormendi & Meguire (1985), no significant growth effects are found; whereas Landau (1983, 1986), Grier & Tullock (1989), Alexander (1990) and Barro (1991) all find strong *negative* correlation's.

Author	Countries	years	econometric method	length of average	main results
Landau (1983)	104	1961-76	cross-section	16 years	government consumption expenditure has a significant negative effect
Kormendi, Meguire (1985)	47		cross-section	28 years	government consumption expenditure has a no significant effect
Ram (1986)	115	1960-80	cross-section, time series	10	size of government produces significant positive coefficients
Landau (1986)	LDCs		cross-section		government consumption expenditure has a significant negative effect
Grier, Tullock (1989)	115	1950-81	panel data	5-years	government consumption expenditure has a significant negative effect
Romer (1989a)	94	1960-85	cross-section	16 years	government consumption expenditure has a significant positive effect
Romer (1989b)	112	1960-85	cross-section	16 years	government consumption expenditure has a significant positive effect
Romer (1990)	90	1960-85	cross-section	16 years	government consumption expenditure has a significant positive effect
Alexander (1990)	13 OECD	1959-84	panel	annual	government consumption expenditure has a significant negative effect
Barro (1991)	98	1960-85	cross-section	16 years	government consumption expenditure has a significant negative effect
Devarajan, Swaroop & Zou (1996)	21 OECD	1970-90	panel	5-year moving average	consumption expenditure
Mendoza, Milesi-Ferreti & Asea (1997)	18 OECD	1965-91	panel	annual, 5-year	government consumption expenditure insignificant
Agell, Lindh & Ohlsson (1997)	22 OECD	1970-90	cross-section	21 years	total expenditures insignificant
Folster & Henrekson (1997)	22 OECD	1970-95	panel	5-years	total expenditures significant negative
Fuente (1997)	21 OECD	1965-95	panel	5-years	total expenditures significant negative, government consumption expenditure insignificant

Table 5. 2: Review of the Empirical Relationship Between Government Consumption Expenditure and Growth

Transfer Payments / Welfare Expenditure

This same pattern of inconsistent results is repeated for studies that include transfer payments. McCallum & Blais (1987), Castles & Dowrick (1990), Sala-i-Martin (1992), Cashin (1995) and Nazimi & Ramirez (1997) estimate a *positive* relationship; Landau (1983, 1985) and Hanson & Henrekson (1994) estimate there to be no statistically significant relationship; while Korpi (1985), Weede (1986, 1991), Nordstrum (1992) and Persson & Tabellini (1994) all find significant *negative* growth effects from government welfare programmes.

Author	**Countries**	**years**	**econometric method**	**length of average**	**main results**
Korpi (1985)	OECD	1970-87	panel	18 years	transfer payment expenditure has a significant positive effect
Landau (1985)	16 OECD	1952-76	panel/ cross-section	annual	transfer payment expenditure has no significant effect
Weede (1986)	19 OECD	1960-82	panel/ cross-section	7-years	transfer payment expenditure has a significant negative effect
McCallum, Blais (1987)	17 OECD	1960-83	panel/ cross-section	7-years	transfer payment expenditure has a significant positive effect
Castles, Dowrick (1990)	18 OECD	1960-85	panel	6 years	transfer payment expenditure has a significant positive effect
Weede (1991)	19 OECD	1960-85	panel	7-years	transfer payment expenditure has a significant negative effect
Nordstrum (1992)	14 OECD	1970-89	cross-section	20 years	transfer payment expenditure has a significant negative effect
Sala-i-Martin (1992)	75		cross-section		transfer payment expenditure has a significant positive effect
Persson, Tabellini (1994)	14 OECD	1960-85	cross-section	16 years	transfer payment expenditure has a significant negative effect
Hanson, Henrekson (1994)	OECD	1970-87	cross-section	18 years	transfer payment expenditure has no significant effect
Cashin (1995)	23 OECD	1971-88	panel	5-years	transfer payment expenditure has a significant positive effect
Fuente (1997)	21 OECD	1965-95	panel	5-years	transfers insignificant
Nazimi, Ramirez (1997)	Mexico	1950-90	time-series	annual	transfer payment expenditure has a significant positive effect

Table 5. 3: Review of the Empirical Relationship Between Social Security and Welfare Payments and Growth

Public Investment

In contrast to the expenditures reviewed above there does seem to be some pattern from the studies that have included public investment variables within a growth regression. Where significant coefficients have been estimated these are usually confined to transport & communication expenditure (see for example Barro (1989, 1991), Easterly & Rebelo (1993) and Devarajan et al. (1996)). Total public investment and disaggregated forms of investment (which have included education, health and defence) typically has no significant relationship with growth (see for example Bath & Bradley (1987), Barro (1991), Landau (1986) and Easterly & Rebelo (1993))

Author	Countries	years	econometric method	length of average	main results
Landau (1986)	LDCs				education, defence, capital expenditure insignificant
Bath, Bradley (1987)	16 OECD	1971-83	cross-section	13 years	total public investment insignificant
Barro (1989)	72	1960-85	cross-section	16 years	total investment significant
Barro (1991)	98	1960-85	cross-section	16 years	transport & communication significant, total public investment insignificant
Easterly, Rebelo (1993)	100	1970-88	cross-section	19 years	transport & communication significant, total investment, education, health insignificant
Devarajan, Swaroop, Zou (1996)	14 developed countries	1970-1990	panel	5-year moving average	health, transport & communication significant positive, defence, education significant negative. Total capital expenditure significant positive
Kocherlakota & Yi (1997)	US, UK	US 1891-1991 UK 1831-1991	time-series	annual, (10 lags)	public investment insignificant when included individually, significant when included with tax variables
Fuente (1997)	21 OECD	1965-95	panel	5-years	public investment significant positive

Table 5. 4: Review of the Empirical Relationship Between Public Investment and Growth

5.2 Non-robustness

From this review it appears that only two consistent relationships between fiscal policy and growth emerge from the literature; government expenditures on transport & communication infrastructure has a positive effect on growth and; income taxation (no matter how measured) has a negative relationship with the growth rate of a country. This conclusion can however, be criticised on the grounds that the studies reviewed account with varying degrees of success for the statistical problems of estimating growth regressions (Folster & Henrekson (1997)). Collinearity and simultaneity between the regressors along with omitted variable bias and heterogeneity of the parameter estimates can lead to a bias in the parameter estimates and a false set of conclusions being drawn. In this section we review these statistical problems, the potential biases they introduce along with methods for dealing with them.[1] We then re-review the empirical literature.

5.2.1 Multicollinearity

Multicollinearity is the approximate linear relationship between combinations of the independent variables in the regression equation. This is a problem in growth regressions as collinearity amongst the regressors can, from small changes in the set of regressors, bring about large variation in the parameter estimates. Variables then appear to be inconsistent and of little value in finding the determinants of growth.

Although not always explicitly tested for, a number of studies provide evidence that multicollinearity is a problem in growth regressions. The suggestion of collinearity between fiscal variables and the 'other regressors' can be found in the studies by both Levine & Renelt (1992) and Sala-i-Martin (1997).[2] Levine & Renelt (1992) test the robustness of a broad range of variables, some of which are fiscal variables, using error bound analysis (EBA). Robustness in this sense is the consistent sign and significance of a variable under alternative sets of conditioning variables.[3] The fiscal variables included in the study cover a broad range of consumption and investment expenditures in both aggregated and disaggregated forms, along with various types

[1] We do not review all possible problems with the above studies preferring to concentrate on a small number of main issues. From this list we ignore some potentially important reasons such as the poor nature of the proxies used, for example those for taxation (Temple (1998)). However we prefer to take issue with this sort of issue in the empirical section of the thesis.
[2] Although perversely the Levine & Renelt study has itself been criticised for including collinear combinations of regressors in the set of conditioning variables (Temple (1998)).
[3] That is, upper and lower values of the coefficient that cannot be rejected at the 5% level of significance. For a more formal description see the original text.

of, and methods for measuring, taxes. Using data for a cross-section of 119 countries from 1974-89, Levine & Renelt discover that fiscal variables are non-robust to changes in the set of conditioning variables, and enter the regression with the predicted signs only when investment is included. However, the same fiscal variables are not significantly correlated with investment themselves.

Sala-i-Martin (1997) criticises the EBA approach of Levine & Renelt (1992) for being too strong and therefore guaranteed to reject robustness for almost all variables.[4] Sala-i-Martin (1997) instead tests for robustness by calculating the cumulative distribution function of the variable. That is, the number of regressions in which the variable is statistically significant. The regression equations are estimated for a fixed set of conditioning variables (the same ones as Levine & Renelt) and combinations of 3 of the remaining variables.[5] The program is run initially with private investment not included among the set of conditioning variables, and then for a second time with private investment included. Despite the change of approach from EBA, of the four fiscal variables studied none can be 'confidently' described as affecting growth when private investment is not included, and only public investment can be when private investment is included.[6] From this Sala-i-Martin suggests fiscal policies represent 'symptoms' of the true determinants of growth (such as social structures) rather than having any direct effect themselves.

Evidence of multicollinearity can also be found between categories of fiscal policy. Easterly & Rebelo (1993) consider the relationship between a broad range of fiscal variables and growth for 100 countries over the period 1970-88[7]. They find that fiscal variables are non-robust to the inclusion of other fiscal variables within the same regression equation. They find only investment in transport & communication and the budget surplus emerge are robustly correlated with growth.

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[4] A variable needs to change sign or significance only once for it to become 'non-robust' under the EBA approach. Durlauf & Quah (1998) provide a more formal explanation for this.

[5] Sala-i-Martin estimates combinations of three because the typical regression equation is said to have about seven explanatory variables (4 are taken up with the conditioning variables).

[6] Public investment, public consumption expenditure and defence expenditure are not far outside this limit of 'confidence' in the first set of regressions and this remains so for defence and consumption when investment is included.

There is no standard method for dealing with suspected collinearity in the literature and so often it is dealt with by dropping one of the suspected collinear variables from the regression.[8] This is acceptable if the true coefficient on the omitted variable is zero, but if the true coefficient is statistically significant then this will lead to a different bias because a relevant variable has been omitted. We review the effects of the omission of relevant variables below.

5.2.2 Simultaneity

The results from Levine & Renelt (1992) and Sala-i-Martin (1997) can be used to indicate possible simultaneity amongst the regressors as well as multicollinearity. OLS estimation assumes that all of the right hand side variables are exogenous (for example fiscal policy cause growth but growth does not cause fiscal policy). Yet, possible endogeneity between growth and fiscal policy has long been identified in the literature. Hsieh & Lai (1994) using a VAR approach on annual data for 7 OECD countries from 1885-1987 find in 3 out of the 7 countries under study (Germany, Italy and the US) causality runs from growth *to* government consumption expenditure but not back.[9] While Conte & Darrat (1988) who, using a larger sample (22 OECD countries) but over a shorter time period (1960-84), find that in 9[10] of the 22 countries there is evidence that growth Granger causes total government outlays (and borders significance for 3 more[11]). A failure to account for endogeneity leads to inconsistent estimates of the parameters as the regressors are not independent of the error term.

The most likely sources of endogeneity between fiscal policy and growth are the business cycle and Wagner's law. Certain categories of expenditure, such as welfare payments, and most types of taxation are likely to be correlated with the business

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[7] In practice the sample size for any particular regression is much smaller because of missing information form many countries.
[8] For additional options see Kennedy (1992).
[9] In Canada, UK and Japan causality is found to run in the opposite direction.
[10] These are Finland, Iceland, Ireland, Italy, Japan, Luxembourg, Portugal Switzerland and the UK.
[11] These 3 countries are Denmark, Netherlands and the US.

cycle. On the expenditure side as growth slows over the cycle welfare expenditures increase as an 'automatic stabiliser' on aggregate demand. While tax revenues will rise and fall with the level of demand in the economy. The usual procedure for dealing with the effects of the business cycle is to use a combination of period averaging and expressing fiscal variables as a ratio to GDP. If taxes are proportional and move pro-cyclically with GDP then expressing fiscal variables as a ratio to GDP will eliminate the effects of the business cycle from the data.[12] If taxes are only approximately linear then expressing the tax revenues as a ratio will work only imperfectly. This method will not work for social security expenditure however, and indeed will exacerbate the business cycle effect in the data as social-security expenditure is likely to move counter-cyclically with growth. As a consequence some form of period averaging is usually also employed on the data to smooth the business cycle. Although various lengths of average have been used the consensus appears to be for using 5-year periods (although no justification is given for this over alternatives).

Wagner's law is the idea that certain categories of expenditure have an elasticity of demand that is greater than one. Therefore, as national income rises so does the expenditure on these goods. Evidence for Wagner's law is however, generally weak. Easterly & Rebelo (1993) find only health and social security expenditures to have risen with income whereas expenditures on education, transport & communication and general public services have fallen as income increases. Easterly & Rebelo also find that this relationship disappears at the highest levels of income in their sample. Aschauer (1990) argues against the slowdown in growth as an explanation for declining expenditures on investment capital by governments by pointing out that these expenditures peaked some 5 to 8 years before the usual dating of the productivity decline in 1973. Sundrum (1990) provides a very comprehensive review of this literature and concludes that the appearance of a relationship has more to do with the changing role of the nation state rather Wagner's law. Instead, Sundrum argues that a stronger correlation appears between government tax revenues and income because revenues increase with income and the tax structure does not change

[12] Fiorito (1997) indeed finds tax revenues to vary pro-cyclically with growth over the business cycle

greatly over time. Easterly & Rebelo (1993) too find strong correlations between tax revenues and GDP.

The problem of Wagner's law would suggest that only comparing studies which include both rich and poor countries will lead to misleading conclusions and instead concentration should be made on studies which have used a sample of rich countries. In addition Folster & Henrekson (1997) argue against using data averaged over long period of time as this is more likely to increase possible simultaneity if not from Wagner's law then from demographic variables.[13] For example, rising incomes have been associated with longer life-expectancy. Longer life-expectancy is in turn likely to lead to more payments on social welfare for the elderly. Faster income growth then is likely to be simultaneously determined with social security expenditure.[14]

The final method for dealing with simultaneity amongst the regressors commonly used is estimation by instrumental variables. The variables that are believed to be endogenous are regressed on a series of 'instrumenting' variables. These instruments are (in theory at least) correlated with the regressors of interest but not the error term. These yield predicted values, which are then substituted into the first regressions hence removing the potential endogeneity. Problems with this technique revolve around the choice of instruments and what the resulting regressions mean (Mankiw (1995)).

5.2.3 Omitted Variables

A further problem with estimating growth regressions is that we have little idea as to what the relevant variables to be included in the regression equation are. The omission of relevant variables from the regression equation leads to a bias in the

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for a sample of G-7 countries.

[13] This may also form an additional argument against using cross-section estimation techniques in which data are typically averaged over fairly long time periods.

[14] Easterly & Rebelo (1993) also find strong correlations between population size and fiscal variables. Capital spending, transport & communication, agriculture and general public services all fall as population size increases whereas defence expenditure rises. However, when they try to instrument for fiscal variables using the measures of scale they find to be correlated with fiscal variables they found the significant coefficients they estimated in previous regressions now become insignificant.

estimation of the remaining parameters; whereas the inclusion of irrelevant variables reduces the efficiency of the estimates. If we follow the empirical literature as a whole we might conclude that 'everything matters' for growth, whereas if we follow Levine & Renelt (1992) and include only 'robust' regressors we would conclude that only initial GDP and the investment ratio should be included. In turn economic theory adds little to our ability to limit the number of proposed regressors. The neoclassical model concludes only unobservable technological change and some structural parameters such as the rate of time preference matter for growth, whereas in endogenous growth models 'everything matters'.[15]

As means of limiting the number regressors estimation has typically been through a Barro-type regression equation. In the Barro regression growth is regressed on a matrix of conditioning variables, which includes the robust determinants of growth, and a set of 'other variables', which are the variables under test. The set of conditioning variables is suggested by both theory and previous empirical evidence as important determinants of growth and is generally fairly consistent across studies.[16]

Evidence of statistical bias introduced by the omission of relevant fiscal variables is identified by Miller & Russek (1993) through the inclusion of the entire government budget constraint in the regression equation. They develop a methodology first proposed by Helms (1985) and Mofidi & Stone (1990) and show that the sign and significance of fiscal variables depends upon which fiscal variables are included in the regression and, as importantly, which variables are left out.[17] Interestingly, in unrelated studies Kocherlakota & Yi (1996) and Kocherlakota & Yi (1997) note the importance of including both tax and expenditure terms in the regression equation.

[15] This description of the endogenous growth models is not strictly true but there is scope in the models for a theorist to make 'anything matter'.
[16] These regressions have the disadvantage that they can be criticised as not being derived from a theoretical framework (i.e. Mankiw, Romer & Weil (1992)) and therefore cannot be used to test between models. Given the previous empirical literature has demonstrated no consistent relationships from which to build formal models we suggest at this point in time that the lack of restrictions placed on the model may be an advantage.
[17] Miller & Russek (1993) use a constraint with 15 categories of fiscal variable. Within that, significant effects from changing the specification of the constraint changes the sign and/or

The omission of country and time specific effects from the regression equation can also be dealt with by estimating using panel data techniques. Panel data estimators allow us to account for unobservable variables such as the level of technology that may be correlated with other explanatory variables. Country and time specific effects can be assumed to be either fixed or random. We review the advantages and disadvantages of these two approaches in Appendix B.

5.2.4 Parameter Heterogeneity

The final statistical problem we review arises from the heterogeneity in the parameter estimates across countries. Estimation by OLS assumes that each country in the sample can be described as coming from a 'common surface'. That is, the true parameters of the model should be homogeneous across the countries contained within the sample. Evidence of heterogeneity can be found within the empirical literature, but more pointedly also within growth theory itself. The Barro (1990) model suggests that the relationship between growth and productive forms of expenditure is quadratic over the range of government size when financed by distortionary taxation (see Chapter 4 Section 4.2 for an explanation). The estimated parameter may then vary between positive and negative amongst the countries within the sample. Further evidence of heterogeneity can be found from the empirical literature. Levine & Renelt (1991), Durlauf & Johnson (1995) and Durlauf & Quah (1998) all conclude that parameter heterogeneity is a problem in growth regressions. None of the tests they propose have been used in the studies reviewed here but some general evidence can be found. Atkinson (1995), in a review of the empirical relationship between social welfare payments and growth, notes the sensitivity of the estimated parameters to the in(ex)clusion of Japan from the sample. When Japan is included in the sample of countries there is an increased chance that the estimated relationship between welfare payments and growth will be negative. Many of the suggestions to account for heterogeneity, such as stochastic parameter estimation, regression trees and robust estimation (Temple (1998)), require a length of data set

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coefficient on all variables except income, profit and capital gains taxation, social security tax, greater than that available at present. Instead possible heterogeneity is reduced by restricting the sample to a single country or more commonly to a small number of similar countries, such as the OECD.

5.3 Re-review of the literature

The statistical problems involved in the estimation of growth regressions suggest that when attempting to determine the strength of the empirical relationship between growth and fiscal policy we should concentrate only on those studies that adequately account for them (Folster & Henrekson (1997)). Concentrating on studies that use a sample of developed nations should reduce problems of collinearity along with parameter heterogeneity and simultaneity and estimate by panel data to reduce bias from omitted variable and heterogeneity across the intercept terms may also improve the consistency of the results. In addition we further restrict the sample of studies to those in which the data has been averaged across time to remove possible simultaneity from business cycle effects (but not too long in case of simultaneity from Wagner's law). Finally the study must be aware of collinearity with other fiscal variables and have used instrumental variable estimation to at least check the stability of the results. Once this is done we are left with five studies, Miller & Russek (1993), Cashin (1995), Devarajan et al. (1996), Mendoza et al. (1997) and Fuente (1997). From these we choose to ignore the Miller & Russek (1993) study because of potential endogeneity bias from the use of annual data, along with the Devarajan et al. (1996) study because of the likely collinearity between total expenditures and the sub-categories of expenditure included in the same regression. There is little acknowledgement of possible collinearity between types of fiscal variables in either the Mendoza et al. (1997) study or the Cashin (1995) study, but as the results appear reasonably robust we choose to include them.

Differences in the set of conditioning variables may account for some of the variation in the results between studies if fiscal policies have indirect effects on growth, such as on the decision to invest in physical capital. Cashin (1995) and Mendoza et al.

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taxation of international trade and expenditure on transport & communication.

(1997) include a measure of human capital but not physical capital investment amongst their set of conditioning variables; while Fuente (1997) omits and then includes both human capital and private capital investment together in the regression. Mendoza et al. only include investment in human capital in the regression when instrumenting for investment. All studies include a measure of initial GDP to capture conditional convergence to which Mendoza et al. (1997) add a measure of terms of trade, whereas Fuente (1997) adds demographic variables (such as the labour force participation rate, unemployment and the growth of population).

Taxation in the Mendoza et al. (1996) study is effective taxation and calculated[18] as the ratio of total tax revenue from each element, (e.g. total consumption taxation), to the value of the taxed element, (e.g. pre-tax value of consumption) for 18 OECD countries and for the time span 1965-91. They argue that these measures more accurately reflect the ad valorem taxes used in the growth literature. Of the three types of tax ratio they calculate (consumption taxation, capital income tax and labour income tax) none enters the regression with a significant effect on growth.

In contrast, Cashin (1995), for a sample of 23 OECD countries from 1971-88, using total tax revenues as a ratio to GDP estimates this measure of the tax burden to have a significant negative effect on growth. This result from Cashin matches similar ones in Fuente (1997) for a sample of 19 OECD when government consumption expenditure is excluded from the regression but not when it is included. The difference in the estimated effect of taxation between the Mendoza et al. study and the other two is surprising given that it could be argued that the effective tax rates they estimate more accurately reflect the marginal rate of tax. One would expect, if accurately measured, marginal tax rates to produce stronger correlations with growth than the tax burden. At first appearances this difference may be thought to be due to the inclusion of investment in the Fuente study, for as Levine & Renelt (1992) conclude the inclusion of private investment is crucial for estimating sensible fiscal parameters in studies of growth. However, an additional explanation offers itself. Comparing Mendoza et al. and Fuente when both private capital investment and

[18] These estimates follow a methodology designed by Mendoza, Razin & Tesar (1994).

human capital are included in the same regression shows that taxation remains statistically insignificant in the Mendoza et al. study but, significant in Fuente only when government consumption expenditure is excluded from the regression. Government consumption expenditure is included in the set of conditioning variables by Mendoza et al. This suggests that it is not the inclusion of investment but collinearity of taxation with government consumption expenditure that drives the differences between the results.

Comparing the results for the other fiscal variables one finds government consumption expenditure is consistently estimated as having an insignificant effect on growth in the Mendoza et al. regressions but, insignificant in the Fuente regressions *only* if either total government expenditures or total tax revenues are included in the same regression.

Cashin estimates that social security expenditure and public investment have positive effects on growth. This is repeated in the Fuente study but again, only if particular combinations of taxation and expenditure terms are included in the same regression.

We can conclude from this improved review that once many of the statistical issues are accounted for there are ***no*** consistent relationships between fiscal policy and growth in the literature. Even when studies are matched as closely as possible in terms of data set, specification of the regression equation and econometric technique inconsistencies still arise. Nor does this appear to be due to differences in the measurement of the fiscal variables (notably those for taxation). When the regressions are specified in a similar way, results generally match, but where specification differs so do the results.

The lack of consistent relationship between fiscal policy and growth can then, only be explained through a failure to account for additional factors from the statistical issues reviewed above. One possible source of additional factors is economic theory. We identify four conclusions from the review made of the theoretical literature in Chapter 2 to 4 that might help explain non-robustness and in turn be used to shape the empirical analysis. These four conclusions constitute the four empirical chapters of this thesis and we review them very briefly here as way of an introduction.

5.4 *Theoretical Issues*

Within the review of the empirical literature we noted the non-robustness of taxation variables to the inclusion or exclusion of government consumption expenditure from the regression. However, variation of the parameter estimates can also be thought to be consistent with the predictions from models of economic growth. For example the effect on growth of an increase in productive expenditures depends on the method of financing. If financed by non-distortionary taxation then the effect is unambiguously positive; whereas if financed by distortionary taxation the effect may vary between positive (at small sizes of government) to negative (when the size of government is large). Thus far the empirical literature has failed to tie these two branches of the literature together. We build on the work of Miller & Russek (1993) who demonstrate that parameter estimates on fiscal variables depend on specification of the government budget constraint. That is, the direction of the omitted variable bias depends upon which fiscal variables are included and excluded from the regression.

A second issue is the distinction between the short run and long run information contained within the data. Growth models are distinguished by their implications for long run growth. The predictions do not hold if the economy is in transition from one steady state to another because of changes to one or more parameters (Kocherlakota & Yi (1997)). Standard practice in the literature has been to use five, ten or even longer period-averages to remove business cycle effects from the data, yet the relative benefits and costs of doing so have not been established.[19]

A third issue is the level of aggregation of the data. Growth theory suggests fiscal variables should be categorised into productive and non-productive types according

[19] Hsieh & Lai (1994) find exactly this when investigating the impulse response functions of their estimated VAR equations. They find that in the first few time periods in some countries the effect on growth of a change in government consumption expenditure is negative, but this becomes positive after longer time periods. They do not equate the long run effect on the growth rate of this change.

to their inclusion in the demand or the supply side of the model. Even at this simple level the theory does not predict anything about the likely coefficients on total expenditures or total tax revenues sometimes included within regressions. Further to this it can be demonstrated that there are possible significant growth effects from changes in the mix of productive expenditures within the model (Devarajan et al. (1996)). The merits of assuming homogeneity across parameter estimates in the theoretical model has not been satisfactorily demonstrated and requires empirical testing. Too much aggregation risks widening the confidence intervals of different coefficients when they should be characterised by different coefficients. While too much disaggregation risks losing the signal in the noise as individual fiscal categories constitute a smaller percentage of GDP.

A final explanation for non-robustness is the direct versus the indirect effects of fiscal policy. In growth models fiscal policy simultaneously determines both growth and investment. For example distortionary taxes reduce the returns to investment and hence the steady state rate of growth. The empirical relationship between fiscal policy and growth is weak. Levine & Renelt (1992) note the importance of the inclusion of investment in the regression equation but can find no evidence of a correlation between fiscal policy and investment. A better understanding of the relationship between fiscal policy and investment may therefore aid our understanding of the statistical relationship between fiscal policy and growth.

Chapter 6

Growth and the Government Budget Constraint

6.1 Introduction

As we have seen in earlier chapters, endogenous growth theory predicts that some elements of government expenditures and taxation affect the steady-state growth rate whereas others do not. Forms of taxation that lower the returns to investment, (such as income taxation), reduce the steady-state growth rate; whereas increases to forms of expenditure that aid the private productive process, (such as investment in transport and communication), increase the growth rate. There are also forms of taxation, (such as lump-sum and consumption taxation), and forms of expenditure, (such as transfer payments and welfare expenditure) which have no affect on the steady-state rate of growth. These predictions have not generally been supported by empirical research to date. We provide evidence however that, once implicit financing of an element of the government budget constraint is taken into account, there is consistent empirical support for the Barro model.

The implication of research by Levine & Renelt (1992) and Easterly & Rebelo (1993) and the varied results obtained by other researchers is that fiscal variables are not statistically robust determinants of long-run growth rates. This conclusion is premature, because it ignores the role of the government budget constraint. The government budget constraint implies that we cannot interpret the coefficients on fiscal variables within growth regressions without reference to the other fiscal variables in the model.

Once the effect of the government budget constraint is allowed for in the regression, the apparent lack of statistical robustness is in fact consistent with the theory rather than a genuine lack of robustness. The empirical results produced here are highly consistent with the simple public policy endogenous growth model of Barro (1990). The results and the model both imply that an alteration in the revenue stance away from distortionary forms of taxation and towards the use of non-distortionary forms of taxation has a growth-enhancing effect. Whereas an alteration in the expenditure stance away from productive forms of expenditure and towards non-productive forms of expenditure is growth-retarding. Non-distortionary tax-financed increases in productive expenditures have a significant positive impact upon the growth rate, whereas with distortionary-tax financing the growth effect is insignificant. Finally, distortionary tax-financed increases in non-productive expenditures have a significant negative growth effect, whereas the effect is insignificant if financed through increases to non-distortionary taxation. These results are found to be robust to some, but not all, changes in the specification of the data and regression.

The next section provides a brief review of the existing empirical literature. This summarises the empirical findings from Chapter 5 and then discusses the implications of the government budget constraint (Helms (1985), Mofidi & Stone (1990) and Miller & Russek (1993)). A brief review of the theoretical literature is made in Section *6.2.2* and the empirical results are discussed in Section *6.3*. A series of tests for the robustness of the results is reported in Section *6.4*. Finally, the empirical results are compared to the theoretical literature in Section *6.5* and *6.6* concludes.

6.2 Literature Review

6.2.1 Existing Empirical Evidence

As shown in Chapter 5 the results for similar fiscal variables can vary across studies irrespective of the data set or econometric technique employed. Part of this failing can be explained through the statistical problems of estimating growth regressions. Levine & Renelt (1992) and Sala-i-Martin (1997) provide evidence of non-robustness with respect to the set of conditioning variables and initial conditions. While Easterly & Rebelo (1993) and Miller & Russek (1993) demonstrate how the results are sensitive to the inclusion and exclusion of other fiscal variables. Miller & Russek (1993) find that the results change systematically by varying the specification of the budget constraint. However, even if one accounts for these statistical problems still no consistent picture as to the relationship between fiscal policy and growth emerges.

6.2.2 The Government Budget Constraint

The issue of how a change in a given tax or expenditure variable is financed was first addressed by Helms (1985) and Mofidi & Stone (1990) in an analysis of growth in different states of the US. Miller & Russek (1993) developed this idea and applied it in a panel study of annual data to 39 countries from 1975-84. Miller & Russek found that the growth effects of expenditures depend crucially upon the way in which they are financed. In general their results suggest that changes in expenditure financed by taxation produce insignificant growth effects (except for education expenditure). Negative growth effects, where they occurred, tended to be associated with changes in the mix of expenditures, or reductions in taxation, financed by an increase in the budget surplus.

The theory of the government budget constraint is relatively straightforward. The principal underlying assumption is that growth is a function of fiscal variables from both sides of the government budget. In equation (6.1) growth, g, in country i at time t is a function of conditioning (non-fiscal) variables found to be robustly correlated with growth from previous studies, $\beta_i Y_{it}$, and a vector of fiscal variables, $\gamma_i X_{it}$.

Equation 6. 1

$$g_{it} = \alpha + \sum_{i=1}^{k} \beta_i Y_{it} + \sum_{j=1}^{m} \gamma_j X_{jt} + u_{it}$$

Assuming that all elements of the budget (including the surplus/deficit) are included, so that $\sum_{j=1}^{m} X_{jt} = 0$, then because the government budget constraint is a linear constraint one element of X must be omitted from the regression to avoid perfect multicollinearity. The omitted variable is effectively the assumed compensating element within the constraint. Thus the coefficient on each individual category must be interpreted as the effect of a unit change in that variable offset by a unit change in the omitted category. Changing the omitted category alters the estimated coefficients of the individual categories. For example, assume for simplicity that the government budget constraint is made up of the two expenditure variables defence expenditure (*edf*) and non-defence (*end*) and the two tax variables[1] income taxation (*tin*) and consumption taxation (*tco*) and that these are included in our generally specified growth regression.

Equation 6. 2

$$g_{iy} = \ldots\ldots {}_1 edf_t +\, {}_2 end_t +\, {}_3 tin_t +\, {}_4 tco_t + \ldots\ldots\ldots$$

Since *edf* + *end* = *tin* + *tco*, we may write edf as [*tin* + *tco* - *end*].

Equation 6. 3

$$g_{it} = \ldots\ldots \gamma_1 [tin + tco - end]_t + \gamma_2 end_t + \gamma_3 tin_t + \gamma_4 tco_t + \ldots\ldots\ldots$$

Collecting terms and simplifying leads to,

Equation 6. 4

$$\begin{aligned} g_{it} &= \ldots\ldots \phi_1 end_t + \phi_2 tin_t + \phi_3 tco_t + \ldots\ldots\ldots \\ \phi_1 &= \gamma_2 - \gamma_1 \\ \phi_2 &= \gamma_1 + \gamma_3 \\ \phi_3 &= \gamma_1 + \gamma_4 \end{aligned}$$

If however, we chose to use end_t as the compensating fiscal variable, the regression equation in (6.1) would be altered to read,

Equation 6. 5

$$\begin{aligned} g_{it} &= \ldots\ldots \mu_1 edf_t + \mu_2 tin_t + \mu_3 tco_t + \ldots\ldots\ldots \\ \mu_1 &= \gamma_1 - \gamma_2 \\ \mu_2 &= \gamma_2 + \gamma_3 \\ \mu_3 &= \gamma_2 + \gamma_4 \end{aligned}$$

The estimated coefficients on the tin_t and tco_t variables therefore depend crucially on the compensating expenditure variable chosen. We cannot make the prior assumption that $\phi_2 = \mu_2$ or $\phi_3 = \mu_3$ without formally applying the correct hypothesis tests to the

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[1] We assume for simplicity here that the government is constrained to fully finance its budget at every moment in time and as such there is no budget surplus/deficit term.

estimated coefficients. Previous interpretations of fiscal parameters have typically been based on inappropriate tests (although often implicitly so in the sense that fewer than (m-1) elements of the budget constraint appear in the regression). In economic terms this implies an assumption that all tax revenues are returned to households as non-productive forms of expenditure (i.e. any form of expenditure does not have an effect on the rate of growth), and all forms of expenditure are financed by non-distorting forms of taxation (or indeed any form of taxation that does not affect the rate of growth). Within the above examples this would be assuming that the coefficients on the two expenditure terms, edf_t and end_t, from equation (6.4) and (6.5) equal zero ($\gamma_1 = \gamma_2 = 0$), then $\gamma_3 = \phi_2 = \mu_2$, and $\gamma_4 = \phi_3 = \mu_3$. That is the growth effects of income tax financed increases in defence expenditure has an identical growth effect to an income tax financed increase in non-defence expenditure; and a consumption tax financed increase in non-defence expenditure is identical in its effect on the rate of growth to a consumption tax financed increase in defence expenditure. This is clearly a strong assumption and one that requires formal testing.

It is also clear from the above that the coefficients on fiscal variables in the previous empirical literature cannot be interpreted as estimating the direct effects of a single fiscal variable on the rate of growth (i.e. they are estimating μ's and ϕ's rather then γ's). This in turn implies that the interpretation of the coefficients depends on the precise specification of the government budget constraint used. The range of the results noted in the review of the empirical literature above might therefore be explained through the omission of different compensating fiscal variables from the regressions.

A further part of the dispersion of the results could be explained from omitted variable bias caused by the inappropriate exclusion of relevant explanatory fiscal variables. With *m* elements of the government budget constraint, we have seen that only *(m-1)* elements can be included in the regression to avoid multicollinearity. If, as has been frequently the case in practice, fewer than *(m-1)* elements are included, then the estimated coefficients will reflect some kind of weighted average of financing by each of the omitted elements.

To avoid this problem, we estimate a complete matrix of results which maps coefficient estimates of each element of the government budget constraint against each method of financing.[2] The matrix indicates the estimated growth impact of the tax mix, the expenditure mix and the size of government. Table 6.1 shows an example of the type of fiscal matrix produced from each set of regressions. Each column of the matrix indicates the fiscal variable excluded from the regression and each row the fiscal variables that remained within the regression. The tables are split into four quadrants.[3] Working first from top left (the first quadrant), this shows the effects of changes to the *government revenue mix*, that is increases (decreases) to one type of revenue whilst leaving the government budget in balance through decreasing (increasing) an alternative source of government revenue. Quadrant 3 shows the growth effects of the *expenditure mix*, that is increases (decreases) to one form of expenditure whilst leaving the government budget in balance through changes to an alternative expenditure. Quadrants 2 and 4 show changes across the government budget, that is changes to the *size of government*.[4] When the estimated coefficients are significantly different from zero (at a minimum of the 10% level of significance) the coefficients are indicated as bold symbols (the significance level is indicated by asterisks), insignificant variables are represented as fainter symbols. It is also possible to use the government budget constraint methodology to exclude irrelevant fiscal variables from the regression equation. We include an example of this amongst the regression results but choose not to follow the results up any further.

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[2] This is essentially the development made by Miller & Russek (1993) on the work of Helms (1985) and Mofidi & Stone (1990). Helms (1985) and Mofidi & Stone (1990) exclude only transfer payments from the regression (without formally testing that it has a zero coefficient).

[3] The budget surplus is not included in the table because we use it to balance the budget after period averaging. More of this is made below.

[4] The consistency of the regression matrix can be tested for by comparing the results from each quadrant along the central diagonal. For the tax and expenditure mixes to be considered consistent a negative (positive) coefficient of the left-hand triangle of either quadrant 1 or 3 must be matched by a positive (negative) coefficient in the corresponding position in the right-hand triangle of the quadrant. For example an increase in consumption financed by a decrease in income taxation has a significant positive effect upon the rate of growth then in order to be considered consistent an increase in income taxation financed by a decrease in consumption taxation must have a significant negative coefficient. Coefficients in quadrant 2 must have identical signs to the corresponding position in quadrant 4 in order to be considered consistent. That is in both quadrants an income tax financed increase in defence expenditure must have identical signs.

Table 6. 1: Example Fiscal Matrix

		Omitted Fiscal Variable	
		Tax Variable	**Expenditure Variable**
Included Fiscal Variable	**Tax Variable**	Tax Mix	Size of Government
	Expenditure Variable	Size of Government	Expenditure Mix

This chapter uses a sample of 22 developed countries for the period 1970-94 in order to examine the sensitivity of the coefficients on fiscal variables to the specification of the government budget constraint. The data come from two sources. The government budget data come from the GFSY, the standard source for these sorts of studies, while the remaining data comes from the World Bank Tables. Data sources and characteristics are discussed in Appendix A.

6.2.3 The Theoretical Predictions

One of the aims of this study is to demonstrate how the sign and significance switching of fiscal variables can be consistent with much of the existing theoretical literature. In order to do this we briefly review the results from the theoretical models concentrating on the new public policy endogenous growth models.

As we saw in Chapters 2 to 4 the public-policy neoclassical growth models, such as those by Chamley (1986) and Judd (1985), consign the role of fiscal policy to one of determining the level of output rather than the long-run growth rate. The steady-state growth rate is driven by the exogenous factors of population growth and technological progress, while fiscal policy can affect only the transition path to this steady-state. In contrast to these neoclassical models the public-policy endogenous growth models of Barro (1990) and Barro & Sala-i-Martin (1992, 1995) provide a mechanism for fiscal policy to determine both the level of output and the steady-state growth rate. The existence of public goods within the private consumption function produces constant returns to the accumulation of capital and hence constant growth rates.[5] A constant growth rate allows the temporary growth effects of fiscal policy within the neoclassical model to become permanent in the endogenous growth model.

Predictions from the one-sector public-policy endogenous growth model are derived by classifying taxes and expenditures into one of four categories: distortionary or non-distortionary taxation and productive or non-productive expenditures. Distortionary taxes affect the investment decisions of agents creating tax wedges and hence distorting the steady-state rate of growth. Non-distortionary taxation does not affect the saving/investment decisions of agents because of the assumed nature of the preference function and hence has no effect on the rate of growth. Government expenditures are differentiated according to whether they are included as arguments into the private production function or not. If they are, then they are classified as productive and hence have a direct effect upon the rate of growth. If they are not then they are classified as unproductive expenditures and do not affect the steady-state rate of growth.

Several papers have extended the Barro (1990) and Barro & Sala-i-Martin (1992, 1995) analysis. Glomm & Ravikumar (1994, 1997) assume that government-provided goods are productive in stock rather than flow form,[6] which introduces transitional dynamics into the model. Mendoza et al. (1996) consider different types of taxation, while Devarajan et al. (1996) consider multiple forms of productive expenditure in the same model.[7] The models have also been extended to a second sector by assuming that human capital is produced under an alternative technology. These models have predominantly concentrated on the tax side of the government budget (Rebelo (1991), Stokey & Rebelo (1995)) rather than the expenditure side of the model (Capolupo (1996)). The results from these models are less robust to

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[5] Public goods are accumulated within the model as the economy grows preventing diminishing marginal returns to capital returning the growth rate to that of the exogenous factors.

[6] We attempt to account for this difference in the Sensitivity tests of Section 6.4

[7] We consider the effect of relaxing the assumption of homogeneity of productive expenditures in Chapter 8.

changes in the underlying assumptions.[8] Despite this the results are still essentially driven according to whether expenditures are included within the production function or whether taxation affects the reproducible inputs in the production function.

6.3 Empirical Investigation

The regression equation we estimate in this study follows a similar form to that in equation (6.1) above. The constant set of conditioning variables, the method of averaging the data to remove the effects of the business cycle, and the estimation procedure are taken from standard practice within the literature in order to ensure that our results do not derive from deviations from normal procedure. The conditioning variables we use are typical of those found in the usual of the Barro-type regression. In order to avoid the inclusion of irrelevant variables and possible collinearity with the fiscal variables we restrict their number compared to previous studies. Given the sample of countries, it is unlikely that the political instability measures usually included in the 'Barro' conditioning matrix are relevant, and are therefore omitted. In addition the possible correlation between measures of human capital and education expenditures, (which will be present in some form in the X matrix), along with that between measures of macroeconomic instability and fiscal policy recommends us to exclude these measures also from the regression.[9] The set of conditioning variables was thus reduced to the investment ratio, *(inv)*[10], the labour force growth rate, *(lbfg)*, and initial GDP, *(GDP70)*.[11] Data for growth rates are taken from the World Bank

[8] For example through the introduction of a labour-leisure choice consumption taxation, which is non-distortionary in the one-sector models, becomes distortionary through its effect on the accumulation of human capital. We may then only be able to distinguish between taxes which are less distortionary using the methodology of the budget constraint

[9] The exclusion of the human capital variable is the more troublesome omission given several of the theories we review on Chapters 1-4 suggest a relationship between human capital and growth. An attempt was made to include human capital measures from the Nehru et al. (1995) data set. In the resulting regression human capital (measured as secondary or a combination of all levels of education) entered with an in-significant coefficient (and also negative), the initial GDP variable was rendered insignificant and the investment ratio negative (but insignificant). Of the fiscal variables the main relationships do not appear to alter, although there does seem to be some evidence that non-productive expenditures has a positive effect on the growth rate. This issue clearly requires further investigation with alternative measures of human capital.

[10] The private investment ratio, from Chapter 9, was also used but the results did not differ from those for the aggregate investment ratio.

[11] Initial GDP refers to the initial value of GDP for each sub-period.

CD ROM and measured as the log difference of GDP per capita across yearly periods (for further details see Appendix A).

The results from the Barro (1990) model are dependent upon by the classification of fiscal variables as one of four types. In accordance with this we aggregate the GFSY functional classifications of the fiscal variables into these four categories. This process is described in Table 6.2 below. We classify consumption taxation as a form of non-distortionary taxation. This is consistent with the theoretical predictions of the one-sector model but not all of the versions of the two-sector model reviewed in Chapter 3. Under such circumstances this form of taxation would be better thought of as reflecting *less-distortionary* forms of taxation.

Several of the functional classifications in the GFSY have no theoretical counterpart and are relegated to the 'other expenditure' and 'other revenue' terms[12]. The final fiscal variable is the government budget surplus. We test for the sensitivity of the results to this classification of the data in section 6.4. These aggregated fiscal variables were then expressed as percentage ratios of GDP in order to minimise the effect of the business cycle on tax revenues.

Data is available for 22 OECD countries[13] for the period 1970 to 1994. The sample is limited to OECD countries partly by data availability and partly as an attempt to minimise statistical problems such as heterogeneity across the estimated parameters. In order to remove the effects of the business cycle from the data and Wagner's law we follow standard practice and average the data across time. The common standard

[12] The GFSY includes an expenditure category entitled 'lending minus repayments' which can take either negative or positive values. In order to overcome problems of how to classify this variable it was decided to include this item as a separate variable within the regressions but not to discuss it. It appears under the variable name *elmr* in the results.

[13] These are Austria, Australia, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, UK and US.

is 5-year averages, and this is the length we chose here[14] (the first time period beginning in 1970).[15]

Table 6. 2: Functional/Theoretical Classifications

New Classification	Functional Classification
distortionary taxation *(rdis)*	taxation on income and profit social security contributions taxation on payroll and manpower taxation on property
non-distortionary taxation *(rndis)*	taxation on domestic goods and services
other revenues *(roth)*	taxation on international trade non-tax revenues other tax revenues
productive expenditures *(eprd)*	general public services expenditure defence expenditure educational expenditure health expenditure housing expenditure transport and communication expenditure
unproductive expenditures *(enprd)*	social security and welfare expenditure expenditure on recreation expenditure on economic services
other expenditure *(eoth)*	other expenditure

[14] The issue of how to best to capture long-run growth rate under different econometric techniques is discussed within the next chapter.
[15] At least three years of data for a country were required within a specific time period before the period was used.

In order to maintain equality across the government budget constraint after period averaging, it was necessary to classify one of the 7 available fiscal variables as the balancing item. Two methods were used for this: the first was to balance the budget through the surplus term and the second through the 'other expenditure' and 'other revenue' terms.[16] The empirical results suggest there was no difference between the two methods and only those where the surplus term is the balancing item are discussed. Although the surplus variable itself is reported, it is omitted from the discussion of the results because it is likely to contain a certain amount of statistical error.

Estimation is by panel data rather than the cross-section approach more commonly used in the literature. Panel data has the advantage of accounting for unobserved country and time specific effects, such as the level of technology and its growth over time, and therefore correct for omitted variable bias. For further information on the techniques used we refer the reader to Appendix B. The estimation package LIMDEP calculates 5 different forms of panel data estimator for each regression. These are pooled OLS regression, one-way (country dummies) fixed (by OLS) and random (by GLS) and two-way (country and time effects) fixed and random effects models. It is clearly not feasible to discuss individually the results from all of these models, nor to present them all within an appendix. We discuss briefly the relevant diagnostics that lead to the choice of model but these diagnostics are not presented within the text. LIMDEP provides information regarding the log-likelihood and the adjusted R^2 for the pooled OLS and the fixed effects models (both one-way and two-way error models). We prefer the model with the higher log-likelihood (absolute) value and higher adjusted R^2.[17]

The two-way form of the regression equation receives greatest support from the diagnostics and this is the one on which we focus. In both cases it has the highest adjusted R^2 and highest log-likelihood value. The Hausman test accepts the

[16] The new surplus variable was calculated as the sum of the averaged revenue terms minus the averaged expenditure terms. The new 'other revenue' variable was calculated as the sum of the averaged total revenues minus the sum of the averaged sub categories of revenue excluding other revenues. The 'other expenditure' variable was calculated in a similar manner.

alternative hypothesis of correlation amongst the individual effects and the regressors and so the random effects models are not reported (details of this test can be found in Appendix B). We estimate the regression equation initially, including only the conditioning variables and; then including fiscal variables either singularly or in pairs. These regressions represent those commonly found within previous studies. The results are displayed in Table 6.3.[18]

Table 6. 3: Estimation with an Incomplete Budget Constraint

Estimation Technique	5-year aves, 2 way FE					
Dependent variable	per capita growth			n= 98 (22 countries)		
	1	2	3	4	5	6
initial GDP x 10^{-3}	**-0.467*** (0.20)	**-0.501*** (0.18)	**-0.576*** (0.18)	**-0.389*** (0.19)	**-0.386*** (0.18)	**-0.395*** (0.17)
inv	0.069 (0.07)	-0.027 (0.06)	0.007 (0.06)	0.064 (0.06)	-0.024 (0.06)	-0.029 (0.06)
lbfg	-0.535 (0.34)	-0.522 (0.31)	-0.342 (0.31)	-0.363 (0.33)	-0.522 (0.31)	-0.379 (0.30)
elmr	-	0.150 (0.18)	0.280 (0.18)	-	-	-
roth	-	-	-0.055 (0.10)	-	-	-
eoth	-	0.025 (0.09)	-	-	-	-0.02 (0.08)
sur	-	**0.165**** (0.09)	**0.269*** (0.07)	-	-	-
rdis	-	-	**-0.260*** (0.08)	**-0.245*** (0.08)	-	-0.133 (0.09)
rndis	-	-	0.222 (0.14)	-	-	**0.303*** (0.14)
eprd	-	-0.009 (0.09)	-	-	-	-
enprd	-	**-0.229*** (0.08)	-	-	**-0.301*** (0.07)	**-0.286*** (0.07)
adj R^2	0.453	0.572	0.591	0.512	0.571	0.598

Notes: 1) standard errors in parenthesis.
2) * denotes significance at the 5% level, ** at the 10% level.

When the list of regressors is limited to just the conditioning variables only the initial GDP term enters with a significant coefficient. Such a finding is consistent with the idea of conditional convergence of income levels amongst the sample countries over the period. Neither of the other two conditioning variables, the investment ratio[19] and

[17] Only the value of the adjusted R^2 is presented in the results tables.
[18] Within the results tables throughout this text the large bold figures represent significant variables, the small faint figures non-significance.
[19] The finding of a negative coefficient on the investment ratio in the static regression is troublesome. However, Mendoza et al. (1996) estimate a similar coefficient also using a static panel approach with 5-yearly averaged data. We tested further the robustness of this result to the use of the private

the labour force growth rate, are statistically significant, whereas both the time and country dummies are collectively significant. This suggests that the set of conditioning variables is not complete, and that the complete variation of growth rates across time and space is not being fully captured by the regression equation. One obvious missing conditioning variable is the accumulation of human capital over time (or indeed the fiscal variables). We do not account for this here because the available proxies for human capital are likely to be highly correlated with government expenditures on education.

By including different combinations of fiscal variables on a fairly ad hoc basis we are able to recreate many of the typical findings of growth regressions. This would also suggest that our variables reflect reasonably well the fiscal variables used in previous studies, despite the new classifications of the data. For example, distortionary taxation *(rdis)* and non-productive expenditure *(enprd)* are consistently estimated as having a significant negative effect on growth. These represent two of the most common findings in the literature (for example Barro (1991) or Fuente (1997)).

This result is robust in all except regressions (6), where the addition of the non-productive expenditure term to the regression renders the distortionary tax term in-significant. This supports a conjecture made in Chapter 5 that the different results for taxation found in the Fuente (1997) and the Mendoza et al. (1997) studies are conditional upon the inclusion or exclusion of non-productive expenditure in the regression. This we believe provides strong evidence that the omission of relevant fiscal variables leads to a bias in the remaining fiscal variables through the budget constraint.

The results from Table 6.3 can be contrasted with those found in Table 6.4 where the government budget constraint has been accounted for in estimation. The specification of the government budget constraint does appear to be important for the estimated effect of fiscal variables on growth as expected. The sign and the significance on the

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investment variable calculated in Chapter 9 and found no change. Drawing upon work presented further below leads us to believe that this is a result is a consequence of the econometric methodology used.

theoretical classifications of the data can be seen to depend crucially upon which compensating fiscal variable is omitted from the regression. For example the significance of the distortionary tax term is lost when productive forms of expenditure are removed from the regression; whereas non-distortionary taxation term is insignificant only when non-productive expenditure is the compensating item. This variation in sign and significance has interesting implications for policy. For example, our results suggest that raising productive expenditures *(eprd)* as a ratio to GDP by one percentage point raises the growth rate by 0.29 of a percentage point if financed by non-distortionary taxation *(rndis)*, by 0.25 of a percentage point if financed by reductions in non-productive expenditure and *lowers* growth by 0.16 of a percentage point if financed by distortionary taxation. Although possibly large in magnitude these estimates are consistent with those found in Miller & Russek (1993), Wang & Yip (1992) and Folster & Henrekson (1997).

Table 6. 4: Estimation with Complete Specification of the Budget Constraint

Estimation Technique			5-year aves, 2 way FE		
Dependent variable			per capita growth	n= 98 (22 countries)	
	Omitted Fiscal Variable				
	rdis	**rndis**	**eprd**	**enprd**	**enprd/rndis**
initial GDP x 10^{-3}	**-0.490*** **(0.2)**	**-0.490*** **(0.2)**	**-0.490*** **(0.2)**	**-0.490*** **(0.2)**	**0.483*** **(0.17)**
inv	-0.020 (0.06)	-0.020 (0.06)	-0.020 (0.06)	-0.020 (0.06)	0.020 (0.06)
lbfg	-0.327 (0.30)	-0.327 (0.30)	-0.327 (0.30)	-0.327 (0.30)	-0.336 (0.29)
elmr	-0.030 (0.19)	**0.417**** **(0.23)**	0.127 (0.20)	**0.380*** **(0.18)**	**0.384*** **(0.18)**
roth	**0.293*** **(0.13)**	-0.154 (0.19)	0.136 (0.15)	-0.117 (0.10)	-0.118 (0.10)
eoth	-0.131 (0.10)	**0.315** **(0.16)**	00025 (0.11)	**0.279*** **(0.11)**	**0.289*** **(0.11)**
sur	0.0006 (0.10)	**0.446*** **(0.16)**	0.156 (0.10)	**0.410*** **(0.09)**	**0.416*** **(0.08)**
rdis		**-0.446*** **(0.17)**	-0.156 (0.10)	**-0.410*** **(0.10)**	**-0.410*** **(0.09)**
rndis	**0.446*** **(0.17)**		**0.290**** **(0.14)**	0.037 (0.16)	
eprd	-0.156 (0.10)	**0.290**** **(0.14)**		**0.253**** **(0.13)**	**0.268*** **(0.11)**
enprd	**-0.410*** **(0.10)**	0.037 (0.16)	**-0.253**** **(0.13)**		
adj R^2	**0.602**	**0.602**	**0.602**	**0.602**	**0.621**

Notes: 1) standard errors in parenthesis.
2) * denotes significance at the 5% level, ** at the 10% level.

When we exclude both *enprd* and *rndis* together from the regression we find that the standard errors of the remaining fiscal variables improve (become smaller in size), which is consistent with the removal of irrelevant variables from the regression. In addition the null that the coefficients on the *rndis* and *enprd* variables are jointly equal to zero is accepted. This matches a prediction from the Barro (1990) model that non-distortionary taxation and non-productive expenditure have no effect on the steady state growth rate. From this we suggest that regression when interpreting the results greater weight should be given to the regressions where *rndis* and *enprd* are excluded as these regressions do not contain an omitted variable bias from the exclusion of *eprd* or *rdis* from the regression. Kocherlakota & Yi (1997) estimate significant growth effects from fiscal variables only when public investment and the marginal tax rate are included in the same regression and therefore make similar conclusions. Kocherlakota & Yi do not however explicitly set up the budget constraint.

The results from Table 6.4 take no account of differences in the relative size of expenditures and revenues. An increase in *eprd/GDP* of one per-cent may involve a far greater *relative* change than a one per cent change in *enprd/GDP* due to differences in the relative size of expenditures on *eprd* and *enprd*. The coefficient from the tax mix quadrant suggests that a 1% reduction in non-distortionary taxation and its replacement by distortionary forms of taxation leads to a 0.084 of a percentage point reduction in the long run rate of growth (e.g. from 2% per annum to 1.916% per annum). These are obviously greater in size compared to the estimated effect of a 10% reduction in capital and labour taxes found from the simulation studies in Mendoza et al. (1996) who predict that the growth effects are in the range 0.1 to 0.2 of a percentage point. Comparisons with the empirical results from their study are more problematic because of differences in measurement of the taxation variables.

Compared to the tax mix quadrant, the growth effects of a change in the expenditure mix are relatively modest. A 10% reduction in non-productive expenditure and a compensating increase in productive expenditure leads to a 0.37 percentage point increase in the rate of growth in the rate of growth. This is substantially greater than the magnitude of the coefficients in the expenditure mix study be Devarajan et al. (1996) for defence, health, education and transport and communication expenditure, but again is similar to the estimated coefficients of the expenditure mix found in Miller & Russek (1993).

Within the other two quadrants the size of the coefficients are highly variable according to which is the compensating fiscal variable. The effects of increases in non-productive expenditure financed by distortionary forms of taxation are very large relative to non-distortionary tax-financed increases, at -0.410 and 0.037 respectively. The estimated coefficients of increases in productive expenditure differ greatly in magnitude, being -0.156 when distortionary tax financed but 0.290 when non-distortionary tax financed.

6.4 Robustness Testing

In this section we test the robustness of the above results to changes in the specification of the data and the regression equation (6.1). The first is to estimate the regression without the initial GDP term (Easterly & Rebelo (1993)) while the next two changes in specification examine whether the above results are robust to the classifications of the data.[20] A fourth test is for parameter heterogeneity from the financing of productive expenditures by distortionary taxation across countries. The fifth change tests for sensitivity to the number of years used in period-averaging.[21] Finally we attempt the use of instrumental variables within the regression to correct for possible bias between fiscal variables and growth. This section discusses the results only in terms of their consistency with those discussed above.

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[20] The sensitivity of the results to different level of aggregation of the data are studied in depth within Chapter 8

[21] Alternative methods of estimating the long-run and the sensitivity of the results to these different measures are studied in greater depth with Chapter 5.

6.4.1 *Initial GDP*

Easterly & Rebelo (1993) show that the estimated coefficients on fiscal variables are sensitive to the inclusion of initial GDP term in the regression. They explain this as due to the likely simultaneity between fiscal policy and the level of development through Wagner's law. If the elasticity of demand for some types of expenditure is greater than one then as incomes rise so do expenditures. The removal of the initial GDP term collapses equation (6.1) to a simple form of growth accounting equation. The results for this regression are displayed in Table 6.5 below.

Table 6. 5: Estimation with Initial Income Omitted

Estimation Technique	5-year aves, 2 way FE			
Dependent variable	per capita growth		n= 98 (22 countries)	
	Omitted Fiscal Variable			
	rdis	**rndis**	**eprd**	**enprd**
inv	**0.020*** **(0.06)**	**0.020*** **(0.06)**	**0.020*** **(0.06)**	**0.020*** **(0.06)**
lbfg	-0.015 (0.29)	-0.015 (0.29)	-0.015 (0.29)	-0.015 (0.29)
elmr	-0.113 (0.19)	0.314 (0.24)	0.041 (0.21)	**0.353**** **(0.19)**
roth	**0.326*** **(0.14)**	-0.101 (0.20)	0.172 (0.16)	-0.140 (0.11)
eoth	-0.127 (0.11)	**0.301**** **(0.17)**	0.028 (0.11)	**0.340*** **(0.12)**
sur	-0.071 (0.10)	**0.357*** **(0.16)**	0.084 (0.11)	**0.400*** **(0.09)**
rdis		**-0.427*** **(0.18)**	-0.155 (0.11)	**-0.467*** **(0.10)**
rndis	**0.427*** **(0.18)**		**0.273**** **(0.15)**	-0.039 (0.17)
eprd	-0.155 (0.11)	**0.273**** **(0.15)**		**0.312*** **(0.13)**
enprd	**-0.467*** **(0.10)**	-0.039 (0.17)	**-0.312*** **(0.13)**	
adj R^2	**0.574**	**0.574**	**0.574**	**0.574**

Notes: 1) standard errors in parenthesis.
2) * denotes significance at the 5% level, ** at the 10% level.

The results for the growth accounting regression are virtually identical to those produced above. The only change in the fiscal matrix is on the *enprd/rndis* variable where the sign remains insignificantly different from zero but is negative instead of positive. It appears therefore that the sensitivity of the growth effects of fiscal variables to the level of development is not apparent in this data set.

6.4.2 *Level of Classification*

The second change we make to the regression equation is to change the nature of the variables included within the fiscal matrix. The allocations of the data from the GFSY in creating the theoretically based classifications are obviously imprecise. We attempt two alternative classifications of the data in order to demonstrate that the results are robust to this. The first simply aggregates upwards until we have three fiscal variables: total revenue, total expenditure and the government budget surplus. The surplus term is again used as the constraining item to ensure the budget identity is satisfied across each data point.

Our second sensitivity exercise invokes further disaggregation in order to focus on some variables that are either commonly used in previous studies; produce some of the consistently strong results; or constitute such large proportions of total revenues or expenditures as to possibly swamp the other results. The additional sub-classifications of the data drawn out are: income taxation, health expenditures and social security expenditures. It should also be possible to use these variables in order to determine how much of the results from the theoretical aggregations above are driven by these categories. The distortionary taxation variable has been sub-divided into revenues from income taxation, given that this is a commonly used measure in applied studies, and the remaining distortionary tax revenues that we label as factor income taxation. There is no longer a non-productive expenditure category as expenditures on recreation and economic services have instead been included within the other expenditure category and ignored. The other difference from the previous aggregation is the separation out of those expenditures which are perceived to be productive as a *flow* of goods and services, such as defence, and those arguably productive as a *stock* of goods, such as transport and communication infrastructure. The theory suggests that there is a difference between the nature of public goods as either stocks or flows such as its subjection to the forces of congestion and that this may have bearing upon the significance of the results. Table 6.6 below explains how the data from the GFSY has been re-classified to generate this new data set.

Table 6. 6: Re-classified Fiscal Data

New Fiscal Variable	Category from GFSY
Surplus/ deficit *(sur)*	Surplus/ deficit
income taxation *(rinc)*	taxation and income and profit
factor income taxation *(rfac)*	social security contributions taxation on payroll and manpower taxation on property
consumption taxation *(rndis)*	taxation on domestic goods and services
other revenues *(roth)*	taxation on international trade non-tax revenues other tax revenues
productive flows *(epf)*	general public services expenditure defence expenditure
productive stocks *(eps)*	educational expenditure housing expenditure transport and communication expenditure
health expenditure *(ehlth)*	health expenditure
social security and welfare expenditure *(ess)*	social security and welfare expenditure
other expenditure *(eoth)*	expenditure on recreation expenditure on economic services other expenditure

The results for the two adjusted data sets are displayed as tables 6.7 and 6.8 below.

Table 6. 7: Estimation with Aggregated Fiscal Data

Estimation Technique	5-year aves, 2 way FE		
Dependent variable	per capita growth	n= 98 (22 countries)	
	Omitted Fiscal Variable		
	trev	**texp**	**sur**
initial GDP x 10^{-3}	**-0.545* (0.19)**	**-0.545* (0.19)**	**-0.545* (0.19)**
inv	0.024 (0.06)	0.024 (0.06)	0.024 (0.06)
lbfg	-0.498 (0.32)	-0.498 (0.32)	-0.498 (0.32)
texp	**-0.098** (0.05)**		**-0.214* (0.06)**
trev		**-0.098** (0.05)**	0.117 (0.09)
sur	0.117 (0.09)	**0.214* (0.06)**	
adj. R^2	**0.545**	**0.545**	**0.545**

Notes: 1) standard errors in parenthesis.
2) * denotes significance at the 5% level, ** at the 10% level.

Table 6. 8: Estimation with Re-classified Data

Estimation Technique				5-year aves, 2 way FE			
Dependent variable				per capita growth		n= 98 (22 countries)	
	Omitted Fiscal Variable						
	rinc	**rfac**	**rndis**	**epf**	**eps**	**ehlth**	**ess**
initial GDP x 10^{-3}	**-0.529* (0.18)**	**-0.529* (0.18)**	**-0.529* (0.18)**	**-0.529* (0.18)**	**-0.529* (0.18)**	**-0.529* (0.18)**	**-0.529* (0.18)**
inv	-0.058 (0.07)	-0.058 (0.07)	-0.058 (0.07)	-0.058 (0.07)	-0.058 (0.07)	-0.058 (0.07)	-0.058 (0.07)
lbfg	-0.210 (0.33)	-0.210 (0.33)	-0.210 (0.33)	-0.210 (0.33)	-0.210 (0.33)	-0.210 (0.33)	-0.210 (0.33)
elmr	0.022 (0.19)	0.188 (0.25)	**0.546* (0.25)**	0.178 (0.27)	0.175 (0.25)	0.270 (0.27)	**0.509* (0.20)**
roth	0.199 (0.14)	0.032 (0.20)	-0.325 (0.20)	0.042 (0.21)	0.046 (0.20)	-0.049 (0.25)	**-0.289* (0.14)**
eoth	-0.137 (0.11)	0.029 (0.15)	**0.387* (0.16)**	0.019 (0.18)	0.016 (0.17)	0.111 (0.21)	**0.350* (0.13)**
sur	0.035 (0.11)	0.202 (0.16)	**0.559* (0.17)**	0.192 (0.19)	0.188 (0.16)	0.283 (0.21)	**0.523* (0.12)**
rinc		-0.166 (0.16)	**-0.524* (0.19)**	-0.157 (0.19)	-0.153 (0.16)	-0.248 (0.22)	**-0.488* (0.13)**
rfac	0.166 (0.16)		**-0.358** (0.21)**	0.010 (0.24)	0.014 (0.19)	-0.081 (0.23)	**-0.321* (0.14)**
rndis	**0.524* (0.19)**	**0.357** (0.21)**		0.367 (0.24)	**0.371* (0.19)**	0.276 (0.24)	0.036 (0.18)
epf	-0.157 (0.19)	0.010 (0.24)	0.367 (0.23)		-0.004 (0.21)	0.091 (0.29)	0.331 (0.22)
eps	-0.153 (0.16)	0.014 (0.19)	**0.371* (0.19)**	0.004 (0.21)		0.095 (0.28)	0.335 (0.21)
ehlth	-0.248 (0.22)	-0.081 (0.23)	0.276 (0.24)	-0.091 (0.29)	-0.095 (0.28)		0.240 (0.20)
ess	**-0.488* (0.13)**	**-0.321* (0.14)**	0.036 (0.18)	-0.331 (0.22)	-0.335 (0.21)	-0.240 (0.20)	
adj R^2	**0.582**	**0.582**	**0.582**	**0.582**	**0.582**	**0.582**	**0.582**

Notes: 1) standard errors in parenthesis.
2) * denotes significance at the 5% level, ** at the 10% level.

Increasing the level of aggregation of the data obviously increases the number of opposing forces at work within each quadrant; however, under both data sets there is still strong evidence that the choice of the compensating variable matters for the sign and significance of the fiscal variable. A failure to account for the budget constraint will lead to incorrect interpretations of the results whatever level of aggregation is used. The variability of the sign and significance on any one variable can also be seen to increase the greater the level of disaggregation.

According to the results from the very aggregated form of the data tax-financed increases to expenditure reduce the long-run growth rate significantly. When we disaggregate the data we find that this negative effect applies only to the social-security and welfare expenditure variable and only if financed by income or factor taxation. Under both specifications, within the set of conditioning variables, the investment ratio and the labour force growth rate remain individually insignificant whereas the initial GDP term remains significant (and negative).

6.4.3 Parameter Heterogeneity

In using data from a cross-section of countries we have assumed that the true parameter estimates for each variable are identical across these countries. Economic growth models however, show that the coefficient of distortionary tax financed increases in productive expenditure can depend on the current level of expenditure. If below some optimal point then an increase in productive expenditures raises growth; whereas if already above the optimum level then an increase in productive expenditures lowers the growth rate. This is clearly an assumption that requires formal testing.

Testing for heterogeneity is through the use of slope dummies for each country on the productive expenditure variable. As in equation (6.6) below a dummy variable is added for each country when *rdis* is the compensating variable. An F-test on the joint significance of these slope dummies then test whether homogeneity is a valid assumption. The results from the regression equation are presented in Table 6.9. The slope dummies are omitted to conserve space but the value of the F-test is included. There is a clear acceptance of the assumption of homogeneity in this sample of countries (the 5% critical value is 1.92 against a test statistic of 0.97). This result can be interpreted as indicating that the countries within the sample provide productive expenditure through distortionary taxation at an optimum level.

Equation 6. 6

$$g_{it} = \alpha + \sum_{i=1}^{k} \beta_{1i} Y_{it} + \sum_{l=1}^{22} \beta_{2l} Y_{it} + \sum_{j=1}^{m} \gamma_j X_{jt} + u_{it}$$

where β_{2l} is a slope dummy for each country. $\beta_{2l}=1$ for each $i = l$ and zero otherwise. The F-test is on the null hypothesis $\sum_{i=1}^{k} \beta_{1i} Y_{it} = 0$.

Table 6. 9: Robustness Test for Parameter Heterogeneity

Estimation Technique	5-year aves, 2 way FE	
Dependent variable	per capita growth	n= 98 (22 countries)
initial GDP x 10^{-3}	**-0.482*** **(0.22)**	
inv	-0.033 (0.07)	
lbfg	-0.441 (0.38)	
elmr	-0.172 (0.22)	
roth	**0.372*** **(0.18)**	
eoth	-0.134 (0.12)	
sur	-0.073 (0.13)	
rdis		
rndis	**0.497*** **(0.22)**	
eprd	-0.328 (0.26)	
enprd	**-0.500*** **(0.12)**	
adj R^2	**0.603**	
F-test	**0.9708**	

Notes: 1) standard errors in parenthesis.
2) * denotes significance at the 5% level, ** at the 10% level.

6.4.4 *The Long Run*

In this sensitivity exercise we use different length of average through which to remove the business cycle effect. Period averaging is used to help remove the business, and therefore possible simultaneity, from the data. Although 5-year period averages are the most common length of period average chosen within the data no rationale exists behind this choice. To test the sensitivity of the results to this choice we average the data across ten-year periods. Table 6.10 displays the results. Folster & Henrekson (1997) warn that caution is needed when choosing the length of period average and argue that a choice too long in length may aggravate simultaneity between fiscal policy and growth through Wagner's law. Under such conditions we may find some elements of expenditure to be positively correlated with growth.

Table 6. 10: Estimation using 10-year Averages

Estimation Technique	10-year aves, 2 way FE			
Dependent variable	per capita growth		n= 36 (20 countries)	
	Omitted Fiscal Variable			
	rdis	**rndis**	**eprd**	**enprd**
initial GDP x 10^{-3}	-0.308 (0.408)	-0.308 (0.408)	-0.308 (0.408)	-0.308 (0.408)
inv	0.407* (0.15)	0.407* (0.15)	0.407* (0.15)	0.407* (0.15)
lbfg	-0.559 (0.48)	-0.559 (0.48)	-0.559 (0.48)	-0.559 (0.48)
elmr	-0.156 (0.43)	0.798 (0.47)	0.053 (0.41)	0.216 (0.40)
roth	0.901* (0.35)	-0.052 (0.33)	0.693 (0.38)	0.530 (0.27)
eoth	-0.168 (0.20)	0.785 (0.32)	0.040 (0.31)	0.203 (0.24)
sur	-0.299 (0.30)	0.653 (0.29)	-0.091 (0.23)	0.071 (0.27)
rdis		-0.953* (0.39)	-0.208 (0.30)	-0.371 (0.25)
rndis	0.953* (0.39)		0.745 (0.27)	0.582 (0.27)
eprd	-0.208 (0.30)	0.745 (0.27)		0.163 (0..27)
enprd	-0.371 (0.25)	0.582 (0.27)	-0.163 (0.27)	
adj R^2	0.627	0.627	0.627	0.627

Notes: 1) standard errors in parenthesis.
2) * denotes significance at the 5% level, ** at the 10% level.

The change in the method of averaging the data does have a significant impact upon the results. A comparison of the results between the 10-year averages and the 5-year averages show them to be identical in terms of the signs on the estimated coefficients but different in terms of the significance. The significance of both the *enprd/eprd* and *enprd/rdis* variables is lost with 10-year averages, whereas the *enprd/rndis* variable gains significance under the 10-year averages. In creating 10-year averages we move from 98 available observations down to 36. This reduction in degrees of freedom is likely to increase the size of the standard errors and therefore to a greater probability of finding insignificant coefficients. Such an increase in the standard errors is evident in the results, which could also help to explain the loss of the significance of the *enprd/eprd* and *enprd/rdis* variables. A reduction in the degrees of freedom does not however explain why the *enprd/rndis* variable gains significance when we use 10-year period averages. We suggest this result reflects simultaneity between growth and non-productive expenditure as predicted by Folster & Henrekson (1997). The sensitivity of the significance of the estimated coefficients to changes in the method of estimating the long-run is investigated in depth within the next chapter and so we chose not follow the results up here. Instead we simply note that the use of the budget constraint remains an important determinant of the coefficients on fiscal variables even in these regressions.

The other change in the results from the change in the measurement of the long-run is in the conditioning variable matrix. The initial GDP term is no longer significant under the 10-year averages while the investment ratio is significant. Both of these results again suggest that the results are sensitive to the measurement of the long-run.

6.4.5 Instrumental Variables

The estimation of regression (equation (6.1)) assumes that all of the right hand side variables are exogenously determined. Easterly & Rebelo (1993) and Hsieh & Lai (1994) both discuss the simultaneity problem between fiscal variables and the level of GDP and the rate of growth and find it to be a problem. The most likely sources of simultaneity in the regression are the business cycle and Wagner's law (the positive income effect of some categories of government expenditure). Period averaging was used as an attempt to control for simultaneity but it is possible that some noise still remains within the data (especially where the period averages do not coincide with the business cycle).

There is some general evidence against simultaneity being a problem in these regressions. The variable *enprd*, which contains social security and welfare payments, is the most likely expenditure variable to be correlated with the growth rate both from the business cycle (as unemployment increases over the cycle) and from Wagner's law (increased payments on pensions). On no occasion is this variable found to have any effect on the growth rate in the results above.[22] Indeed if one employs a general to specific approach in determining the variables from the government budget constraint to be excluded from the regression then along with non-distortionary taxes the null for its removal is accepted. In addition the results appear reasonably robust to the exclusion of initial GDP and alternative period-averages.

The choice of instruments is a problem in these sort of regressions and we chose the most common form found in the literature which is the first lag of the fiscal variables. However, lagged values cannot be used as instruments in fixed effects models due to potential biases from the presence of fixed effects. We therefore follow Folster & Henrekson (1997) and estimate the regression in first differences. The first differences of the fiscal variables are instrumented by lagged levels of the respective fiscal variable, the level and first difference of the population and initial GDP variables and country specific effects (Folster & Henrekson (1997)). The growth equation is also run in first difference form and the variables in Table 6.11 should be interpreted as such. In order to ensure that the government budget remains an identity the surplus term is generated as a balancing item between revenues and expenditures. The surplus term is not therefore, an instrumented variable. The results when instrumenting for of all the remaining fiscal variables are displayed in Table 6.11 below.

Table 6. 11: Estimation by Instrumental Variables

Estimation Technique		5-year aves,		
Dependent variable		per capita growth	n= 76 (22 countries)	
	Omitted Fiscal Variable			
	rdis	**rndis**	**eprd**	**enprd**
initial GDP x 10⁻³	**-0.125** (**0.03**)	**-0.125** (**0.03**)	**-0.125** (**0.03**)	**-0.125** (**0.03**)
inv	0.129 (0.08)	0.129 (0.09)	0.129 (0.08)	0.129 (0.09)
lbfg	-0.244 (0.47)	-0.244 (0.55)	-0.244 (0.50)	-0.244 (0.51)
elmr	-0.186 (0.35)	0.389 (0.52)	0.105 (0.42)	0.270 (0.37)
roth	0.371 (0.26)	-0.204 (0.45)	0.080 (0.34)	-0.084 (0.25)
eoth	-0.309 (0.20)	0.266 (0.37)	-0.018 (0.19)	0.147 (0.25)
sur	-0.055 (0.17)	**0.630**** (**0.38**)	**0.346**** (**0.18**)	**0.511**** (**0.16**)
rdis		-0.575 (0.39)	-0.290 (0.19)	**-0.455*** (**0.16**)
rndis	**0.575**** (**0.34**)		0.284 (0.32)	0.119 (0.34)
eprd	-0.290 (0.18)	0.284 (0.34)		0.165 (0.24)
enprd	**-0.455*** (**0.15**)	0.119 (0.37)	-0.165 (0.24)	
adj. R^2	**0.506**	**0.339**	**0.442**	**0.424**

Notes: 1) standard errors in parenthesis.
2) * denotes significance at the 5% level, ** at the 10% level.

The results for these instrumental variable regressions display only a weak resemblance in terms of significance of the variables. However, this appears to be due to inflation of the standard errors rather than through any large change in the value of the coefficients. The results for the instrumental variable regressions appear to be dependent upon which of the set of fiscal variables are included or left out of the regression equation. For example when *rdis* is the excluded fiscal variable the fit of the regression is 50.6% yet when *rndis* is the excluded fiscal variable the fit of the regression is only 33.9%. This also appears to affect the magnitude of the standard errors in the regressions. For example, when *rdis* is the excluded fiscal variable the standard errors of the fiscal variables are around 1.5 times those found in Table 6.4; whereas when *rndis* is the compensating variable then the standard errors are around

[22] Additional evidence against simultaneity caused by Wagner's law is the robustness of the results to the exclusion of initial GDP from the regression equation.

three times as large. We suggest that this is due to a loss of efficiency from using IV for a large number of variables rather than a loss of robustness.

Some support for this conclusion can be found when we include fiscal variables singularly within the regression (i.e. do not take account of the budget constraint) and; when we instrument individually for fiscal variables taking account of the budget constraint. In all of these regressions the general findings from Table 6.4 are supported. Evidence can also be found against the choice of instrumenting variables by referring to results found in the next chapter. Within that chapter we find that the addition of lagged explanatory variables to the regression cannot be rejected. That is, fiscal policy within the previous period adds significantly to the ability to explain growth within this period. The choice of lagged variables as instruments will therefore potentially bias the results because the instruments will themselves be correlated with growth. This may also help to explain why the results change little when instrumenting for one fiscal variable at a time, as within previous studies, but are less robust when we instrument for the entire budget constraint.

6.5 Interpreting the Results

Table 6.12 below presents a summary of the expected coefficients from the Barro endogenous growth model along with the regression results in the fiscal matrix in Table 6.4 above. The theoretical prediction is displayed in the left hand side of the cell and the empirical result on the right hand side. The bold and large signs on the coefficients represent variables that are significantly different from zero at the 10% level or above, and the fainter coefficients those that are not significantly different from zero.

The degree of matching of the Barro model and empirical literature once the government budget constraint has been accounted for is quite remarkable. In all cells, (excluding those where no prior predictions were possible), the expected coefficient from the theoretical literature is reproduced by the empirics.

Table 6. 12: A Comparison of the Theoretical Predictions and Empirical Results

	distortionary taxation	**non-distortionary taxation**	**productive expenditures**	**non-productive expenditures**
distortionary taxation		- -	? -	- -
non-distortionary taxation	+ +		+ +	0 -
productive expenditure	? -	+ +		+ +
non-productive expenditure	- -	0 -	- -	

Note: (theoretical prediction/empirical result)

Quadrant 1 provides evidence on the growth effects of the tax mix. The distinction within the model as to whether one type of taxation has a significant direct effect upon the steady state rate of growth or not concerns whether it fits into the consumption or the production side of the model. Distortionary taxes reduce the returns to investment the rate of accumulation of capital and hence the steady state growth rate. Non-distortionary taxes are introduced into the model within the consumption function and (because of the assumption of infinitely lived households) have no effect upon the steady state rate of growth. The tax measures within the Barro (1990) model are progressive taxes and hence the average and marginal tax rates are identical. In reality taxes are in general not progressive and the tax revenue categories we use more accurately reflect *average* rather than *marginal* tax measures. Nonetheless evidence of significant coefficients within the tax mix quadrant exists. This suggests average tax measures are reasonably well correlated with marginal tax rates in this data set possibly because of high compliance ratios in the sample of countries.

It does not necessarily follow from this result that consumption taxation is non-distortionary. The coefficients estimate the net rather than direct effect of fiscal policy on growth. Mendoza et al. (1996) in a two-sector endogenous growth model allow for the possibility that consumption taxation is distortionary but predict (partially based on their empirical findings) that consumption taxation is *less* distortionary than human capital and physical capital taxation. Such a conclusion would be consistent with the findings from this study also. When we attempt a general to specific test of the government budget constraint we find that we can simultaneously exclude *rndis* and *enprd* from the regression. This would suggest that non-distortionary taxes have no effect on the growth rate in our sample and therefore we favour the first of our conclusions.

Information regarding the effect of changes to the mix of expenditures is contained within quadrant 3. Again it appears that the empirics support the notion that it is the supply side of the model that drives the growth effects of fiscal policy. Productive expenditures raise the marginal product of capital encouraging more investment and increase the growth rate. Non-productive expenditures are perfect substitutes for private consumption and have no effect upon the investment decision and hence on the steady state rate of growth. Any change in policy that leads to an increase in expenditures on productive goods financed from reduction in non-productive expenditures will increase the long-run rate of growth. This conjecture appears to receive strong empirical support from this study.

The results from quadrants 2 and 4 are also highly consistent with the theory and with those from the tax mix and expenditure mix quadrants. The effect on growth of distortionary tax financed increases in productive expenditures is not possible to predict because the relationship is quadratic (Barro (1990)). Increases in productive goods are positive for all sizes of government[23] but subject to diminishing marginal returns; whereas the marginal effect of an increase in distortionary taxation is a negative constant at all rates of taxation. The *net* marginal benefit of these two is positive when the size of government is small but negative when the size of government is large. The insignificant coefficient on the *eprd/rdis* variable suggests the results estimated here are consistent with Barro (1991) that the provision of

[23]Devarajan et al (1996) find some evidence of non-linearity of changes in the government expenditure mix but the budget constraint used here makes this difficult to investigate further.

productive goods financed by distortionary taxation is at an optimal level. Additional support can be found from the test for parameter heterogeneity in Section 6.4.3.

No optimal provision of productive expenditure funded by non-distortionary taxation exists because there are no negative growth effects from this form of taxation. The marginal growth effect of an increase in productive expenditure financed by non-distortionary taxation should be positive at all sizes of government. The coefficient estimated on the *eprd/rdis* variable suggests that there is scope for further increases in productive expenditure financed by non-distortionary taxes.

The optimal provision of unproductive expenditure from distortionary tax revenues is zero within the theory. Any deviation from this position will lead to a reduction in the rate of growth. The empirical evidence here supports this theoretical prediction. Finally non-distortionary tax financed increases to non-productive expenditures will have no significant growth effects because both fiscal variables affect the consumption side of the model. The growth effect of a non-distortionary tax financed increase in non-productive expenditures is positive but insignificant as expected.

The results are also consistent with many of the extensions of the Barro model that have appeared in the literature. For example when public goods are subject to congestion unless the level of congestion is maintained at a constant level (and technology is 'AK') then fiscal policy has no effect on the growth rate. If the level of congestion is constant then fiscal policy becomes a structural characteristic of the steady state rather than its engine. In such a model the effect of fiscal policy on the growth rate are the same as in the Barro model.[24]

The results could also be used to argue against the Cashin (1995) model in which non-productive expenditures become 'productive' (this is achieved by including 'non-productive' expenditures in the production function). Perhaps more interestingly though we find no evidence that non-productive expenditure (of which

[24] This result might be considered interesting in a second sense as constant returns to capital models allow no convergence of growth rates across countries. Yet we find evidence of conditional convergence through the initial GDP term.

social-security and welfare payments are the largest part) have negative effects on the growth rate of a country.[25]

The data set is perhaps in far too aggregated a form to argue convincingly for or against any particular form of two-sector model. For example the estimated positive effect on growth from changes in the tax mix away from distortionary taxes and towards non-distortionary taxes would also be consistent with a two-sector model which includes a labour-leisure choice in which consumption taxation is distortionary. It could then be argued that this result reflects the situation in which consumption taxation is simply *less* distortionary than other distortionary taxes (Mendoza et al. (1996) argue this). However, the insignificant effect estimated from non-distortionary financed increases in non-productive expenditures is evidence against this kind of model.[26]

The results could be used as evidence against extreme forms of the two-sector model such as Lucas (1990) in which the human capital sector is a non-market sector and has linear production with human capital as the only input. In this model the growth rate is given by the technology parameter in the human capital sector and is therefore independent of taxation (productive expenditures in the human capital sector would have an effect on the growth rate in this model).

6.6 Conclusions

This chapter argues that the specification of the government budget constraint is an important determinant of the coefficients on fiscal variables within growth regressions. We demonstrate that the failure to take this constraint into account helps explain for the dispersion of results found in previous studies. In other words, the apparent non-robustness of fiscal variables in other studies is in fact consistent with the theory rather than true statistical non-robustness.

[25] There are negative effects on growth if they are financed by distortionary taxes, but if they are financed by non-distortionary taxes they do not appear to significantly change the growth rate.
[26] Or at least is only consistent with one in elasticity of labour supply is low.

Data for 22 developed countries averaged over 5-year periods from 1970-94 was analysed using the empirical methodology developed by Helms (1985), Mofidi & Stone (1990) and Miller & Russek (1993). It was found that the principal results from the Barro (1990) model namely that altering the tax mix from distortionary towards non-distortionary taxes, and the expenditure mix from non-productive towards productive forms of expenditure are growth-enhancing do in fact receive strong empirical support.

The results are found to be robust to the inclusion or exclusion of the initial GDP term, to the level of aggregation and to a test of parameter heterogeneity. The results are however sensitive to whether five-year or ten-year averages are used estimation by instrumental variables.

The results from this chapter could be used to conclude in favour of all growth models that separate expenditures and taxes into the four basic types used here. However, the level of aggregation of the tax and expenditure variables suggests that this conclusion may be too strong. We may be safer in concluding that we find evidence in favour of the general class of endogenous growth models, and that we find no evidence for the more extreme assumptions made in some endogenous growth models such as Lucas (1990) or where public goods are subject to congestion (Barro & Sala-i-Martin (1992)).

Chapter 7

Growth and the Steady State

7.1 *Introduction*

Growth models (both new and old) typically contain strong predictions about the long run steady state. As Kocherlakota & Yi (1997) show, new and old theories have different steady state predictions with respect to the impact of fiscal variables in a growth regression. No fiscal policy variables feature in the steady state of the neoclassical model whereas certain types of fiscal policy do feature in the endogenous growth models. These predictions often do not hold if the economy is in transition from one steady state to another as a result of a change in one or more parameters. In both models fiscal policy helps to determine the rate of transition to the steady state but the transition depends very much on the initial state, so few general predictions can be made.

Within the most simple public policy endogenous growth model, (Barro (1990)), fiscal variables which are included in the supply side of the model, (public goods, which appear in private production functions, and the taxation of output or returns to factor inputs), affect the steady state; whereas those fiscal variables which are included on the demand side of the model (expenditures on welfare payments to households or the taxation of consumption or lump-sum taxation) have no influence on the steady state. The statistical non-robustness of the relationship between fiscal policy and growth may therefore be due to differences in the ability of the various econometric techniques and data transformations used in the literature to distinguish between the business cycle, the transition and the steady state.

A major empirical issue concerns the appropriate use of the available data in order to test theoretical hypothese. In practice we have a finite time-span of annual data on fiscal variables for a limited number of countries. We could use each year as a separate observation, in order to maximise degrees of freedom, but even if we allow for lagged effects there is a high risk of being unable to distinguish the steady state from transitional and business cycle effects. The business cycle would be expected to influence the short-run behaviour of the dependent and many of the independent variables. Alternatively, we can aggregate the data into averages of 5, 7 or even 10-years, hoping to smooth out many of the short-run effects and isolate the long run relationships, but at the expense of a loss of a great deal of potentially useful information.

Kocherlakota & Yi (1997) use data from the UK and US for 150 and 100 years respectively in a time series framework with long lag structures in order to assess the impact of a limited number of fiscal variables on the rate of growth. We address similar issues using data on a panel of 22 developed countries over 24 years with a complete government budget. Our initial approach is to estimate a standard static panel regression with the data organised as 5-year period averages. To this we add a dynamic element to the regression through a single lag of the explanatory variables. If the static regression with 5-year period averages fully captures the long run component of the data the addition of this lagged term will have no explanatory power and can be legitimately removed from the regression equation. On the contrary we find that the null hypothesis of no explanatory power from the lagged variables cannot be accepted. That is, the standard approach with regard to the measurement of the long run within the literature is misspecified.

We test the sensitivity of the results to a number of alternative estimators and means of treating the data. This in turn throws up some interesting results. Our results suggest that the treatment of the data have no real effect when testing between the neoclassical and endogenous growth models as all favour the endogenous growth model. However, the choice of methodologies is found to be important when testing between variants of the endogenous growth model. That is, we consistently find a statistically significant relationship between fiscal policy and growth but not always for the same combinations of fiscal variables.

Section 7.2 summarises the existing literature (both empirical and theoretical) and reviews the available panel data econometric methodologies (Section 7.2.2). Section 7.3 considers the empirical methodology along with the design of the data set and section 7.4 the results. Section 7.5 performs some sensitivity analysis and finally section 7.6 concludes.

7.2 Existing Literature

The non-robustness of fiscal variables estimated by Levine & Renelt (1992) and Easterly & Rebelo (1993) and reviewed in Chapter 5 would appear to hold, irrespective of the choice of period averaging and econometric methodology employed. Chapter 6 demonstrates that at least part of the explanation is due to an incomplete specification of the government budget constraint but this was only investigated for static panels using five-year period averages. The robustness tests included in Section 6.4 indicate that these results may be sensitive to the choice of period average to remove the short run effects from the data.

In the public policy neoclassical growth models fiscal policy affects the level of output but not the long run growth rate. In contrast, public policy in the endogenous growth models of Barro (1990) and Barro & Sala-i-Martin (1992, 1995) fiscal policy determines both the level of output and the steady state growth rate (for the details see Chapters 2 to 4).[1] We can use this difference in the determinants of the long run growth rate to distinguish between the new and old growth theories. Within the endogenous growth models not all elements of fiscal policy are expected to help determine the steady state growth rate. The growth effects of fiscal variables can be easily summarised depending on whether they influence the production or the household side of the model. As explained in Chapter 4 those policies that affect the production side, (distortionary taxation and productive expenditure), help to determine the rate of growth; whereas those that are included on the household side, (non-distortionary taxation and non-productive expenditure), do not.

This distinction between types of policy is sufficient to characterise the effect on growth in many of the extensions that have been made to the basic model, but not all. In certain forms of the model it is possible to have either no expenditure, or no tax, or neither taxation nor expenditure affecting the steady state, even when the growth rate is endogenously determined. For example if public goods are subject to congestion and capital (either physical or human) is subject to diminishing returns then the steady state growth rate is independent of fiscal policy. Fiscal policy can be reintroduced as a determinant of the steady state if constant returns to capital are assumed and the level of congestion (the expenditure/GDP ratio) remains constant in the steady state.[2]

The results may also be used to distinguish between some of the more extreme forms of two-sector model. For example Lucas (1990) in a two-sector model of taxation demonstrates that under certain assumptions taxation policy has no effect on the steady state growth rate. Clearly evidence of significant relationship between taxation and growth would provide evidence against a model in which the human capital sector is a non-market sector and linear in its production of human capital.

7.3 *Econometric Methodology*

Neither the theoretical nor the empirical literature provides us with much insight into how to manipulate the data in order to accurately capture the determinants of the long run growth rate. One thing we are clear about however, is that if we are searching for the determinants of the steady state then we must distinguish it from the business cycle and the transition which are also contained within the data. The business cycle is clearly going to contaminate annual observations of the data; while the transitional

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[1] Public goods are accumulated within the model as the economy grows, in so doing this prevents diminishing returns to capital and hence declining growth rates.

[2] Given the limits of the data set available (around 20 years in length) to be able to distinguish between these two sets of assumptions requires that the degree of congestion is relatively large such that congestion occurs quickly. If however the degree of congestion is small (as can occur under Glomm & Ravikumar (1994), Fisher & Turnovsky (1998)) then we may incorrectly conclude in favour of fiscal policy as a determinant of the growth rate. From a policy perspective this distinction may appear uninteresting but from a modelling perspective it is crucial for the structure of the model.

dynamics appear because of the dynamic nature of the theory, but no clear information exists as to its length. Both of these are likely to affect the short-run behaviour of the dependent and possibly the independent variables within the regression. Further complications are added because the transition is dependent upon initial conditions making any *a prior* theoretical prediction about the path to the steady state difficult.

Of the panel data studies that exist within the literature the most common form uses a non-dynamic panel regressions with period averages around 5-years in length. Alternative techniques, such as those of dynamic panel data, are available but are less used. In this chapter we demonstrate the sensitivity of the results to differences in the econometric methodology used to model the long run relationship between fiscal variables and the rate of growth. More specifically we compare the results from non-dynamic and dynamic panel data regressions.

Panel data estimators are used to investigate the relationship between fiscal policy and long run growth because they offer several advantages over the use of cross-section[3] or time series models alone given the shape of the available data set in this thesis. A time dimension of only around 20 observation per country prevents the use of time series techniques, while using cross-section estimation would leave us with only 22 observations. Data availability prevents us from collecting additional data in order to use time series techniques, while collecting data on more countries is likely to aggravate simultaneity and parameter heterogeneity problems identified in Section 5.2.2 and 5.2.4. Panel data estimators therefore have the advantage in increasing the available degrees of freedom, but more importantly, because it exploits the time dimension of the data set, allow us to use more of the information contained within the data to improve the efficiency of the parameter estimates. A final advantage of using panel data estimation is that we can account for country and time specific omitted variables.

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[3] See Temple (1998) and Durlauf & Quah (1998) for a comprehensive review of the problems of cross-country growth regressions.

Two different types of panel data technique are applied to the data set, these are the static panel techniques (no lagged values) and dynamic panel techniques (includes lagged values). The properties of these two estimators are quite different and we compare only their general specification here, leaving the details of the estimation procedures to Appendix B.

7.3.1 Static Panel Data Estimators

The basic static panel data regression runs over the equation,[4]

Equation 7. 1
$$y_{it} = \alpha + X'_{it}\beta + u_{it}$$

where y_{it} is the dependent variable and X_{it} is a matrix of explanatory variables.[5] The error term is assumed to be a random disturbance, but contain the effects of the omitted variables. The error term, u_{it}, can then be decomposed into parts that are country specific and those that are time specific effects.

Equation 7. 2
$$u_{it} = \mu_i + \lambda_t + \varepsilon_{it}$$

where μ_i are country varying time invariant effects; λ_t are time-varying, country-invariant effects; and ε_{it} is a classical error term with the properties that it is IID(0, σ_ε^2) and $E(\varepsilon_{it}, X_{it})=0$. The estimators of the parameters contained within the β matrix are unbiased and consistent as both N and T tend to infinity. The properties of μ_i and λ_i depend upon the asymptotic properties of $T\rightarrow\infty$ and although consistent are not reported at any point below. Instead concentration is made solely upon the β matrix.

The estimation program used within this chapter is LIMDEP (Green (1992)). LIMDEP automatically estimates standard OLS, least squares dummy variable fixed effects models (with both one way and two way error terms) and two-step feasible GLS random effects models. The principal features of the fixed and random effects

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[4] We simplify this equation from equation (6.1) for ease.
[5] We combine the conditioning variable matrix with the fiscal variable matrix from equation (1) in the previous chapter into a single term for ease

models are discussed here and the reader is referred to Hsiao (1986) or Baltagi (1995) for the details. The Hausman specification test is used to test between the random effects models (see Appendix B for the details) and we continually find evidence in favour of the fixed effects model. As in the previous chapter we find the fixed effects model is consistently estimated as having a higher log-likelihood (absolute) value and higher adjusted R^2.

7.3.2 *Dynamic Panel Data Estimators*

Pesaran (1997) argues that in order to estimate empirically the long run or steady state from economic growth models then "the steady state solutions can be embedded within a suitable multivariate dynamic model."[6] One possible econometric procedure for studying the steady state of the type of growth models reviewed in Chapters 1-4 is through dynamic panel data models. Dynamic panel data regression equations are, essentially, identical to static panel data techniques except the dynamic regressions add lagged values of the explanatory variables. However, the addition of these terms complicates the estimation procedure and the choice between the different estimation techniques must be made partially on the nature of the data set and the properties of the different estimation procedures.

The dynamic panel data regression simply extends equation (7.1) to include a series of lagged terms,

Equation 7. 3
$$y_{it} = \alpha_{it} + \sum_{j=1}^{\infty} \lambda_i y_{i,t-j} + \sum_{k=0}^{\infty} \beta_i x_{i,t-k} + \varepsilon_{it}.$$

Ignoring the exact nature of the unobserved coefficients for the moment, (whether fixed or random effects) in order to estimate an equation for the steady state a dynamic equation of the following form is required:

Equation 7. 4
$$\Delta y_{it} = \alpha_{it} + \sum_{j=1}^{n} \lambda_i \Delta y_{i,t-j} + \sum_{k=0}^{p} \beta_i \Delta x_{i,t-k} + \sum_{m=0}^{q} \chi_i z_{i,t-m} + \varepsilon_{it}$$

If y represents output then the regression for the growth of output is estimated on lagged growth and two vectors of explanatory variables, the first containing explanatory variables in levels (for example government expenditures) and the second variables in first difference form. This is an unusual dynamic panel data equation but follows from a basic ECM equation in which the long run component is zero - see Appendix B.

Long Run Parameter Estimates

In order to employ the econometric techniques discussed above requires the ability to translate the steady state equations from the theoretical models into a form of regression equation. Kocherlakota & Yi (1996) do this by nesting the exogenous growth model within the endogenous growth model and we choose not to repeat the analysis here. Put simple they show that the steady state growth rate can be expressed as distributed lags of the variables of interest. Within the regression equation and the theoretical model the growth effects of fiscal policy are determined by the joint significance of the distributed lags. Within the exogenous growth model the sum of the lags is zero whereas in the endogenous growth model the sum of the lags is non-zero. As Yi & Kocherlakota write "the different coefficient sum capture the idea that permanent changes in policy variables can have long run effects of growth rates in endogenous growth models, but do not have long run effects in exogenous growth models."[7] We assume the same process here but for a wider range of fiscal variables. Estimation of equation 7.4 yields a series of short run parameter estimates. These can be converted to long run estimates under a simple transform the details of which we save to Appendix B (Section B3).

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[6] Pesaran, M.H. (1997) "The role of economic theory in modelling the long run" Economic Journal, vol.107, no.440, January, pp. 178-9

[7] Yi K., Kocherlakota N. 'Is there endogenous long run growth? Evidence from the US and the UK' *Federal Reserve Bank of New York December 17 p. (1996)*

7.4 Empirical Methodology

As demonstrated in the previous chapter correctly testing that the rate of growth is a function of fiscal variables implies the use of the government budget constraint within the regression. We therefore, continue its use within this chapter and refer the reader to Section 6.2.2 for an explanation of the approach.

7.5 Empirical Results

7.5.1 Results

The dynamic regression using 5-yearly averaged data includes the current value of the explanatory variables, as in the non-dynamic regression, and one lagged value of the explanatory variables, as its dynamic component. Longer lag structures were precluded by the limitations of the time series element of the data set. The two way fixed effects model is favoured by the diagnostics for the static panel regression, but the period effects in the dynamic regression were only marginally significant at the 10% level and hence we made the decision to exclude them from the regression. The results of the other variables are not changed by their omission. Thus, the dynamic regression is a one way fixed effects model that includes country effects but not period effects. The dynamic regression explains some 67.9% of the variation of growth, whereas the static regression explains 61.5%. A Wald test on the joint significance of the lagged dependent variables leads to a rejection of the null hypothesis that the coefficients on these terms are jointly zero. This suggests that the static panel regression estimated in Chapter 6 is misspecified as the model does not fully capture the dynamics present in the data.[8]

Of the conditioning variables the investment ratio is statistically insignificant in both the static or the dynamic regression; while the labour force growth rate is significant

[8] A similar process was attempted for with the inclusion of period effects leading to the same result.

(and negative) in the dynamic regression. The inclusion of the initial GDP[9] term with a negative coefficient in the regressions implies convergence of GDP levels, with, ceteris paribus, faster growth at lower starting values of GDP. The lagged growth term from the dynamic regression is also significant and negative, suggesting persistence in short-run dynamics.

Consider next the fiscal parameter estimates. The signs and significance on the estimated coefficients from the static and dynamic panel regressions are displayed in Table 7.1 below.[10] Comparing the first two elements from Table 7.1 suggests that there is some sensitivity of the estimated long run[11] effects of fiscal policy to the choice of how we model the long run. Concentrating on the long run coefficients from the table; two variables, *enprd/eprd* and *eprd/rdis*, have different significance across the two types of regression. The significance of the *enprd/eprd* variable in the static regression set is lost in the dynamic regression whereas, the coefficient on the *eprd/rdis* variable gains significance in the dynamic regression. This latter case leads us to believe that it is not simply a reduction in degrees of freedom (caused by the inclusion of lagged explanatory variables) in the dynamic regression that causes the results to alter.[12]

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[9] Initial GDP refers to the level of GDP at the start of each averaged period. For example the GDP for 1970 is used as initial GDP for the data span 1970-74.

[10] The table displays the results from only the bottom half of the fiscal matrix in order to conserve space. If at any point in the empirical results the matching cell of the matrix does not have the correct matching sign or significance this is indicated by colouring the cell grey and the result is explained as a footnote. The figures in parenthesis under the parameter values are the t-statistic of the null hypothesis that the coefficient of the variable is insignificantly different from zero. The t-statistics under the long run coefficients of the dynamic regression refer to test of the null hypothesis that the sum of the short-run parameters is equal to zero. This switch from the previous chapter is made for ease of comparison between the static and dynamic panel regressions and is used consistently throughout the chapter.

[11] An explanation how the long run coefficients of the fiscal variables from the dynamic regression set were calculated can be found in the appendix.

[12] This may also have implications for which variables can be excluded from the regression if we adopt a general to specific approach. We choose not to follow up this result here.

Table 7. 1: Comparing Static and Dynamic Panel Data Estimators

panel		Static	Dynamic		
length of average		5-year			
			long run	current	1st lag
increase / decrease	rndis / rdis	**0.446*** **(2.60)**	**0.602*** **(3.05)**	0.450 (1.56)	0.474 (1.59)
increase / decrease	enprd / eprd	**-0.253**** **(1.95)**	-0.114 (0.80)	**-0.454*** **(2.48)**	0.279 (1.34)
increase / decrease	eprd / rdis	-0.156 (1.514)	**-0.289*** **(2.04)**	**-0.299**** **(1.75)**	-0.144 (0.91)
increase / decrease	enprd / rdis	**-0.410*** **(4.21)**	**-0.403*** **(3.44)**	**-0.754*** **(4.09)**	0.135 (0.99)
increase / decrease	eprd / rndis	**0.290**** **(1.98)**	**0.313**** **(1.91)**	0.150 (0.57)	0.330 (1.31)
increase / decrease	enprd / rndis	0.037 (0.23)	0.199 (1.30)	-0.304 (0.99)	**0.609**** **(1.93)**

Notes: 1) t-statistics in parenthesis.
2) * denotes significance at the 5% level, ** at the 10% level.

It is also worth noting the importance of the dynamic specification of the regression equation for the magnitude of the coefficients. This has important consequences for government policy. For example, using the results from the dynamic regression an increase of productive expenditures as a ratio to GDP of one percentage point raises growth by 0.114 of a percentage point when financed by reduction in *enprd*; whereas, the growth rate increases by 0.253 of a percentage point when we use the results from the static regression.

The results from Table 7.1 take no account of differences in the relative size of expenditures and revenues. An increase in *eprd/GDP* of one per cent may involve a far greater *relative* change than a one per cent change in *enprd/GDP* due to differences in the relative size of expenditures on *eprd* and *enprd*. To demonstrate these differences in relative size consider the growth effect of a increase of one percent of non-productive expenditure[13] financed by distortionary taxation. Taking the average rate of growth per annum across all countries and all time periods, this would decrease the rate of growth from 2.30% to 2.237% under the static regression results. Now if we instead increase revenues of distortionary taxation by 1 per cent and chose to spend this increase in revenues on non-productive expenditure the rate of growth falls by a greater amount to 2.223% (under the static regression results). The fall in the average rate of growth is different in the two cases because of the difference in the relative size of *rdis* and *enprd* and what it means to increase the revenues/expenditures by 1 percent; we display the outcome for this and all other possible changes in fiscal policy in Table 7.2 below.

The largest changes to the rate of growth are from when we increase revenues from distortionary taxation and decrease revenues from non-distortionary taxation, (the rate of growth drops to 2.216% using the static regression results and to 2.187% in the dynamic regression), and finance increases in non-productive expenditures through distortionary taxation, (2.237% or 2.223% in the static regression or 2.238% or 2.224% in the dynamic regression).

Table 7.2 also provides us with information about the preferred method, in terms of the rate of growth of the economy, of financing a change of fiscal policy. For example if the government wishes to finance increases in non-productive expenditures (of which payments on transfers and welfare constitute the largest amount) then they have the choice to finance this through increases in distortionary or non-distortionary taxation, or a reduction in productive forms of expenditures. The preferred (growth-maximising) method of financing this increase would be through non-distortionary taxation. Taking the results from the dynamic regression the growth rate would increase to 2.330% under this method; whereas if financed by distortionary taxation the growth rate would be reduced to 2.238% and; to 2.283% if financed by reducing expenditures on productive goods and services.

[13] In the above example this increases the ratio of non-productive expenditures to GDP from 5.29 to 5.44.

Table 7. 2: Rate of Growth from Changes in Fiscal Policy

panel		Static growth rate	Dynamic growth rate	panel		Static growth rate	Dynamic growth rate
increase decrease	rndis rdis	2.341	2.355	increase decrease	rdis rndis	2.216	2.187
increase decrease	enprd eprd	2.261	2.283	increase decrease	eprd enprd	2.337	2.317
increase decrease	eprd rdis	2.277	2.258	increase decrease	rdis eprd	2.271	2.246
increase decrease	enprd rdis	2.237	2.238	increase decrease	rdis enprd	2.223	2.224
increase decrease	eprd rndis	2.342	2.346	increase decrease	rndis eprd	2.326	2.329
increase decrease	enprd rndis	2.306	2.330	increase decrease	rndis enprd	2.303	2.318

Note: per capita growth rate under no change in fiscal policy is 2.3%.

Differences in measurement of the variable makes comparisons to previous works difficult. The results from previous works using cross-section estimators, (such as Mendoza et al. (1996), Easterly & Rebelo (1993) and Koester & Kormendi (1987)), are in general smaller in magnitude than the estimates of the long run parameter from the dynamic regressions here. For the Mendoza et al. study the estimated effect of a 1% increase in taxation is around 0.02 of a percentage point but this does reach 0.06 when a fixed effects estimator is used. However, as argued in Chapter 6 the coefficients estimated by Mendoza et al. are biased towards zero by incomplete specification of the government budget constraint.

The estimated growth effects of fiscal tax policy, displayed in Table 7.2, are also significantly larger than the estimates of a 10% change in taxation from studies which have used simulation techniques (such as Lucas (1990), Stokey & Rebelo (1995), Mendoza et al. (1996)). These studies find that decreasing distortionary taxation by 10% and replacing them with non-distortionary taxes raises the growth rate by around 0.1 to 0.2 of a percentage point. The equivalent estimate in this study of a 10% increase in distortionary taxation (increase in non-distortionary taxation) is 0.84 of a percentage point reduction in the growth rate (a 0.41 of a percentage point increase) from the static panel results and even larger 1.13 of a percentage point reduction (0.55 of a percentage point increase) from the dynamic panel regression estimates.

The long run parameter estimates from the expenditure mix quadrant are very close to those estimated for the public capital stock measures by Kocherlakota & Yi (1997) for the UK and US for over 100 years of data. The parameter estimates are also reasonably in line with those from the cross-section studies of Barro (1991), Easterly & Rebelo (1993) and Miller & Russek (1993). They are however, larger than the estimates for developed countries in Devarajan et al. (1996), but their data is in a more disaggregated form and expressed as a ratio to total expenditure hindering comparisons.

7.5.2 Application to the Theory

Table 7.3 lists the coefficients we expect on the long run fiscal parameters under four different forms of model; the neoclassical model (in which there are no long run effects from fiscal policy); and the three different endogenous growth models (in which there are long run effects from fiscal policy).[14] These are the Barro (1990) one-sector model, the Barro & Sala-i-Martin (1992, 1995) congested public goods model,[15] and a two-sector model which includes a labour-leisure choice (hence consumption taxation is distortionary - Mendoza et al. (1996)), congested public goods, assumes the education sector is taxable and is not linear in its production technology.[16] It is clear from Table 7.3 that developing the model from the simple form used by Barro (1990) leads to problems of interpreting the estimated coefficients.

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[14] For a more complete summary of the results for particular fiscal policies along with the necessary assumptions see the conclusions to Chapters 2,3 & 4.

[15] We assume that physical capital does not display constant returns. The results are sensitive to this assumption and its employment returns the results to those of the Barro (1990) model.

[16] The results from the two-sector model are highly stylised and assumption dependant. For example, we ignore from here the growth effects from the changes in the mix of expenditures between sectors, and the taxation between sectors.

Table 7. 3: Summary of the Steady State Effects of Fiscal Policy in Economic Growth Models

		Theory			
		Exogenous	Endogenous		
			Barro	Barro & Sala-i-Martin (congestion)	Two-sector Model
increase decrease	rndis rdis	0	+	0	+/0/-
increase decrease	enprd eprd	0	-	0	-
increase decrease	eprd rdis	0	+/0/-	0	+/0/-
increase decrease	enprd rdis	0	-	0	-
increase decrease	eprd rndis	0	+	0	+/0/-
increase decrease	enprd rndis	0	0	0	-

The key difference between the neoclassical and endogenous growth models is the prediction of significant coefficients on the long run parameters within the fiscal matrix. Since our empirical results include significant long run coefficients within the fiscal matrices in both the dynamic panel regression and static panel regression sets, our evidence favours the endogenous over the neoclassical model.

Evidence also favours the versions of the endogenous growth model, which allow growth effects from fiscal policy. We therefore, do not find evidence of the congestion of public goods.[17] Nor do we find evidence of the extreme results from the two-sector tax model in which the accumulation of capital is linear and the human capital sector is non-taxable (Lucas (1990)).

The coefficients estimated from the static regressions accord very closely to the Barro public policy endogenous growth model (i.e. Chapter 6). The sign and the

[17] According to these models by our findings we provide indirect evidence of constant returns to scale across all reproducible factors in production. We note however that under alternative specifications of congestion (Glomm & Ravikumar (1994) and Fisher & Turnovsky (1998)) if the rate of congestion is sufficiently low then it could be that the congestion of public goods is not being captured in the regression (but then this would imply we are not accurately measuring the long run).

significance matches for all pairs of coefficients where it was possible to make a prior prediction of the expected coefficient. The results therefore, appear to give strong support to the separation of fiscal variables into four basic types, productive and un-productive expenditure and distortionary and non-distortionary taxes. That is, the results are consistent with the idea that the inclusion into the demand or supply sides of the model is enough to fully describe the growth effects of a particular policy.

The use of the dynamic panel data techniques slightly reduces the support for the Barro (1990) model. The model correctly predicts the sign and the significance on the *rdis/rndis*, *enprd/rdis*, *eprd/rndis* and *enprd/rndis* variables but only the sign on the *enprd/eprd* variable.

The predictions of the Barro model in terms of taxation appear to be well captured and the strongest departures appear on the expenditure side. The estimated insignificant effect of changes in the mix of expenditures contrasts with the Barro model, which predicts a significant positive relationship. In the Barro model productive expenditures increase the returns to private investment whereas non-productive expenditures have no effect. Therefore any change in the expenditure mix in the direction of non-productive forms of expenditure should, in theory, decrease the rate of growth.

The insignificant coefficient on the *enprd/eprd* variable could be used as evidence of any one of three conclusions: either both forms of expenditure are in fact productive (as in the Cashin (1995) model)[18]; that productive expenditures are subject to congestion (as in the Barro & Sala-i-Martin (1992) model); or neither form of expenditure is productive. We choose not to follow a general to specific approach to determine which fiscal variables may be excluded from the regression, which in turn may help to distinguish between these three hypotheses. it is however an issue we

[18] The results from the Cashin (1995) model hold because non-productive expenditures are modelled identically to productive expenditures i.e. they are included as inputs into the production function. This might be a reasonable assumption if the non-productive expenditure variable contains elements of public investment as may be the case in this data set.

return to in the next chapter when we disaggregate the expenditure categories from their present form.

7.6 *Sensitivity Analysis*

The standard approach to separating the long and short run information contained within the data has been to use some form of period averaging. This has settled on the use of 5-year period averages with the beginning of the data period chosen as the first available observation to begin this process (usually 1960 or 1970). The basis for organising the data as 5-year periods over possible alternatives is in order to remove as much of the short run effects as possible but to maximise the time series element of the data set. We perform four tests for the sensitivity of the results to these choices. The first test considers the length of period average through which to remove the short run information contained within the data; the second considers the sensitivity to the start date for period averages; and the third test considers alternative estimators for the dynamic panel regressions we have run.[19] Finally we use some alternative lag structures within a dynamic regression.

7.6.1 *Length of Average*

Averaging the data over long time periods has the advantage of smoothing out more of the short-run effects from the data but at the cost that potentially useful information is being removed from the data. Further problems may be encountered if, as Folster & Henrekson (1997) argue, too long a length of period average is used. This being likely to lead to simultaneity between certain types of expenditure and growth through Wagner's law. In order to consider the robustness to the use of alternative period averages we estimate the regression using 10-year period averages.[20] A degrees of freedom problem prevented the analysis of the same problem for dynamic panels and sensitivity tests through instrumental variable

[19] We also tried sensitivity to the level of classification. The results were broadly similar and since the issue of aggregation is taken up in the next chapter we do not report the results here.
[20] The 10-year averages run across the years 1973-82 and 1983-92 producing 36 data points. The average was only taken for the 10-yearly averaged data when 8 or more data points were present which meant both Italy and Portugal were excluded from the data set.

techniques. The results for this regression are displayed in Table 7.4 along with those from the static panel regression from Table 7.1.

Table 7. 4: A Comparison of Static Panel Estimation with 5 and 10-year Averages

panel		Static	
length of average		5-year	10-year
increase decrease	rndis rdis	0.446* (2.60)	0.953* (2.43)
increase decrease	enprd eprd	-0.253** (1.95)	-0.163 (0.61)
increase decrease	eprd rdis	-0.156 (1.514)	-0.208 (0.70)
increase decrease	enprd rdis	-0.410* (4.21)	-0.371 (1.49)
increase decrease	eprd rndis	0.290** (1.98)	0.745* (2.78)
increase decrease	enprd rndis	0.037 (0.23)	0.582* (1.15)

Notes: 1) t-statistics in parenthesis.
2) * denotes significance at the 5% level, ** at the 10% level.

The results for the two static regressions are in places quite similar, and the use of 10-year as opposed to 5-year averages does not remove much of the explanatory power of the regression. The adjusted R^2 for the regressions using 5-year averages is 61.5% while the adjusted R^2 for the regression using 10-year averages is 59.5%. The coefficients on the *rndis/rdis*, *eprd/rdis* and *eprd/rndis* are identical across the two sets of regressions but the significance of the coefficient on the *enprd/eprd* and *enprd/rdis* variables is lost when we use 10-year averages. The magnitudes of the coefficients on the enprd/eprd and enprd/rdis variables are not greatly different between the two static regressions whereas the standard errors on these variables are inflated in the regressions using 10-year averages. It is therefore likely that the loss of significance of these variables reflects the loss of degrees of freedom from averaging the data over longer time periods. Once this possibility is accounted for the results for the two static regressions then appear to take on a stronger degree of similarity and the results appear to be relatively insensitive to the choice of period average.

Such an explanation is however, not consistent with the variable *enprd/rndis* gaining significance. Given it was simultaneity between *enprd* and the growth rate which Folster & Henrekson (1997) argued would be aggravated by increasing the length of the period average this result would appear to support their conjecture. A lack of computing power prevents further analysis of this potential relationship using 2-stage least squares regressions.

A comparison of the magnitudes of the coefficients between the two estimators shows large changes. For example, on the *rndis/rdis* variable the point estimate is 0.45 using 5-year averages and 0.95 using 10-year averages; while the point estimate on the *eprd/rndis* variable is 0.29 using 5-year averages but 0.75 using 10-year averages. Such large changes as these have dramatic implications for policy. For example, according to the results from the 10-year period averaged data the point estimate of an increase in non-distortionary taxation financed by distortionary taxes is almost +1.00 percentage points. Such a figure seems unrealistically large. Curious of this result we reviewed other studies that have report results using alternative period averages. Although they do not highlight this feature, Oulton & Young (1996) find similar effects for the social returns to investment. Period averaging clearly has affects on the magnitude of the coefficients in ways in that are hard to explain.

7.6.2 Period Averaging

As is typical in empirical studies the start date for the period averages here is taken from the first available observation. So for this study 5-year period averages run from 1970-74, 1975-79 and so on. If the period average encompasses the length of the business cycle then this sort of period averaging is an acceptable means of smoothing the short run component from the data and is so doing reducing possible simultaneity between fiscal policy and growth. However, if the choice of period average does not capture fully the business cycle these results may be biased (and the results from the dynamic regressions presented in Section 7.4 already suggest this). One simple way of testing this is to alter the start year of the period average. If 5-years fully captures the effects of the business cycle then such a change will have no effect on the long run relationship between fiscal policy and growth. We construct three alternative sets of period averages all 5-years in length but with start dates in 1971, 1972 and 1973 instead of 1970. Only 5-year period averages are calculated and the regressions are only run for static panels.[21] The results are displayed in Table 7.5 (the results for 1970 as the start years are included as a reminder).

Table 7. 5: Robustness to Alternative Start Years for Period Averaging.

Start Year		1970	1971	1972	1973
increase decrease	rndis rdis	**0.446* (0.17)**	**0.332** (0.20)**	**0.511** (0.26)**	**0.457* (0.22)**
increase decrease	enprd eprd	**-0.253** (0.13)**	**-0.293* (0.13)**	-0.085 (0.18)	0.006 (0.16)
increase decrease	eprd rdis	-0.156 (0.10)	0.031 (0.10)	-0.180 (0.14)	-0.154 (0.13)
increase decrease	enprd rdis	**-0.410* (0.10)**	**-0.325* (0.11)**	**-0.266* (0.13)**	-0.148 (0.11)
increase decrease	eprd rndis	**0.290** (0.14)**	**0.301** (0.18)**	0.331 (0.22)	**0.304** (0.18)**
increase decrease	enprd rndis	0.037 (0.16)	0.007 (0.18)	0.245 (0.22)	0.310 (0.20)
adj. R^2		0.602	0.587	0.339	0.441

Notes: 1) t-statistics in parenthesis.
2) * denotes significance at the 5% level, ** at the 10% level.

The choice over the start year for period averaging clearly has an impact on the results for some of the pairs of fiscal variables but not for others. This can be seen most clearly for the regressions using 1972 as the base year. The significance of the regression falls significantly and the standard errors on the variables increase in size.[22]

[21] The size of the data set falls to 86 observations for each of these alternative start years such that a degrees of freedom problem is soon reached when the regressions are run for dynamic panels. It is possible to aggregate some of the expenditure and taxation terms to reduce the degrees of freedom problem. When we estimate regressions of this kind we find similar results to those from the static regressions. We draw upon some of these results in the next chapter.

[22] This regression also favours one-way rather than two-way fixed effects models. We report the results for the preferred model but we note that the inclusion of time dummies means the results are even less consistent with those using 1971 or 1973 as the base year.

The results would appear to be non-robust for all variables except *rdis/rndis* and *eprd/rndis* (if we treat 1972 as a rogue regression). For the remaining pairs of variables the greater variation appears on the estimated coefficients rather than in the standard errors. For example, the estimated coefficients on *enprd/eprd* varies between -0.293 to +0.006; while for *eprd/rdis* the coefficient varies between +0.156 to -0.154; and for *enprd/rndis* between 0.007 to 0.310. As a consequence the recommended policy prescriptions also vary between models. For example, the point estimate of an increase in non-productive expenditure as a ratio to GDP by 1 percentage point financed by distortionary taxation lowers the growth rate by 0.410 of a percentage point when 1970 is used as the base year and by 0.148 of a percentage point when 1973 is used as the base year. For *enprd/eprd* and *enprd/rndis* such movements are within the upper and lower extreme bounds[23] one might statistically expect the estimated coefficient to vary between given the change in the sample size. In contrast, although the *erpd/rdis* variable remains insignificant, the variation here is well outside what one might reasonably expect.

The results from this section suggest at the very least that caution should be employed when using static panel data techniques and some sensitivity testing to the base year chosen for period averaging should be made. Alternatively, it could be argued that given 5-year period averages do not fully encompass the business cycle they are not capable of distinguishing between short and long run movements within the data. They should not therefore be used to test between models of long run growth.

This result also warns against using lagged periods as instruments when testing for simultaneity in the regressions as the instruments may themselves be correlated with growth. A similar conclusion is reached by Lopez, Fabrizio & Ubide (1997) for the Spanish economy where they estimate the effects of the business cycle may still be present in the data some 15 years later (this compares with typical estimate for the US business cycle of around 6 to 8 years in length).

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[23] Taken as +/- twice the standard error of the estimated coefficient.

7.6.3 Alternative Estimators

The parameter estimates from dynamic panel data regressions are by their very construction biased because of the correlation of the lagged dependent variable, Δy_{it-1}, with the error term. Most solutions to this problem have suggested the use of instrumental variable (IV) techniques as reviewed in appendix B. The consistency of the IV techniques in panel data regression rely heavily on the assumption of a fixed time dimension and a large number of cross-sectional units. Unfortunately the data set used in this study does not have these properties. The use of IV techniques as a solution to this problem therefore becomes questionable. Judson & Owen (1997) run Monte Carlo experiments to estimate the bias of the parameters in typical macroeconomic data sets (small N and small to large T) for 6 types of estimator (OLS, LSDV, corrected LSDV (LSDVc), Anderson-Hsiao (AH), and two forms of generalised method of moments (GMM) estimators. On the principal parameters of interest to us in this study, those on the fiscal variables, Judson & Owen conclude that "the bias of the estimates.... are relatively small for all techniques except OLS, and, thus, cannot be used to distinguish between estimators."[24] Judson & Owen demonstrate that the different estimators do not bias the sign on the estimated coefficient, but do bias the magnitude of the parameter. The bias on the AH and LSDVc estimators is smaller than the LSDV and GMM estimators but at the cost over the LSDV estimator of a lower efficiency of the parameter estimates. The LSDVc estimator requires a balanced panel and is computationally complex, therefore, it was decided to test the robustness of the results found above using the AH estimator.

The AH estimator uses the lagged level to instrument for the lagged difference term, $\sum_{j=1}^{n} \lambda_i \Delta y_{i,it-j}$, in equation (7.4) above.[25] Lagged growth is therefore replaced by

[24]Judson & Owen (1997) *'Estimating dynamic panel data models: A practical guide for macroeconomists'* Federal Reserve Bank of Washington Working Paper

[25] Arellano & Bond (1991) and Kiviet (1995) confirm the superiority of using the lagged level as an instrument over the lagged difference in simulation results.

lagged GDP in equation (7.4). Despite reservations that the estimated regression has the appearance of a growth accounting regression with the assumption that the coefficient on the lagged GDP term is equal to one, the results are displayed in Table 7.6 below.[26]

Table 7. 6: Robustness to the use of AH Estimators

length of average		5-year
instrument		lagged GDP
increase decrease	rndis rdis	1.107** (1.95)
increase decrease	enprd eprd	-0.872* (3.94)
increase decrease	eprd rdis	-0.501* (2.24)
increase decrease	enprd rdis	-1.373* (6.84)
increase decrease	eprd rndis	0.606 (1.27)
increase decrease	enprd rndis	-0.267 (0.47)
adj. R^2		87.8

Notes: 1) t-statistics in parenthesis.
2) * denotes significance at the 5% level, ** at the 10% level.
3) coefficients are long run estimates

Comparing the results in Table 7.6 to those in Table 7.1 shows there to be two changes from the use of AH instrumental variable estimators over the LSDV estimator. The coefficient on the *enprd/eprd* variable still has a negative coefficient but this is now significantly different from zero, while the *enprd/rndis* variable is now negative but remains statistically insignificant. There is therefore, some slight sensitivity of the significance of the parameter estimates to the use of the AH estimators but, a greater amount of sensitivity of the magnitude of the long run coefficients. A comparison of the magnitude of the estimated coefficients from Table 7.6 and Table 7.1 demonstrates that the long run parameter estimates from the AH estimator are consistently larger than those from the LSDV estimator. This result is

[26] The regression includes country and time dummies as instruments but not as regressors.

perhaps unsurprising given that most of the bias from the calculation of dynamic panel data models appear on the estimation of the lagged dependent variable. The lagged dependent variable is used in the calculation of the long run parameter and therefore affects the magnitude of the long run coefficients. Judson & Owen (1997) estimate that the LSDV estimator biases the estimate of the lagged dependent parameter downwards towards zero, whereas the AH estimator leads to an upward bias away from zero. It is probable that the true long run parameters lie somewhere between our two calculations.

7.6.4 Lag Structure

A degrees of freedom problem prevents the use of 5-year averages in comparing different lag structures and so instead we turn to the use of annual data. Not averaging the data provides us with many more degrees of freedom and captures additional information that may be contained within the past history of the dependent variable. Estimates of the long run effects of policy using annual observations may be misleading if the data period is too short and does not contain enough variation over the cycle. This is unlikely to be a problem in the data set used here but the decision was made to exclude countries with a short time-series element so that long lag structures could be estimated to overcome these problems.[27] We anticipate that some of the differences in the results between the annual data observations and those using 5-yearly averaged data may be because of the reduction in the number of countries. In order to make meaningful comparisons with the annual data regressions we re-run the regressions using 5-year averages of the data over the smaller sample of countries. It is the results from these regressions that are reported in Table 7.7 as the dynamic regressions using 5-year period averages.

The reduction in the country dimension of the sample has little impact on the results for the regression set using 5-year averaged data. The difference in the results is on the *enprd/rndis* variable, which has a significant coefficient in Table 7.7 where before the estimated coefficient was insignificant. The results from the restricted sample finds evidence in favour of the Cashin (1995) version of the Barro model in which transfers have a positive effect on the rate of growth.

Table 7. 7: Comparison of Dynamic Panel Estimation with Annual Observations and 5-year Averages

length of average		5-year	annual	annual	annual
number of lags		1	6	7	8
increase decrease	rndis rdis	**0.766** **(3.55)**	**0.663** **(4.60)**	**0.479** **(4.28)**	**0.263** **(1.73)**
increase decrease	enprd eprd	-0.175 (1.31)	**-0.270** **(4.27)**	**-0.279** **(6.05)**	**-0.348** **(5.49)**
increase decrease	eprd rdis	**-0.262** **(1.84)**	**-0.192** **(2.33)**	-0.103 (1.62)	0.017 (0.18)
increase decrease	enprd rdis	**-0.437** **(3.74)**	**-0.462** **(6.60)**	**-0.382** **(7.12)**	**-0.331** **(4.55)**
increase decrease	eprd rndis	**0.504** **(2.97)**	**0.471** **(4.60)**	**0.377** **(4.88)**	**0.279** **(2.88)**
increase decrease	enprd rndis	**0.329** **(2.05)**	**0.201** **(2.10)**	0.097 (1.35)	-0.068 (0.73)
adj. R^2		71.2	64.1	72.5	73.9
Wald test		4.32	17.27	28.91	19.99

Notes: 1) t-statistics in parenthesis.
2) * denotes significance at the 5% level, ** at the 10% level.
3) coefficients are long run estimates

Table 7.7 displays only the estimated long run coefficients from three of the dynamic regressions using annual data we estimated. A comparison between them shows them to be fairly consistent in terms of estimated sign and significance across several of the variables. The choice of lag structures was made using a general to specific approach. The maximum number of lags it was felt that could be reasonably be used given the time series element of the data and still maintain a sensible number of degrees of freedom was nine. Testing between lag structures was made on the null of the joint significance of the last lag of the explanatory variables within the regression. The exclusion of these lagged values is accepted up until the inclusion of

[27] Greece (10-years), Ireland (11 years), Italy (11 years), Portugal (11 years), and Switzerland (15-years) were removed from the data set for the regressions.

an 8th lagged term. The Wald value for the null of the joint significance of the 9th lag is 6.90 against a critical value with 9 degrees of freedom of 14.68 at the 10% level of significance and 16.92 for the 5% level of significance. A separate test on the joint significance of the main fiscal variables (*sur, rdis, rndis, eprd, enprd* - not reported), also rejected the inclusion of the 9th lagged value of the explanatory variables.[28] The Wald test statistics for the other lags are recorded in the results table. The adjusted R^2 rises significantly between the three different types of regression with annual observations. The adjusted R^2 rises from 64.1% when 6 lags are used to 72.5% when 7 lags are used to 73.9% when 8 lags are used, (these compare to 71.2% for the set of dynamic regressions using 5-year averages).

Of the variables contained in the conditioning matrix for the dynamic panels with annual observations, the investment ratio is estimated as having a significant effect on the long run growth rate of a country in irrespective of alternative lag structures. The labour force growth rate is statistically insignificant. Significant long run effects from certain combinations of fiscal policy can also be found in Table 7.7 although this varies over choice of lag structure. For example, the significance of *eprd/rdis* and *enprd/rndis* variables is lost the longer the lag structure of the regression. It appears the results display a greater consistency with the Barro (1990) model the longer the estimate of the 'long run'. Care is, therefore, required when specifying the regression equation so that 'short run' and 'long run' effects of fiscal policy are not confused.

Comparing the dynamic regressions using annual data and 8 lagged explanatory variables with the dynamic regressions using 5-yearly averaged data shows there to be some sensitivity to the differences in the organisation of the data. Where the dynamic regression using 8 lagged terms provides evidence in favour of the Barro endogenous growth model, the regression using 5-yearly favours the Cashin (1995) version of the same model. Several of the parameters are consistently estimated as having the same sign and significance but the *enprd/eprd* variable gains significance in the regressions using the annual data, whereas the *eprd/rdis* and *enprd/rndis* variables lose significance. Evidence of strong positive effects on growth from non-

[28] The Wald statistic for this test was 0.80

distortionary tax financed increases in non-productive expenditure in the dynamic regression with 5-year period averages is consistent with a model such as Cashin where the expenditures we describe as 'non-productive' are better thought of as being productive. The fact that the regression with annual observations of the data and eight lagged variables finds in favour of the Barro model is interesting because the non-dynamic regression we criticise above for being misspecifying the dynamic present in the data set found in favour of the same model.

Table 7.8 below repeats the analysis found in Table 7.2 but using the regression results from the restricted sample dynamic regression with 5-yearly averaged data and the dynamic regression with annual observations and 8 lags of the explanatory variables. It appears from Table 7.8 that there is a consistent set of fiscal variables that have large effects on the growth rate.

Table 7. 8: Change in Growth from a 1% Mean Change of Fiscal Policy

panel		Dynamic	Dynamic	panel		Dynamic	Dynamic
average		5-year	annual	average		5-year	annual
no. of lags		1	8	no. of lags		1	8
		growth rate	growth rate			growth rate	growth rate
increase decrease	rndis rdis	2.370	2.324	increase decrease	rdis rndis	2.156	2.251
increase decrease	enprd eprd	2.273	2.247	increase decrease	eprd enprd	2.326	2.351
increase decrease	eprd rdis	2.262	2.303	increase decrease	rdis eprd	2.251	2.303
increase decrease	enprd rdis	2.233	2.249	increase decrease	rdis enprd	2.218	2.238
increase decrease	eprd rndis	2.374	2.341	increase decrease	rndis eprd	2.346	2.325
increase decrease	enprd rndis	2.350	2.290	increase decrease	rndis enprd	2.323	2.294

Note: per capita growth rate in the absence of change in policy is 2.3%.

The magnitude of the growth effects from changes in fiscal policy for the static panel regression display a stronger degree of similarity to the results from the dynamic regression using annual observations than the two forms of dynamic regression using

5-yearly period averages. The dynamic regressions using 5-year average tend to estimate larger long run effects from a change in fiscal policy. For example the growth effect of a 1% increase in productive expenditure financed by non-distortionary taxation increases growth from 2.3% to 2.342% from the static regression, to 2.346% from the dynamic regression with 5-year period averages (2.374% with the smaller sample) and 2.341% from the dynamic regression with annual observations.

7.7 *Conclusions*

The regression equation we estimate in this chapter embeds the most common form of static panel regression found in the literature into a dynamic version of the same equation. Using data for 22 developed countries from 1970-94 averaged across 5-year periods we find we cannot reject the inclusion of these lagged terms within the regression. That is, the standard approach used within the literature is misspecified in terms of its dynamic component. By implication the present empirical literature provides us with unreliable information when testing between competing theories.[29]

The choice over the econometric methodology and data transformations does not, in conclusion, appear to have a significant impact on the ability to distinguish between growth models. Nor does it appear to offer an explanation as to the large variation of results found from a review of the literature. Under all of the possible alternatives which we consider we find evidence that the endogenous growth model is a closer representation of the data used in our sample. We do not however, conclude that the current methodology is appropriate.

The choice of methodology does affect our choice between classes of endogenous growth model. We observe small variations in the significance of coefficients between studies and large variation in the magnitude of their effects on growth. The results then become constant with the observations from a number of competing endogenous growth models. For example, the strong support we find for the Barro

(1990) version of endogenous growth model from the static regression is weakened when we move to a dynamic regression. Most notably the static regression fails to find the same insignificant coefficient on the productive/non-productive expenditure mix as the dynamic regression. It is not possible to determine whether the results from the dynamic regression favour the Cashin (1995) variant of the Barro model (in which transfers are productive) or the Barro & Sala-i-Martin (1992) version (in which productive goods become congested over time). When we restrict the sample of countries to exclude those with a short time series element the results favour the Cashin variant of the Barro model.

The robustness of these results is tested by considering different period averages, lag structures of the dynamic regression, and alternative estimators. The use of 10-year averages as opposed to 5-year averages has no effect on the signs of the estimated coefficients but does affect the significance (primarily due to a loss of degrees of freedom) and the magnitude of the coefficients (being counter-intuitively greater in magnitude in the regressions using 10-yearly averaged data). These results may, in part, be explained by a possible simultaneity bias induced by too long period averaging (Folster & Henrekson (1997)). This leads us to suggest caution over the length of period average; that some sensitivity to alternative period averages is advisable and that further investigation be made into the 'black-box' of period averaging.

The results from the static panel regression are also sensitive to the base year chosen for the period average. The choice of period average assumes that it adequately filters out any short run information contained within the data. We show that moving the start year forward by one period can dramatically alter the results. Indeed in certain cases the variation in the parameter estimates is well outside the normal statistical sampling variation. From this we again recommend caution when using period averages and that some robustness testing be used. The use of AH instrumental variable estimators has little impact on the significance of the long run fiscal variables but does impact on the magnitude of the coefficients. In our final test of

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[29] In addition, this result also suggests that lagged values should not be used in instrumental variable

robustness we find some slight sensitivity to the use of dynamic panel regressions with annual data and long lag structures. Using a general to specific approach we find the eighth lagged value adds significantly to the explanatory power of the regression which again suggests that 5-year period averages are of an inappropriate length.

The inability to choose between variants of endogenous growth model is explained by the inability of 5-year period averages to remove the short run component of the data and therefore to consistently capture the long growth effects of fiscal policy. This is shown by; the failure to reject the addition of lagged values to the regression and; that the results are sensitive to the choice of start year for period averaging and; the length of period average. The dissatisfying nature of the results from the 10-year period averages indicates that this methodology may prove to be an unattractive alternative. Clearly further investigation is required into what information we remove, or possibly add, to the data set when we use period averaging.

Following Kocherlakota & Yi (1996) we therefore conclude in favour of the use of annual observations and long lag structures in the specification of the regression equation. Limitations on the length of data set currently available inhibit the use of time series techniques hence, further investigation, along the lines of Judson & Owen (1997), into the properties of dynamic panel regressions using typical macro data sets (small N and small to medium T) is warranted. Drawing upon results found in the next chapter we find that the results from such regressions may also be reasonably robust to the use of alternative estimators such as Anderson-Hsiao. Finally, somewhat perversely when we use this kind of estimator the results correspond reasonably closely to those from the static panel regression and also favour the Barro (1990) model.

regressions as they are likely to be correlated with growth themselves.

Chapter 8

Growth and the Homogeneity of Expenditures

8.1 Introduction

As is shown by Levine & Renelt (1992) and the great variety of results reported in the published literature, there is little consensus about the empirical impact of fiscal variables on economic growth. We showed in Chapters 6 and 7 that some of this lack of consensus can be explained by different or incomplete specifications of the government budget constraint, or by different ways of aggregating the data over time. A further issue is the optimal level of disaggregation of the fiscal variables themselves.

To reiterate, Barro (1990) models expenditures as being either productive or unproductive. Increases in productive expenditure, through the increased returns they provide to private production, increase the long run rate of growth of the economy while; increases in unproductive expenditure in contrast, through the assumption of household behaviour, have no effect on the long run growth rate of the economy. There is, therefore, a clear distinction within the model between productive and non-productive expenditures in their effect on the steady state rate of growth and the theory says little about the likely coefficient on the total expenditure term sometimes used in previous research.

Productive goods are assumed in the Barro model to be homogeneous in their effect on output. Productive goods can therefore, be included as a single argument within private production function of the model. In reality it is unlikely that £1 of expenditure on any form of productive good or service has an identical impact on growth as all others (and economists do not always agree on the boundary between productive and unproductive expenditures). Disaggregating the productive expenditure variable used in the previous two chapters captures the possibility that different forms of expenditure and taxation have different magnitude of effect on private production, and in so doing improves the reality of the model (Devarajan et al. (1996), Stokey & Rebelo (1995)).

From an empirical perspective, too high a level of aggregation risks widening the confidence intervals of coefficients when different elements of an aggregate are in fact characterised by different coefficients.[1] On the other hand, too much disaggregation risks losing the signal in the noise, since smaller units of expenditure are likely to have a lower impact on the growth rate, and this implies lower significance levels unless the fit is dramatically improved by disaggregation.

Within this chapter we concentrate on the homogeneity assumption with regard to government expenditures. We draw on the theoretical and empirical work of Devarajan et al. (1996) to show how changes in the mix of expenditures can affect the growth rate.[2] We then use this to test (*i*) whether the data support the separation of expenditures into two types (productive and non-productive) and (*ii*) whether the assumption of homogeneity can account for the non-robust relationship between expenditures and growth. Three levels of aggregation of the data are used. In two of these we arbitrarily classify the data as either productive or non-productive, while in the third we allow the data to suggest the relationship with growth. Data for 17 developed countries over the period 1970-94 are used.[3]

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[1] Too much aggregation carries with it the additional possibility of introducing parameter heterogeneity problems.

[2] It was decided to concentrate on the expenditure rather than the taxation side of the model for two reasons. Firstly the underlying results for taxation are less robust than expenditures to changes in the underlying assumptions. The results just within the endogenous growth models can vary between no predicted relationship to all types of taxation affecting growth. Such sensitivity makes testing between models difficult. Secondly the tax measures used in this study could be thought to more accurately reflect average rather than marginal rates of tax. This is not an issue in the theoretical model because of the assumed nature of taxation but in reality the two are likely to diverge.

[3] The reduction in the number of countries to 17 is required in the grounds of the dynamic panel data estimator being used with annual observations (see Section 7.5.4 for details).

8.2 *Existing Literature*

8.2.1 *Theoretical Literature*

As shown in Chapter 2 the nature of the effect of any particular government expenditures on the steady state rate of growth is determined according to their inclusion in the production or consumption side of the model. If the *level* of expenditure is fixed (which we must assume if we wish to ignore taxation from the model) then the steady state rate of growth can only be increased by replacing non-productive expenditures with productive forms (that is changes in the *mix* of expenditures).

The Barro (1990) model assumes that all productive public goods are homogeneous in their effect on the returns to investment and can therefore be represented as the same single term with the private production function. Devarajan et al. (1996) remove the homogenous public good assumption to allow different forms of expenditure to have a different effect on private production. Again, as shown in Section 2.4, assuming a fixed level of government, the growth affect of an increase in one form of expenditure depends upon its *relative* productivity and the *relative* size of current expenditures compared with the good or service it replaces.

Changes in other characteristics, such as stocks and flows of public goods (Glomm & Ravikumar (1994) or the speed of congestion (Fisher & Turnovsky (1998)) may also lead to differences in the magnitude of the coefficient and be used against aggregating the data. Cashin (1995) allows the non-productive expenditures of the Barro model to have positive effects on growth by including these as additional arguments within the firm's production function. These raise the marginal product of capital and hence growth. These expenditures are not expected to have the same effect on growth as other productive expenditures. This change in the assumptions of the model therefore requires formal testing.

8.2.2 Empirical Literature

Attempting to distinguish whether the level of aggregation of fiscal variables has an impact on the findings from previous works is difficult given the effect on the parameter estimates of the other sources of instability (such as those identified within the previous two chapters). We therefore chose not to provide a detailed review of the previous empirical literature but do note several points in the literature where there does appear to be an obvious relationship between the level of aggregation and the role of fiscal policy. From this review we are able to conclude that, if anything by disaggregating the data we can improve the explanatory power of fiscal variables.

Devarajan, Swaroop & Zou (1996) study the relationship between the rate of growth and the composition of government expenditures for 21 developed countries. Using data for 1970-90 from the GFSY organised as 5-year moving averages, the rate of growth is regressed against four aggregate expenditure categories as a ratio of total expenditures, (health, education, defence and transport & communication), and then regressed again using disaggregated forms of education and health expenditures. When the four aggregate forms of expenditure are included within the same regression only transport & communication expenditure has a significant coefficient. When health and education expenditures are included in disaggregated form several types of expenditures (other education, hospital, other health, primary and secondary schooling and universities) are found to have a negative relationship with growth.

The finding of a positive significant coefficient on the transport & communication expenditure term in the Devarajan et al. study matches those found by Barro (1991) and Easterly & Rebelo (1993). In contrast, when total public investment (of which transport & communication expenditure is a part) is used as the explanatory variable the significant relationship disappears. Barth & Bradley (1987), Barro (1989, 1991) and Easterly & Rebelo (1993) all find insignificant coefficients on total public investment variables.

8.3 *Data and Empirical Methodology*

8.3.1 Data

We use this section to briefly consider the way in which we have aggregated the available data. Three levels of aggregation are used within this study. The first, and most aggregated form, uses the theory as its inspiration; the second uses an expanded theoretical data set that, amongst other things, distinguishing between stock and flow categories (Glomm & Ravikumar (1994); while the third classifies the data by function. This process is described below.

We follow the practice adopted within the previous chapters and, as in Barro (1990), label expenditures as either productive or non-productive[4]. Table 8.1 below is adapted from the previous chapter in order to summarise how the functional classifications of expenditures available in the GFSY have been aggregated and to serve as a reminder.

[4] In preference to the way we have categorised expenditures as productive or non-productive we would have preferred data on capital and current consumption for each country and each form of expenditure. However, this data is not available in a disaggregated form for all countries in the GFSY. We accept that the functional classifications contain information on both current and capital consumption within them but given that have been used before in other studies (Devarajan et al. (1996)) it felt that they could still provide some interesting results.

Table 8. 1: Theoretical/ Functional Classifications

New Classification	Functional Classification
surplus/deficit *(sur)*	surplus/deficit
productive expenditures *(eprd)*	general public services expenditure
	defence expenditure
	educational expenditure
	health expenditure
	housing expenditure
	transport and communication expenditure
non-productive expenditures *(enprd)*	social security and welfare expenditure
	expenditure on recreation
	expenditure on economic services
other expenditure *(eoth)*	other expenditure

The classification of expenditures in the manner described above is open to debate. In order to address this we disaggregate the data in order to focus on some expenditure forms that are either commonly used in previous studies; that produce some of the consistently strong results; or that constitute such large proportions of total expenditures as to swamp the other results. This level of aggregation we call the re-classified data set and is illustrated in Table 8.2.

Table 8. 2: Re-classified Data

New Fiscal Variable	Old Fiscal variable
surplus/deficit *(sur)*	surplus/deficit
productive flows *(epf)*	general public services expenditure defence expenditure
productive stocks *(eps)*	educational expenditure housing expenditure transport and communication expenditure
health expenditure *(ehlth)*	health expenditure
social security and welfare expenditure *(ess)*	social security and welfare expenditure
other expenditure *(eoth)*	expenditure on recreation expenditure on economic services other expenditure

There is no longer a non-productive expenditure category as expenditure on social security and welfare have been separated out (social security expenditure is by far the largest component of both the budget of the average country, and the non-productive expenditure category defined above). The remainder of the *enprd* expenditure category, (recreation and economic services), have been included within 'other expenditures' and are ignored in the subsequent discussion. The other difference from the previous aggregation is the separation out of those expenditures which are perceived to be productive as a *flow* of goods and services, such as defence, and those arguably productive as a *stock* of goods, such as transport & communication expenditure. The expenditure categories described as the stock of productive goods actually represent flows into the stock of public goods. It was felt that the forces of congestion and depreciation that act on the stock expenditure may lead the coefficients on these two variables to differ and hence were separated.

8.3.2 Empirical Methodology

In this study we wish to concentrate on what Devarajan, Swaroop & Zou (1996) describe as the composition effect of government expenditures rather than the level effect. The development of the government budget constraint methodology in Chapter 6 provides with the means of separating these two effects (we refer the reader to Section 6.2.2 for a review). To this we combine the use of dynamic panel regressions with annual observation and long lag structures preferred in Chapter 7.[5] Alternative estimators of the long run are considered in the sensitivity tests of section 8.5.1.

8.4 Empirical Results

Theoretically Restricted Fiscal Data

It is evident from tables 8.3 to 8.5 that the way in which we classify the expenditure data has important implications for the way in which we interpret their impact on growth. We also note the explanatory power of the regression falls as we disaggregate the data. The adjusted R^2 falls from 73.9% when we classify the data according to the theory, to 68.1% when we disaggregate out certain elements of the theoretical classifications, and down to 63.5% when we classify the data by function. The relative number of significant coefficients in the fiscal matrix of results also falls as we disaggregate the data. This fall in the explanatory power and the relative number of significant coefficients may be because the estimated coefficients provide

[5] A degrees of freedom problem meant that the regressions which used the data as classified in the GFSY (i.e. the most disaggregated form of the data) were estimated using an alternative procedure. This approach aggregates upwards from the theoretically restricted data set to leave only one revenue category, one expenditure category and the surplus variable. Two revenue or expenditure categories are then disaggregated out from this and there co-relationship tested. For example expenditure on health and education were disaggregated out of the one aggregate expenditure category and then in turn left out of the regression as before in order to estimate the growth effects of a change in this portion of the expenditure mix. The fiscal matrix is then reduced to one set of coefficients, that of a pair of coefficients relating to the growth effects of the mix between health and education expenditure. This allows us to estimate the regressions without the degrees of freedom problem. The fiscal matrix appears identical in form however as we combine these pairs of coefficients into a single matrix. Under the old method the expenditure mix would have been made up from seven regressions it is now made up from twenty-one regressions.

us with information as to the *net* effect of a change in one form of expenditure *and/or* because the fiscal variables account for much smaller percentages of GDP so that the signal is lost in the noise of the data set.

Table 8. 3: Results Using Theoretical Data Set

	eprd	enprd
eprd		0.348* (5.49)
enprd	-0.348* (5.49)	
adj R^2	0.739	

Notes: 1) t-statistics in parenthesis.
2) * denotes significance at the 5% level, ** at the 10% level.
3) coefficients are long run estimates

Of the variables in the conditioning matrix of the regression there is some sensitivity to the way in which we classify the data. The investment variable has a significant positive effect on the long run rate of growth in the first set of regressions and second set of regressions but is outside of the critical value when the fiscal variables are in their most disaggregated form. The rate of growth of the labour force has an insignificant effect on the rate of growth in the first and third classifications of the data but a significant negative effect (at the 10% level of significance) in the second classification of the data.

In the Barro (1990) and Devarajan et al. (1996) models productive government expenditures are included within private production functions and help to increase output of the economy. Non-productive expenditures, on the other hand, have no effect on output. An increase in productive expenditure funded by a corresponding decrease in non-productive expenditure leads to an increase of the rate of growth of output. Our classification of the data as either productive or non-productive appears to be consistent with the theory. Increasing non-productive forms of expenditure (expenditures on social security, recreation and economic services) as a ratio to GDP by 1% and compensating through a decrease in productive expenditures

(expenditures on general public services, defence, education, health, housing and transport and communication) and leaving constant the overall level of expenditures reduces the growth rate by some 0.348 of a percentage point.

Differences in the organisation of the data as well as interpretation of the coefficients between this and previous works (the coefficients in previous studies contain composition and level effects together) makes comparisons difficult. Government consumption expenditure as a ratio to GDP has often been used as a proxy for the 'non-productive' expenditure category of the Barro model (for example Kormendi & Meguire (1985), Landau (1985) and Barro (1991)); and public investment expenditure used as a proxy for the 'productive' expenditure category (for example Easterly & Rebelo (1993) and Barro (1991)). Those studies that have used government consumption expenditure find similar evidence to that found here. Government consumption expenditure often enters growth regressions with a significant negative coefficient (Landau (1983, 1986), Grier & Tullock (1989), Alexander (1990) and Barro (1991)). The evidence from this study is that the negative coefficient on government consumption expenditure is at least in part attributable to the reductions in 'productive' expenditures implicitly used to finance these increases.

Public capital expenditures generally enter growth regressions with insignificant coefficient (Barth & Bradley (1987), Barro (1989, 1991) and Easterly & Rebelo (1993)). As explained above the government budget constraint allows us to separate out the effect on the rate of growth of an increase of productive goods and services funded by a decrease of non-productive expenditures (the composition effect) from the effect of tax or surplus financed increases in productive expenditure (the level effect). Once this is done there is evidence of a significant affect on growth. Our interpretation of the coefficients in previous studies is that they fail to find significant coefficients because they conflate composition and level effects.

The estimation of an insignificant relationship of public capital expenditure and growth is not consistent across studies, and indeed in certain cases come close to the estimates from the production function approach of Aschauer (1989). For example Fuente (1997) estimates that raising capital expenditure as a ratio to GDP by 1% adds 0.7 of a percentage point to growth. The Devarajan et al. study (1996) comes the closest to the methodology used in this paper through their attempt to control for level and composition effects of expenditures. When they include total expenditures as a ratio to GDP (in order to separate out level effects) with either current expenditures or capital expenditures they find similar results to those here. The effect of a 1% increase in the ratio of current expenditures to total expenditures reduces growth by 0.074 of a percentage point; while a 1% increase in the ratio of capital expenditures out of total expenditure raises growth by 0.072 of a percentage point. If one allows for the fact that the ratio of total expenditures to GDP is on average a little over a third then the results become reasonably close to the estimates from this study.

As we move to a disaggregated form of the data the strong evidence in favour of the general structure of the Barro model remains. But there is evidence that different forms of productive expenditure have very different relationships with the social security and welfare expenditure category, (*ess* expenditure is the largest component of the non-productive expenditure category defined above). The estimated coefficients on expenditures on productive stocks and flows have significant negative coefficients, as expected. Indeed reducing the percentage of *ess* expenditure out of GDP by 1% to fund an increase in *epf* (*eps*) raises growth by a rather large 0.565 (0.587) of a percentage point.

Somewhat out of line with our expectations the coefficient estimated from increasing social security expenditure by decreasing health is positive and insignificant (with a point estimate of 0.151). Assuming the consumption side of the model is correct then this result suggests that there is an over provision of health care by the government (though the estimated effect on growth from switching resources between health and social security is statistically insignificant). Disaggregating the data still further allows us to pursue whether this relationship for health expenditure still holds or whether it is a feature of the aggregation process. We therefore delay any interpretation of this estimated long run coefficient until then.

Table 8. 4: Results Using Re-Classified Data

	epf	eps	ehlth	ess
epf		-0.02 (0.13)	**0.716*** **(4.10)**	**0.565*** **(3.57)**
eps	0.02 (0.13)		**0.737*** **(3.14)**	**0.587*** **(2.81)**
ehlth	**-0.716*** **(4.10)**	**-0.737*** **(3.14)**		-0.151 (1.26)
ess	**-0.565*** **(3.57)**	**-0.587*** **(2.81)**	0.151 (1.26)	
adj R^2	0.681			

Notes: 1) t-statistics in parenthesis.
2) * denotes significance at the 5% level, ** at the 10% level.
3) coefficients are long run estimates

Functional Classification of Fiscal Data

Disaggregating the productive and non-productive expenditure data to the level of functional classification leads to further interesting results. Increases in expenditures on social-security when funded by compensatory decreases in general public services (*egps*), defence (*edef*), housing (*eho*), and transport & communication (*etcm*) all have a negative effect on the long run rate of growth as we would expect but, only in the case of *egps* is this effect significant. This might indicate that the signal is being lost in the noise of the data set as these expenditures now account for around 1.0 to 3.0% of GDP.[6]

[6] The average value for housing across the sample is 0.7% of GDP.

Table 8. 5: Results Using Data Classified by Function

	egps	edef	educ	ehlth	ess	eho	etcm
egps		**-0.820*** **(2.16)**	**0.893*** **(2.38)**	0.203 (1.16)	**0.228**** **(1.66)**	0.308 (0.88)	**-0.451*** **(1.96)**
edef	**0.820*** **(2.16)**		**1.007*** **(2.01)**	**0.863*** **(2.03)**	0.178 (0.58)	**0.766**** **(1.89)**	-0.244 (0.42)
educ	**-0.893*** **(2.38)**	**-1.007*** **(2.01)**		-0.261 (0.62)	**-0.627**** **(1.88)**	**-0.733**** **(1.66)**	**-1.334*** **(3.88)**
ehlth	-0.203 (1.16)	**-0.863*** **(2.03)**	0.261 (0.62)		-0.163 (1.29)	0.227 (0.83)	**-0.647*** **(2.31)**
ess	**-0.228**** **(1.66)**	-0.176 (0.58)	**0.627**** **(1.88)**	0.163 (1.29)		-0.006 (0.03)	-0.191 (1.04)
eho	-0.308 (0.88)	**-0.766**** **(1.89)**	**0.753**** **(1.66)**	-0.227 (0.83)	0.006 (0.03)		**-0.986*** **(3.06)**
etcm	**0.451*** **(1.96)**	0.244 (0.42)	**1.334*** **(3.88)**	**0.647*** **(2.31)**	0.191 (1.04)	**0.986*** **(3.06)**	
adj R2	0.635						

Notes: 1) t-statistics in parenthesis.
2) * denotes significance at the 5% level, ** at the 10% level.
3) coefficients are long run estimates

Productive/Non-productive Expenditure Mix

Certain forms of expenditure traditionally perceived to be 'growth enhancing' are, in Table 8.5, estimated here to have the opposite relationship with social security expenditure and growth to that expected. Increases in expenditures on education (health) funded by decreases in social security expenditures decreases the growth rate by 0.627 (0.163) of a percentage point. The divergence between theory and empirics may exist for a number of reasons. Firstly, the marginal benefit of an increase in health or education expenditure may be negative. The political sensitivity of education and health expenditure may lead to their over-supply by governments. This could, quite reasonably, cause the marginal benefit to the rate of growth to become negative (although this possibility is not currently allowed within the model). Or it could be because expenditures are inappropriately used. As Pritchett (1995) writes "perhaps schooling has created cognitive skills but the typical institutional environment was sufficiently bad that these skills were devoted to privately remunerative but socially wasteful, or even counter-productive, activities."[7] That is, the payoff from education is conditional on the *type* of skills gained not on the *level* of skills gained. Or equally it could be that the time lag between expenditure on education and the addition of this human capital to the labour force is not captured by the lag structure of the current model. Secondly, the positive effects in favour of *ess* may be because social security and welfare expenditure are genuinely growth enhancing. Cashin (1995) perceives transfer payments to be productive through the effect of inter and intra-generation transfers on property rights and hence the returns from investment.

A final explanation is that the functional classifications of expenditure in the GFSY contain consumption expenditure as well as capital expenditures (this may also be true for education and health expenditure). The positive coefficients of social security expenditure against health and education expenditures may, therefore, be a product of the failure to distinguish 'non-productive' expenditure adequately with this data set.

Productive Expenditure Mix

According to the Devarajan et al. (1996) model the growth effects of changes to the mix of productive expenditure depends upon the *relative* marginal productivity, and the *relative* size, of the expenditures. If not at the optimum level then gains can be made from switching resources between types of expenditure. Disaggregating the data from the single productive expenditure variable used up until now allows us to make a direct comparison of the growth effects of different forms of productive expenditure and to tell which components of expenditure in fact conform to the theoretical definitions of productive and non-productive expenditure.

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[7] Pritchett (1995) pp.42

As the 'productive expenditure' category in the theoretical classifications of the data is disaggregated evidence of significant imbalance in the allocation of expenditures becomes apparent. By decreasing expenditures on health and replacing them with either productive stocks or flows we can increase the rate of growth of the economy by significant amounts (the point estimate of both of these categories of expenditure is over 0.7). It does not necessarily follow from these results that the categorisation of health expenditure as *'productive'* is mistaken but, by so doing we raise the confidence intervals on the *eprd* variable unnecessarily. Including health expenditure within the 'productive' expenditure category forces health expenditure to have the same relationship with growth as other forms of productive expenditure (such as productive stocks and flows); when tested this assumption it was found not to hold.

Imbalance within the productive expenditure mix of the average country remains a feature of the data when the functional classifications of the data are used. The significant imbalance between stocks and flows in the above classification of the data appears to be driven by the imbalance between health and defence expenditures (part of the *epf* expenditure category) and transport and communication expenditures (part of the *eps* expenditure category). In both cases by re-allocating expenditures away from health raises the long run growth rate of the average country (by 0.863 of a percentage point in the case of *edef* and 0.647 in the case of *etcm*). Easterly & Rebelo (1993) in a pooled regression using 10-year averages estimate an insignificant effect on growth from increases in health expenditure but their estimate on *etcm* is significant and around 0.6 of a percentage point. Devarajan et al. (1996) find the relationship between health and growth to be non-robust (the coefficients vary between 0.019 and 0.048) but when they disaggregate out certain components of health expenditure they find evidence of strong positive effects from changes to certain types of health expenditure (expenditure on hospitals (0.056) and other health (0.11)). In this study we find that increases in health expenditure only increase the rate of growth if financed by reductions in education or housing expenditure (though in neither case is this effect significant).

The aggregation of the data as productive stocks and flows masks the available gains to the rate of growth from re-allocating government resources between certain components of expenditures. In addition to the results discussed above there appears to be significant under-funding (with respect to growth effects) of: defence expenditure (part of the *epf* expenditure category) in favour of expenditures *egps*, *educ* and *eho*; and of transport and communication (part of the *eps* expenditure category), in favour of expenditures on *egps*, *educ* and *eho*. Indeed by re-allocating 1% of GDP towards *etcm* and away from *eho* there is an increase of almost a one-percentage point (0.986) in the long term growth rate. The positive growth effects of increases in transport and communication expenditure are supported by the results from Devarajan et al. (1996) as well as those by Barro (1991) and Easterly & Rebelo (1993). The significant benefit to the long run rate of growth from increases to transport and communication expenditure are possibly due to the productivity gains that can be achieved through a reduction in congestion in the stock of public goods, such as roads. This result is also interesting given the debate in the literature as to the relationship between public infrastructure and output.[8] For example, Sturm et al. (1995) using a VAR approach on infrastructure, output and machinery investment find evidence that infrastructure Granger causes output (investment has direct effects on output) but does not Granger cause machinery investment (there are no indirect effects of infrastructure on output).[9]

The strong negative effects found from the housing expenditure term are perhaps surprising given that these expenditures account for only some 0.7% of GDP (2% of the total budget) and in light of the very strong positive effects estimated for the same variable by Easterly & Rebelo (1993). They find that increasing expenditures on housing as a ratio to GDP by 1% will raise the growth rate somewhere between 0.88 and 1.49 percentage points. One possible explanation for this difference might be explained by the inclusion of LDCs amongst the sample of countries by Easterly & Rebelo.

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[8] See Sturm et al. (1996) for an excellent summary of the literature.

[9] In their review of the literature Sturm et al. (1996) note that the Sturm et al. (1995) study is based on the most advanced econometric methodology but uses 19^{th} century data, therefore making policy recommendations valueless.

The growth benefits of defence expenditure may be thought of as being an indirect aid to private production by maintaining property rights which lowers the risk premium and raises the returns to private investment (Barro & Sala-i-Martin (1995)). Such an effect is, however, likely to be small in the sample of developed countries used here and possible alternative explanations are the level of R&D investment by the military and the export of defence equipment abroad. The coefficients estimated for defence expenditure here do not support those from Devarajan et al. (1996) who find evidence of a insignificant negative relationship with the rate of growth.

Finally we also evidence from this data set of over-funding of expenditures on education (part of the *eps* expenditure category) at the cost of expenditures on general public services *(egps)* and housing *(eho)*. The appropriate interpretation of these results is not necessarily that education expenditure is non-productive but instead that the net marginal benefit is less than that for other forms of expenditure. This could be because the net benefits of education to the economy are only felt with a considerable lag. Or that the slowest growing countries in the sample spend relatively more on education (possibly in the hope of improving growth rates). Alternatively the slower growing countries of the sample may be directing education expenditures at the wrong areas. Devarajan et al. (1996) disaggregate education expenditure and find evidence that certain types of education expenditure (expenditures on schools and universities) retard the rate of growth, although total education expenditure has an insignificant positive effect.

8.5 Sensitivity Analysis

In this section we test whether the above results are statistical anomalies or whether they are robust to alternative specifications of the regression equation. The first test considers the bias of the estimated coefficients introduced through the inclusion of lagged dependent variables to the regression equation. Anderson-Hsiao instrumental variable estimators (as recommended by Judson & Owen (1997)) are used to replace the lagged dependent variables in the regression equation. The second test considers the averaging of the data across 5-year time periods in order to test whether the results are sensitive to alternative methods employed in the literature to remove the business cycle from the data.

8.5.1 Alternative Estimators

The parameter estimates from dynamic panel data regressions are, by their construction, biased because of the correlation of the lagged dependent variable, g_{it-1}, with the error term. As explained in Chapter 7 Judson & Owen (1997) run Monte Carlo experiments to estimate the bias in typical macroeconomic data sets (small N and small to large T) for 6 types of estimator OLS, LSDV, corrected LSDV (LSDVc), Anderson-Hsiao (AH), and two forms of generalised method of moments (GMM) estimators. Judson & Owen conclude that the bias cannot be used to distinguish between estimators for all except OLS. The bias on the AH and LSDVc estimators is smaller than the LSDV and GMM estimators but at the cost over the LSDV estimator of a lower efficiency of the parameter estimates. The LSDVc estimator requires a balanced panel and is computationally complex, therefore, it was decided to test the robustness of the results found above using the AH estimator.

The AH estimator uses the lagged level to instrument for the lagged difference term. Lagged growth is therefore replaced by lagged GDP[10] in equation (7.4) of Chapter 7.[11] The results are displayed in tables 8.6 - 8.8 below.

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[10] Arellano & Bond (1991) and Kiviet (1995) confirm the superiority of using the lagged level as an instrument over the lagged difference in simulation results.

[11] The regression includes country dummies as instruments and as regressors but time dummies only as instruments.

Table 8. 6 Results Using Theoretical Classified Data and AH Estimators

	eprd	enprd
eprd		**0.305*** **(1.95)**
enprd	**-0.305*** **(1.95)**	
adj R^2	0.538	

Notes: 1) t-statistics in parenthesis.
2) * denotes significance at the 5% level, ** at the 10% level.
3) coefficients are long run estimates

Table 8. 7: Results Using Re-classified Data and AH Estimators

	epf	eps	ehlth	ess
epf		0.045 (0.17)	**0.796*** **(2.13)**	**0.623*** **(2.03)**
eps	-0.045 (0.17)		0.751 (1.56)	**0.578*** **(2.81)**
ehlth	**-0.796*** **(2.13)**	-0.751 (1.56)		-0.174 (0.88)
ess	**-0.623*** **(2.03)**	**-0.578*** **(2.81)**	0.174 (0.88)	
adj R^2	0.554			

Notes: 1) t-statistics in parenthesis.
2) * denotes significance at the 5% level, ** at the 10% level.
3) coefficients are long run estimates

Table 8. 8: Results Using Data Classified by Function and AH Estimators

	egps	edef	educ	ehlth	ess	eho	etcm
egps		-0.1074 (0.77)	0.851 (0.44)	-0.058 (0.10)	0.138 (0.57)	0.207 (0.22)	-0.573 (1.24)
edef	1.074 (0.77)		0.844 (0.96)	0.753 (1.01)	0.333 (0.93)	0.904 (1.42)	-0.721 (1.03)
educ	-0.851 (0.44)	-0.844 (0.96)		-0.272 (0.39)	-0.380 (0.89)	-0.634 (0.68)	**-1.130* (2.33)**
ehlth	0.058 (0.10)	-0.753 (1.01)	0.272 (0.39)		-0.127 (0.83)	0.393 (0.60)	-0.340 (0.528)
ess	-0.138 (0.57)	-0.333 (0.93)	0.380 (0.89)	0.127 (0.83)		0.113 (0.33)	-0.164 (0.68)
eho	-0.207 (0.22)	-0.904 (1.42)	0.634 (0.68)	-0.393 (0.60)	-0.113 (0.33)		**-2.212** (1.85)**
etcm	0.573 (1.24)	0.721 (1.03)	**1.130* (2.33)**	0.340 (0.528)	0.164 (0.68)	**2.212** (1.85)**	
adj R2	0.601						

Notes: 1) t-statistics in parenthesis.
2) * denotes significance at the 5% level, ** at the 10% level.
3) coefficients are long run estimates

The striking feature of the results in tables 8.6 - 8.8 is the similarity of the magnitude of the parameter estimates to those displayed in tables 8.3 - 8.5 above. The significance of the parameter estimates is lost when we use AH-IV estimators which we feel to be a reflection of the expected loss of efficiency from using instrumental variables given the consistency of the parameter estimates. Therefore, large bias on the fiscal parameters through the introduction of lagged dependent variables to the regression equation does not appear to be a feature of the data. Some degree of caution appears to be necessary when we disaggregate the data in order to classify the data by function. There is both a greater difference in the long run parameter estimates of the LSDV and AH-IV estimators and a large reduction in the number of significant variables. This perhaps reflects the 'noise' versus 'signal' problem highlighted at the beginning of this chapter.

8.5.2 5-Year Averages

A common methodology used in the estimation of dynamic panel data models to remove the business cycle effect from the data is to take period averages. The length of the average and the period over which the average is taken is usually chosen on a somewhat arbitrary basis and appears to done more for convenience rather than in any attempt to remove the business cycle from the data. Following this practice we take period averages over five-years of data with the start date for the first time period in 1970. In doing this we take the precedent set in numerous other studies such as (Mendoza et al. (1996)). A dynamic panel data regression of a similar form to equation (8.1) above is estimated but where the dynamic component of the model is captured through the introduction of one lagged (5-year) term. Initial GDP is included as an additional variable to the matrix of conditioning variables for the regressions with period averages to capture the possibility of convergence across the time periods. The results are displayed in tables 8.9 - 8.11 below.

Table 8. 9: Results Using the Theoretical Data Set and 5-year Averages

	eprd	**enprd**
eprd		0.175 (1.31)
enprd	-0.175 (1.31)	
adj R^2	0.524	

Notes: 1) t-statistics in parenthesis.
2) * denotes significance at the 5% level, ** at the 10% level.
3) coefficients are long run estimates

Table 8. 10: Empirical Results Using Re-classified Data and 5-year Averages

	epf	eps	ehlth	ess
epf		-0.929 (0.59)	-0.109 (0.10)	0.275 (0.40)
eps	0.929 (0.59)		0.821 (0.46)	1.205 (0.88)
ehlth	0.109 (0.10)	-0.821 (0.46)		0.384 (0.56)
ess	-0.275 (0.40)	-1.205 (0.88)	-0.384 (0.56)	
adj R^2	0.554			

Notes: 1) t-statistics in parenthesis.

2) * denotes significance at the 5% level, ** at the 10% level.

3) coefficients are long run estimates

The results are clearly sensitive to period averaging of the data to remove the business cycle effect. In both of the first two levels of aggregation the significance of all of the expenditure variables is lost, and it is only when we classify the data by function that there is any evidence of significant effects of fiscal policy on the long run rate of growth. There are no changes to the signs of the coefficients but there are changes to the magnitude of the estimated coefficients (this feature of the use of 5-year period averages was noted in the previous chapter). These results are clearly unsatisfactory and the analysis of section 8.4 would appear to fail this test for robustness, but, given our reservations as to the ad hoc nature of the averaging process, it is worth exploring further the sensitivity of the results to alternative period averages. The period averages calculated so far have taken the beginning of the data set as the year from which the first period average is made (i.e. 1970, 1975, 1980, 1985 and 1990). We test whether moving the start of the period forward two years alters the results[12] (the start year for each 5-year period average becoming 1972, 1977, 1982, 1987 and 1992 producing 70 observations). The regression equation was

[12] It was chosen to move the start of the period average forward two years purely as a 'statistical' exercise and no statistical or economic rationale influenced its choice.

then estimated using the data as classified by the theory[13]. The coefficient on the *enprd/eprd* variable was negative as before but is now significantly different from zero[14] (as predicted by the theory).[15] The results using period averages are sensitive to the choice of start year of the period averages and are therefore unsatisfactory as a test of long run growth theories. This result requires further investigation but a constraint on data prevents further analysis of that sort here.[16]

Table 8. 11: Results Using Data Classified by Function and 5-year Averages

	egps	edef	educ	ehlth	ess	eho	etcm
egps		**-0.450*** **(2.81)**	0.261 (0.13)	**-1.605**** **(1.66)**	-0.279 (0.42)	1.058 (0.80)	**-3.533**** **(1.905)**
edef	**5.450*** **(2.81)**		**3.460*** **(2.16)**	0.743 (0.51)	1.270 (0.71)	**3.047*** **(1.96)**	2.648 (0.91)
educ	-0.261 (0.13)	**-3.460*** **(2.16)**		-0.441 (0.30)	0.865 (0.74)	0.470 (0.31)	-1.547 (0.99)
ehlth	**1.605**** **(1.66)**	-0.743 (0.51)	0.441 (0.30)		0.524 (0.80)	0.885 (1.14)	0.985 (0.68)
ess	0.279 (0.42)	-1.270 (0.71)	-0.865 (0.74)	-0.524 (0.80)		-0.417 (0.43)	0.143 (0.15)
eho	-1.058 (0.80)	**-3.047*** **(1.96)**	-0.470 (0.31)	-0.885 (1.14)	0.417 (0.43)		-1.369 (1.17)
etcm	**3.533**** **(1.905)**	-2.648 (0.91)	1.547 (0.99)	-0.985 (0.68)	-0.143 (0.15)	1.369 (1.17)	
adj R2	0.601						

Notes: 1) t-statistics in parenthesis.
2) * denotes significance at the 5% level, ** at the 10% level.
3) coefficients are long run estimates

[13] The regression was run with country but not period dummies. The estimated regression was run with only one degree of freedom remaining.
[14] The long run parameter estimate was -0.454, and the t-test statistic that the sum of the short run parameters is zero was 4.68
[15] A lack of degrees of freedom prevented testing the sensitivity at other levels of aggregation of the data
[16] We find similar results when we use 1971 and 1973 as the base year in the dynamic regressions.

8.6 Conclusions

The aim of this chapter is to investigate the effect of aggregation on the stability of the relationship between fiscal policy and growth. In so doing it is hoped that this might also reveal information as to the support for the assumption of homogeneity across government expenditures as modelled by Barro (1990) that exists in the data. In order to provide this test we draw upon the work by Devarajan, Swaroop & Zou (1996) which removes the homogeneity assumption and the work contained within the previous two chapters. Against the desire to improve the realism of the models must be tempered two empirical problems that are faced when aggregating or disaggregating data. Too high a level of aggregation risks widening the confidence intervals of coefficients when different elements of an aggregate are in fact characterised by different coefficients. In contrast too much disaggregation carries the opposite risk of losing the signal in the noise.

Empirical tests are undertaken on a sample of 17 developed countries for the time period 1970-94. Government expenditures are categorised in three ways. These range from organising the data according to the theory down to data classified by function (as available at source). Estimation is by dynamic panel regressions with annual observation and long lag structures. Some tests of robustness to alternative estimators is made.

In general we find there are gains to be made from disaggregating the expenditure categories both in terms of the insights into the underlying structure of the model and the composition of expenditures within the average country. From this we suggest inappropriate aggregation may help to explain the large variation in the results from previous research.

Using a very aggregated form of the fiscal variables it appears the data are well represented by a model that separates non-productive expenditures into the consumption side of the model and productive expenditures within the production side of the model. As we disaggregate the data we find that the positive growth effects from increases in non-productive expenditures funded by a decrease in productive expenditures in general still holds. When the data is classified by function the strength of this relationship is at its weakest. Indeed, we find for some expenditure we *a-priori* perceived as productive, such as education and health, are not consistent with observation in this data set. The unusual behaviour of the education and health expenditure categories in the results is interesting. The negative coefficient against social security and welfare expenditure suggests the possibility that the marginal benefit of these two forms of expenditure (health and education) is negative, although this possibility is not currently allowed within the model. We cannot however, rule out the possibility that this result is explained by the growth enhancing effects of social security payments (as modelled by Cashin (1995)) or that the data contains 'consumption' and 'capital' expenditures together in the same functional classification.

We also find support for the Devarajan et al. (1996) model over the simpler Barro (1990) model. This conjecture is made on the basis of the significant growth effects we estimate from changes in the mix of productive expenditures present in the more disaggregated forms of the data. Further to this we estimate that there are some forms of expenditure which might traditionally be thought of as productive which do not display the expected relationship with growth when we analyse the data. When the theoretical data set is disaggregated we discover that there is a difference between health care and the other forms of productive expenditure. When we classify the data by function we find evidence of an over-provision of education and health expenditure against all other forms of expenditure. Given the politically sensitive nature of these two expenditure categories this result is perhaps unsurprising. Like many previous studies we estimate that re-allocating expenditures towards transport and communication expenditures and defence expenditure can increase the rate of growth within the average country.

The sensitivity of the above results is tested by using Anderson-Hsiao Instrumental Variable estimators to correct for the bias introduced by the inclusion of lagged dependent terms within the regression equation. We find that in general the parameter estimates are insensitive to the use of AH-IV estimators. Where non-robustness occurs it appears that this can be explained by the increase in the standard errors through the reduced efficiency of the estimator. The loss of efficiency does not appear to create a significant problem within the aggregated forms of the data set but as we disaggregate the data the loss of efficiency does impact upon the results.

The second test for robustness we attempt is to use 5-year averages of the data in order to remove the business cycle effect. The results from this test are non-robust to this change. These results require further analysis, but a problem with the available degrees of freedom limits research using this data set.

Chapter 9

Fiscal Policy, Investment and Growth

9.1: Introduction

According to models of economic growth, such as Barro (1990), fiscal policy determines investment and the steady-state rate of growth simultaneously. Taxes, such as those on capital, labour and income taxation, distort downwards the returns to the factors of production and hence, lower the rate of investment; while certain forms of expenditures, such as public infrastructure, because they are included as inputs into the private production function raise the marginal product of capital and growth. Once again we find however, that the empirical relationship is less clear. Levine & Renelt, (1992) find that fiscal variables only enter growth regressions with the expected sign when investment is also included as an explanatory variable. Yet, they can find no statistical relationship between fiscal policy and investment.

Thus far in this thesis we have been interested in estimating the relationship between fiscal variables and growth conditional on the level of investment. In this chapter we search for the direct effects of fiscal policy on investment. Comparisons are made between the direct and indirect (via investment) effects of fiscal policy on the growth rate in order to determine its use as an explanation for the non-consistent relationship between fiscal policy and growth found in the literature. By doing so it is hoped that this will also provide information regarding whether the simple mechanisms in the endogenous growth model adequately capture the direct and indirect channels evident in the data. The main empirical tests are conducted by extending the methodology developed in Chapters 6-8 for a sample of 17 countries from 1970-94.

The results from this chapter lead us to conclude that at first appearances the Barro (1990) one-sector model captures well the relationship between fiscal policy, investment and growth that exist within the data, even when the direct effects of policy are included. However, our analysis throws up a number of areas where the Barro model is incapable of providing an explanation for the results and some of the extensions that have been made to this model appear empirically relevant.

The results for distortionary taxation are strong and accord well with the existing literature but the relationship between government expenditure and investment is less clear. It is therefore, on the expenditure side of the model where we feel the greatest scope for developments of the model appear (such as following Barro & Sala-i-Martin (1995) to allow certain expenditures to affect investment rather than growth directly).

Section 9.2 reviews briefly the theoretical and empirical literature on the relationship between fiscal variables and the level of investment. Of the existing empirical literature we concentrate only on those papers from the growth literature that have estimated both the investment and growth effects of fiscal policy. Section 9.3 discusses the additional data used in this chapter and refers the reader to the relevant sections of the thesis for the empirical methodology being used (including details of the panel data estimators and the government budget constraint). Finally section 9.4 presents the empirical results and 9.5 concludes.

9.2: Literature Review

9.2.1: Theoretical Literature

In the Barro (1990) model government taxation and expenditures determine the rate of growth both directly, and indirectly through investment. Factor income taxation reduces the private marginal product of capital and hence the level of investment, which, in turn lowers the rate of growth, while productive expenditures have a direct rather, and indirect effect on growth through their inclusion in the production function (Fuente (1997)). The direct effect on productivity raises output growth but also raises the returns to capital, which encourages faster investment. Consumption, lump-sum taxation and non-productive expenditure, because of the assumptions regarding the household utility function, have no effect on the rate of growth either directly or indirectly (see Chapters 2 and 3).

9.2.2: Empirical Literature

In order to separate out the relationship between fiscal policy and investment from that between fiscal policy and growth it is necessary to review the studies that have attempted to estimate both of these relationships. The empirical literature relating private investment to fiscal policy is thin and if we restrict the sample still further to those studies which account for the econometric problems of estimating growth regressions then this number falls to just two (Mendoza et al. (1996) and Fuente (1997)). Therefore, we offer a brief overview of the entire literature for investment and then consider in greater detail the combined direct and indirect effects of fiscal policy from Mendoza et al. and Fuente.

General Overview

Easterly & Rebelo (1993) offer perhaps the most comprehensive list of fiscal variables to be included in a single study of private investment using both cross-section (100 countries, 1970-88) and panel data (28 countries, 1870-1988) techniques. Table 9.1 describes the results for this and the other studies reviewed here by separating the results into two types; consistently significant negative (positive) and in-consistently negative (positive).[1]

The most consistent of any relationship between fiscal policy and investment to be found is that for taxation. Increases in taxation significantly decrease the rate of

[1] The categorisation of the fiscal variables under the various headings is made according to whether the sign and significance estimated on the fiscal variable remains the same despite changes in *either* the set of fiscal variables or in the set of conditioning variables. This is obviously not the same definition of robustness found in Levine & Renelt (1992) as we allow the possibility of sign and significance switching of fiscal variables through the concept of the government budget constraint as discussed in Section 6.2.2 of the thesis. We make the decision not to investigate why certain fiscal variables appear to have a non-robust relationship with the investment ratio in the those papers

private investment in the economy (only the total tax revenue variable from Fuente (1997) suggests an inconsistent relationship). This strong negative relationship is present both when aggregate forms of taxation are used (as in Easterly & Rebelo (1993) and Fuente (1997)) and disaggregated forms of taxation are used (as in Easterly & Rebelo(1997) and Mendoza et al. (1997)). The exception to this general rule is the finding by Mendoza et al. (1997) of a significant positive relationship between government consumption taxation and investment. They explain this result by arguing that their methodology indicates the effects of the tax-mix on investment and that consumption taxation is less-distortionary than labour and capital taxation. Hence, any shift in the tax-mix towards the increased use of consumption taxation raises the rate of private investment.

By contrast, when government expenditures are used as explanatory variables we witness the same instability in the sign and significance of parameters as observed for growth regressions in Chapter 5. For example, in Barro (1991) and Easterly & Rebelo (1993) government consumption expenditure has a consistently significant negative effect on investment, while Fuente (1997) estimates the relationship for this same variable to be non-robust (i.e. it is sometimes statistically significant and sometimes not). In contrast, Nazimi & Ramirez (1997) estimate a statistically significant, positive relationship between government consumption expenditure and investment.

The consistency of the estimated coefficients on the total public investment variable are also poor but, Easterly & Rebelo (1993) find that certain components of total public investment have a significant relationship with investment (namely education, health, housing and transport & communication expenditures).

As noted above only Fuente (1997) and Mendoza et al. (1997) adequately account for some of the statistical biases within the data (although those due to misspecification of the government budget constraint persist) when estimating the relationship between fiscal policy, investment and growth. For this reason we only use these two

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reviewed because none impose the government budget constraint on the regression equation any studies to compare estimates of the combined direct and indirect effects of fiscal policy on growth. We note immediately from this that the same inconsistencies that dog comparisons between these studies in Chapter 5 arise again here, despite the similarities in the chosen estimation technique and data sample of the two studies. Comparisons are made additionally difficult by differences in measurement of the variables and the fact that fiscal variables are included and excluded from the regression on a fairly ad hoc basis by Fuente. As demonstrated in Chapter 6 this gives the impression, albeit possibly false, that relationships are non-robust. However, there are several reasonably strong results.

Mendoza et al. estimate taxation to have a significant effect on investment but can find no significant effect on growth from taxation (this relationship is estimated by instrumenting for investment). While Fuente uses tax revenue as a ratio to GDP and estimates this measure of the tax burden to have a significant negative effect on both investment and growth.

The effect of including (as opposed to excluding) investment within the growth regression is found by Fuente to reduce both the magnitude of the estimated coefficients and the number of significant variables. Both tax revenues and public capital investments remain reasonably robust to the inclusion and exclusion of investment, although significance is more often at the 10% level when investment is included. Mendoza includes investment by two-stage least squares and finds that there is little difference for the parameter estimates between the combined direct and indirect effects of fiscal policy.

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attempts to impose one on the results is simply too difficult.

Table 9. 1: Evidence of the Empirical Relationship Between Fiscal Policy and Investment

Author(s)	Sample	Year/ Estimation technique	Consistently Significant positive	In-consistently Significant positive	Consistently Significant negative	In-consistently Significant negative
Barro (1991)	76	1970-85, cross-section	-	-	govt. Consumption expenditure less educ & defence	-
Easterly & Rebelo (1993)	100(28)	1970-88, (1870-1988), cross-section, (panel)[2]	govt. Surplus, (education), (health), (housing), (transport & communication)	-	govt. Consumption less educ. & defence, domestic taxes/GDP, domestic taxes/C+I, internat. Trade taxes/X+M, marginal income tax, (total public investment), (agricultural investment)	general public services
Mendoza, Milesi-Ferretti & Asea (1997)	18 OECD	1965-91, panel (5-yr aves)	consumption taxation	-	labour taxation, capital taxation	-
Nazimi & Ramirez (1997)	Mexico	1950-90, dynamic time series (annual data obs.)	current & lagged (1 period) govt. consumption	-	current & lagged (1 period) govt. investment	-
Fuente (1997)	19 OECD	1965-95, panel (5-yr. aves.)	govt. Surplus, public investment, subsidies to enterprises	transfers to households	total govt revenue, total tax revenue, interest payments	tax revenue[3], govt. consumption

As in Chapter 5 the divergence between these two studies is somewhat perplexing given they are both based on a panel of OECD countries and correct for many of the statistical problems encountered when estimating such regressions (see Chapter 5 for some discussion of these issues). We suggest from this that the divergence between the results from the two studies is explained by a failure to account for the theoretical issues raised in Chapter 5 and investigated in Chapter 6 to 8. Both include a

[2] The results in parenthesis in the Easterly & Rebelo (1993) study indicate those from the panel data regressions rather than the cross-sectional regressions.

[3] The difference in the results for the tax revenue and government consumption expenditure variables in the Fuente (1997) study are due to the different data sources used (see the paper for details).

reasonably large number of fiscal variables, but the budget constraint is not complete and coefficients are interpreted as the full effect rather than the net effect via the budget constraint. Both studies use 5-year period averages but no tests are made to the choice of period average; while, Fuente includes a mix of both aggregated (such as tax revenues) and disaggregated variables together. However, a potentially important additional bias to these is the simple inclusion or exclusion of investment from the conditioning matrix for growth by Fuente (1997). If fiscal policy is correlated with investment then not controlling for the determinants of investment (as in Mendoza et al. (1996)) introduces an omitted variable bias into the results. The direction of the bias is determined by the correlations between the omitted and included variables. This bias might also be used to explain why Levine & Renelt (1992) can only find sensible results for fiscal policy when investment is included in the regression and why Sala-i-Martin (1997) finds the robustness of fiscal variables improves when investment is included. Briefly surveying the other studies in Table 9.1 we note that only Barro (1991) reports regressions with both investment included and excluded. The parameter estimates for government consumption expenditure are however, reasonably consistent across the regressions and remain significant.

9.3: Data and Empirical Methodology

9.3.1: Empirical Methodology

As demonstrated in Chapter 6 accurate testing of the relationship between fiscal policy and growth requires the use of the government budget constraint. We continue its use within this chapter and refer the reader to Section 6.2.2 for an explanation of this approach. Within Chapter 7 we find in favour of using dynamic panel estimators with annual observations and a long lag structure.[4] These have the advantage over

[4] When the data is classified by function (i.e. the most disaggregated form of the data) we soon hit a degrees of freedom problem. Therefore, the regression were estimated using an alternative procedure. This involved aggregating upwards to leave only total revenues, total expenditures and the surplus variable. The pair of fiscal variables under test were then disaggregated out from this and this regression estimated. For example, if we are interested in the growth effects of changing the mix of expenditures on health and education then these are disaggregated out from the total expenditure category and then in turn left out of the regression as before in order to estimate the growth effects of a change in this portion of the expenditure mix. We do not report the coefficients from all of these

period averages of the data in demonstrating greater robustness to changes in the arrangement of the data set and the choice of estimator. Finally, we choose to follow the theoretical classifications of the data to facilitate comparisons with previous chapters but do follow up several of the results in more disaggregated form.

9.3.2 Additional Data and Sources

This Chapter uses a number of additional variables in the estimation of the relationship between fiscal policy, investment and growth. These are described in greater detail in Appendix A3.

The investment variable used in estimation throughout chapters 6 to 8 is total investment. The more common choice of investment variable used when the determinants of investment are also investigated is the private investment rate. Although some robustness testing showed no difference in this chapter, or in previous chapters, to the use of total investment we follow standard procedure and use the private investment rate. The private investment rate is calculated as the net of total investment less government capital investment. Data is collated from the World Bank CD-ROM and is available for 17 countries (see Appendix A3) from 1970-94. As with total investment this is then expressed as a ratio to GDP.

The choice over the variables to be included in the conditioning matrix for private investment are based on those already found in the literature (see Section 9.4.2). Greater detail of the exact nature of these variables is left to Appendix A3. These other variables are also taken from the World Bank CD ROM and are: the rate of growth of prices per annum to represent the inflation rate; exports plus imports as a ratio to GDP to measure openness to international trade; the government bond yield less the inflation rate to represent real interest rates, and the relative price of investment which is calculate as the inverse of the relative price of investment to the price of GDP

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other variables only the pair we are interested in. The fiscal matrix appears identical in form but where under the old method the expenditure mix would have been made up from seven regressions it is now made up from twenty-one regressions.

9.4: Empirical Results

9.4.1 Fiscal Policy, Investment and Growth

In order to estimate the relationship between fiscal policy, investment and growth Fuente (1997) estimates the following system of equations.

Equation 9. 1
$$g_{it} = \alpha_i + \alpha_t + \sum_{i=1}^{k} \beta_{1i} Y_{it} + \sum_{j=1}^{m} \gamma_{1j} X_{jt} + u_{it}$$

Equation 9. 2
$$g_{it} = \alpha_i + \alpha_t + \sum_{i=1}^{l} \beta_{2i} W_{it} + \sum_{j=1}^{m} \gamma_{2j} X_{jt} + u_{it}$$

Equation 9. 3
$$pinv_{it} = \alpha_i + \alpha_t + \sum_{i=1}^{n} \beta_{2i} Z_{it} + \sum_{j=1}^{m} \gamma_{3j} X_{jt} + u_{it}$$

where g_{it} is the growth rate per-capita in country i at time t; Y_{it} is a set of conditioning variables for growth which includes investment; W_{it} is a set of conditioning variables for growth which does not include investment; Z_{it} is a set of conditioning variables for investment and; X_{it} is a set of fiscal variables; and α_i and α_t are country and time dummies respectively.

Fuente uses equation (9.1) to estimate the direct effects (also known as the 'allocation effect') of fiscal policy on growth, that is the effect of fiscal policy for a given level of investment. The results from this equation are then compared to those from equation (9.2). In equation (9.2) the matrix of conditioning variables, W_{it}, does not contain investment and therefore the fiscal policy parameters contain estimates of both the direct and indirect effects (also known as the 'crowding-out effect') on growth. Finally, equation (9.3) is used to estimate the relationship between a matrix of conditioning variables for investment (matrix Z_{it}) and a matrix of fiscal variables (matrix X_{it}).

Fiscal Policy and Growth

Table 9.2 below displays the results for the estimation of equation (9.1). These estimates can be seen to be very similar to those for total investment in Table 7.7. The use of private investment does not appear to significantly alter the results. Of the conditioning variables private investment enters with a significant positive coefficient and labour force growth a negative but statistically insignificant coefficient. The overall pattern of the relationship between fiscal policy and growth estimated using the private investment variable is identical to that estimated using total investment. For a given size of government Table 9.2 indicates that the rate of growth can be increased if we replace distortionary taxation *(rdis)* with non-distortionary taxation *(rdis)* and productive expenditure *(eprd)* with non-productive expenditure *(enprd)*. According to the results displayed in the table we can also significantly increase the long run rate of growth if we finance increases in productive expenditures by non-distortionary taxation, or if we decrease non-productive expenditures and distortionary taxation together. Increases in productive expenditure funded by distortionary taxation and non-distortionary tax financed increases in non-productive expenditure have no effect on the long run growth rate.

Following Fuente (1997) The results from this regression can then be compared to those estimated from equation (9.2) where private investment is no longer included in the regression equation (Table 9.3). According to Fuente the coefficients on the fiscal variables now measure both the direct and indirect effect of fiscal policy on growth.

Comparing Tables 9.2 and 9.3 it is clear that the relationship between fiscal policy and growth is much stronger when investment is excluded from the regression equation. The results are non-robust to changes in the set of conditioning variables. Like Fuente (1997) the results from Table 9.3 suggest the combined direct and indirect effects of policy on growth are much larger than the direct effects alone.

Table 9. 2: Results Using Private Investment

Estimation Technique	annual data 2 way FE			
Dependent variable	per capita growth (17 countries)			
	Omitted Variable			
	rdis	**rndis**	**eprd**	**enprd**
prinv	**0.147*** (4.02)	**0.147*** (4.02)	**0.147*** (4.02)	**0.147*** (4.02)
lbfg	-0.154 (1.15)	-0.154 (1.15)	-0.154 (1.15)	-0.154 (1.15)
elmr	0.353 (1.26)	0.125 (0.45)	-0.286 (1.02)	-0.084 (0.30)
roth	**0.404*** (4.39)	-0.008 (0.08)	**0.369*** (4.08)	0.087 (1.35)
eoth	**0.028*** (5.12)	0.026 (0.27)	**-0.350*** (5.68)	-0.069 (1.27)
sur	**-0.217*** (2.83)	**0.195*** (2.28)	**-0.181*** (3.08)	**0.100*** (2.28)
rdis		**-0.412*** (3.35)	-0.036 (0.44)	**-0.317*** (5.03)
rndis	**0.412*** (3.35)		**0.376*** (4.62)	0.095 (1.29)
eprd	-0.036 (0.44)	**0.376*** (4.62)		**0.281*** (5.06)
enprd	**-0.317*** (5.03)	0.095 (1.29)	**-0.281*** (5.06)	
adj R^2	0.728	0.728	0.728	0.728

Notes:
1) t-statistics in parenthesis.
2) * denotes significance at the 5% level, ** at the 10% level.
3) coefficients are long run estimates

Table 9. 3: Estimation Excluding Private Investment from the Regression

Estimation Technique	annual data 2 way FE			
Dependent variable	per capita growth (17 countries)			
	Omitted Variable			
	rdis	**rndis**	**eprd**	**enprd**
lbfg	0.027 (0.22)	0.027 (0.22)	0.027 (0.22)	0.027 (0.22)
elmr	**0.487**** **(1.74)**	0.225 (0.80)	-0.312 (1.11)	-0.106 (0.38)
roth	**0.475*** **(5.91)**	**-0.182*** **(2.15)**	**0.246*** **(3.25)**	-0.013 (0.23)
eoth	**-0.484*** **(6.49)**	**0.173*** **(2.22)**	**-0.255*** **(4.77)**	0.004 (0.08)
sur	**-0.353*** **(4.96)**	**0.304*** **(4.41)**	**-0.124*** **(2.31)**	**0.135*** **(3.17)**
rdis		**-0.657*** **(6.65)**	**-0.230*** **(3.53)**	**-0.489** **(9.71)***
rndis	**0.657*** **(6.65)**		**0.428*** **(6.06)**	**0.168*** **(2.63)**
eprd	**-0.230*** **(3.53)**	**0.428*** **(6.06)**		**0.259*** **(5.04)**
enprd	**-0.489*** **(9.71)**	**0.168*** **(2.63)**	**-0.259*** **(5.04)**	
adj R^2	**0.700**	**0.700**	**0.700**	**0.700**

Notes: 1) t-statistics in parenthesis.
2) * denotes significance at the 5% level, ** at the 10% level.
3) coefficients are long run estimates

There are several noticeable changes between the results in Tables 2 and 3. According to Table 9.3 the combined direct and indirect effects of changes in *eprd/rdis* and *rndis/enprd* are significant on growth whereas the direct effects alone are insignificant. The point estimates on these two variables are -0.230 and 0.168 in Table 9.3 compared to -0.036 and 0.095 in Table 9.2. The increase in the magnitude of the coefficients on these two combinations of policy is also evident elsewhere in the results. For example, from Table 9.3 the effect of a one percentage point increase in the ratio of distortionary tax revenue as a ratio to GDP funded by a compensatory decrease in non-distortionary taxation is estimated to lower the growth rate by 0.657 of a percentage point compared to 0.412 of a percentage point in Table 9.2.

The failure to account for the budget constraint by Fuente (1997) makes comparisons with the results here difficult. For example, the point estimates for total tax revenue from Fuente varies between 0.01 to 0.09 of percentage point (depending on the measure of tax revenue chosen). These are below those found in Table 9.3 but this may be because estimates are for total tax revenue rather than the more disaggregated forms of tax revenue used here. The point estimates for public capital expenditure by Fuente are also variable (they vary between 0.5 to 0.9 of a percentage point depending on the specification of the regression equation) but in general these are above estimates for the productive expenditure variable used here.

If fiscal policy is correlated with investment, as both we and Fuente find it to be, then the exclusion of investment from the conditioning matrix for growth in (2) introduces an omitted variable bias. Equation (9.2) should instead be estimated by solving for the determinants of investment from equation (9.3). Mendoza et al. (1996) adopt a two-stage least squares approach and instrument for investment in (9.1) and this would be the preferred method here but for the limitation on the computer power of the dynamic panel estimator computer package.

In order to solve for investment firstly we need to estimate the determinants of investment, which we do in the next section. Section 9.4.2 then returns to the question of the combined direct and indirect effects of policy.

9.4.2: Fiscal Policy and Investment

Benchmark Regression

Equation (9.3) estimates the direct effects of fiscal policy on the rate of private investment. Following Chapter 7 a general to specific approach was adopted in order to determine the lag structure of the dynamic regression. Test were begun with 9 lags of the explanatory variables and completed after the acceptance of the joint significance of the 7th lagged term. Included in the *Z* matrix of equation (9.3) is a set of conditioning variables specific to investment. The choice of conditioning variables were based on the empirical literature as reviewed in Table 9.2 above. Limitations on the availability of data in the conditioning matrix for investment meant that equation

(9.3) was estimated across data for 15 rather than the 17 countries used to estimate equations (9.1) and (9.2). This reduction in the size of the sample was tested for by regressing equations (9.1) and (9.2) across the smaller sample. The results from the reduced sample regressions were found to be very similar to those from the larger sample and so we choose not to present the results. We begin with the estimation of equation (9.3) only using the set of conditioning variables as determinants of investment. The results from this regression can be found in Table 9.4.

The adjusted R^2 value in Table 9.4 is high at 0.878 but is perhaps not unsurprisingly high given the lagged explanatory variables in the regressions and that the investment ratio does not alter greatly over the sample period.[5] The lagged growth term, which, may be thought of as representing either technological catch-up (the scope for imitation of the technology of the leader country) or the Keynesian accelerator (greater investment expenditure in the current period leading to greater output and hence investment in later periods), enters with the expected negative coefficient. This suggests either positive feedback between growth and investment (in the case of the accelerator) or technological catch-up over the period (in the case of imitation) or both. Lagged GDP rather than growth[6] is more commonly used to proxy for technological catch-up (see Barro (1991), Easterly & Rebelo (1993) Mendoza et al. (1997) and Fuente (1997)) and enters investment regressions consistently with a significant negative coefficient.

Of the remaining conditioning variables the real interest rate (as previously used by Nazimi & Ramirez (1997)) and the relative cost of investment (as previously used by Fuente (1997) and in a related form by Easterly & Rebelo (1993)) enter the regression with the expected signs and coefficients, and are in agreement with the previous literature.[7] The results suggest an increase in the real interest rate and an

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[5] A Wald test of the joint significance of the country dummies and time dummies shows them to be statistically significantly different from zero. In the case of the time dummies this significance is around the 10% level but given there was little impact on the estimated coefficients it was decided to report the results with the time dummies included.

[6] The exception is the Nazimi & Ramirez (1997) paper.

[7] For the Fuente measure this is a positive coefficient and for the Easterly & Rebelo negative. The difference relates to the fact that the Fuente measure is written as the inverse of the relative cost of investment goods.

increase in the relative cost of investment (relative to output) both lead to a reduction in the level of investment.

Measures of international trade are commonly used as conditioning variables in investment regressions although they differ in interpretation. Easterly & Rebelo (1993) and Nazimi & Ramirez (1997) use measures which aim to reflect the effects of the expansion or the openness to trade on investment while Mendoza et al. (1997) use changes in terms of trade as a proxy for macroeconomic instability. The insignificant coefficient on the *exim* variable in Table 9.3 compares well with Nazimi & Ramirez who find no evidence of a statistically insignificant relationship using growth of exports and Easterly & Rebelo who find a non-robust relationship using the trade share. Finally the insignificant coefficient on the macroeconomic instability variable used in this study (the rate of inflation) does not appear to have a significant effect on investment that the proxy used by Mendoza et al. (changes in the terms of trade) has. This may be due to the poor nature of the proxy for macroeconomic instability used here.

Table 9. 4: Benchmark Regression for Investment

Estimation Technique	annual data 2 way FE
Dependent variable	pinv
lgrowth	**-1.808*** **(6.51)**
inf	-0.244 (1.28)
exim	0.576 (0.17)
r-rate	**-0.525*** **(3.63)**
rcinv	**0.244*** **(4.24)**
adj R^2	**0.878**

Notes: 1) t-statistics in parenthesis.
2) * denotes significance at the 5% level, ** at the 10% level.
3) coefficients are long run estimates

Fiscal Policy and Investment

Table 9.5 presents the results for the estimation of equation (9.3) with the set of fiscal variables included as determinants of the investment ratio. The addition of current and lagged fiscal variables to the regression increases the explanatory power of the regression equation from 88% to 93% of the variation in investment. Of the variables contained within the conditioning matrix the lagged growth term now becomes insignificant while the real interest rate variable is positive and significant. The loss of the significance of the lagged growth term suggests misspecification in Table 9.4. The change in the sign on the real interest rate term is more difficult to explain. One potential explanation is that the real interest rate term is correlated with the government budget surplus (which is included in the regression equation but not reported). Upon investigation even the strongest correlation between interest rates and the surplus, for up to seven lags of each variable, never exceeds +/- 0.16. Perhaps unsurprisingly when we re-estimate the regression with the interest rate term omitted the parameter estimates and t-statistics on the variables in the fiscal matrix displayed change little.[8] Other alternative explanations such as the correlation between contemporaneous interest rate and the rate of inflation (due to the way in which they were constructed) were investigated (by omitting either the inflation or the interest rate term). There were no significant changes to the results for the fiscal matrix from this exercise although it did succeed in producing a significant negative coefficient on the inflation term (when interest rates were omitted) and an insignificant, although still positive, term on the real-interest rate variable (when inflation was the omitted variable).

The most notable result from the fiscal matrix in Table 9.5 is the strength of the distortionary effects on investment of the variable *rdis*. An increase in the revenue from distortionary forms of taxation and the use of the proceeds to finance either a; reduction in consumption taxation (*rndis*); increase in productive expenditure (*eprd*) or; increase non-productive expenditures (*enprd*) leads to a reduction in the long run aggregate investment ratio. This matches well the results from the previous literature. The negative relationship of taxation with investment (when measured as total revenue, average tax rates or marginal rates of taxation) was by far the most consistent result from the previous literature and is replicated in this study when we use tax revenue. Mendoza et al. (1997) and Fuente (1997) also estimate coefficients of a similar magnitude to those here, despite the differences in the measurement of the tax variables and specification of the regression equation.

Table 9. 5: Empirical Relationship Between Fiscal Policy and Investment

Estimation Technique	annual data	2 way FE		
Dependent variable	pinv	(15 countries)		
	Omitted Variable			
	rdis	**rndis**	**eprd**	**enprd**
lgrowth	-0.716 (0.81)	-0.716 (0.81)	-0.716 (0.81)	-0.716 (0.81)
inf	-0.186 (0.43)	-0.186 (0.43)	-0.186 (0.43)	-0.186 (0.43)
exim	16.797 (1.35)	16.797 (1.35)	16.797 (1.35)	16.797 (1.35)
r-rate	**0.902** (1.86)**	**0.902** (1.86)**	**0.902** (1.86)**	**0.902** (1.86)**
rcinv	**0.305* (2.53)**	**0.305* (2.53)**	**0.305* (2.53)**	**0.305* (2.53)**
elmr	**2.890** (1.71)**	**6.541* (3.13)**	**4.943* (2.64)**	**4.569* (3.11)**
roth	-0.780 (1.16)	**2.873* (3.00)**	**1.274** (1.71)**	**0.900** (1.88)**
eoth	**1.798** (1.90)**	**-1.855** (1.92)**	-0.256 (0.26)	0.118 (0.13)
sur	-0.588 (0.87)	**3.065* (2.95)**	1.466 (0.80)	1.092 (1.26)
rdis		**-3.653* (3.08)**	**-2.054* (2.23)**	**-1.680* (2.05)**
rndis	**3.653* (3.08)**		1.599 (1.50)	**1.970* (2.05)**
eprd	**-2.054* (2.23)**	1.599 (1.50)		-0.374 (0.54)
enprd	**-1.680* (2.05)**	**1.970* (2.05)**	0.374 (0.54)	
adj R^2	**0.930**			

Notes: 1) t-statistics in parenthesis.
2) * denotes significance at the 5% level, ** at the 10% level.
3) coefficients are long run estimates

[8] We tried estimating the regression without the country dummies but including the real interest rate. In those regressions the real interest rate returns with the expected sign and significance.

The results in Table 9.5 also appear to capture the same relationship within the tax mix as Mendoza et al. (1997). A reduction in revenues from distortionary tax (which contains capital and labour taxes) and its replacement by non-distortionary taxation (revenue from consumption taxes) so as to leave the overall size of government constant has a significant positive effect on the level of investment. In a simple one sector growth model the reduction in the returns to the factors of production through their increased taxation and the benign effect of consumption taxation on the investment decision (due to the nature of household preferences) leads to an increase in the rate of investment.

The results in Table 9.5 can be used to support the view that the relationship between government expenditures and investment depends crucially on the method of financing. Distortionary tax financed increases in productive or un-productive expenditures are significant and negative (as noted above) but when financed by non-distortionary taxation the coefficient is significant only if it is non-productive expenditures that are increased. The results for this fiscal variable go some way to explain the finding of a positive but non-robust, effect of transfers to households on the investment ratio by Fuente (1997). The results for government expenditure are somewhat surprising given the simple one sector model suggests that if any type of expenditure should enter the regression with an *insignificant* coefficient it should be non-productive expenditure. Non-productive expenditures have no effect on either investment or growth in the theoretical model whereas productive expenditure are expected to increase the marginal product of capital and therefore investment and growth. Cashin (1995) and Fuente both allow for the possibility that expenditures traditionally thought of as being non-productive may be in some way productive but model them as inputs into the production function. Cashin argues that some forms of transfer payments such as inter and intra-generational transfers increase the marginal product of capital by helping to enforce property rights through reductions in crime. Similarly, Fuente (1997) highlights the productive potential of non-productive expenditures by arguing they contribute to 'social cohesion' (although he does also discuss their potential negative effects).

The finding of a strong positive relationship between non-productive expenditures and investment can be contrasted with the results for the same variable with growth. In Chapter 6 we could find no statistically significant effects from this variable and when a general-to-specific approach was used to specify the budget constraint could not reject the null hypothesis that it could be safely excluded from the regression. In order to model transfers as having *only* an indirect effect on growth through investment they would have to affect the incentives to investment, as in Barro & Sala-i-Martin (1995), rather than the production function. Barro & Sala-i-Martin (1995) argue the expected returns to investment are a function of government expenditures because of their effect on the protection of property rights. Investment is then an increasing function of government expenditure and the effect of government expenditures on growth is indirect rather than direct.

Public investment (for which we use the *eprd* variable as a proxy) is found to have no statistically significant effect on the rate of (private) investment when financed by either reductions in non-productive expenditure or non-distortionary taxation and a significant negative one if financed by distortionary taxation. The negative relationship between private investment and public investment found in the previous literature (for example Easterly & Rebelo (1993) and Nazimi & Ramirez (1997)) has been used to argue in favour of crowding out of private investment by public investment. We find no evidence in support of such a claim.[9] Here it was found that productive expenditures have a strong direct effect on the growth rate.

The results from Table 9.5 can also be used to indicate the likely direction of the bias from the exclusion of investment in the estimation of equation (9.2). The strong negative effects of taxation on investment are likely to bias the same coefficients away from zero (either positively or negatively depending upon the choice of compensating fiscal variable) when investment is excluded from the growth regression. The positive coefficient on *enprd/rndis* is likely to be biased away from zero in a positive direction the same variable in a growth regression; whereas the

[9] We could also look at the surplus term to support or refute this argument but due to the way that the surplus term has been used to enforce statistical balance across the government budget identity, and therefore potentially contains any errors from the data set, this is not appropriate.

insignificant parameter on *eprd/rndis* is likely to direct the bias for this variable towards zero when investment is excluded from the growth regression.

9.4.3 Fiscal Policy, Growth and the Determinants of Investment

In the estimation of equation (9.2) the exclusion of investment may lead the parameter estimates to include some bias from the omission of relevant variables. In this section we re-estimate equation (9.2) by solving for the determinants of investment estimated in the previous section. The availability of data limits the number of countries to 15 and the data period from 1970 to 1992. Estimation is of a regression in the form of equation (9.4). The parameter estimates in the fiscal matrix X contains estimates of the direct and indirect effects of fiscal policy. Ideally estimation would be through two-stage least squares. Equation (9.3) would be estimated and then the predicted values from this regression included in place of investment in equation (9.1) (the same approach as in Mendoza et al. (1996). However, a lack of computing power means we are limited to estimating an equation of the following form.

Equation 9.4

$$g_{it} = \alpha + \sum_{i=1}^{l} \beta_{2i} W_{it} + \sum_{i=1}^{n} \beta_{3i} Z_{it} + \sum_{j=1}^{m} (\gamma_{2j} + \gamma_{3j}) X_{jt} + u_{it}$$

The results from the fiscal matrix are robust to the use of a reduced form estimation of equation (9.2) and the likely direction of the bias indicated in the results from Table 9.3 appears to be confirmed. The number of degrees of freedom is reduced sharply by the inclusion of such a large number of variables but the fit of the regression rises to 0.803. The most notable departures from the results in Table 9.3 is the estimation of an insignificant coefficient on the *eprd/rdis* and *enprd/rndis* variables. In the case of *enprd/rndis* this appears to be due to an increase in the standard error of the parameter rather than any large change in the point estimate (0.152 in Table 9.6 against 0.168 in Table 9.3).

Table 9. 6: Empirical Relationship Between Fiscal Policy and the Determinants of Investment

Estimation Technique	annual data 2 way FE			
Dependent variable	per capita growth (15 countries)			
	Omitted Variable			
	rdis	**rndis**	**eprd**	**enprd**
lbfg	**-0.691*** **(2.35)**	**-0.691*** **(2.35)**	**-0.691*** **(2.35)**	**-0.691*** **(2.35)**
inf	0.029 (0.39)	0.029 (0.39)	0.029 (0.39)	0.029 (0.39)
exim	2.802 (1.39)	2.802 (1.39)	2.802 (1.39)	2.802 (1.39)
r-rate	0.119 (1.52)	0.119 (1.52)	0.119 (1.52)	0.119 (1.52)
rcinv	0.029 (0.92)	0.029 (0.92)	0.029 (0.92)	0.029 (0.92)
elmr	-0.386 (1.54)	0.133 (0.47)	-0.249 (0.87)	-0.019 (0.09)
roth	0.246 (1.80)	**-0.273**** **(1.71)**	0.108 (0.77)	-0.122 (0.94)
eoth	**-0.246*** **(2.13)**	**0.273*** **(1.96)**	-0.108 (0.83)	0.121 (0.72)
sur	-0.174 (1.55)	**0.345** **(2.72)**	-0.037 (0.35)	**0.193*** **(2.04)**
rdis		**-0.519** **(2.96)**	-0.138 (0.82)	**-0.367*** **(2.34)**
rndis	**0.519*** **(2.96)**		**0.382*** **(2.74)**	0.152 (1.14)
eprd	-0.138 (0.82)	**0.382*** **(2.74)**		**0.230*** **(1.89)**
enprd	**-0.367*** **(2.34)**	0.152 (1.14)	**-0.230*** **(1.89)**	
adj R^2	0.803	0.803	0.803	0.803

Notes: 1) t-statistics in parenthesis.
2) * denotes significance at the 5% level, ** at the 10% level.
3) coefficients are long run estimates

In general the estimates from Table 9.6 are significantly larger than the point estimates from Mendoza et al. (1996). For example, according to Mendoza et al. the point estimates from a change in taxation on growth is around 0.1 to 0.2 of a percentage point; whereas we estimate the same change to be in the region 0.14 to 0.52 of a percentage point depending on the choice of compensating fiscal variable. The failure to fully account for the government budget constraint by Mendoza et al. makes comparison difficult.

The results from Table 9.6 are interesting as a test of the public policy endogenous growth models. The results suggest that even if we include the effects of fiscal policy on investment within the regression equation then the results still match the predictions from the Barro (1990) model. That is, the effects of fiscal policy on growth are adequately captured by the simple model that separates fiscal policy into one of four types (distortionary and non-distortionary taxation and productive and non-productive expenditure). The discussion of the results in Table 9.5 indicates however, that the model is not able to account for all of the movement in the data. In order to draw out these possible extensions to the model we choose to disaggregate the data further.

9.4.4 Government Expenditures and Investment

We observe in the previous section weak effects of government expenditures and non-distortionary taxation on the level of investment but strong negative effects from the use of certain types of taxation (those that were pre-classified as distortionary). Given this it is more interesting to investigate further the relationship between government expenditures and the investment ratio rather than the much stronger relationship of taxation and investment. Following Chapter 8 this is achieved by disaggregating the expenditure data in two stages and concentrating on the results for the expenditure mix.[10] The first level of disaggregation (the results for which are in Table 9.7) separates out health and social security expenditures and categorises the remaining productive expenditures as either likely to be productive as a stock or as a flow (details of this disaggregation can be found in Chapter 8). The second level of disaggregation (the results from which are in Table 9.8) uses the functional classification of expenditures from the GFSY. Only three forms of expenditure were considered at this level of disaggregation (social security (*ess*), general public expenditures *(egps*) and defence expenditures (*edef*)). The choice of these three expenditures was decided on the basis of the results from using the first level of disaggregation and is explained further below.

[10] The *elmr* is been subsumed into the surplus term and so is not included in the table of results.

Table 9. 7: Government Expenditures and Investment Using Re-classified Data

Estimation Technique	annual data 2 way FE			
Dependent variable	pinv (15 countries)			
	Omitted Variable			
	epf	**eps**	**ehlth**	**ess**
lgrowth	**1.228 (2.43)**	**1.228 (2.43)**	**1.228 (2.43)**	**1.228 (2.43)**
inf	-0.283 (1.08)	-0.283 (1.08)	-0.283 (1.08)	-0.283 (1.08)
exim	0.384 (0.08)	0.384 (0.08)	0.384 (0.08)	0.384 (0.08)
r-rate	-0.092 (0.35)	-0.092 (0.35)	-0.092 (0.35)	-0.092 (0.35)
rcinv	**0.186 (3.57)**	**0.186 (3.57)**	**0.186 (3.57)**	**0.186 (3.57)**
sur	-0.343 (0.50)	0.771 (1.21)	0.651 (0.95)	0.442 (0.72)
trev	0.380 (0.48)	-0.734 (1.38)	-0.615 (0.89)	-0.484 (0.69)
epf		1.114 (1.03)	0.995 (1.23)	**1.054 (1.71)**
eps	-1.114 (1.03)		-0.120 (0.13)	-0.060 (0.07)
ehlth	-0.995 (1.23)	0.120 (0.13)		0.059 (0.09)
ess	**-1.054 (1.71)**	0.060 (0.07)	-0.059 (0.09)	
adj R^2	**.926**	**.926**	**.926**	**.926**

Notes: 1) t-statistics in parenthesis.
2) * denotes significance at the 5% level, ** at the 10% level.
3) coefficients are long run estimates

There is a reduction in the explanatory power of the regression in terms of the value of the adjusted R^2 as we disaggregate the fiscal variables.[11] The previously significant positive relationship of the real interest rate disappears however. According to Tables 7 and 8 there is no long-run relationship between the real interest rate and the decision to invest (in contrast to the earlier level of aggregation). The real interest rate appears to affect the *timing*, rather than the *level*, of investment. Of the remaining conditioning variables there is little change in the relationship with the investment ratio, with only the relative cost of investment appearing to have a significant effect on the long run level of investment.

[11] This is probably due to the fact that as the fiscal variables now account for smaller percentages of GDP the *signal* is more likely to get lost in the *noise*

The fiscal matrix within Tables 7 and 8 provide us with information regarding the effect on investment of changes in the mix of expenditures (the replacement of one kind of government expenditure with another but keeping total government expenditures constant). The statistically insignificant relationship of government expenditures with the investment ratio can be seen to hold as we move to the next level of aggregation of government expenditures. Only by replacing social security expenditure with expenditures on productive flows (expenditure on general public services and defence) can we increase the long run investment ratio. It is this relationship we chose to investigate further by disaggregating the *epf* variable into its component parts (expenditures on general public services and defence).

From Table 9.8 we discover that there is in fact a difference between the way general public services financed increases in social security expenditure and defence expenditure finances increases social security expenditure affect investment. The long run level of investment can be increased by 1.82 percentage points if social security expenditure is replaced with general public services, but decreased by 2.99 percentage points if social security expenditure is replaced with defence expenditure. General public service expenditure contains expenditure on law and order that could reasonably be thought of as protecting property rights and therefore the returns to investment (as in Barro & Sala-i-Martin (1995)). Earlier in this chapter, we also discovered evidence of a significant effect on growth from this pair of expenditures.

The coefficients estimated in Table 9.8 measure the net effect of changes in pairs of expenditure items. There therefore exists a multiplicity of possible interpretations of the estimated coefficients. Defence expenditure is often used (justified) as an example of expenditures that reduce the risk factor of investment through the maintenance of property rights (Smith (1977)). In this sense the coefficient on this variable is surprising but not inconsistent with previous findings. Smith (1977) also finds a significant negative relationship of defence expenditure with the investment ratio for 15 OECD countries using a cross sectional approach and a panel of annual time series observations (in both cases the time period used is 1960-70). Further investigation using input-output tables leads Smith to explain at least some of this negative relationship as a result of a supply constraint caused by military equipment often being produced by investment good industries. It is difficult to use this to explain the long run negative relationship as presumably a short run supply constraint is just that: short run. Smith however argues that the continual diversion of resources away from investment may lead to a capacity constraint on the economy and possibly inefficiencies in industries as a result of 'soft' government contracts. A similar process may also exist if military R&D expenditure crowds out the private sector from the stock of human capital. Alternatively, the significant coefficient on *ess/edef* may have been caused by the positive investment effects of social-security expenditures (as already discussed above).[12]

Table 9. 8: Government Expenditures and Investment Using Data Classified by Function

Estimation Technique	annual data	2 way FE	
Dependent variable	pinv	(15 countries)	
	Omitted Variable		
	egps	**edef**	**ess**
lgrowth	0.678 (1.59)	0.678 (1.59)	0.678 (1.59)
inf	-0.392 (1.40)	-0.392 (1.40)	-0.392 (1.40)
exim	-9.424 (1.57)	-9.424 (1.57)	-9.424 (1.57)
r-rate	-0.011 (1.04)	-0.011 (1.04)	-0.011 (1.04)
rcinv	**0.249** **(4.01)**	**0.249** **(4.01)**	**0.249** **(4.01)**
sur	0.587 (1.54)	-1.233 (1.19)	**0.725*** **(2.80)**
trev	-0.332 (0.91)	1.488 (1.40)	**0.794*** **(2.56)**
texp	0.208 (0.53)	-1.612 (1.53)	**0.798*** **(2.64)**
egps		-	**1.820** **(1.65)**
edef	-		**-2.993** **(2.11)**
ess	**-1.820** **(1.65)**	**2.993** **(2.11)**	
adj R^2	**0.910**	**0.910**	**0.910**

Notes: 1) t-statistics in parenthesis.
2) * denotes significance at the 5% level, ** at the 10% level.
3) coefficients are long run estimates

[12] In the growth regression equivalent in chapter 6 the estimated relationship was statistically insignificant.

9.5 Conclusions

In this chapter we have attempted to estimate the long run effects of different government taxation and expenditure polices on the private investment ratio and growth. Using data for 17 countries from 1970-94 we estimate a dynamic panel regression using annual observations and long lag structures taking account of the government budget constraint. We find that a great deal of the apparent non-robustness of the relationship between fiscal policy and investment may be accounted for by the same issues investigated in Chapters 6 to 8 for growth. However, further explanation is found for by the exclusion of investment from the set of conditioning variables. We find that the exclusion of investment from the regression strengthens the relationship between fiscal policy and growth (similar findings are made by Fuente (1997)). This contrasts with Sala-i-Martin (1997) who, like Levine & Renelt (1992), find that the relationship between fiscal policy and growth is more likely to be statistically significant when investment is included within the regression. We show however, that the bias induced on the parameters by the exclusion of investment from the regressions depends in part on the excluded fiscal variables also. It is the importance of the government budget constraint for the direction of the bias that we feel explains for the differences between the Fuente, Levine & Renelt and Sala-i-Martin studies. Once we control for the determinants of investment the strong support for the Barro (1990) model is restored. However, in searching for the relationship between fiscal policy and investment we find a number of results which are left unexplained by the Barro model.

The strongest relationships we estimate between fiscal policy and investment occur for distortionary taxes. Within the Barro model increases in distortionary taxation have an un-ambiguously negative relationship with private investment. Factor taxation reduces the returns to investment and hence the level of investment. The long run relationship of government expenditures with investment is less clear and there is a greater dependence on the method of financing on the parameter estimates than with taxation.

In contrast to our *a-priori* predictions we find some evidence of a positive effect on investment from non-productive expenditures, but only if financed by non-distortionary taxation (in Chapter 6 we found no evidence of a direct relationship on the long run rate of growth). This leads us to suggest that certain forms of expenditure (such as those we pre-classified as non-productive) affect investment rather than growth. This sort of relationship is captured best by the Barro & Sala-i-Martin (1995) extension to the basic model. Certain government expenditures may affect the perceived returns to investment that leads to changes in the level of investment.

We can find no significant relationship between productive expenditures and investment in our results: the 'crowding out' effects of public investment on private investment found by Easterly & Rebelo (1993) and Nazimi & Ramirez (1997) are therefore not apparent in this data set. Further investigation of the relationship between government expenditures and investment demonstrates that we can gain additional insights from disaggregating the data further. We find that financing increases in social-security expenditure by decreasing defence expenditure increases the long run investment ratio but if financed by decreases in general public services the long run investment ratio falls. Possible theoretical extensions might therefore concentrate on the distinction between direct and indirect growth effects of government expenditures.

Chapter 10

Conclusions, Further Research and Policy Implications

The weight of evidence in the thesis allows us to conclude that it is important to consider both the *level* and the *mix* of policy when explaining the slowdown in growth over the post-war period. The increase in social security and welfare payments at the expense of productive expenditures (evident in Figures 1.1 and 1.2 of Chapter 1) offers part of the explanation, along with differences between countries in the method chosen to finance these increased expenditures. The increased use of distortionary taxation, by lowering the returns to and discouraging investment, significantly slows down growth.

10.1 Predictions from Theory

The public-policy *neoclassical* growth models (for example, Judd, 1985 or Chamley, 1986) consign the role of fiscal policy to one of determining the level of output rather than the long-run growth rate. The steady-state growth rate is driven by the exogenous factors of population growth and technological progress, while fiscal policy can affect growth only in the transition path to this steady-state. In these models, tax and expenditure measures that influence the savings rate or the incentive to invest in physical or human capital ultimately affect the equilibrium factor ratios rather than the steady-state growth rate. By contrast, the public-policy endogenous growth models of Barro (1990), Barro and Sala-i-Martin (1992, 1995) and Mendoza et al. (1997) fiscal policy determines both the level of output and the steady-state growth rate. By restricting the form of the production function, or using productive expenditures to raise the marginal product of capital to such an extent that diminishing marginal returns are permanently offset, the growth rate is a positive constant.[1] Our explanation of the slowdown in growth is therefore, consistent only with the endogenous growth models.

The endogenous growth models are rich enough for fiscal policy to display a wide range of characteristics (for example Barro & Sala-i-Martin (1992), Glomm & Ravikumar (1994), Capolupo (1996)). The most important, though, for determining the effect on growth is which of the sectors the policy affects consumption or production. Those policies that affect the production sector affect either the savings rate or the incentive to invest in physical or human capital.[2] Policies that affect consumption have no effect on growth but may affect the equilibrium factor ratios.

There are only two caveats to this conclusion in the literature. The first is when productive expenditures are subject to congestion. Under such conditions productive expenditures cannot be used to prevent diminishing marginal returns in the accumulation of capital and, in the absence of technological change, the growth rate falls to zero. However, if diminishing marginal returns to capital are assumed away and the level of congestion is maintained at a constant level in the steady state (i.e. G/Y is assumed constant rather than G) then fiscal policy still affects the growth rate. The second caveat is when a leisure-education choice is included in households' preference function. If the supply of labour is not perfectly inelastic then greater consumption taxation encourages education, lowering the returns to investment and hence growth.

It follows from the endogenous growth models that the size of government is not the only determinant of the growth rate and instead the *mix* of available policies is as important. If an increased proportion of the expenditure budget is used for productive over non-productive expenditure (Chapter 2) or revenues collected from non-distortionary rather than distortionary taxation (Chapter 3) then the growth rate is increased. Devarajan et al. (1996) and Rebelo (1991) extend this to show that further gains to the growth rate can be made if the marginal effect of different types of

[1] Fiscal policy generates endogenous growth only in models which include both productive expenditures *and* distortionary taxation (see Chapter 4).
[2] If there is more than one reproducible factor then this depends on the relative tax rate on each factor.

productive expenditures and of distortionary taxes is non-homogenous. Both halves of the government budget are brought together in Chapter 4 and from this we conclude the method of financing is important for the effect on growth of a change in expenditures. For example, if increases in productive expenditures are financed through non-distortionary taxation the model predicts the effect on growth to be positive; whereas if distortionary tax financed the effects on growth from the same increase in productive expenditure can vary between negative and positive depending on the current level of expenditures.

10.2 Empirical Evidence

Empirical testing of the relationship between fiscal policy and growth has, generally, been only loosely based around the findings from the theoretical models. It can be argued that this failing helps to explain the inconsistency of the results for similar variables even within similarly specified regressions found in the literature. Within Chapter 5 we identify a number of empirical issues that have been identified as creating a statistical bias in the parameter estimates from growth regressions and show that, even once many of these empirical issues have been accounted for, comparisons of results still imply a non-robust relationship.

We use this finding as evidence that so far the empirical tests of growth models have been incomplete. Accordingly, we draw out four potential explanations for non-robustness from the review of the theoretical literature. The first stresses the method of financing a given change in policy by developing a methodology proposed by Helms (1985), Mofidi & Stone (1990) and Miller & Russek (1993) (Chapter 6). Chapter 7 distinguishes between the steady state implications for fiscal policy between new and old theories of growth. We test the robustness of the current statistical methodology adopted in the literature to a list of possible alternatives. Chapter 8 tests the homogeneity of productive expenditure assumption in the Barro model. Tests are based around a similar study by Devarajan et al. (1996) but where level and composition effects of expenditure are correctly separated. The final test, Chapter 9, separates the direct from the indirect (via investment) effects of fiscal policy on growth.

In order to avoid many of the statistical biases identified in Chapter 5 the study adopts many features from other studies. In addition, this also suggests our results do not derive from deviations from normal procedure. A sample of 22 OECD countries is used with data stretching over the period 1970 to 1994. OECD countries are chosen in order to reduce possible simultaneity bias caused by Wagner's law (Easterly & Rebelo (1993)) and heterogeneity of parameters across countries. These data are then averaged across 5-year periods to again reduce possible simultaneity caused by Wagner's law but also from the business cycle. Estimation is through panel data techniques to reduce bias from omitted country and time specific effects. The data on fiscal expenditures and tax revenues are taken from the GFSY. These are expressed as ratios to GDP and classified in accordance with the theory i.e. as productive or un-productive expenditures and as distortionary and non-distortionary taxation.

The classification of the data in accordance with theory does not appear to alter our ability to replicate the results from previous studies. We find that two of the most common results, the negative coefficient on distortionary taxation and the negative coefficient on non-productive expenditure, are easily replicated. One of the most interesting findings from this section is that the negative coefficient on distortionary taxation is non-robust to the inclusion of non-productive expenditure within the same regression. This matches a conclusion made in Chapter 5 when comparing the results across the Fuente (1997) and Mendoza et al. (1996) studies.

The evidence presented in the thesis supports the endogenous over the neoclassical growth models. Consistently the long run relationship between fiscal policy is estimated as being statistically significant. In turn, of the various forms of endogenous growth model the strongest support is found for the Barro (1990) one-sector model we reviewed in Section 4.2.1. Policies that are perceived to affect the supply side of the model are found to significantly alter the growth rate whereas those that affect the demand side of the model do not. However, the evidence for the Barro model is not absolute and by changing the statistical methodology it possible to remove some but not all of the results.

In Chapter 4 when the expenditure and revenue sides of the budget are brought together consideration as to the method of financing is important in determining the effect of policy changes on the growth rate. Helms (1985), Mofidi & Stone (1990) and Miller & Russek (1993) show that the estimated coefficient of one element of the government budget will vary according to the specification of the estimating equation with respect to the other elements. We draw out this work to form our empirical tests in Chapter 6.

When we specify the budget constraint completely we find that the estimated coefficients on a given fiscal variable depend upon the choice of the compensating fiscal variables. However, we find the non-robust relationship between fiscal policy and growth matches exactly that predicted by the Barro (1990) public policy growth model. This leads us to conclude that tests for statistical robustness along the lines of Levine & Renelt (1992) or Sala-i-Martin (1997) are, at least in the case of fiscal variables, misdirected. Non-robustness is a feature of the data generating process for fiscal variables, and would therefore occur even if one could account for the statistical problems which Levine & Renelt and Sala-i-Martin (perhaps incorrectly) attribute to non-robustness. We conclude that the relationship between fiscal policy and growth is statistically non-robust but theoretically robust (i.e. the non-robustness corresponds to misspecification biases that we can explain theoretically).

The findings from this chapter are robust to tests for some of the statistical bias that might remain in the data, but not all. The exclusion of initial GDP from the regression equation, in contrast to Easterly & Rebelo (1993), does not in this case lead to a change in the results. Nor does there appear to be significant heterogeneity across parameters. Economic theory tells us that the effect of distortionary tax financed increases in productive expenditure by distortionary taxation on growth depends on the current level of expenditure. Below some optimum value the growth effects are positive but if above then they are negative. Testing within this study leads us to conclude, like Barro (1991), that productive expenditure are 'optimally' supplied via distortionary taxation within the countries of this data set.

Period averages of the data are commonly used in the literature to remove possible bias caused by simultaneity between fiscal policy and growth. Within Chapter 6 we adopt the most common standard and average the data across 5-year periods. When we test the robustness of the results to the use of 10-year period averages and estimation by instrumental variables we find evidence that simultaneity remains within the data. When 10-year period averages are used the standard errors on the coefficients become inflated and the parameter values themselves noticeably larger. Part of the difference with earlier results in the chapter can be explained by the reduction in degrees of freedom after calculating 10-year period averages, but this cannot explain for all of the movement in the results. Similar problems are encountered when the regression is estimated with instruments of the fiscal variables. However, results from Chapter 7 lead us to contest the validity of these two tests for robustness and therefore the conclusions drawn from them.

Chapter 7 uses the different predictions regarding the steady state growth rate between the neoclassical and endogenous growth models to explain for the non-robust relationship between fiscal policy and growth found in the literature. In the neoclassical model the government cannot affect the steady state through its use of fiscal policy but does affect the transition; whereas in the endogenous growth model fiscal policy affects both the transition and the steady state. Despite the strength of this distinction little testing for alternative measures of the steady-state (beyond the use of 5-year period averages in a static panel framework) has been attempted. We use a number of different arrangements of the data (annual, 5-year and 10-year period averages), and two different estimators (static and dynamic panels), but find that this has little bearing on the finding of significant parameters. From this we conclude that there is strong evidence from our results in support of the endogenous growth model. However, we do find the choice of estimator to be important when testing between variants of the endogenous growth models. That is, we do not continually find the same fiscal variables to be significant in all regressions (the tax mix is the exception to this) and therefore evidence in favour of the same version of the endogenous growth model.

The empirical section of Chapter 7 begins by nesting a typical static panel growth regression with 5-year period averages into a dynamic version of the same model (with a single lag of the dependent variable used to capture possible dynamics within the data). We find we cannot reject the null of the joint significance of these lagged dependent terms. That is, the static panel regression with 5-year averages of the data is misspecified and incorrectly concludes in favour of the Barro growth model. The results from the dynamic regression can also be used to argue against the choice of lagged values as instruments in Chapter 6 as the instruments will also be correlated with the error term.

The robustness of the results are tested against a number of alternatives (10-year period averages; moving the start year of the period average forward; and using annual observations together with and long lag structures in a dynamic regression). The finding of non-robust results from these regressions leads us to conclude the choice of estimator is important when testing between versions of the endogenous growth model. Most notably the results warn against the use of 5-year period averages without testing for the sensitivity of the results. The problems with period averaging appear to be compounded when longer period transformations of the data or dynamic regressions with period averages are used. Period averaging clearly transforms the data in ways that are not fully understood and requires further research.

The sensitivity of the results to period averages lead us to favour the use of dynamic panel estimators with annual observations of the data and long lag structures. However we also recommend that further research, along the lines of Judson & Owen (1997), into the properties of these estimators when using 'macro-shaped' data sets (small N and small to medium T). Interestingly when we use this type of estimator the results are very similar to those from the static panel regression with 5-year averages which we criticised for being misspecified!

The third explanation for the inconsistent relationship between fiscal policy and growth surveyed in Chapter 5 is that of inappropriate aggregation. The Barro (1990) model suggests that government expenditures need only be classified into one of two types (whether they affect the supply or the demand side of the economy) in order to determine their effect of growth. Devarajan et al. (1996) develop this model and demonstrate that further gains to growth can be achieved by changes in the mix of productive expenditure. If the ratios of current expenditure and relative productivity are away from their optimum levels then the growth rate can be increased by changes in their relative mix. That is, productive expenditures are non-homogeneous in their effects on growth and the inappropriate aggregation of the data may increase the confidence intervals on the productive expenditure term. Against the desire to increase the realism of the model must be balanced the problem that too much disaggregation risks losing more of the signal within the noise as expenditures now account for a much smaller percentage of GDP.

Evidence from this chapter supports the Devarajan et al. model in which productive expenditures are categorised by different coefficients. The assumption of homogeneity appears to be a reasonable first approximation and does not upset the results but the fit of the model is improved by disaggregation. Of special interest in this set of results is the finding of strong negative effects from increases in both education and health expenditure. In the case of education this negative effect is even found when compensated by decreases in social security expenditure. From a theoretical perspective the possibility of a negative marginal effect from the over-supply of productive expenditures is not possible in either the Devarajan et al. or Barro models; while from an empirical perspective, research into the 'value added' from these expenditure types is warranted. These results are found to be robust to the use of AH-estimators (up until a very disaggregated form of the data) but not to the use of 5-year period averaged data (greater robustness is found when 5-year period averages are used with the lowest level of aggregation of the expenditure data).

The final explanation for non-robustness that we investigate is the choice of conditioning variables, namely the rate of private investment. Levine & Renelt (1992) find that fiscal policy variables only enter growth regressions with the expected sign when investment is included amongst the regressors. Yet, they can find no relationship between fiscal policy and investment itself. Similarly, Sala-i-Martin (1997) finds that the relationship between fiscal policy and growth is only 'statistically robust' when investment is included amongst the set of conditioning variables. We demonstrate that the divergence of these results may be due to a failure to account for the issues raised in Chapter 6-8 along with an additional omitted variable bias caused by the exclusion of investment from the regression. The direction of this bias depends in part upon the specification of the budget constraint. This helps to explain further the diversity in the estimated coefficients for fiscal variables between studies. Once we control for the determinants of investment (as in Mendoza et al. (1996)), fully specify the budget constraint and use dynamic panel estimators with annual observations and long lag structures we find that the support for the Barro version of the endogenous growth model returns.

When we investigate further the way in which fiscal policy affects investment we notice, in places, further divergence from the Barro model. Somewhat surprisingly however it is the non-productive expenditure term (which consists mostly of social security expenditure) which appears to affect investment positively. This would suggest that increases in these (indirectly productive) expenditures raise the probability of maintaining ownership over the returns from investment and therefore investment itself. When we research this result further we find there is still strong support but only for certain categories of expenditure. The assumption of homogeneity across productive expenditures affecting investment also appears to be inappropriate. Positive growth effects are found from general public services (which includes expenditures on policing) funded by decreases in social-security expenditure but negative growth effects from defence expenditure for the same increase in social security expenditure are also estimated. Only the first of these findings is consistent with the original Barro & Sala-i-Martin (1995) paper. It is unclear whether the latter of these two results is because of crowding out by defence expenditure or positive growth effects from social-security and welfare expenditure.

If we collect together all of the results using the fiscal data as classified by the theory then we notice a strong measure of consistency across different econometric techniques and methods of averaging the data. For example, in the 14 sets of results we display in Table 10.1 all find significant positive growth effects from increasing non-distortionary taxes and decreasing distortionary ones. From this we can perhaps also conclude that the strongest explanation for the lack of consistent results we find within the thesis is that of the government budget constraint. That is, once the omitted variable bias from incorrectly specifying the budget constraint is accounted for the results become remarkably robust to most other changes. Where different measures of the long run are employed these tend to affect the significance of the variables rather than the sign. We find however that this is important for testing between variants of the endogenous growth model where the theory predicts some but not all coefficients to significantly affect growth.

If we ignore those regressions which use period averages, static panel regression estimation or contain an omitted variable bias from excluding investment then we are left with only two sets of regression results, those for regressions 11 and 14. If the results from these regressions are then compared to the summary of the expected findings from the Barro model (presented as the first row of the table) then we can conclude that the Barro model is a good representation of the data set. However, as we begin to disaggregate the data in Chapters 8 and 9 (but do not include in the table) then we find the strength of this relationship is weakened. Elements of expenditure we a-priori predicted to be either productive or non-productive no longer enter the regression with the expected sign or significance. This we feel to be a failing of the theory rather than the statistical procedures adopted.

Table 10.1: Summary of the Results for the Theoretically Classified Data

	Estimation Technique	rndis/ rdis	eprd/ enprd	eprd/ rdis	eprd/ rndis	enprd /rdis	enprd /rndis
	Barro Model	+	+	?	+	-	0
	Static, 5-year						
1	22 countries	+	+	-	+	-	+
2	first period begins 1971	+	+	+	+	-	+
3	first period begins 1972	+	+	-	+	-	+
4	first period begins 1973	+	-	-	+	-	+
5	17 countries	+	+	-	+	-	+
6	GDP excluded	+	+	-	+	-	-
7	IV	+	+	-	+	-	+
8	**Static 10-year**	+	-	-	+	-	+
	Dynamic						
9	5-year, 1-lag	+	-	-	+	-	+
10	AH, 5-year, 1-lag	+	+	-	+	-	-
11	annual, 8 lags	+	+	+	+	-	-
12	private invest., 15 countries	+	+	-	+	-	+
13	private invest. excluded	+	+	-	+	-	+
14	determinants of invest.	+	+	-	+	-	+

10.3 Policy Implications

We use the next section of this chapter to draw out some possible policy implications of the work contained in Chapter 6 to 9. The results from this thesis suggest that there are significant gains (and losses) to be made from adjusting the fiscal mix within a country. Although one should be cautious about using the parameter estimates from any study to give precise measures of the effect on growth from changes in policy, we choose to consider such changes in order to compare of the relative size of government between countries. To do this we begin by extending the analysis made in Tables 7.2 and 7.8 of Chapter 7. That is, we show the effect on growth from a 10% increase in each pair of fiscal variables. We consider four changes: *i)* an increase in productive expenditure funded by increases in distortionary tax revenues, and vice versa; *ii)* changing the expenditure mix in favour of productive (non-productive) expenditure; *iii*) changing the revenue mix in favour of distortionary taxation (non-distortionary) and; *iv*) increases in non-productive expenditure financed by distortionary taxation. The analysis is performed on a sample of 5 representative countries along with the average across all countries. The growth estimates present in the tables are therefore based on each county's own particular expenditure and revenue mix. Calculations are based on averages for the last available 5-year period in our data set 1990-94, summary statistics for which are presented in Table 10.2.

As can be seen in Table 10.2 there is a reasonable degree of variation amongst the countries we use for the policy analysis. Perhaps the most notable of this variation is the difference in the per capita growth rate across countries. This mostly reflects differences in the point in the business cycle covered by the period, while the German figure is high relative to the others because of German reunification.

Table 10.2: Summary Statistics of the Variables Used in for Policy Analysis

	Average	*1990-94*		*(% of GDP)*		
	Growth	*Investment*	*rdis*	*rndis*	*eprd*	*enprd*
France	1.48	22.27	26.31	11.16	16.89	21.06
Germany	4.05	21.84	20.35	7.82	11.73	15.91
Sweden	-0.79	18.67	23.14	13.00	13.87	27.09
UK	-0.70	15.54	22.10	11.22	16.46	14.03
US	1.86	18.30	17.18	0.75	12.50	8.04
All	1.79	20.80	19.98	9.70	14.48	16.57

The size of government is in general above the average of the full sample of 22 countries (with the exception of the US) because of the bias in the sample selection towards European countries. However, there is still great variation in the policies chosen between countries. For example, in France some 26.31% of GDP is collected by the government as distortionary taxes (the average is 19.98%), while the US collects only some 0.75% of GDP as non-distortionary taxes (the average is 9.70%). The largest spenders on productive forms of expenditure are the UK and France at roughly 16%. This is interesting in the case of the UK as this country had one of the slowest per capita growth rates over the period. Sweden, perhaps unsurprisingly, is the largest spender on non-productive expenditure at some 27.09% of GDP compared to the US which is the lowest at 8.04%.

Table 10.3 below presents the results conditional on the level of investment. An increase in productive expenditure by 10% is *not* equivalent to a 10% change in non-productive expenditure as each represents a different proportion of GDP. The growth effects estimated for both of these policy changes are presented in the table, with an increase in the second of the policy variables in the column headings presented in parenthese.

The implications for growth can be seen to vary significantly both between policies and between countries for the same policy. The growth effects of increases in productive expenditure by distortionary taxation are very small (only 0.026 of a percentage point on average); whereas the same increase in productive expenditure funded by decreasing non-productive expenditures are much larger (0.539 of a percentage point on average).

The largest growth effects in Table 10.3 can be found, however, from changes in either distortionary taxation or non-productive expenditure. Increases in revenues from distortionary taxation in France (which accounted for 26.31% of GDP in 1990-94) decreases the growth rate by 0.692 of a percentage point if used to decrease revenues from non-distortionary taxation, while increases in non-productive expenditure in Sweden by 10% (which accounts for 27.09% of GDP in 1990-94) decreases the growth rate 0.943 of a percentage point if increased at the expense of productive expenditures.

Table 10.3: Growth Effect of Changes in Government Policy

policy change (coefficient)	*eprd/rdis (0.017)*	*eprd/enprd (0.348)*	*rdis/rndis (-0.263)*	*enprd/rdis (-0.331)*
France	0.029	0.588	-0.692	-0.147
	(0.045)	(-0.733)	(0.294)	(0.045)
Germany	0.020	0.408	-0.535	0.087
	(0.035)	(-0.554)	(0.206)	(0.035)
Sweden	0.024	0.483	-0.609	-0.460
	(0.039)	(-0.943)	(0.342)	(0.039)
UK	0.028	0.573	-0.581	0.059
	(0.038)	(-0.488)	(0.295)	(0.038)
US	0.021	0.435	-0.452	-0.232
	(0.029)	(-0.280)	(0.020)	(0.029)
All	0.026	0.539	-0.525	-0.282
	(0.034)	(-0.577)	(0.255)	(0.034)

Table 10.4 considers the same changes as Table 10.3 but with the effects of fiscal policy via investment included. The growth effects of changes in policy are accordingly significantly larger in Table 10.4. Indeed, the growth effects of changes in the tax mix are over 1 percentage point in growth in all of the countries shown except for the US. Non-distortionary taxation accounts for such a small percentage of GDP in the US that the growth effects from changes in the tax mix in favour of non-distortionary taxation has a relatively small effect on per capita growth only 0.039 of a percentage point.

Table 10.4: Growth Effects of Changes in Policy both Direct and Indirect Via Investment

policy change (coefficient)	*eprd/rdis (-0.138)*	*eprd/enprd (0.230)*	*rdis/rndis (-0.519)*	*enprd/rdis (0.367)*
France	-0.233	0.388	-1.366	-0.773
	(-0.363)	(-0.484)	(0.579)	(-0.966)
Germany	-0.162	0.270	-1.056	-0.584
	(-0.281)	(-0.366)	(0.406)	(-0.747)
Sweden	-0.191	0.319	-1.201	-0.994
	(-0.290)	(-0.623)	(0.675)	(-0.849)
UK	-0.227	0.379	-1.147	-0.515
	(-0.305)	(-0.323)	(0.582)	(-0.811)
US	-0.173	0.288	-0.891	-0.295
	(-0.237)	(-0.185)	(0.039)	(-0.630)
All	-0.214	0.356	-1.037	-0.608
	(-0.276)	(-0.381)	(0.504)	(-0.733)

Finding 'natural experiments' with which to test the results from the thesis are difficult without knowing how changes in expenditure are financed. One recent possibility that presents itself however is the UK Spending Review by Gordon

Brown in July 1998. We again advise caution in applying the results from the thesis to any one country and simplify the proposals set out by the Chancellor in order to concentrate on the four main tenets of the speech, the increased expenditure on education, health and transport and the (relative) reduction on social security spending. Once one takes out the effects of inflation then education and health expenditure are set to increase in real terms by around 2.75% a year for three years. Transport is to receive a once-and-for-all increase of 25% and social security is set only to rise by the increase in inflation (approximately). We stylise these proposals somewhat and assume that these increases in expenditure will not require additional sources of funds and therefore hold constant the level of total expenditures as a ratio to GDP.[3] If the level of total expenditures to GDP is to be maintained at a constant rate and we do not allow financing by other means then in order to increase expenditure on education, health and transport & communication expenditure as a ratio to GDP then social security expenditure must fall as a ratio to GDP.[4]

The parameter estimates in the thesis provide us with information as to the effect on growth of a given change in expenditure as a percentage ratio of GDP. Along with the proposed increases in expenditure we therefore need to predict the expected increase in GDP, the growth rate. We choose 2.25% as being an average made by various commentators. Combining these figures then we surmise that the education and health expenditures will rise as a percentage ratio to GDP by around 15% (from 1.32% to 1.53% of GDP for education and 5.66% to 6.53% of GDP for health) over the three years and close to 17% in the case of transport (we do not separate transport from communication expenditure in the data and so expenditures rise from 0.87% to 1.02% of GDP). These increases in expenditure are assumed to be funded by decreases in social-security and welfare. Although social-security expenditure is expected to decline as a percentage ratio to GDP over the period (because of the growth of GDP) within the budget we assume for simplicity that no other category of expenditure is altered. This probably overestimates the compensating decrease in

[3] This is amongst the aims of the Chancellor but it is envisaged that additional revenues will be made available through reductions in other expenditures such as defence.
[4] This is again consistent with the Chancellors position where social security expenditure is maintained in real terms but because of the growth in output falls as a ratio to GDP.

social-security and welfare expenditure that are likely to occur. The results from this hypothetical exercise are presented in Table 10.5 below.

The effect on the long run growth from this crude approximation to the Chancellor's proposed spending plans can at best be described as modest. Even at their largest the growth effects of increasing education expenditure is expected to be around only 0.1 of a percentage point, and this effect is negative. Only one of the coefficients, *ess/educ*, was estimated as being significant in Table 8.5 in Chapter 8 and one could assume that the effect of the other changes in policy may get lost in the 'noise' contained within the data. This reflects the fact that once the increases in inflation and GDP are accounted for the increases in expenditure in fact represent only very small changes in GDP.

Unfortunately we do not have standard errors on the long run coefficients from which to produce confidence intervals of these growth estimates. However we do have standard errors from the sum of the short run fiscal parameters. We use these as an approximation. These confidence intervals are displayed in column four of the Table 10.5. Even when we include the confidence intervals the results remain relatively modest, but we can be less sure about the direction of the effect on growth. The largest changes are once again from increasing education expenditure where the effect on growth lies within the range -0.458 to +0.202 of a percentage point.

Table 10.5: Estimated Growth Effects of UK Spending Review, July 1998

	Relevant Coefficient	*Average (1990-94)*	*Growth Effect*	*Confidence Interval*
educ/ess	-0.627	1.33	-0.128	-0.458 → 0.202
ehlth/ess	-0.163	5.66	-0.033	-0.159 → 0.093
etcm/ess	0.191	0.88	0.028	-0.152 → 0.208

10.4 Further Research

The availability of data; the number of degrees of freedom and computing power has limited the empirical research conducted in this thesis to an investigation into the way fiscal policy affects the growth rate directly, or indirectly via investment. For this reason, the tests conducted in Chapters 6 to 9 can best be thought of as a test of the one-sector growth models and there remains much scope for the extension of this analysis into both existing models and new models of economic growth.

The work conducted in Chapters 8 and 9 allude to the fact that our understanding of the channels by which fiscal policy affects growth even in the one-sector models is somewhat limited. Most notable of these limitations is that the government budget constraint methodology cannot determine between a number of competing explanations of the same result. For example, in Chapters 8 and 9 social security expenditures were found to positively affect either growth or investment against several forms of expenditure that were perceived *a-priori* to be productive. Under the budget constraint this may be either because social security expenditure is 'productive', or because the marginal product on some of the 'productive' expenditure terms is negative. Two methods to deal with this would be to either collate data in which the capital investment component contained within the functional classifications are removed from the consumption component; or extend the general-to-specific specification of the budget constraint discussed in Chapter 6.

The main results from the thesis are concentrated on the developments made to the expenditure side of the model. The emphasis is placed here rather than on the tax side because of the estimates we use for the marginal tax rate. Within the theoretical models marginal and average rates of taxation are identical (because all taxes are proportional). Such proportionality is unlikely to occur in practice and therefore the tax revenues we use are more likely to reflect average rather than marginal rates of tax. Although marginal and average tax rates are possibly correlated (and the strength of some of the results on the tax variables seems to confirm this) it is the marginal rate rather than the average rate which is likely to determine the decision of the marginal agent. An interesting extension of the results investigated here would be to include measures of the marginal rate of taxation along with the government budget constraint. This may change the exact interpretation of the budget constraint for, although the method of financing changes in expenditure would still be important, the relationship with growth might appear on the marginal rather than the average tax rate. Support for the idea that the budget constraint may still be important can be found in Kocherlakota & Yi (1997), where significant growth effects from fiscal policy are only found when public investment is included with an estimate of the *marginal* tax rate in the regression.

Tests of taxation within the two-sector models have so far only been investigated through simulation studies (Rebelo (1991), Stokey & Rebelo (1995)). The Mendoza et al. study is a first attempt at empirical testing of these models but the incomplete specification of the budget constraint leaves their results open to criticism. The two-sector models have also ignored the expenditure component of fiscal policy. The education model of Capolupo (1996) is a useful first breach into the testing of the implications of these models by simulation, but empirical testing requires reliable measures of human capital. The two-sector congestion model discussed in Section 4.3.1 may provide an more interesting contrast to those studies which have considered only taxation, as the results are less likely to rely on extreme assumptions about the elasticity of labour supply and the production technology of the human capital sector (see Section 3.4.3 for a discussion of these issues).

As mentioned above, fiscal policy has been limited in this thesis to policies that affect growth directly or indirectly via investment. However, fiscal policy may further affect growth by a number of additional channels such as the accumulation of additional factors of production, or through the invention, innovation and implementation of new technology.

The most obvious additional factor of production that may be accumulated is human capital. Many of the current human capital measures available are based on school enrolment data, which may be correlated with expenditures on education leading to problems of collinearity amongst the regressors. Improved measures of human capital are available, but these are generally only calculated for 5-year periods (Gemmell (1996)) or for single countries (Jenkins (1995)). The results from Chapter 7 warn against drawing conclusions from regressions using 5-year period averages without testing for robustness. Nonetheless we feel that this line of research may prove to be both interesting and fruitful.

Perhaps the richest line of possible research is into the way fiscal policy affects the innovation or the transmission of new technology into the economy. At present we can find only one example of a model in which fiscal policy determines the rate of technological change (Levine & Krichel (1996) discussed in Section 2.4). This is perhaps surprising given the growth of the recent literature on endogenous growth models into the R&D decision of firms (Aghion & Howitt (1998)). Government support for R&D is perhaps the obvious starting point for this research but a number of more subtle channels may also exist. For example, fiscal policy may affect the appropriation of knowledge through international trade, foreign direct investment, or by creating the right social-structures.

10.5: Final Remarks

Differences in the policies adopted by governments over time and space add significantly to our ability to explain the per capita growth rate in a sample of OECD countries. In this sense the endogenous growth model, where certain types of fiscal policy affect the steady state growth rate, can be better thought of as a closer representation of the data set under use than the neoclassical growth model.

Providing evidence that is consistent with these endogenous growth models requires solving the statistical biases that cloud comparisons of the results from previous studies. Most notable of these is the bias from the exclusion of relevant fiscal variables (Chapter 6), but extends to other factors such as the, measurement of the long run (Chapter 7), the aggregation of the data (Chapter 8) and, the exclusion of investment from the regression equation (Chapter 9). The results presented in the thesis suggest that the description of growth provided by the Barro (1990) receives the strongest support and forms a useful basis from which to conduct further research.

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Appendix A:

Data Sources and Characteristics

We use this appendix to describe the sources and characteristics of the data used in the empirical Chapters 6 to 9. We begin with a description of the fiscal data before moving on to the conditioning variables and the growth rate used in Chapters 6 to 8 (Section A2). The additional variables used in Chapter 9 are described separately (Section A3) as they refer to a smaller number of countries. Finally, although the ADF tests strictly follow from the discussion made in Appendix B we choose to present them here.

A1: Fiscal Variables

A1.1: Data Sources

The fiscal data used in the thesis is collated from the Government Financial Statistics Yearbook (GFSY) published by the IMF. Data was available for 22 OECD countries, with a dominant time span from 1970 (or 1972) to 1992 (or 1994). This time span is not consistent across countries for example data for Switzerland exits only for 1970-84. The level of government used in the study is the consolidated level and therefore includes data for local, national and supranational levels of government.

Mendoza et al (1997) note the principal difficulty in empirical investigations of fiscal policy is constructing measures of taxation and government expenditure to accord with those found in the theory. The tax measures used in the theory are ad valorem taxes which have the appealing feature that the marginal and average tax rates are equal but are simplistic in comparison to the real tax structures of countries. Any accurate measure of taxation has to compete with problems such as tax exemptions and non-progressive taxes: problems which are further complicated when comparisons are to be made across countries. Although accepting that the true measures of the tax burden should calculate the marginal rate of tax it is not clear how such measures would fit with the idea of the government budget constraint considered in Chapter 6. Instead we use tax revenue measures from the GFSY. These perhaps most accurately reflect average rather than marginal rate of tax.[1] The tax revenue variables collected are income, profit and capital gains tax, social security contributions, taxation on payroll and manpower, taxation on property, taxation on domestic goods and services, taxation on international trade, surplus financing and other taxes and non-tax revenues.

The treatment of public expenditures is generally considered to be less problematic in transferring from the theoretical to the empirical literature. However, our choice of the functional classifications of the expenditure are imperfect in the sense that they contain both consumption (non-productive) and public investment expenditures (productive) together. Such classifications do provide us with an indication of the area of the economy at which the measures are directed at. Data limitations prevent us from improving on these classifications. The expenditure categories collected include expenditure on general public services, defence, education, health, social-security & welfare, housing & community amenities, recreational & cultural services, economic services, transport & communication and other expenditure.

A1.2 Data Characteristics

Our analysis of the characteristics of fiscal policy concentrates on classifications of the fiscal data taken from the GFSY rather than the aggregated forms used Chapters 6 to 9, although we do provide a brief description of this data in Section A.1.3 below.

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[1] The use of aggregate tax measures is not unprecedented in the theory, for example see Koester & Kormendi (1989) and Easterly & Rebelo (1993).

Aggregate Measures

Considering first the broad fiscal aggregates. The average[2] ratio of total revenue to GDP per country across all countries is 32.38%.[3] This ranges between Turkey which has the smallest size of government under this measure at 18.05% to the Netherlands at 49.6%. If total expenditures are used to measures the size government then the figures are slightly larger in value. The average across all countries is 34.8%, which ranges from Netherlands (53.06%) as the upper limit to Switzerland at the lower boundary (18.4%). Table A1 presents averages over the period for a small sub-sample of countries in order to highlight differences in the size of government across countries.

Table A. 1: Aggregate Fiscal Data (% of GDP) for a Sub-Sample of OECD Countries

	Per-Capita Growth	Total Revenue, % of GDP	Total Tax Revenue, % of GDP	Total Expenditure, % of GDP
Australia	3.07	25	23	26
Austria	2.68	34	31	37
UK	1.95	35	31	37
US	2.53	20	18	23
All	2.84	32	29	35

In general the size of government has increased over the period. This has been most pronounced in Australia and Belgium, where government has increased from 23.2% (1970-74) and 38.8% (1970-74) respectively to 27.1% (1990-94) and 54.3% (1985-89). In contrast, Ireland has actually seen a decline in the size of government over the period (from 51.9% (1980-84) to 46.2% (1990-94)).

The increase in government over the period is sometimes used as an explanation for slower growth rates across countries, however, borrowing data from Section A.2 we can show that there is little correlation between these aggregate measures and

[2] All averages discussed in this section are calculated as the average across all data points.

growth. Figure A1 shows a scatter of the average total revenue GDP ratio per-country against average growth, while Figure A2 shows a scatter of the average total expenditure to GDP ratio per country against average growth. Upon investigation it was found that the partial correlation between government expenditures and growth never exceeds 0.25 although the exact correlation varies across countries.

Figure A. 1

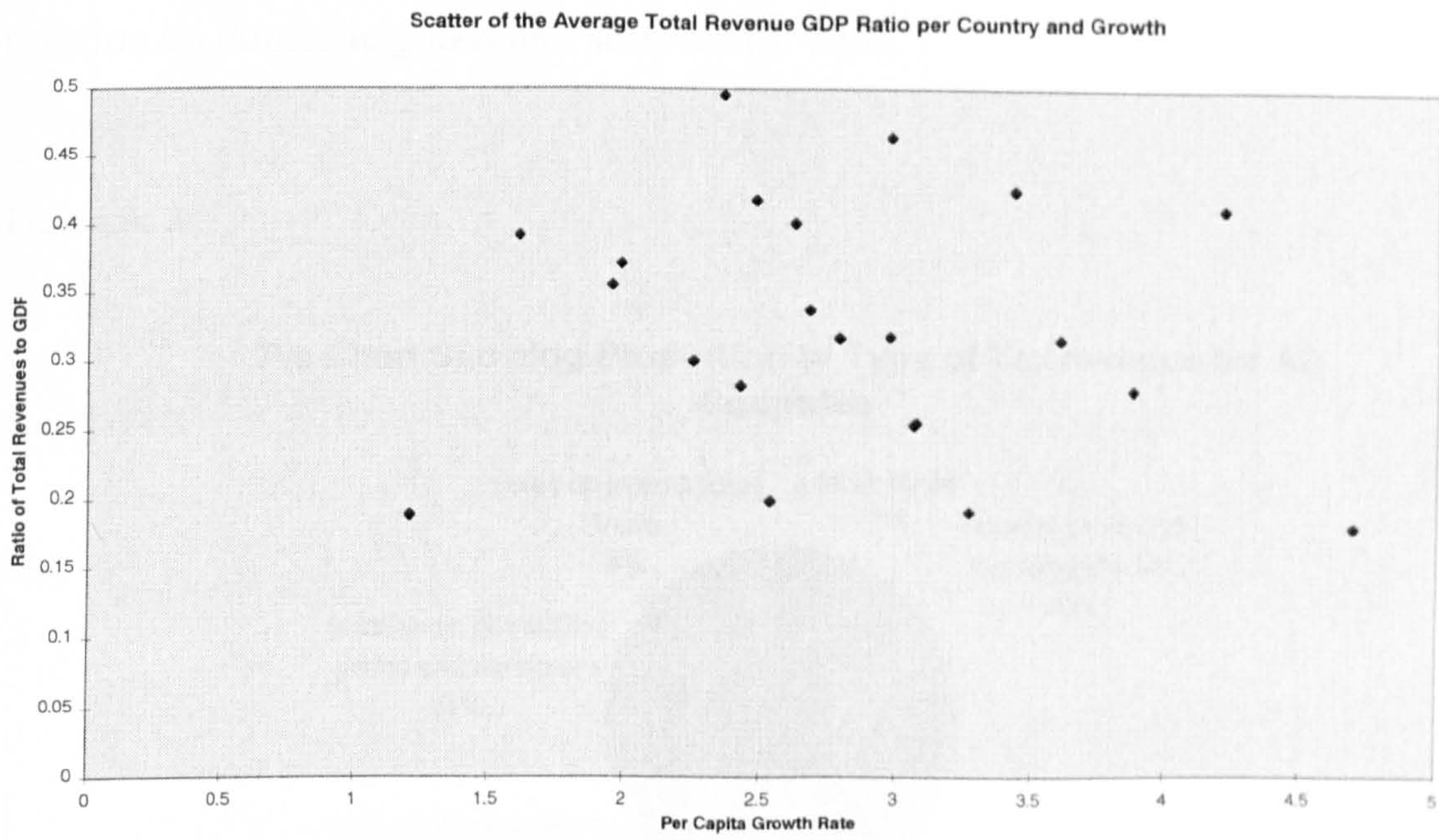
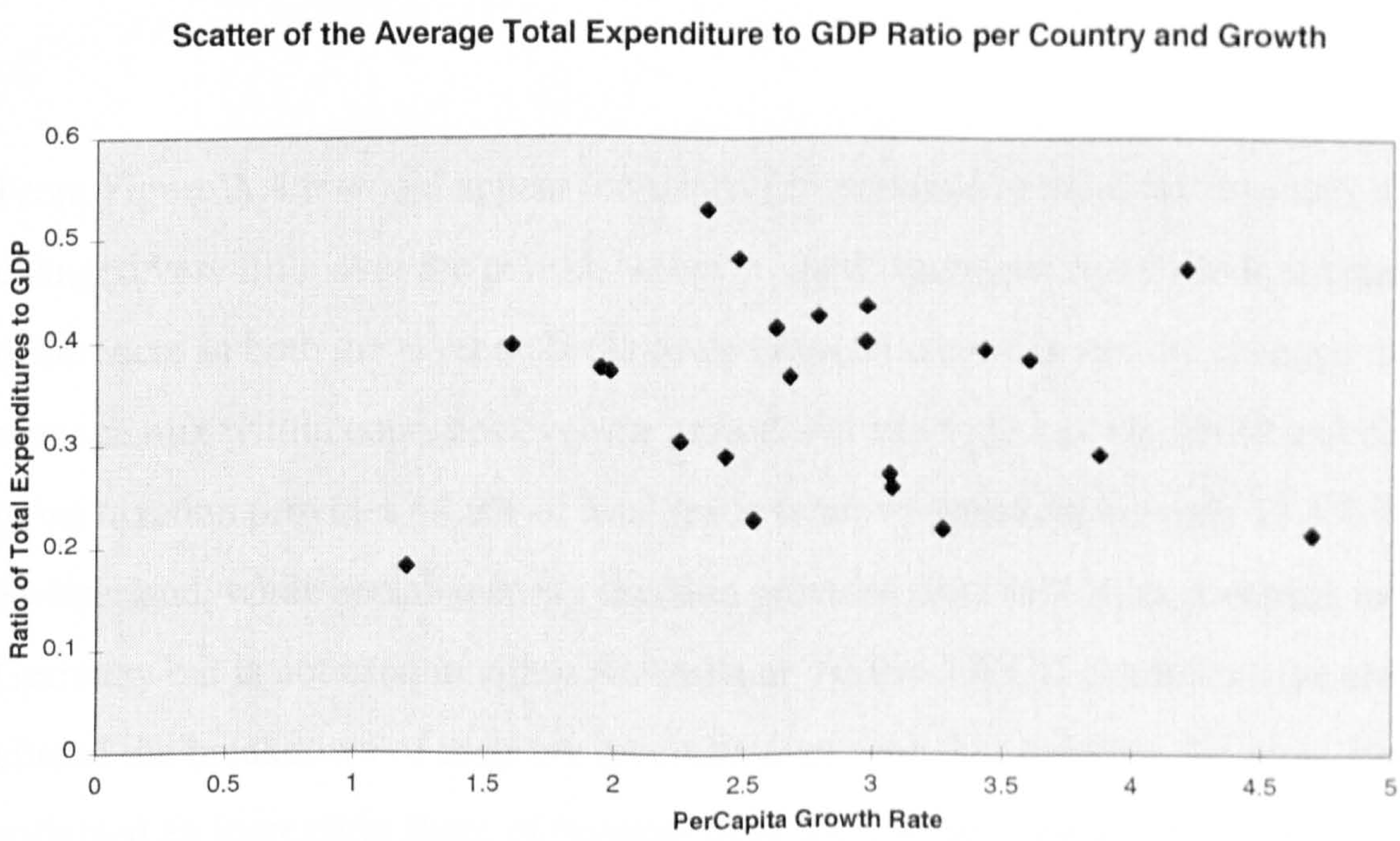


Figure A. 2

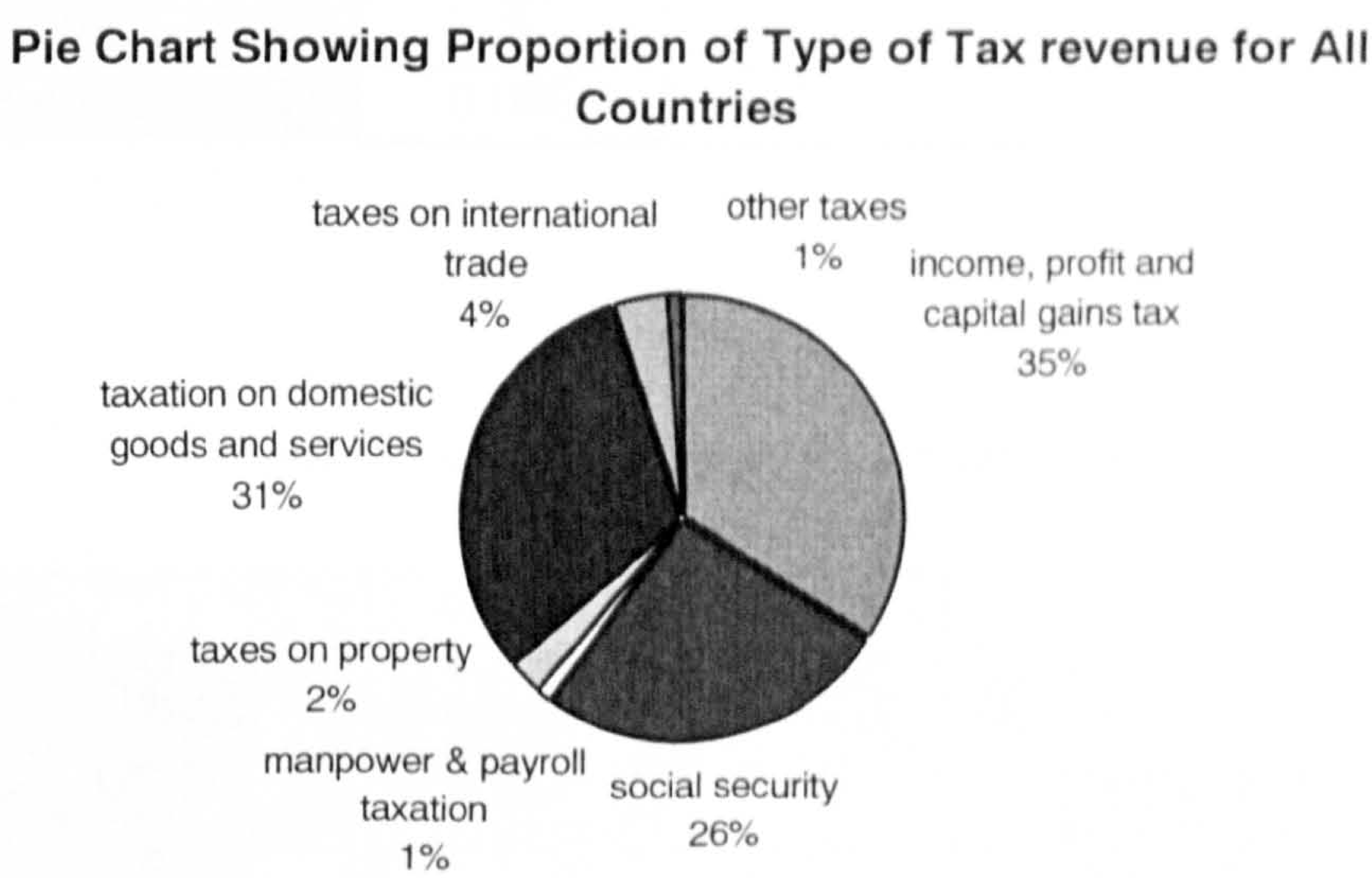


[3] The total expenditure term discussed here does not include lending minus repayments which are considered as a separate item below.

Taxation

Within the disaggregated data set three main types of taxation dominate the average tax budget. These are taxation on income, profit and capital gains, taxation on social security and taxation on domestic goods and services (as shown in Figure A.3). The revenues are obtained in similar proportions with income, profit and capital gains taxation accounting for 35% of the average budget, social security for 26%, and taxation on domestic goods and services for 31%.

Figure A. 3

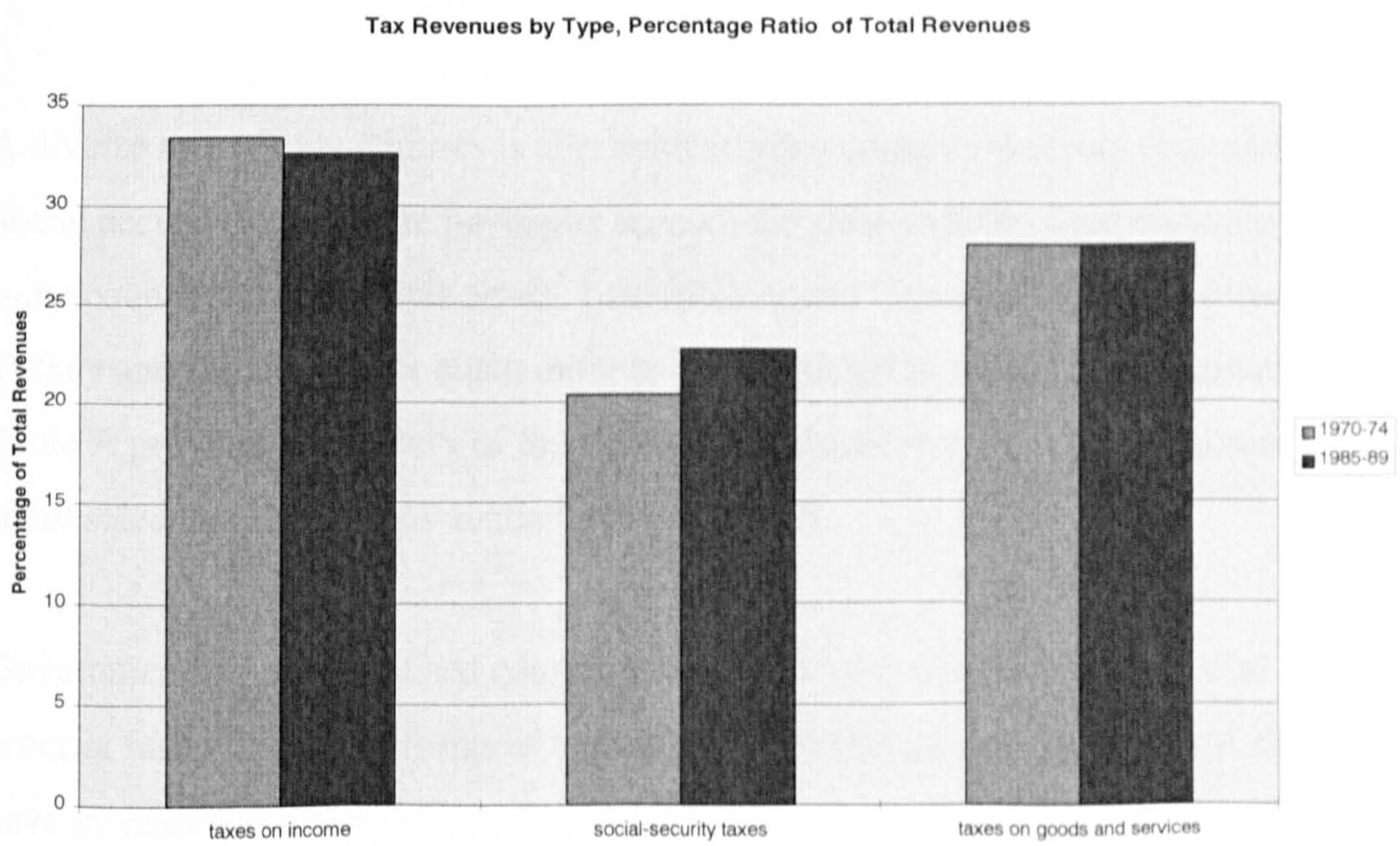


From Figure A.4 it would appear the relative importance of these tax revenues has changed very little over the period, however, these aggregate figures hide substantial differences in both the revenue breakdown between countries and the changes in the revenue mix within countries over the period. For example income, profit and capital gains taxation provides 68.9% of total tax revenue in Australia but only 15.4% in Switzerland: while social-security taxation provides over half of tax revenues in Germany but is not used in either Australia or Turkey. OECD countries have also altered the breakdown of their tax revenues over time. For example Belgium, have collected an increasing share of revenue from income taxes rather then taxes on goods and services while others, such as the UK, has adopted the opposite strategy. Germany and the US have collected a decreasing proportion of revenues from taxes on income and goods and services taxation in favour of increased revenues from social security taxation, while Finland has not changed the makeup of its tax revenues over the period.

Table A. 2: Tax Revenues (% of Total) for a Sub-Sample of OECD Countries

	Australia	Austria	UK	US		All
Income, profit & capital gains	69	21	48	58		34
Social Security	0	37	19	36		26
Payroll & Manpower.	0.9	7	1	0		1
Property	0.5	2	3	1		2
Domestic goods & services	24	29	31	5		31
Internat. trade	5	2	0.3	2		4
Other taxes	0.006	2	0.02	0.003		1

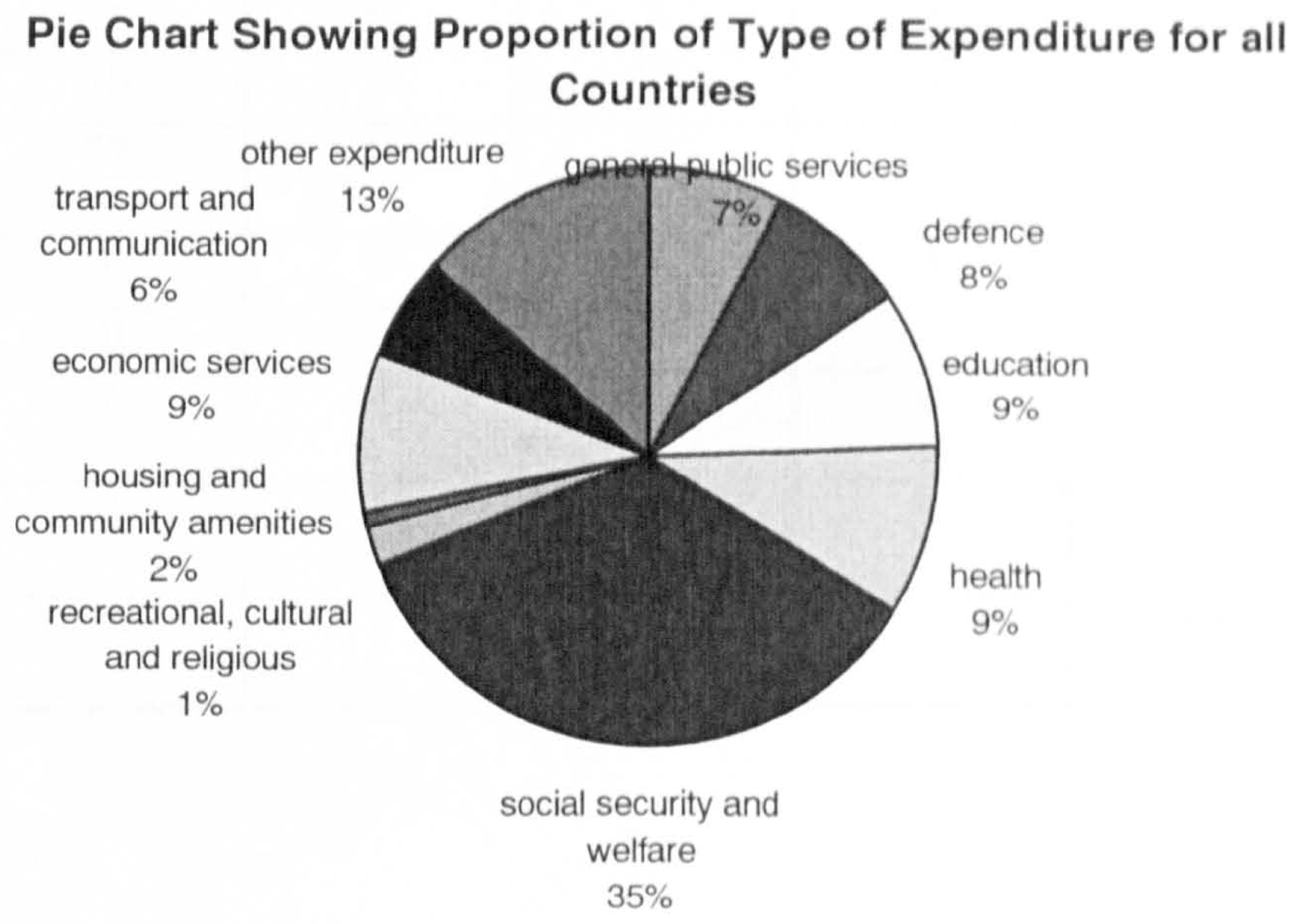
Figure A. 4



Expenditures

Social security and welfare expenditures dominate the average expenditure budget for the OECD countries in our sample. As shown in Figure A5 social security and welfare payments account for 36% of the expenditure budget, far higher than expenditures on general public services[4] (7%), defence (8%), education (9%), or health (9%)

Figure A. 5



A diverse mix of expenditures is also evident when comparing across countries. Social security and welfare payments account for close to 50% of expenditures in some countries (for example Spain, Luxembourg and Germany), whereas Iceland, Turkey and the UK offer a much more balanced budget in terms of expenditure. Table A provides a summary of the average of the different type of expenditure for a small selection of countries available in our sample.

Governments in industrialised countries have increased expenditures on social security faster than other forms of expenditure. For this reason (see Figure A.6) these have increased as a percentage of total expenditure from 30.1% in 1970-74 to 35.8% in 1985-89. Of the other forms of expenditure in the chart only one, health expenditure, has also increased as a percentage of the average budget over the period.

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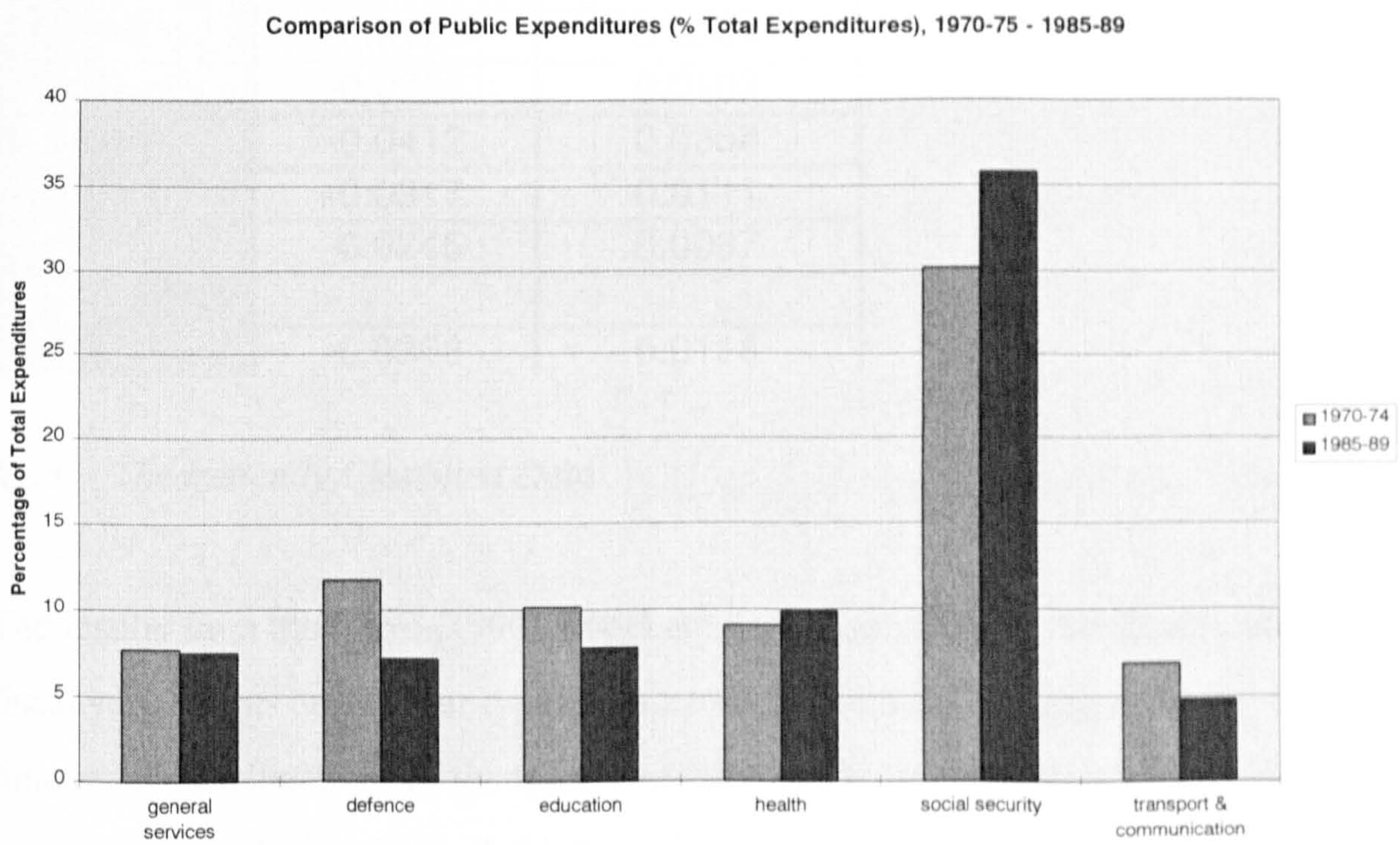
[4] Expenditures on general public services include expenditures on public order and safety which are disaggregated in later editions of the GFSY

Table A. 3: Average Expenditures (% of Total) for Sub-Sample of OECD Countries

	Australia	Austria	UK	US	All
General pub. serv.	8	5	5	5	7
Defence	10	3	13	24	8
Education	7	10	3	2	9
Health	10	12	13	12	9
Social Security	27	46	28	31	35
Housing...	1	3	3	3	2
Religion..	0.01	0.007	0.3	0.3	0.9
Economic Services	7	4	7	6	9
Transport Commun	2	7	2	3	6
Other Expends	26	8	6	14	13

Figure A. 6



The final fiscal variables to considered are the government budget surplus/deficit and the lending minus repayments. Table A.4 gives the average budget surplus/deficit and lending minus repayment figures for a small sub-sample of countries over the time period 1970 to 1994. The average budget surplus was 3.68% of GDP, while the only country to display a net budget surplus over the period is Luxembourg (a surplus of 1.83% of GDP). The majority of budget surplus are below the EMU convergence criterion of 4% of GDP except for some of the poorer EU countries (Greece (11.06%), Ireland (7.28%), Italy (11.82%), Portugal (11.21%)) and Belgium (7.29%).

Lending minus repayment refers to "government lending for public policy purposes - less repayments to government - and government acquisition of equity participation for public policy purposes - less any sales of such equities by government."[5] Very little is made of this variable in the text and we include it in the table only for completeness.

Table A. 4: Summary Statistics for Budget Surplus and Lending, Minus Repayments

	Overall surplus	Lending minus repayments
Australia	-0.0158	0.0085
Belgium	-0.0729	0.0082
Germany	-0.0122	0.0034
Ireland	-0.0728	0.0103
Sweden	-0.0412	0.0354
UK	-0.0317	0.0111
US	-0.0345	0.0037
All	-0.0368	0.0118

A1.3: Theoretically Classified Data

The results from the Barro (1990) model are dependent upon by the classification of fiscal variables as one of four types. In accordance with this we aggregate the GFSY functional classifications of the fiscal variables into these four categories. This process is described in Table A.5 below. Several of the functional classifications in the GFSY have no theoretical counterpart and are relegated to the 'other expenditure' and 'other revenue' terms[6]. The final fiscal variable is the government budget

[5] Introduction to GFSY (1995) published by IMF.

[6] The GFSY includes an expenditure category entitled 'lending minus repayments' which can take either negative or positive values. In order to overcome problems of how to classify this variable it was decided to include this item as a separate variable within the regressions but not to discuss it. It appears under the variable name *elmr* in the results.

surplus/deficit. The sensitivity of the results to this classification of the data is tested for in Section 6.4 and extensively in Chapter 8.

Table A. 5: Functional/Theoretical Classifications

New Classification	Functional Classification
distortionary taxation *(rdis)*	taxation on income and profit
	social security contributions
	taxation on payroll and manpower
	taxation on property
non-distortionary taxation *(rndis)*	taxation on domestic goods and services
other revenues *(roth)*	taxation on international trade
	non-tax revenues
	other tax revenues
productive expenditures *(eprd)*	general public services expenditure
	defence expenditure
	educational expenditure
	health expenditure
	housing expenditure
	transport and communication expenditure
unproductive expenditures *(enprd)*	social security and welfare expenditure
	expenditure on recreation
	expenditure on economic services
other expenditure *(eoth)*	other expenditure

The theoretical classifications of the data are averaged across 5-year periods in order to reduce some of the statistical bias likely to be evident within the data (as discussed in Chapter 5). In order to maintain equality across the government budget constraint after period averaging, it was necessary to classify one of the 7 available fiscal variables as the balancing item. Two methods were used for this: the first was to balance the budget through the surplus term and the second through the 'other expenditure' and 'other revenue' terms. The new surplus variable was calculated as the sum of the averaged revenue terms minus the averaged expenditure terms. The new 'other revenue' variable was calculated as the sum of the averaged total revenues minus the sum of the averaged sub categories of revenue excluding other revenues. The 'other expenditure' variable was calculated in a similar manner. The empirical results suggest there was no difference between the two methods. Finally, some descriptive statistics for this data are presented in Table A.6 below.

Table A. 6: Descriptive Statistics for Theoretical Data Set

Variable	Mean	Standard Deviation	Minimum (country)	Maximum (country)
sur (% of GDP)	-3.08	3.39	-11.76 (Portugal)	1.65 (Luxembourg)
elmr (% of GDP)	1.22	1.39	0.11 (Ireland)	4.49 (Norway)
rdis (% of GDP)	18.76	7.25	7.10 (Iceland)	33.47 (Netherlands)
rndis (% of GDP)	9.15	4.22	0.96 (US)	16.77 (Norway)
roth (% of GDP)	4.56	2.96	1.51 (Germany)	16.72 (Ireland)
eprd (% of GDP)	14.69	4.57	7.35 (Canada)	23.74 (Italy)
enprd (% of GDP)	15.24	6.05	4.96 - Turkey	24.31 - Luxembourg
eoth (% of GDP)	4.44	3.07	0.98 - Finland	9.16 - Ireland

A2: Conditioning Variables and Per Capita Growth

A2.1 Sources

The other variables we use in the empirical tests contained in Chapters 6 to 8 are the per capita growth rate, the investment ratio, the labour force growth rate and initial GDP. Summary statistics of these variables can be found in Table A.7.

Table A. 7: Descriptive Statistics of Conditioning Variables

Variable	Mean	Standard Deviation	Minimum (country)	Maximum (country)
GDPp.c. growth (% p.a.)	2.79	1.66	1.54 (Switzerland)	5.09 (Turkey)
initial GDP (GDP70)	10710	3378.78	2966 (Turkey)	15313 (US)
invest. (% of GDP) **(inv)**	22.06	3.61	18.11 (UK)	29.43 (Portugal)
lab. force growth (lbfg)	1.06	0.80	-0.06 (Germany)	2.06 (Iceland)

In accordance with usual practice the growth rate is taken as the log difference between annual per capita GDP figures taken from the World Bank CD ROM. We do not correct for differences in international prices to allow the growth data to reflect the domestic prices agents actually face (Nuxoll (1994)).The investment rate and the labour force growth rates were taken from the same source, and then investment expressed as a ratio to GDP. Following Nuxoll (1994) initial GDP is taken from the Penn World tables (Summer & Heston (1991)).[7]

A2.2 Characteristics

The relationship between growth and initial GDP is shown in Figure A7 below. The diagram is based on 5 period averaged data. A weak negative correlation of around -0.5 is found which is typical of that found amongst a sample of OECD countries (for example Devarajan et al. (1996)). This can be used as evidence of convergence amongst income levels in our sample of countries aver the period 1970 to 1994.

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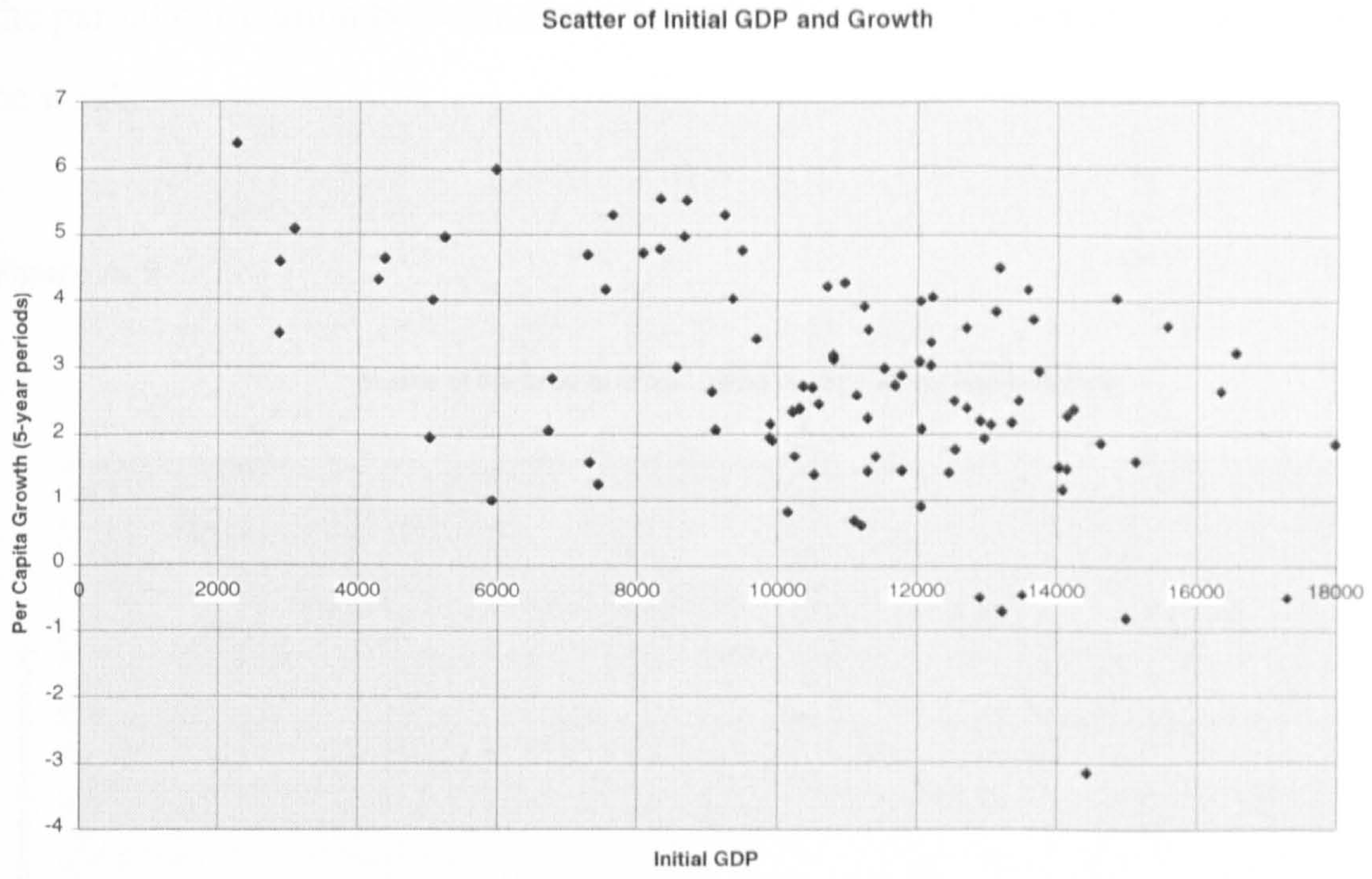
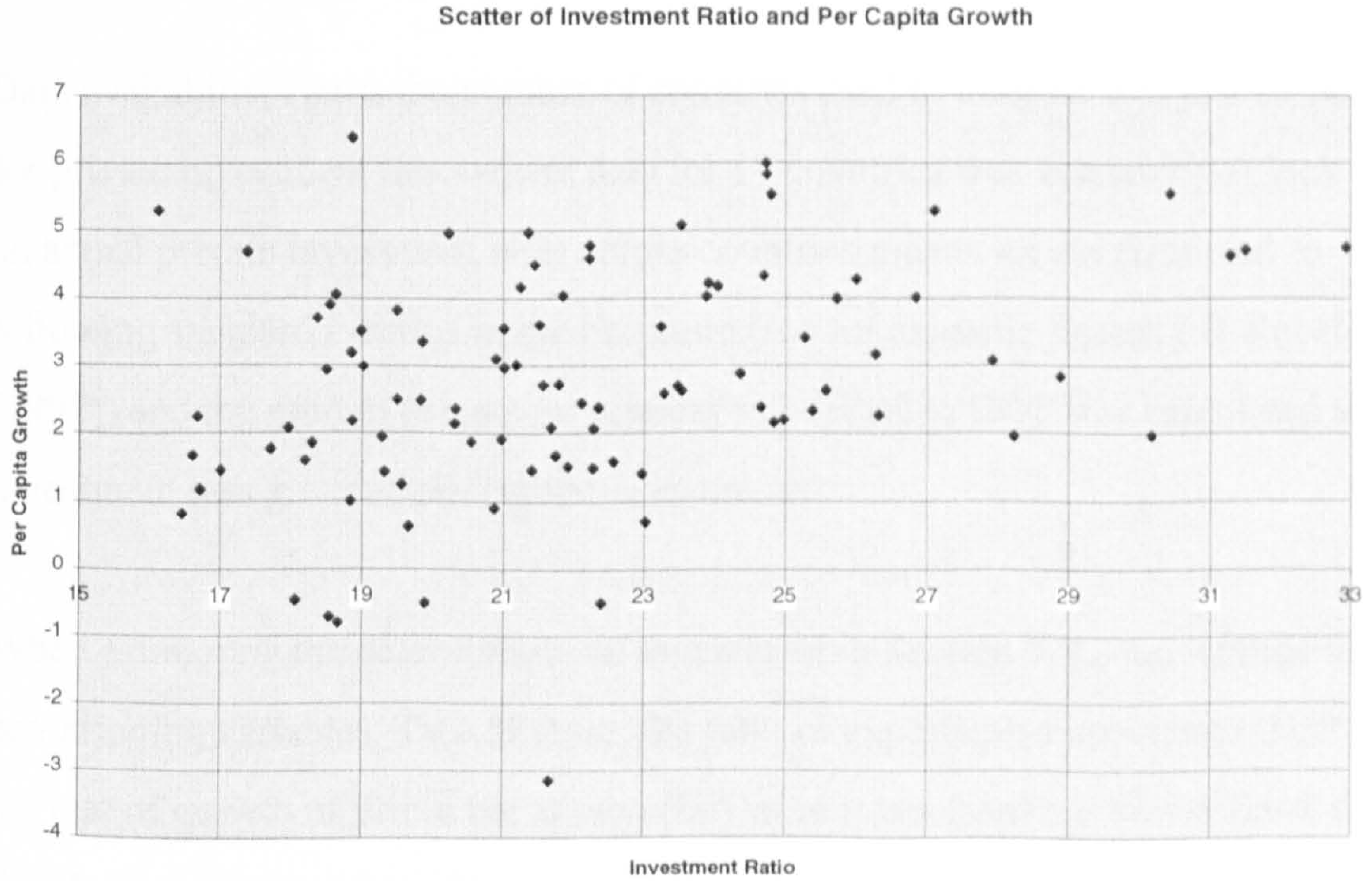
[7] For a discussion of the reasons for using non-PPP adjusted data for growth rates, but PPP adjusted for initial income see Temple (1998).

Figure A. 7



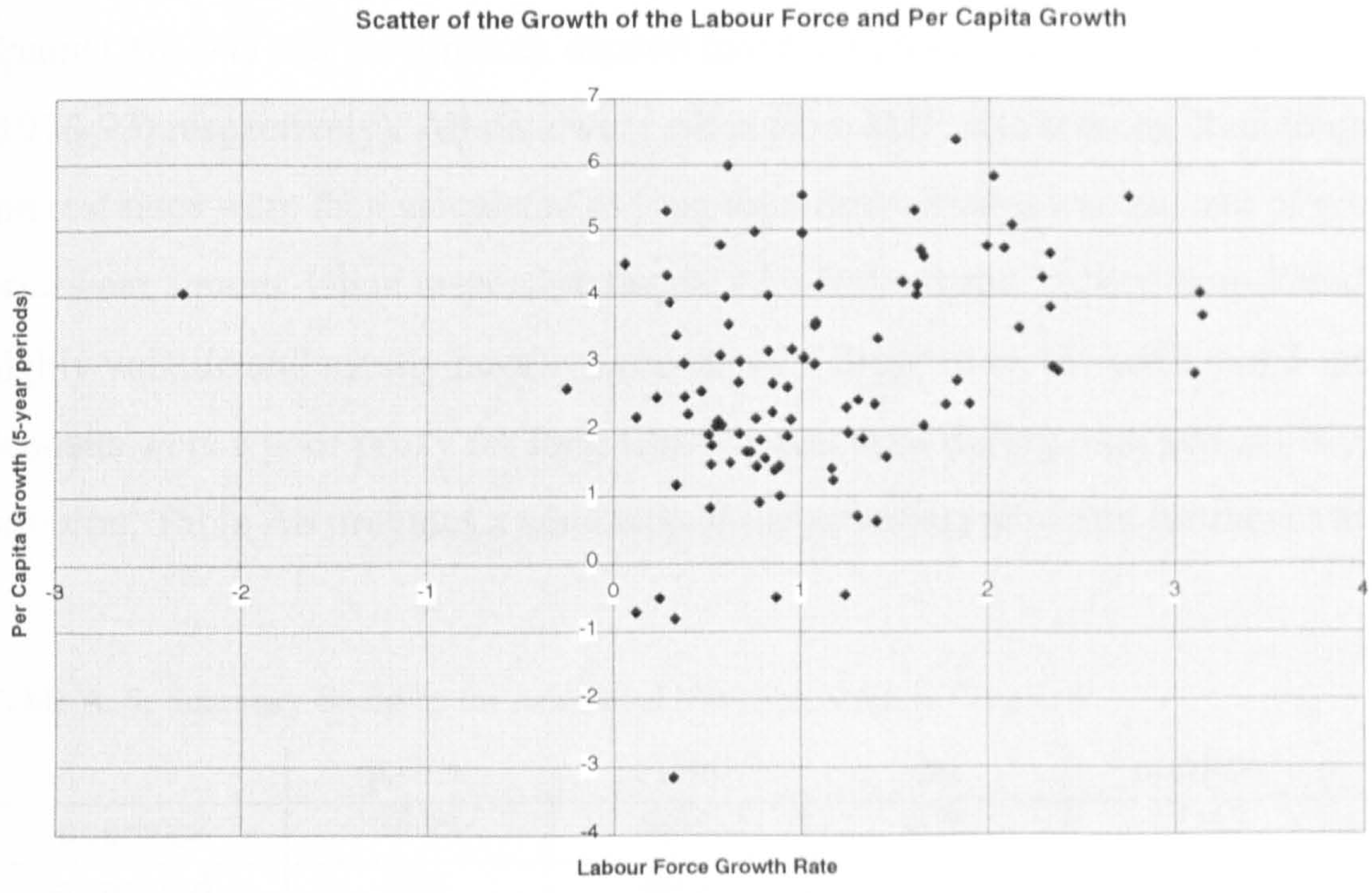
The scatter of the investment ratio and the growth rate is given in Figure A.8. It is clear that no strong pattern exists and upon investigation the correlation is found to be 0.25. The average across all countries is 22% of GDP although this varies between Ireland (16.3%) and Norway (30.3%). In general there has been a decline in this ratio over the period.

Figure A. 8



The final variable to consider is the growth of the labour force. Figure A9 presents the partial correlation between these two variables, which once again can be seen to be weak.

Figure A. 9



A3 Variables from Chapter 9

Data availability limits the number of countries used in Chapter 9 to just 15 (except for private investment ratio where data for 17 countries was available). A lack of data on actual private investment rates across countries means we are restricted to following standard practice in the literature (see for example Easterly & Rebelo (1993)) and the ratio of private investment rate (*pinv*) to GDP was calculated as total investment less government capital investment.

When estimating the determinants of investment in Section 9.4.2 we include several conditioning variables. Two of these, the ratio of exports plus imports to GDP (*exim*), the rate of growth of prices per annum (*inf*) were taken from the World Bank CD ROM. The relative price of investment (*rcinv*) was calculated as the inverse of the ratio of the price of investment to the price of GDP taken from the Penn World tables. This data was available only for 1970-92.

Long run interest rates were proxied by the government bond yield. Limitations on data availability meant this measure was used for 13 countries[8], while the 24 month deposit rate was used for Finland (1981-94), the 6-12 month deposit rate for Spain(1978-94) and the 3 month deposit rate for Turkey and Iceland ((1978-93) and (1976-93) respectively). All data were taken from IMF data sources. Real long term interest rates were then calculated as long term interest rates less the rate of growth of prices per annum. Upon inspection the data for Iceland and Turkey were found to be highly volatile and mostly negative and so were dropped on the basis that 3-month deposits were a poor proxy for long term interest rates during high periods of inflation. Table A8 provides a summary of the necessary statistics for these variables.

Table A. 8: Summary Statistics for Additional Variables Used in Chapter 9.

	prinv	exim	inf	rcstinv	rrrate
average	18.99	0.68	6.76	1.1163	3.12
standard deviation	3.84	0.42	3.95	0.923	3.84
minimum (country)	10.66 (Canada)	0.12 (US)	-1.30 (Norway)	0.8917 (Austria)	-11.93 (Spain)
maximum (country)	34.33 (Norway)	2.08 (Luxembourg)	26.29 (UK)	1.4308 (Canada)	14.49 (Norway)

A4 Stationarity Tests

The specification of the dynamic panel equation in Chapters 7 to 9 (and discussed further in Appendix B) requires the variables to be stationary. The majority of the variables used within this study are expressed as a ratio of GDP and are therefore bounded between zero and one. Non-stationarity is unlikely to be evident within the data set but nonetheless Dickey-Fuller (DF) and Augmented Dickey-Fuller (ADF) stationarity tests were carried. Unfortunately stationarity tests for panel data series

[8] Australia, Austria, Belgium, Canada, Denmark, France, Germany, Luxembourg, Netherlands, Norway, Sweden, UK and the US.

are relatively under-developed. For this reason we choose to extend the basic DF and ADF specification in the following way. The DF test is written as,

Equation A. 1

$$\Delta y_{it} = \cdot\ {}_{i} + \cdot\ y_{i,t-1}$$

and the ADF test as,

Equation A. 2

$$\Delta y_{it} = \mu_i + \phi_0 y_{i,t-1} + \sum_{i=1}^{n} \phi_i \Delta y_{i,t-i}$$

where the hypothesis $\phi = 0$ is used to test for the stationarity of y (if $\phi = 0$ then the null of non-stationarity is accepted).

Tests carried out for the fiscal variables are presented first followed by the tests on the remaining variables. Evidence of autocorrelation amongst the residuals when running DF test meant that ADF tests with two lagged dependent variables were used for the tests on the fiscal data.[9] No critical values specifically for panel data test for stationarity could be found and so for want of an alternative the critical values from the standard ADF test (Harris (1995)) were used. The critical values at the 5% level of significance were 3.68 when we have 500 observations (we have around 300 observations) and 3.95 when for a time dimension of 25. In the absence of adequate alternatives we use these as the limits for the critical values for panel ADF tests. When compared to the t-statistics presented in Table A.9 clear rejection of the null is found, with only *elmr* coming close to being rejected with a t-statistics of 4.764. From this evidence we conclude that the fiscal data appears to be stationary.[10]

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[9] County dummies were also included within the regression.
[10] Tests were also carried out for each country individually. However, despite the weak power of the test with very few observations available for each country a significant number of rejections of the null of non-stationarity was found for most of the fiscal variables.

Table A. 9: Stationarity Tests for the Fiscal Data

Variable	sur	rnt	rinc	rss	rpay	rprop	rgds	rint	roth	elmr	egps
t-value	-8.598	-20.588	-33.595	-11.198	-8.026	-19.415	-13.587	-10.699	-8.768	-4.764	-24.182
Variable	edef	educ	ehlth	ess	eho	erec	eserv	etcom	ecap	eoth	
t-value	-21.091	-15.607	-16.623	-6.057	-9.034	-13.320	-14.778	-16.207	-15.201	-12.660	

Conditioning Variables

The additional variables used in this study (the growth rate, the investment to GDP ratio and labour force growth rate) were also tested using the panel data approach. Tests favored the ADF test with one lagged dependent variable, the results for which are presented in Table A.10.[11] Using the critical values for the ADF test as 3.95 (T=25) and 3.68 (N*T=500). As with the fiscal variables the t-statistics are clearly above the critical values taken from Harris (1995) and so the alternative of stationarity of the conditioning variables is accepted.[12]

Table A. 10: Stationarity Tests for the Additional Data

	ADF (one lag)
Growth	-13.231
Investment	-11.661
Labour Force Growth Rate	-13.451

[11] The regressions were again estimated including country dummies.
[12] The results for investment match similar ones made by King, Plosser, Stock & Watson (1991).

Appendix B

B1 Introduction

We use this appendix to describe the characteristics of the panel data estimators used throughout chapters 6 to 9. We use in Chapter 6 to 9 two different types of panel data technique: static panel techniques (no lagged values), and the dynamic (includes lagged values). The properties of these two estimators are quite different and we therefore review them in some detail here. We begin with a discussion of the static panel regressors (section B2) before moving onto the more complex dynamic panel regressors (Section B3). The final section of the Appendix (Section B4) is used to describe the long run parameters from the dynamic panel regression.

Panel data estimation offers several advantages over alternatives such as cross-section[1] or time series estimation for this study, the most important of which is the shape of the available data set. A time dimension of around 20 observations per country is too short to be able to apply time series techniques, whereas if cross-section regressions are used we are left with only 22 observations. Data availability prevents finding long time series while, the problems of simultaneity and the heterogeneity of parameters (see Sections 5.2.2 and 5.2.4) can be used to argue against finding data for a greater number of cross-sectional units. Using panel data techniques allows us to increase the available degrees of freedom without aggravating simultaneity or parameter heterogeneity and more importantly allow us to use more of the information contained within the data to improve the efficiency of the parameter estimates. Panel data estimators also allows us to account for unobservable country and time specific effects such as the growth of technology.

[1] See Temple (1998) and Durlauf & Quah (1998) for a comprehensive review of the problems of cross-country growth regressions.

B2: Static Panel Data Estimators

The basic static panel data regression runs over the equation,

Equation B. 1 $$y_{it} = \alpha + x_{it}'\beta + u_{it}$$

where y_{it} is the explanatory variable and x_{it} is a matrix of explanatory variables. The error term is assumed to be random but contain the effects of omitted variables. The error term u_{it} can be decomposed into three parts: country varying time invariant effects μ_i, time varying country invariant effects λ_t, and a classical error term ε_{it} (with the classical properties of IID(0, σ_ε^2) and E(ε_{it}, x_{it})=0).

Equation B. 2 $$u_{it} = \mu_i + \lambda_t + \varepsilon_{it}$$

The parameter estimates in the β matrix are unbiased and consistent as both N and T tend to infinity, while the properties of μ_i and λ_t depend upon the time dimension of the data series, $T\rightarrow\infty$. The estimation program used within this thesis, LIMDEP (Greene (1992)), automatically estimates standard OLS, least squares dummy variable (LSDV) fixed effects models (with both one way and two way error terms) and two-step feasible GLS random effects models. We discuss the principal features of the fixed and random effects models here, but the reader is referred to Hsiao (1986) or Baltagi (1995) for further details.

B2.1 Fixed Effects

Under the fixed effects model the omitted variable terms μ_i and λ_t are assumed to be fixed parameters to be estimated. Equation (B1) can therefore be written as,

Equation B. 3 $$y_{it} = \alpha + x_{it}'\beta + \mu_i + \lambda_t + \varepsilon_{it},$$

where dummy variables are used for μ_i and λ_t at the appropriate points and ε_{it} is an error term which has the classical properties described above. Both two way error component models (where the country and time specific effects are the two error components) and one way error components models (where the one way error component are the country specific effects) are calculated by LIMDEP using a common transform of (B3) to remove country and time specific effects and conserve degrees of freedom.[2] The estimated regression for the two way error component model with fixed effects is therefore calculated as,

Equation B. 4 $$(y_{it} - \bar{y}_i - \bar{y}_t + \bar{y}_{..}) = \beta(x_{it} - \bar{x}_i - \bar{x}_t + \bar{x}_{..}) + (\varepsilon_{it} - \bar{\varepsilon}_i - \bar{\varepsilon}_t + \bar{\varepsilon}_{..})$$

where $\bar{y}_i, \bar{y}_t$ are the means of the cross country and time series elements respectively and $\bar{y}$ is the overall mean of the variable.

B2.2 Random Effects

The random effects model treats the country specific and the time specific effects as being randomly drawn from a known population. The error term u_{it} is assumed to have the following properties,

Equation B. 5
$$\begin{gathered}
E(\mu_i) = E(\lambda_t) = E(\varepsilon_{it}) = 0 \\
E(\mu_i\lambda_t) = E(\mu_i\varepsilon_{it}) = E(\lambda_t\varepsilon_{it}) = 0 \\
E(\mu_i\mu_j) = \begin{cases} \sigma_\mu^2, i = j \\ 0, i \neq j \end{cases} \\
E(\lambda_t\lambda_s) = \begin{cases} \sigma_\lambda^2, s = t \\ 0, s \neq t \end{cases} \\
E(\varepsilon_{it}\varepsilon_{js}) = \begin{cases} \sigma_\varepsilon^2, i = j, s = t \\ 0, i \neq j, s \neq t \end{cases}
\end{gathered}$$

That is μ_i, λ_i and ε_i display the properties of the classical error term and μ_i, λ_i and ε_i are independent of both x_i and of each other.

The variance of y conditional on the variables x_{it} is given by,

[2] This has the additional advantage of removing any correlation between the fixed effects and the regressors in x_{it}. More of this is made below.

Equation B. 6 $$\sigma_y^2 = \sigma_\mu^2 + \sigma_\lambda^2 + \sigma_\varepsilon^2$$

LIMDEP estimates the RE model using two stage GLS (the details of which can be found in Greene (1992)), where GLS estimates are more efficient than those from LSDV estimators of the RE model. The variance components are estimated by using the residuals from the LSDV FE model described above.

B2.3 Fixed or Random Effects?

"The fixed-effects model is viewed as one in which investigators make inferences conditional on the effects that are in the sample. The random-effects model is viewed as one in which investigators make unconditional or marginal inferences with respect to the population of all effects. There is really no distinction in the 'nature (of the effect).' It is up to the investigator to decide whether to make inference with respect to the population characteristics or only with respect to the effects that are in the sample."[3] We follow common practice in the use of macro-shaped data sets (small N, small to medium T) in favouring the results from the fixed effects model because the sample contains almost all OECD countries rather than a random sample of them: and secondly, because of the likely correlation between the explanatory variables and the country specific effects (Judson &Owen (1997)).

Formal testing between the FE and RE models is made using the Hausman (1978) specification test. Correlation among the regressors and the country specific characteristics results in biased and inconsistent parameter estimates from the GLS estimator of the RE model. The transformation used to estimate the FE model (given by equation B4 above) does not suffer from this problem as the fixed effects are removed from the equation. The null hypothesis is therefore that the estimators of β from the FE and RE models are identical. That is, that there is no correlation between the variables in x_{it} and the individual characteristics. The FE estimators can be used

[3] Hsiao, C. (1986) "Analysis of Panel Data", Econometric Society Monographs, pp.42

whether the null hypothesis is accepted or not but the GLS estimator is BLUE only when the null is accepted. The null hypothesis is consistently rejected when estimating the RE model in Chapter 6 and 7 and so at no point do we present the results from the RE models.

B3 Dynamic Panel Data Estimators

Pesaran (1997) argues that in order to estimate empirically the long run or steady state from economic growth models then "the steady state solutions can be embedded within a suitable multivariate dynamic model."[4] One possible econometric procedure for studying the steady state of the type of growth models reviewed in Chapters 1-4 is through dynamic panel data models. Dynamic panel data regression equations are essentially identical to static panel data techniques except the dynamic regressions adds lagged values of the explanatory variables. The addition of these terms both complicates the estimation procedure and the choice between estimation techniques. Indeed Judson & Owen (1997) conclude that no estimator is appropriate in all circumstances and the best technique varies with the dimensions of the data set.

The dynamic panel data regression extends equation (B1) to include lagged terms,

Equation B. 7 $$y_{it} = \alpha_{it} + \sum_{j=1}^{\infty} \lambda_i y_{i,t-j} + \sum_{k=0}^{\infty} \beta_i x_{i,t-k} + \varepsilon_{it}$$

Ignoring for the moment the exact nature of the unobserved coefficients at (there fixed or random effects): in order to estimate an equation for the steady state a dynamic panel data equation of the following form is required,

Equation B. 8 $$\Delta y_{it} = \alpha_{it} + \sum_{j=1}^{n} \lambda_i \Delta y_{i,t-j} + \sum_{k=0}^{p} \beta_i \Delta x_{i,t-k} + \sum_{m=0}^{q} \chi_i z_{i,t-m} + \varepsilon_{it}$$

[4] Pesaran, M.H. (1997) "The role of economic theory in modelling the long run" Economic Journal, vol.107, no.440, January, pp. 178-9

If y represents output then the solution for the steady state regresses the growth of output on lagged growth and two vectors of explanatory variables, one which contains variables in level form (such as government expenditures) and a second which contains first differenced variables. This is a somewhat unusual dynamic panel data equation compared to those typically found in the literature but follows from specifying the regression as an Error Correction Model (ECM) with the long run component set to zero. To see this assume that output is cointegrated to some set of explanatory variables. A Granger ECM can be used to represent this relationship,

Equation B. 9 $$\Delta y_{it} = \alpha_{it} + \delta(\gamma_i x_{i,ti-1} - y_{i,t-1}) + \sum_{j=1}^{\infty} \lambda_i \Delta y_{i,t-j} + \sum_{k=0}^{\infty} \beta_i \Delta x_{i,t-k} + \varepsilon_{it}$$

Postulating no long run relationship between output and the error correction component of the regression (i.e. assuming that all variables are I(0)) means that the coefficient δ is assumed to be zero and can be dropped. For the vector of fiscal variables, $z_{i,t}$, to added into equation (B9), so as to leave an equation if the form in equation (B8), requires the fiscal variables must also be stationary. King, Plosser, Stock & Watson (1991) demonstrate that for a number of key US macroeconomic time series when expressed a ratio to GDP this is indeed the case.[5] Consumption, investment and output are found to be integrated to order 1, I(1), with drift but stationary when written as a ratio to GDP. Evidence that the growth rate, the set of conditioning variables and the fiscal variables (as a ratio to GDP) are I(0) can be found in Appendix A (Section A4).

B3.1 Fixed or Random Effects?

A number of different estimation procedures for panel data are described in the literature each referring to a different size of N and T. However, these techniques are usually applicable to data with small T and large N (such as instrumental variables), or large N and T (such as slope heterogeneity) and so do not match the specifications of the data set used in this thesis. Judson & Owen (1997) discuss the benefits and

[5] Additional advantages to expressing the data as a ratio to GDP can be found in Section 5.2.

costs of a number of alternative estimators in typical macro data sets and we follow their review of the literature closely here. Only fixed effects models are reviewed, given; the likely correlation between the country-specific characteristics and the other regressors and; the data set is likely to contain most of the countries of interest (Judson & Owen (1997)). To this list we add that the random effects estimators are consistent only when the data set has a large cross-section unit. It is felt that the reliance on such asymptotics precludes their use in this study.

B3.2 Fixed Effects

We begin by simplifying equation B8 to match regression equations more commonly discussed in the literature,

Equation B. 10 $$\Delta y_{it} = {}_{i} + {}_{t} + \Delta y_{i,t-1} + {}'x_{it} + u_{it}$$

$i = 1, \ldots\ldots N \qquad t = 1, \ldots\ldots T$

$Eu_{it}=0, \qquad Eu_{it}u_{js} = \sigma_u^2 \;\; if\; i=j,\; t=s \qquad Eu_{it}u_{is}=0 \;\; if\; i \neq j,\; t \neq s.$

Where γ is a scalar, x_{it} is a K×1 vector of explanatory variables, β is a 1×K vector of constants, α_i is the unobserved country specific effect, λ_t is the unobserved time specific effect and u_{it} is the stochastic error term. We further assume for simplicity that only individual effects are relevant, although adding time-specific effects adds little complication.

Baltagi (1995) shows that Least Squares Dummy Variables (LSDV) estimation of the fixed effects model leads to serial correlation between the error term and lagged dependent variables and inconsistent results. This bias approaches zero as the time dimensions approaches infinity (Nickell (1981)), but Pesaran & Smith (1995) show in a study with a time series element of 29 observations the bias is not serious. When a large time series is not available Anderson-Hsiao (1981) suggest two possible solutions; first differencing B8 to remove the fixed effects and estimating by instrumental variables (where lagged levels are commonly adopted as the most appropriate instruments - Arellano (1989), Arellano & Bond (1991) and Kiviet

(1995)); or secondly, using some form of Generalised Method of Moments (GMM) estimator. The GMM estimators improve on the AH estimators by using all lagged values of the dependent variables plus lagged values of the exogenous regressors as instruments in order to gain efficiency. However, the properties of instrumental variables are such that they are efficient only in large N. The final estimation procedure discussed by Judson & Owen (1997) is one by Kiviet (1995) which subtracts the estimated bias from the LSDV coefficients. Unfortunately this procedure requires a balanced data set (each country to have identical T).

Judson and Owen (1997) demonstrate using Monte Carlo techniques that the for macro-shaped data sets the bias in the parameter estimates of the x matrix are small and cannot be used to distinguish between estimators. This is interesting in the sense of this study as it is the estimates of these parameters which are the principal concern. The bias in the lagged dependent variables is found to display greater variation between estimators.[6] The AH and GMM estimators are found to improve when N becomes large (as expected) while all estimators (except OLS) improve as T becomes large. Judson & Owen argue that AH and corrected LSDV consistently outperform the others for typical macro-data sets, but show in an empirical example that these computationally more complex procedures inflate the standard errors of the parameters of interest (those on the x matrix) leading to a greater number of insignificant coefficients. As Judson & Owen write "the Anderson-Hsiao estimator seems to apply a cure that is worse that the disease."[7] For this reason in this study we initially use LSDV estimators but test the robustness of the results to the use of AH estimators. We do not use the corrected LSDV approach because of the requirement of a balanced data set and the potential loss of efficiency in the parameter estimates that results from this reduction in observations.

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[6] This is likely to affect our estimates of the long run coefficients (see Section B4 below).
[7] Judson & Owen (1997) pp.16

B3.3 Heterogeneous Slopes

The standard pooling techniques of the regression equation in either (B7) or (B8) assumes that the slope coefficients on β and λ are equal.[8] If slope homogeneity is an incorrect restriction then the estimated coefficients will be biased. The bias exists because of the serial correlation with the error term and leads to inconsistent estimates no matter the size of either the number of countries, N, or the time dimension, T (greater detail can be found in Pesaran, Smith & Im (1995), Pesaran & Smith (1995) or Lee, Pesaran & Smith (1997)). Pesaran, Smith & Im (1995) suggest that slope heterogeneity is commonplace, but argue that its effects are diminished if a reasonable time dimension (T greater than 25) is contained within the data set. Given the large number of regressors used in this study (leading to a problem with degrees of freedom) along with the moderately large time series element of the available data set, leads us to reject the use of techniques to correct for parameter heterogeneity here. However, we accept its possible presence and follow the advice given by Pesaran, Smith & Im that "it is perhaps more prudent to admit the limitations of one's data and be more cautious about the conclusions that can be drawn from dynamic panels"[9].

B4 Long Run Parameter Estimates

The long run parameter estimates of interest in this study can be easily calculated from the short-run estimates given in the estimation of a dynamic regression such as B8. Assume for simplicity that the estimated regression contains only one explanatory variable, *x*, and lags of the dependent variable growth, *g*. The estimated regression is then of the following form,

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[8] Lee, Pesaran & Smith (1996) explain slope heterogeneity with regard to convergence of growth rates. They describe slope heterogeneity as the case where countries no longer grow at identical rates toward their conditional steady states as is assumed under slope homogeneity.

[9] Pesaran, M.H., Smith, R. & Im, K. (1995), "Dynamic linear models for heterogeneous panels" DAE Working Paper No. 9503. pp. 2.

Judson R., Owen A. 'Estimating dynamic panel data models: A practical guide for macroeconomists' *Federal Reserve Board Discussion Paper 97-3 p. (1997)*

Equation B. 11 $$g = \hat{\alpha}_1 g_{t-1} + \hat{\alpha}_2 g_{t-2} + \hat{\beta}_1 x_t + \hat{\beta}_2 x_{t-1}$$

The long run elasticity of the variable x with respect to growth, g, is then calculated as,

Equation B. 12 $$\xi = \hat{\beta}_1 + \hat{\beta}_2 \Big/ (1 - \hat{\alpha}_1 - \hat{\alpha}_2)$$

Kocherlakota & Yi (1996) and Kocherlakota & Yi (1997) demonstrate that the difference between the neoclassical and endogenous growth models rest on the significance of these long run parameters. This can be simplified by recognising that in order for ξ to be equal to zero, the top part of the function $\hat{\beta}_1 + \hat{\beta}_2$ must be equal to zero. The test is therefore simplified to one of testing whether the sum of the short run parameters estimates of x are significant. This test is performed using a Wald test and is very similar in style to that proposed by within a time series framework by Kocherlakota & Yi (1997).Unfortunately however, this simplification does not yield standard errors of the long run parameters themselves (which depend in part on the covariance terms between lagged values of x and the lagged explanatory variables).

Equation B. 13 $$H_o : \xi = \hat{\beta}_1 + \hat{\beta}_2 \Big/ (1 - \hat{\alpha}_1 - \hat{\alpha}_2) = 0$$