# The Economic Impact of Uncertain Tourism Demand in Hawaii: Risk in a Computable General Equilibrium Model

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## CONTENTS

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**ABSTRACT**

This thesis estimates the economic impact of uncertain tourism demand in Hawaii. It does this by incorporating risk into a Computable General Equilibrium (CGE) model. CGE models have been used to investigate a wide range of policy issues. To date, none have investigated how uncertainty regarding future tourism demand impacts on an economy.

The context in which this research is set is the US State of Hawaii. The economy of Hawaii is heavily dependent on tourism as a source of income and a generator of employment. Shocks originating outside of Hawaii have resulted in sharp decreases in visitor arrivals to Hawaii. Yet, these events and the risks associated with future possible shocks to an economy is something that needs to be factored in when planning for the future hence the need to understand what type of impacts uncertain tourism demand will have on the economy.

This thesis develops a new method for incorporating uncertainty within an applied economic model. The method involves incorporating uncertainty through different states of the world or paths that the economy may take. The risk then is that one or more of the paths may experience an external shock, which in the example used is a downturn in tourism demand. This thesis then adds to the body of knowledge methodologically.

The multi-sector forward-looking CGE model with risk shows the impact of uncertainty on the economy. The results show that, where there is an asymmetric shock, the possibility of a future tourism demand shock creates a welfare loss. The welfare gains along the non-shocked path are a result of household's risk aversion and their substituting resources away from the shocked path. The difference in the monetary values of the welfare on the different paths can be interpreted as the 'price' of the risk. It is the price households would pay to remove the possibility of the tourism shock. Therefore, this research was able to quantify the monetary value of the risk. Several government policy decisions, such as the imposition of a tourism tax, are simulated to mitigate the impact of the uncertainty.

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# CHAPTER ONE

# INTRODUCTION

## 1.1 Introduction

With increasing global connectedness, one country's economy, health issues and political structures are becoming more interdependent on the economic and political well-being of other countries. Not only countries, but also regions and states are affected by this interdependence. Shocks in one part of the world ripple across borders to impact other economies. Global events such as the outbreak of SARS and terrorist attacks adversely affect tourism and adversely impact economies. In this new era, policy makers need to be able to better understand the role increased uncertainty plays in the economy and determine ways of minimize economic downturns.

To assess the economic impact of these occurrences, economy-wide modelling is usually conducted using either input-output analysis or computable general equilibrium (CGE) modelling. Economy-wide modelling disaggregates the economic impacts to an industry-level and examines the effect of a shock on economic welfare, gross value added and other economic variables of interest.

International and domestic tourism are both important generators of employment opportunities, income, government revenue, and foreign exchange. Tourism's economic impact is complex because it does not occur within the framework of a single commonly defined industrial sector. Tourism is a multi-sector activity. Tourists purchase goods and services each of which use inputs from other sectors of the economy and compete for their employment of factors of production with all other sectors. With tourism being such an important activity for many regional and national economies, the need to measure the economic impact of tourism's contribution, both positive and negative, has become increasingly important for policy makers and those businesses and employees involved in tourism.

Due to their generally unrealistic assumptions and incomplete representation of the way an economy works, Input-Output (IO) models may give misleading results. Any measures of the impact of a change, such as the expansion and contraction of tourism demand, must take into account the positive and negative impacts on economic activity. CGE models not only have an Input-Output model embedded in them but also include other markets, and the links between these markets are modelled explicitly. CGE models are underpinned by microeconomic theory of the consumer and firms. In these models, resources are limited and allocated through the price mechanism. It is for the above reasons that this research will implement a CGE methodology to assess economic impacts.

While estimating the economic impact of shocks to an economy is important, equally important is quantifying the importance of uncertainty in the economy. The role of risk or uncertainty has been examined across a range of disciplines. Within the discipline of economics, various strands of research have evolved; from expected utility theory to financial risk and risk perceptions. With such a diverse range of definitions and conceptualisations of risk, it is important to limit the scope of this research and identify exactly the type of risk and uncertainty will be under examination.

Very little research has been conducted around the role of risk in applied general equilibrium models. What research that has incorporated uncertainty into CGE models has tended to treat these concepts as exogenous to the model. Previous attempts to endogenise uncertainty tend to use a risk premium to capture variability around the variable of interest, such as the price or supply of a commodity. This thesis develops a methodology to incorporate uncertainty into CGE models. The context within which the research is set involves tourism in Hawaii. Using a dynamic forward-looking CGE model, this research will model the economic impacts of the uncertainty of tourism demand. Results will be contrasted to a model where a tourism demand shock is simulated with certainty.

## 1.2 Risk

The concept of risk has been examined from many different disciplines: from an economic perspective, from a sociological perspective, from a financial perspective. Risk is a complex construct. Risk has been defined in many different ways. One frequently cited definition of risk is Knight's (1921). He defines risk as "measurable uncertainty". Denenberg *et al.* (Denenberg, Eilers, Melone, & Zelten, 1974) simply define risk as "uncertainty of loss". There can be many types of losses as well. Denenberg *et al.* take a very narrow view of risk defining loss as the loss of wealth or profit. This research will encompass a broader definition. Loss should be a loss of satisfaction/happiness or utility as in the economic meaning of utility. So a loss of utility could involve a financial loss or may involve dissatisfaction or simply just the loss of happiness. This can be measuring as a loss in economic welfare. Further definitions exist with regard to risk. Pure risk involves the situation where a gain will not occur. The best possible outcome is that of no loss occurring. Speculative risk involves the situation where either a gain or a loss may occur. Another way to categorise risk is whether the risk is diversifiable or non-diversifiable. Diversifiable risk is that which can be mitigated through a process of pooling risks. Conversely, for a non-diversifiable risk, the opposite is true.

Risk is a pervasive part of all actions. While some try to minimise risk, no one can avoid risk completely. As MacCrimmon and Wehrung point out (1986), "along with death and taxes, risk is one of the certainties of life". The attitudes toward risk, especially among business leaders, impact firm performance, market orientation and opinion leadership amongst other variables. Attitudes towards risk among tourists may affect the decision to travel or not, the choice of destination or choices and behaviour while at the destination. Some risks are dramatic such as the possibility of natural disasters or crossing a busy street, while others are much more insidious such as borrowing money or working in a polluted environment. Some risks might affect many people, while other risks may be isolated to one individual.

An individual (including an organisation) faces risk when they are exposed to a contingent adverse event. The event in question is adverse in that the person concerned would prefer that it did not occur. The event is contingent in that it may or may not occur. Therefore, where there is a risk there are at least two possible outcomes. Where all possible outcomes are adverse, the risk is said to be a "pure risk". If there is at least one adverse outcome and at least one favourable outcome, the situation is said to contain "mixed risk". Where all outcomes are favourable, it is called a "lottery".

### 1.2.1 From an Economic Perspective

From these differing perspectives, several ways have evolved of examining risk. At a microeconomic level, one of the earliest developments of the concept of risk is expected utility theory, first developed by von Neumann and Morgenstern (1944). Expected utility theory formulates economic agents making choices among lotteries, each represented by a probability distribution. A key assumption being that economic agents have a preference ordering defined over the probability distributions, represented by their utility function. The curvature of the utility function reflects their risk attitude. An agent is risk averse if he/she prefers the expected value of a lottery with certainty to the lottery itself. The agent is risk neutral if indifference always holds and risk loving if the preference is reversed. Pratt (1964) and Arrow

(1965) first formulated a measurement to capture the 'degree' of risk aversion, a concept which has been significantly built upon.

Expected utility theory makes several strong assumptions. The strength of these assumptions has lead to strong critiques of the theory (Allais, 1953; Bernoulli, 1954 translated from 1738, for example).

The theory of von Neumann-Morgenstern assumes objective probabilities. In real world applications, there are no objective probabilities for a random event. The odds of various economic crises occurring in the next six months, say, are not clear at all. How agents act and the decisions they make depend critically on what they subjectively assess as the odds of the outcome. Savage (1954) extends the von Neumann-Morgenstern model to include choice where there is subjective uncertainty. However, one downfall of this model is that the probabilities of the states do not depend on the act chosen. That is, they are state independent.

Anscombe and Aumann (1963) derived a simpler derivation of subjective expected utility theory where they introduce the presence of lotteries with objective probabilities. They assume is that an action is no longer merely a function from states to outcomes, but rather a set of simple probability distributions on the set of outcomes.

Rothschild and Stiglitz (Rothschild & Stiglitz, 1970, 1971), in their work on risk theory, compare risks rather than measure risk aversion. These authors note that Y may be said to be riskier than X if all risk averse individuals prefer X to Y, or if Y has more weight in the tails of its distribution than X, or if Y equals X plus noise. Rothschild and Stiglitz observed that these three notions of risk are equivalent.

Kahneman and Tversky (1979) develop an alternative to expected utility theory, what they term 'Prospect Theory' that addresses some of the criticisms of expected utility theory. The term "prospect" can be interchanged with what has previously been referred to as risks, lotteries or gambles, that is, a set of outcomes with a probability distribution over them.

Prospect theory attempts to describe decisions under uncertainty, and has also been applied to the field of social psychology. Prospect theory differs from expected utility theory in a number of important respects. First, it differs from expected utility theory in the way it handles the probabilities attached to particular outcomes. Prospect theory treats preferences as a function of "decision weights", and it assumes that these weights do not always correspond to probabilities. Specifically, prospect theory postulates that decision weights tend to overweight small probabilities and underweight moderate and high probabilities. This leads to risk aversion when individuals evaluate a possible gain; since individuals prefer avoiding losses to making gains. This explains the curvilinear shape of the prospect theory utility graph in the positive domain. Conversely individuals strongly prefer risks that might possibly mitigate a loss - risk seeking behaviour. Prospect theory leads back, to some extent, to a more psychological approach to risk.

One implication of loss aversion is that individuals have a strong preference to remain at the status quo. The reason for remaining with the status quo is the disadvantages of leaving the status quo loom larger than advantages. Samuelson and Zeckhauser (1988) affirmed the status quo bias in several experiments.

Another way to view risk from an economic perspective is as a negative externality. The basic trade-off in risk analysis is that resources used to assess and manage some risks are resources that could otherwise be used to manage other risks, or produce something else of value. In this sense, opportunity cost is the basic concept used to analyse trade-offs and explore alternatives. Opportunity cost is the value of the next-best use of a resource, where value is measured as foregone alternative benefits. All costs are opportunity costs and all opportunity costs are foregone benefits.

Risk should be reduced up unto the point where the marginal benefit of reducing the risk equals the marginal cost. Reducing risk beyond this point will result in a situation where any additional risk reduction will add more to costs than it produces in benefits. Yet benefit measurement is somewhat problematic. Benefit estimation suffers from inaccurate identification and measurement issues. Nevertheless, one conventional approach to measuring benefits is to estimate “willingness to pay” and market prices. The willingness to pay for the elimination of a risk can be interpreted as a risk premium, in this context. This premium can then be added on, like a tax, to the price of a risky product.

### 1.2.2 From a Financial Perspective

The study of Finance branched out the discipline of Economics and examines, among other things, risk as it relates to financial markets. The study of Finance has burgeoned, creating its own definitions and concepts of various types of risk. Financial risk is essentially any risk associated with any form of financing. Branching out from financial risk are investment-related financial risk and debt-related financial risk. With investment-related risk, the literature generally defines three types of associated risk. Holding to the positive relationship of risk and return, high risk investments have greater potential rewards, but there is a greater probability that the investor will lose their money. When the investor loses their investment, that is their capital, this is referred to as capital risk. If the investment is held in another currency there is a risk that currency movements alone may affect the value. This is referred to as currency risk. Lastly, liquidity risk involves risk regarding the time it may take to convert investments in one form to investment in another form.

Debt-related risk can be further disaggregated into credit risk and interest rate risk. Credit risk is the risk of loss due to a debtor's non-payment of a loan or other line of credit (either the principal or interest (coupon) or both) (Bluhm, Overbeck, & Wagner, 2002). Interest rate risk is where a change in the absolute level of interest rates, in the spread between two rates, in the shape of the yield curve or in any other interest rate relationship changes the value of the investment. It is the risk that the relative value of an interest-bearing asset, such as a loan or a bond, will worsen due to an interest rate increase. Interest rate risk can come in four forms: basis risk, yield curve risk, re-pricing risk and option risk.

In sum, from a finance perspective, risk has been and continues to be a subject of much research. From definitions of different types of risk to modelling of risk and the management of risk, academic literature abounds.

### 1.2.3 Risk from a Technical Perspective

A technical definition of risk would be the probability that an outcome will occur times the consequence, or level of impact, should that outcome occur (Kammen & Hassenzahl, 1962). Technical approaches to evaluating probabilities and outcomes incorporate both positive and negative changes in the state. Kammen and Hassenzahl (1962) argue it has become a dominant tool for energy, environmental, health and safety decisions both in the private and public arenas. The common elements of understanding risk from a technical perspective include hazard identification, dose-response relationship (how is quantity, intensity, or concentration of a hazard related to adverse effect, exposure analysis (who is exposed? to what? and how much? how long? other exposures?) and risk characterisation (review of all previous items and calculations based on data, with all assumptions clearly stated).

### 1.2.4 From a Psychological Perspective

Finucane and Holup (2005) assert that there is no such thing as real risk but that risk is inherently subjective. It is a social construct, meaning different things to different people and cannot be measured independent of context. Technical, statistical analysis of risk may be important to make important risk decisions but looking at risk from this perspective does not account for the decisions people make with regard to choice under uncertainty that are observed empirically.

Studies of risk perception attempt to understand why it is that our perceptions are often at variance with what the experts say we should be concerned about (technical risk). One common approach to understand and predict responses to perceived risk is via the psychometric paradigm. Slovic (Slovic, Fischhoff, & Lichtenstein, 1985; Slovic, 1986, 1987) produces perceptual maps to better understand risk attitudes and perceptions. This method relates the quantitative judgements about the riskiness of various hazards with risk attributes such as, for example, voluntariness, dread, controllability and catastrophic potential. Using factor analysis, a method of data reduction, Slovic derived a perceptual map represented on two main dimensions of “Dread risk” and “unknown risk”. Dread risk is depicted as risks with a lack of control, dread, catastrophic potential, and fatal consequences. On the other axis, unknown risk is perceived as including hazards perceived as unknown, unobservable, new, and delayed in their manifestation of harm. Slovic found that the higher the dread, the more people want these risks reduced, and the more people want to see public policy regulations in order to achieve this risk reduction (Slovic *et al.*, 1985). Slovic points out that it is perceptions of risk appear to have a strong influence on public policy than experts' opinion or objective facts.

Barry Glassner (1999) in his book "The Culture of Fear" reinforces a commonly held belief that the average person does not have an accurate assessment of the risks they face from day to day. As a result, they allocate resources inappropriately to address these risks. He argues the communicators perpetuate this climate of fear for their own personal gain, both economic and political. This inaccurate assessment can cause problems. High risk perceptions about a hazard that may statistically be a low risk event may result in extensive regulations, product rejection, anxiety, and economic failure. Perceptions of low risk may result in failure to take precautionary measures, injury, death or legal action. Balancing these two extremes may be difficult, as those responsible, possibly government agencies, seek to promote health and safety while concurrently avoiding economic loss (Glassner, 1999).

### 1.2.5 Conclusion

Risk is essentially the probability that the outcome maybe damaging or result in a loss. Risk has been encountered from the very existence of society and touches upon all elements of day-to-day life. Yet, risk can rarely, if ever, be completely eliminated. As such, it is not feasible to examine risk from all disciplines and sub-disciplines. Given this thesis will investigate economic impacts, this thesis will view risk from an economic perspective. Yet even within the discipline of economics, there are certain methodological boundaries within which risk can be examined. Economic modelling takes a particular view of the world and the underlying assumptions within these models determine the way risk and uncertainty can be analysed and treated. Therefore, this research will analyse risk and uncertainty using a CGE model to represent a real world economy. This leads to the following research question that this thesis will seek to answer.

## 1.3 Research Questions

The key research questions to be answered through this research are as follows:

1. How does uncertainty regarding future tourism demand impact on an economy?
2. What is the cost of uncertainty in terms of economic welfare?
3. What can policy makers do, if anything, to mitigate the effects of uncertainty on an economy?

## 1.4 Application to Tourism in Hawaii

Having argued that CGE modelling is the appropriate methodology to examine economy-wide impacts of risk / uncertainty, the research needs a context. The thesis will exam the issue of uncertainty in future tourism demand in the state of Hawaii. There are several reasons for choosing this context: the importance of tourism to the economy of Hawaii is one reason. As will be shown, tourism is a vital part of Hawaii's economy and a source of revenue that is vulnerable to exogenous shocks. A second important reason is the fact that exogenous risk who source originates outside of Hawaii has impacted Hawaii's economy in the past. Hawaii has been affected by several large external shocks such as the Gulf War of 1991 and the terrorist attacks of September 11, 2001 that occurred across the other side of the country. The fact that the source of these shocks originates outside of Hawaii is important. Hawaii has been exposed to these risks as a consequence of events elsewhere.

### 1.4.1 Uncertainty regarding Tourism in Hawaii's Economy

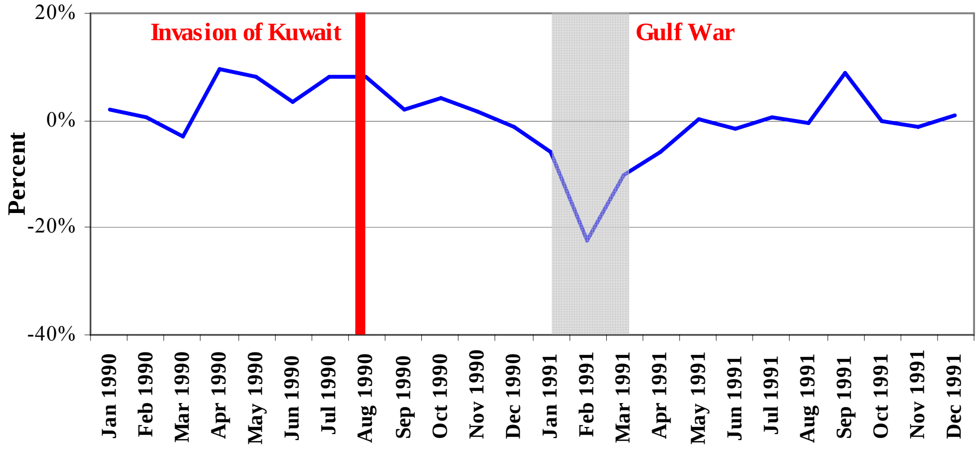
This section looks at events in Hawaii's recent past that have had an adverse impact on the economy. Two events to be examined are the Gulf War in 1991 and the terrorist attacks in the United States on September 11, 2001. The two incidents involved the United States but not Hawaii directly. Nevertheless, it will be shown that the events adversely impacted Hawaii's tourism and economic performance more generally. The visitor arrival data suggest that, not surprisingly, Hawaii is subject to the realised risks and uncertainties of adverse political and economic shocks. Visitor arrivals fell approximately 13% overall as a result of the Gulf War. This shock preceded a slump in Hawaii's economy, which was to last through the 1990s. The attacks of September 11, 2001 had a far reaching impact not only in the US and Hawaii but the world over as heightened security became the norm.

While the drop in visitor arrivals was deeper for September 11 compared to the Gulf War, the time it took for Hawaii to recover to pre-shock visitor arrival numbers was approximately the same as the Gulf War. This has been attributed to a strong local economy and expansionary fiscal and monetary policies of the US Federal government.

### 1.4.2 The Gulf War

The 1991 Gulf War was a conflict between Iraq and a coalition force, led by the United States and mandated by the United Nations. It was Iraq's invasion of Kuwait on August 2, 1990, following unproven Iraqi contentions that Kuwait was illegally "slant-drilling" oil across Iraq's border, which was seen as the precedent to the War. The invasion was met with immediate economic sanctions by the United Nations against Iraq. Hostilities commenced in January 1991, which lasted until March 10, 1991, resulting in a decisive victory for the coalition forces, which drove Iraqi forces out of Kuwait with minimal coalition deaths.

**Figure 1.1: Gulf War: Annual Growth of Hawaii Visitor Arrivals**




As a direct consequence of the Gulf War, Hawaii lost 13% of its visitors during the 1st quarter of 1991. Overall, there was a drop of 3.1% in the calendar year of 1991. The sluggishness of the visitor market to recover has been attributed to the mainland US recession that was underway. Specifically, California's recession was particularly lengthy where real income growth did not reach pre-war levels until 1955 (Bonham & Gangnes, 2001). The impact of the War was felt in other sectors also as the Gulf War grounded up to half the world's private maritime shipping vessels, increasing shipping rates, and driving up oil prices (PacificBusinessNews, January 28, 2003).

### 1.4.3 September 11 Attacks

The September 11, 2001 attacks (also referred to as 9/11) were a series of coordinated suicide attacks upon the United States of America carried out on Tuesday, September 11, 2001, in which a total of nineteen Arab hijackers simultaneously took control of four U.S. domestic commercial airliners. The

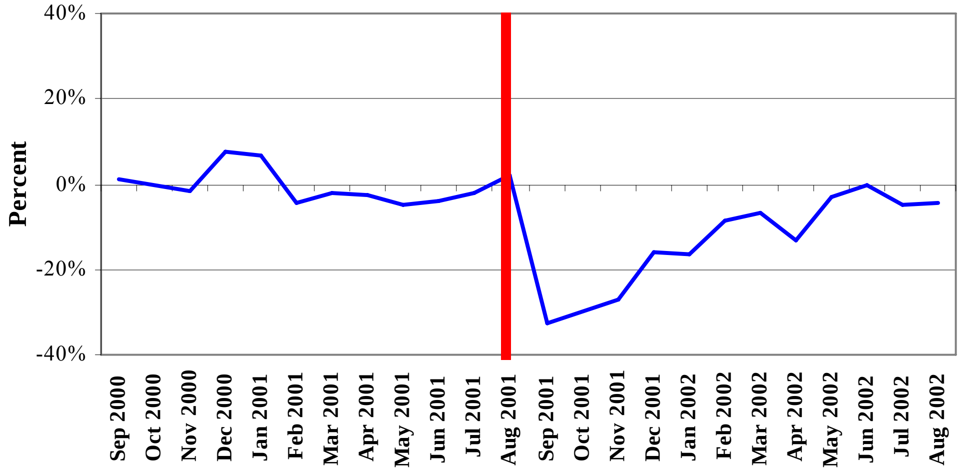
September 11 attacks had a profound impact in terms of the political, psychological, and economic effects that followed in the United States and other parts of the world. The attacks and the subsequent US-led wars in Afghanistan and Iraq have raised concerns about security and safety regarding international and domestic travel to a new level.

The attacks had significant short-term economic impact for the United States and world markets. One initial impact was felt on the US financial markets. The New York Stock Exchange (NYSE), the American Stock Exchange and NASDAQ did not open on September 11 and remained closed until September 17. NYSE facilities and remote data processing sites were not damaged by the attack, but member firms, customers and markets were unable to communicate due to major damage to the telephone exchange facility near the World Trade Center. When the stock markets reopened on September 17, 2001, after the longest closure since the Great Depression in 1929, the Dow Jones Industrial Average stock market index fell 684 points, or 7.1%, to 8920, its biggest-ever one-day point decline. By the end of the week, the same index had fallen 1369.7 points (14.3%), its largest one-week point drop in history. U.S. stocks lost $1.2 trillion in value for the week. The ASDAQ fell 16% for the week. Fortunately, these financial markets rebounded quickly. By early October 2001 the markets had recovered to near pre-crisis levels.

Goodrich (2002) outlines many of the travel and tourism industry impacts. After the attacks, casinos in Las Vegas reported declines of up to 50% in attendees as patrons feared flying. During the first three months or so after the tragedy, hotel bookings across the USA declined by some 20-50% as individuals and groups cancelled vacations and business travellers postponed conventions, corporate meetings and trade shows.

The attacks of September 11 on the World Trade Center and Pentagon had a far-reaching adverse impact on the economy of Hawaii. Hawaii is more vulnerable than many other states in the USA because of its reliance on air travel and tourism. Visitor arrivals to Hawaii were completely interrupted for two days following the attacks. For the year September 2001 to August 2002, visitor arrivals dropped 13.5%. Figure 1.2 shows the drop and subsequent rebound in visitor arrivals after September 11. Domestic visitors returned more quickly than International visitors and among Domestic US visitors who are closer in proximity to home returned to Hawaii more quickly than longer-haul visitors.

**Figure 1.2: 911: Hawaii Visitor Arrivals as a % of Previous Year**

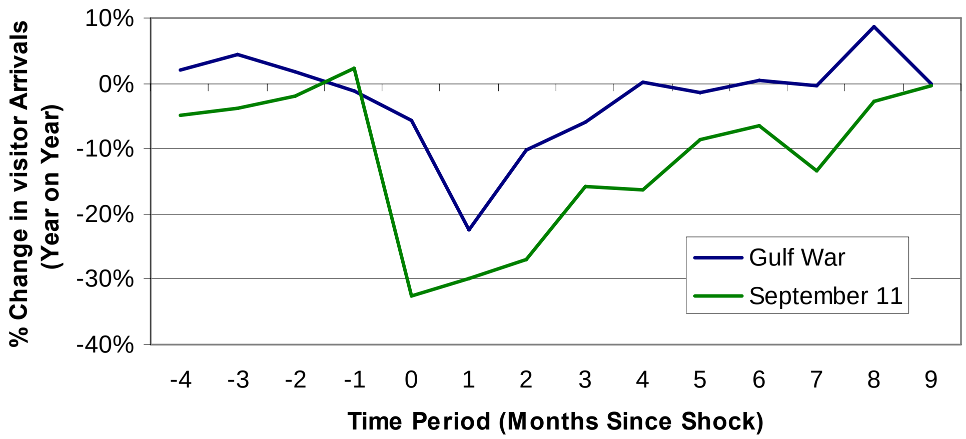


In Hawaii, there were nearly 17,000 initial claims for unemployment insurance benefits in the month following the September 11 attacks. Bonham and Gangnes (2001) estimate that about 11,000 are attributable to the attack and half of these were in the hotel industry and the rest in other sector related to tourism.

### 1.4.4 Discussion

The two shocks outlined above have had a major impact on Hawaii's economy over the last two decades. The timing of the Gulf War preceded a decade of slow economic growth in Hawaii. The 9/11 attacks had a dramatic impact on many tourism destinations including Hawaii. While the drop in visitor arrivals in the year following the attacks was deeper and lasted longer than that of the Gulf War, the economy has recovered strongly (Figure 1.3). Much of this has to do with the structure of Hawaii's economy and the wider economic climate.

**Figure 1.3: Comparing the Impact of Shocks on Visitor Arrivals**



Another key factor in economic recovery after exogenous shocks is tourists' attitudes towards vacations and air travel. There needs to be willingness to travel and a certain level of consumer confidence. It appears that this is less of an issue for US travellers (domestic visitors) than for international visitors. While not tested in this research, with increasingly common adverse regional and/or global events, it may be that heightened security and increased uncertainty may be the new modus operandi for tourists venturing abroad. These two factors might instil a willingness to keep travelling and vacationing regardless of unfavourable world-wide events. There appears to be a role for Destination Marketing Organisations (DMOs) and governments to re-assure tourists that their safety and security is paramount and that it is safe to travel.

### 1.4.5 Conclusions

Hawaii is an appropriate context with which to examine the issue of uncertainty regarding future tourism demand and the impact it has on an economy. In recent times, Hawaii has suffered two major shocks; the source of the shocks originating outside of Hawaii. The Gulf War of 1991 and the terrorist attacks of September 11 impacted tourism and then rippled through the rest of the economy. Shocks are not one-off events; they will keep occurring. Building an economic model to measure the impact of shocks and modelling the risk associated with the timing and magnitudes of such shocks will contribute to the body of knowledge with respect to applied economic modelling as well as have practical managerial and policy making implications.

**1.5 Research Contribution**

This thesis seeks to make original contributions towards the current body of knowledge both methodologically and in an applied sense. This thesis will explore several previously unresearched areas and will be very practical for policy makers and government as well as contributing to the body of knowledge.

CGE models are now the most appropriate way to estimate the economic impacts of tourism. CGE models have been used to estimate impacts on an economy and while estimating economic impacts using CGE models is not unique in itself, simulating uncertainty regarding the future path of the economy and several policy responses to the uncertainty has, until now, yet to be explored. This thesis will develop a new methodology for incorporating uncertainty within an applied economic model. Recently, several pieces of research have attempted to incorporate some aspect of risk or uncertainty into a CGE model. This thesis will present a novel way to do this, hence adding to the body of knowledge methodologically. The model in this thesis is made more practical with the additional characteristics of, not only a dynamic forward-looking model but also, the incorporation of unemployment and a flexible labour supply in the model as well as the ability to vary the proportion of investment that comes 'on-line' in the current year.

The research findings will have policy implications for businesses, policy makers and governments. In the area of tourism, the traditional way to investigate the economic impacts on an economy is through Input-Output (IO) analysis. While this type of analysis is of some value, more sophisticated techniques better able to represent a real economy are now available. The CGE models developed in this thesis may allow DMOs to better understand the impacts on the tourism industry and wider economy when there is uncertainty regarding future tourism demand. Risk management strategies may be implemented to mitigate some of the impacts of the uncertainty.

Other issues for policy makers such as governments may be the use of macroeconomic policy instruments such as fiscal policy. Can government use taxation to offset some of the impacts induced by the uncertainty? Minimal research has been undertaken analysing tourism and taxation in a dynamic CGE framework. Analysing the adjustment paths for anticipated changes to different taxes may provide a better understanding of how households, firms and government behave over the long term.

## 1.6 Structure of the Thesis

Chapter Two will outline the theoretical frameworks for the two commonly used methods of estimating economy-wide impacts, input-output modelling and CGE modelling. The chapter then goes on to review how CGE model have been used to investigate a wide range of policy issues. Reviewing some applied Input-Output tourism models; this chapter critiques these models, concluding that using a CGE methodology is the most appropriate way to assess economic impacts. With a brief review of existing CGE tourism models, gaps in the body of knowledge will be highlighted.

Chapter Three sets the research in context, highlighting several features of the economy in Hawaii and specifically the tourism industry before going on to describe salient features of the benchmark data set, the 2002 Hawaii Input-Output table, that will be used to calibrate the CGE model found in latter chapters.

Chapter Four serves two purposes. The first purpose is to describe the CGE methodology used. The second purpose of the chapter is to build up the model's sophistication and show intermediate results of a simulated tourism shock at different stages, The reader will see the impact of a hypothetical tourism decline, starting with a static CGE model then moving through to a dynamic recursive model, a dynamic forward-looking model and finally a multi-sector dynamic forward-looking model.

Chapter Five reviews recent research that has attempted to introduce elements of risk and uncertainty into CGE models. This chapter also explains how uncertainty regarding the future path of the economy can be introduced conceptually into CGE models.

Chapter Six takes the conceptualisation of the uncertainty explained in Chapter Five and applies it to the Hawaiian economy to show the impact of the uncertainty on the economy. The implications the uncertainty has for the behaviour of the different economic agents (households, tourists, government, and industry) are highlighted. Several government policy decisions are simulated to mitigate the impact of the uncertainty and the results are discussed.

Chapter Seven concludes this thesis, highlighting again the contributions that have been made as well as outlining areas for further research and the limitations contained in the research.

# CHAPTER TWO

# ECONOMIC IMPACT MODELLING: THEORY & PRACTICE

## 2.1 Introduction

Economic impacts have been estimated and evaluated via a range of different methodologies by researchers and policy makers for many decades. This chapter will discuss in detail two of the most common ways of estimating economy-wide economic impacts, namely Input-Output (IO) models and computable general equilibrium (CGE) models. This chapter will review the theoretical foundations of both Input-Output modelling and CGE modelling and will then go on to review a range of applied models in the literature, focussing specifically on estimating the economic impact of tourism. A significant portion of the chapter will outline CGE modelling superiority over IO modelling. After a review of the main contributions in this area, the scope for further research in the current body of knowledge is outlined and areas where future contributions can be made are specified.

Estimating economic impacts of policy decisions, shocks or events is grounded, not surprisingly, in economic theory. One technique to estimate economic impacts is via a cost-benefit analysis. However, this method is partial in its approach and a number of explicit and implicit assumptions must be made during the process of model construction (Fletcher, 1989). The results of cost-benefit analyses tend to be only as good as the researcher's insight into the workings of the economy of interest and extensiveness of tourism's impact. For these reasons, this chapter will examine the two economy-wide methods of estimating economic impacts.

A distinction needs to be made between direct economic impacts and total (or direct and indirect) economic impacts. Direct economic impacts are often estimated through visitor surveys. Surveys collect data such as length of stay, purpose of trip, total expenditure by category. This data is then grossed up by estimates of total visitors to the region. The total visitors to the economy may be derived from national surveys, border or customs counts or from accommodation occupancy rates to estimate a grossed up overall direct economic impact. These direct impacts are akin to a partial equilibrium analysis, where impacts for the tourism sector are estimated. To estimate the total economic impact, these direct impacts are then inputted into an economy-wide model to estimate the impact for the entire economy, be it country, region or city.

The distinction between economic impact and economic benefit is an important one. It is not appropriate to apply the impact measure as if it were the benefit for a cost-benefit analysis. Therefore it is important to distinguish clearly between the impacts and the net benefits of tourism growth. Dwyer *et al.* (Dwyer, Forsyth, Spurr, & Ho, 2002) rightly make the point that there has been a tendency to refer to 'impacts' interchangeably with 'benefits'. These two terms are not the same. Benefits can be defined as how much better off an economy is a result of tourism development, whereas an economic impact can be positive or negative.

The traditional way to investigate the economic impact of tourism on an economy is through an Input-Output model. While this type of analysis is of some benefit, more sophisticated techniques which are better able to represent a real economy, are now available. To keep using IO analysis to estimate tourism impacts would not take advantage of the advances in economic modelling. It may lead to bias in reporting all possible economic impacts.

Computable General Equilibrium (CGE) models (also referred to as Applied General Equilibrium Models) are now starting to be used to estimate economic impacts on an economy in a tourism context. CGE modelling has been used extensively in other areas of economic policy inquiry, yet is still somewhat under-utilised when examining tourism impacts.

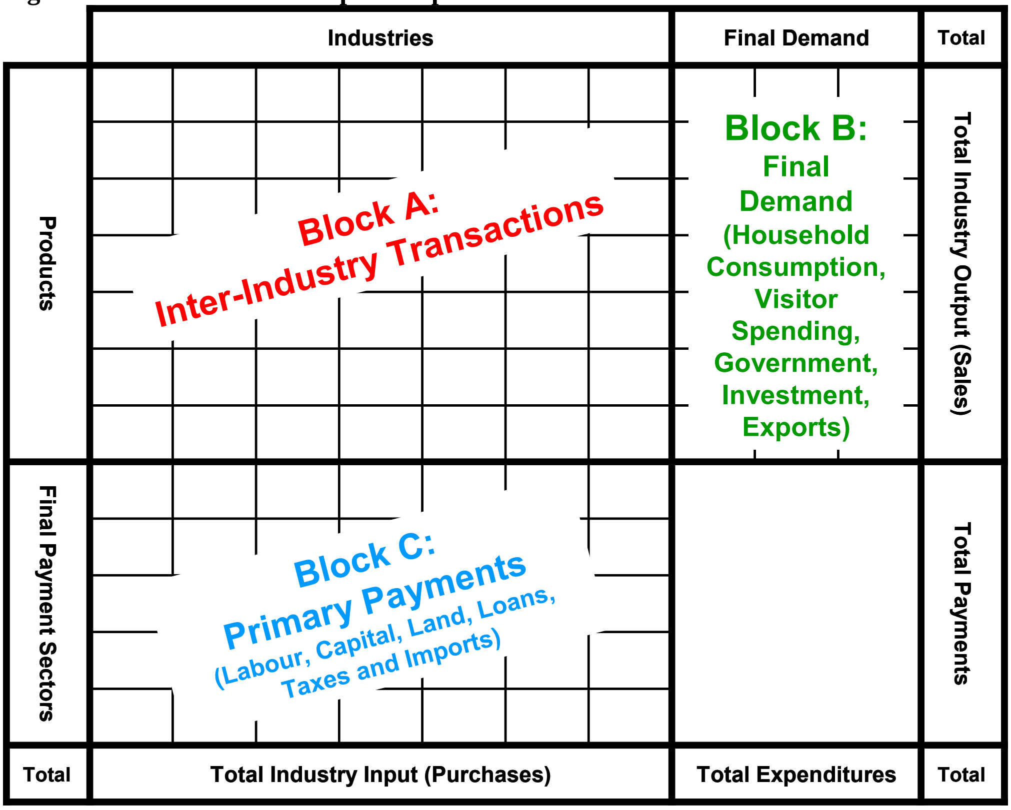
The chapter is set out as follows: Section 2.2 reviews conceptually how IO models work while Section 2.3 provides a broad overview of how CGE models operate. Section 2.4 examines empirical IO analysis based studies that have been conducted on the economic impact of tourism while Section 2.5 provides a brief look at the non-Tourism CGE literature and then goes on to critically evaluates the research to date on the economic impacts of tourism estimated using CGE models. An analytical discussion of the reviewed literature is contained in Section 2.6. Section 2.7 points out the literature gap this research hopes to address and Section 2.8 concludes.

## 2.2 Review of Theoretical Foundations of Input-Output Modelling

The 'standard' way to determine economic impacts has been Input-Output analysis. The framework for Input-Output analysis was developed by Wassily Leontief in the 1930s, initially for the USA (Leontief, 1936, 1951).

It is important to distinguish between an IO table and IO models. An IO table depicts a comprehensive and detailed set of accounts of sales and purchases of goods and services among the producing industries, final consumers (residents, visitors, exports and government), and resource owners (labour, capital and land) during a particular time period (usually a year) for a specific economy. An IO table is not a model in itself and can be used in other types of modelling, such as Social Accounting Matrix (SAM) modelling and CGE modelling. A standard IO table is composed of three blocks or components. These are inter-industry transactions (block A), final demand (block B), and value added (block C) (See Figure 2.1). Each of these blocks consists of a series of rows and columns. The producing or selling sectors are shown in rows and the purchasing or buying sectors are shown in columns.

**Figure 2.1: Structure of an Input-Output Table**




The inter-industry transactions (Block A) portion of the table accounts for the intermediate demand and supply of goods and services among the producing industries in the economy. The final demand component (Block B) shows the demand (sales) of commodities and services by each industry to final users (resident households, government, visitors (tourism expenditures), investors and exports). The value-added component (Block C) shows primary payments to the owners of production. These include payments to the primary factors of production (labour, land and capital), corporate tax payments to the government, investment payments for business loans, and payments for imported goods and services for intermediate use. The accounting framework of an IO table means that total receipts of sellers must equal total expenditures of buyers. Total output equals total inputs for each producing sector in the economy. In the IO framework, industry sales and purchases are valued at producers' prices. To transform the IO table into an IO model, the table must be converted into a technical coefficients matrix.

The relationships outlined above can be represented mathematically, as a system of equations. Hence, the distribution of each industry's total output to industries and final demand sectors can be represented as follows:

$$X_i = \sum_{j=1}^{n} Z_{ij} + \sum_{k=1}^{m} Y_{ik} + \sum_{k=1}^{m} T_{ik} \qquad \textbf{(2-1)}$$

where:

i , j = 1,2,…,*n* industries;

k = 1,2,…,*m* final demand sectors;

$X_i$ = Total output of the *i*th industry, including intermediate sales and final sales;

$Z_{ij}$ = *i*th industry's inter-industry sales to the *j*th industry;

$T_{ik}$ = *i*th industry's final sales to the *k*th tourism demand sector; and

$Y_{ik}$ = *i*th industry's final sales to the *k*th other final demand sector.

Similarly, the flow of inter-industry demand can be expressed as a system of another set of *n* equations, showing the distribution of industry *j*'s total input from *n* industries and imports, and payments to *s* final payments sectors as follows:

$$X_j = \sum_{i=1}^{n} Z_{ij} + M_j + \sum_{r=1}^{s} W_{rj} \qquad \textbf{(2-2)}$$

where:

i , j = 1,2,…,*n* industries;

r = 1,2,…,*k* final payment sectors, including imports;

$X_j$ = Total input of the *j*th industry, including intermediate purchases and total final payments;

$Z_{ij}$ = *j*th industry's inter-industry purchases to the *i*th industry;

$M_j$ = imports of industry *j* as intermediate input; and

$W_{rj}$ = *j*th industry's final payments to the *r*th final payment sector.

To determine the direct effect of an economic impact using IO analysis, the next step is to calculate the direct requirement table. Each element in the direct requirement table shows the demand of column sector *j* from row sector *i* to produce a dollar of output in sector *j*. Designated as $a_{ij}$, this technology coefficient is derived by dividing each column entry of the transactions table (Block A in Figure 2.1) by the corresponding column total, that is,

$$a_{ij} = Z_{ij} / X_j \quad \textbf{(2-3)}$$

Each column in the direct requirements table represents a production function for the corresponding producing sector. Because these technical coefficients are fixed, these production functions are characterised by constant returns to scale. Each industry's production process is described in terms of the average technology being used by that particular industry.

The total requirements table shows the direct and indirect effects on all producing sectors due to a change in final demand of one dollar. The direct effects, explained above, lead to a series of successive or indirect impacts on the producing sectors. The total effect can be calculated as follows: re-arranging Equation 2.3, substituting into Equation 2.1 and writing in matrix algebra form, Equation 2.1 can be written as:

$$X = AX + Y + T \qquad \textbf{(2-4)}$$

Solving for $X$, the vector of total industry outputs can be written as:

$$X = (I - A)^{-1}(Y + T) \qquad \textbf{(2-5)}$$

where:

$X$ = the $n$ x 1 vector of industry total outputs;

$I$ = An $n$ x $n$ Identity matrix;

$A$ = An $n$ x $n$ technology matrix;

$T$ = An $n$ x 1 vector of tourism demand; and

$Y$ = the n x 1 vector of total other final demands.

$(I - A)^{-1}$ is known as the total requirements matrix or the Leontief inverse matrix. In this matrix, each column represents the direct and indirect impact on the row industry sector of a \$1 change in the column sector's final demand.

IO analysis assesses the effects of an exogenous change on the economy through the use of IO multipliers.

The direct and indirect impact of a change in tourist expenditure ($\Delta T$) can be represented as:

$$\Delta X = (I - A)^{-1} \Delta T \qquad \textbf{(2-6)}$$

If the household sector is exogenous, the direct plus indirect (Type I) final-demand output multiplier for the *j*th sector ($O_j$) can be obtained by summing down the *j*th column of the Leontief matrix as:

$$O_j = \sum_{i=1}^{n} (i - a)_{ij} \qquad \textbf{(2-7)}$$

where the $(i - a)_{ij}$ s are elements of the final-demand output multiplier table, representing the change in output of sector *i* due to a one dollar change in tourism demand of sector *j*. The direct effect measures the initial effect attributable to the exogenous change, while the indirect effect measures the subsequent intra-industry and inter-industry demand for inputs as a result of the initial change in output of the directly affected industry. Hence:

$$Type.I.Multiplier = \frac{Direct.effect + Indirect.effect}{Total.Tourism.Demand} \qquad \textbf{(2-8)}$$

This formulation of the multiplier is known as the "ratio" multiplier. A ratio multiplier shows the ratio of the direct plus indirect income created by a unit of tourist expenditure to the direct income. An alternative way multipliers are reported, known as the "normal" multiplier, shows by how much the initial effect is multiplied to get the total effects. There is some confusion and misunderstanding with the interpretation of multipliers and caution must be exercised by comparing multiplier values across destinations or time (see Archer, 1984; Hughes, 1994).

There are a range of IO multipliers, such as output, earnings (income), employment (job) and import multipliers. For example, final-demand earning multipliers measure the economic impact of changes in final-demand (for example, tourism) in terms of changes in the industry's payments to households' earnings (income). The final-demand earnings multipliers are obtained using the total requirements table and direct earnings coefficients as:

$$C = L.(I - A)^{-1} \quad \textbf{(2-9)}$$

where:

$C$ = the final-demand income multiplier table;

$L$ = An $n$ x $n$ matrix containing the $i$th sector's direct income coefficient in its $i$th diagonal and zeros elsewhere;

$I$ = An $n$ x $n$ Identity matrix; and

$A$ = An $n$ x $n$ technology matrix;

The direct plus indirect final demand earnings multiplier for sector $j$ ($I_j^{FD}$) is computed as:

$$I_j^{FD} = \sum_{i=1}^{n} c_{ij} \quad \textbf{(2-10)}$$

Likewise, final-demand employment multipliers measure the change in the number of jobs for a one million dollar change in final demand. To calculate employment multipliers, entries in the total requirements table are transformed to employment equivalents by multiplying each row of the total requirements table by the corresponding sector's direct employment coefficient (employment-to-output ratio).

$$D = E.(I - A)^{-1} \quad \textbf{(2-11)}$$

where:

$D$ = the final-demand employment multiplier table;

$E$ = An $n$ x $n$ matrix containing the $i$th sector's direct employment coefficient in its $i$th diagonal and zeros elsewhere;

$I$ = An $n$ x $n$ Identity matrix; and

$A$ = An $n$ x $n$ technology matrix;

The direct plus indirect final-demand employment multiplier for sector $j$ ($I_j^{DE}$) is computed as:

$$I_j^{DE} = \sum_{i=1}^{n} d_{ij} \qquad \textbf{(2-12)}$$

Direct plus Indirect plus Induced (Type II) multipliers are obtained in an analogous way except that the household sector is assumed to be endogenous. Type II multipliers can be calculated by including the column representing the household consumption (Final Demand: Block B) in the inter-industry transactions (Block A) as well as including the row for primary inputs of wages, salaries, and distributive profits (final payments: Block C) in the inter-industry transactions (Block A). Now the $A$ matrix is augmented to be $A^*$, a $n+1$ x $n+1$ matrix with the $n+i$th row the household sector. The impact can then be written as:

$$\Delta X^* = (I - A^*)^{-1} \Delta T \qquad \textbf{(2-13)}$$

These "induced" effects measure the effects of demand changes on household spending that result in earnings through direct and indirect effects. As income levels rise throughout the economy as a result of the direct and indirect impact of the initial change in final demand, a portion of the income will be re-spent on final goods and services produced within the economy, giving rise to further impacts on output (sales), income (earnings) and employment. The calculations can then be repeated as for direct plus indirect (Type I).

$$Type.II.Multiplier = \frac{Direct.effect + Indirect.effect + Induced.effect}{Total.Tourism.Demand} \quad \textbf{(2-14)}$$

Type II multipliers are larger than Type I multipliers. Because of the induced effects of household spending, Type II multipliers are more widely used in real-world applications (DBEDT, 2002). There is a further distinction into Type III for income multipliers. Type III income multipliers are similar to Type II, except that household consumers are disaggregated by income group and a distinction is made between changes in income of existing households and changes in income of newly employed personnel (Fletcher, 1989).

Fletcher (1989) outlines some of the advantages that IO modelling has over cost-benefit analysis and Archer's ad hoc multiplier (Archer, 1977). These advantages include the fact that IO analysis is a general equilibrium approach, taking a more comprehensive look at the whole economy (in contrast to a partial equilibrium approach). IO analyses focus upon industry interdependencies which exist in the economy. This fact has two further advantages. One advantage is that the technique is argued to be "policy-neutral" as each sector is treated in a uniform manner and it allows for flexible aggregation of sectors so that sectors of particular importance to the study of tourism can be highly disaggregated, whereas sectors of lesser importance can be aggregated to keep the size of the model to a minimum.

Nevertheless, no methodology is without its problems and disadvantages. While little has changed in terms of the application of IO analysis since Leontief's early work, there have been some theoretical developments which look to address some of the weaknesses and restrictive assumptions of this type of analysis. These weaknesses and restrictive assumptions will be discussed in Section 2.5.2. Rose (1995) points out where some theoretical advances have occurred in IO modelling. One criticism of IO modelling is that it is static in nature. However, Leontief developed a dynamic IO formulation (Leontief, 1953, 1970). To counter the argument that IO requires the use of fixed coefficients, Rose points out that IO can allow coefficients to change over time. This is one of the features of the work of Duchin and Lange (Duchin & Lange, 1992).

One of the biggest criticisms regarding IO modelling is that fact that prices play no role in IO analysis. While essentially IO modelling is based on the quantity-balance equation only, Leontief (1986) developed a separate dual price-balance equation so quantity changes in response to changes in prices could be analysed. Nevertheless, the criticism still stands: the basic IO formulation separates the quantity and price determinants. Another criticism pointed out is that the household consumption function is usually aggregated into a single column vector (Fletcher, 1989). This implies than an increase in income will result in a uniform, proportional increase in consumption of output from each of the productive sectors. This will not necessarily be true, as different groups of consumers have different marginal propensities to consume. For example, high-income earners tend to have lower marginal propensities to consume. This problem can be overcome with a more detailed household consumption matrix, which segments consumers by level of income. With this additional detail, the IO table moves towards a Social Accounting Matrix (SAM) – (see Pyatt & Round, 1985 for a description of SAMS).

Another extension to the IO model distinguishes the proportion of imports for each sector that is competitive or non-competitive. So, instead of just one row in the IO table denoting imports in the Final Payments Block, the distinction is made between competitive and non-competitive imports and, based on this distinction, can be treated differently in the model. For example, competitive imports are possible substitutes for domestic production and hence any change in final demand may be met by domestic production, competitive imports, or some combination of both. Whereas given a change in final demand, non-competitive imports tend to respond in a predictable, proportional manner (Fletcher, 1989).

Another criticism of IO modelling is that the standard model does not allow for capacity constraints. This can be a problem for certain industries especially in the short-term where some industries will not be able to respond to an increase in demand. The additional demand may have to be met through an increase in imports rather than domestic demand (ignoring price effects) and hence the IO model would over-estimate the impact of a change in final demand. Methodologically, this problem can be overcome in practice through the incorporation of a matrix of capacity constraints applied to the productive sectors. The constraints range from zero to one. When the constraint is zero, the industry is assumed to experience no capacity constraint. When the value is one, the industry is assumed to be unable to respond to any further increases in demand and additional output is met from imports. Wanhill (1988) tested this capacity constraint matrix on the economy of Mauritius and found that the income multiplier could be up to 28% less than that estimated with the unconstrained model and that the level of employment generated by tourism my be up to 34% less.

Despite some recent theoretical innovations outlined, the vast majority of tourism impact studies apply the standard IO model. A review of the applied IO modelling for tourism is found in Section 2.4.

### 2.3 Review of Theoretical Foundations of CGE Modelling

More recently CGE models have been shown to be superior to IO models in estimating economic impacts. The CGE class of models are empirically estimated Arrow-Debreu (1954) General equilibrium models with empirical data. CGE models were developed in the early 1960s to solve for both market prices and quantities simultaneously, thus simulating the working of a competitive market economy. A CGE model attempts to model the whole economy and the relationships between the economic agents in it. These models move the Walrasian general-equilibrium structure of an abstract representation of an economy to realistic models of actual economies that can be used to evaluate policy changes, among other things (McKibbin, 1998).

The models tend to be constructed from the underlying Input-Output table. One of the first applied CGE models was developed by Johansen (1960) to analyse resource allocation issues and economic growth of the Norwegian economy. The following section will review how impacts can be measured from an economic theory viewpoint for both types of modelling methodologies.

CGE modelling has been used extensively in other areas of economic policy inquiry, yet is still somewhat under-utilised when examining tourism impacts. The theory behind CGE modelling comes from general-equilibrium theory. General equilibrium models are characterised by the following:

1. Multiple interacting economic agents
2. Individuals exhibit optimising behaviour
3. Equilibrium occurs when endogenous variables (such as prices) adjust to clear markets so supply equals demand in each market with the solution being Pareto optimal (subject to their constraints, economic agents cannot do better by changing their behaviour)

General equilibrium theory is somewhat abstract (Markusen, 2002), being concerned with showing that a set of equilibrium prices and hence equilibrium itself exists. To answer questions about the impact of policy changes and tourism growth, for example, and estimate the economic impact of these potential changes on real economies and real policies, a computable general equilibrium model is needed. To make a general equilibrium model computable, the modeller has to make assumptions about the specific functional form of preferences, production functions and the values of parameters such as elasticities. While some of these parameters can be drawn from econometric work or published data, others have sometimes been guesstimates. This can induce criticism from theorists and econometricians, however it is the price that has been paid for delivering answers to economic impact questions set in a general equilibrium context.

Computable general equilibrium models take general equilibrium economic theory and convert it into a mathematical formulation. General equilibrium is then represented as a solution to a well-defined mathematical problem. Markusen (2002) points out that there are two general ways of formulating this mathematical problem. The first is an optimisation problem based on the behaviour of economic agents. The theory of the consumer and theory of the firm both postulate that consumers behave so as to maximise utility while firms maximise profits/minimise costs. However this optimisation problem becomes too unwieldy when there are several households or regions. The second method also follows microeconomic theory. Individual optimising behaviour and decisions of consumers and firms are used to derive demand and supply functions that describe how agents' respond to the values of variables facing them such as changes in prices and taxes. When this is done, general equilibrium becomes a square system of $n$ equations in $n$ unknowns (a system of non-linear equations). These $n$ equations embody individual optimising behaviour. When solved, this formulation yields solutions for the values of the endogenous variables (prices, industry output, etc) for given quantities of exogenous variables (preferences, technologies, factor endowments, etc). Mathiesen (1985) showed how the Arrow-Debreu equilibrium model can presented as a mixed complementarity problem. The complementarity feature comprised of three inequalities that need to be satisfied in this square system of weak inequalities:

1. Zero profit condition: either there is positive output and zero profit for each industry in the economy. If profit is negative, there will be no production in that industry.
2. Market clearance condition: supply must equal demand in each sector.
3. Income balance condition: each agent's (including the government sector/s) value of income must equal the value of factor endowments.

A set of three non-negative variables is solved in this complementarity problem: prices, quantities and income levels.

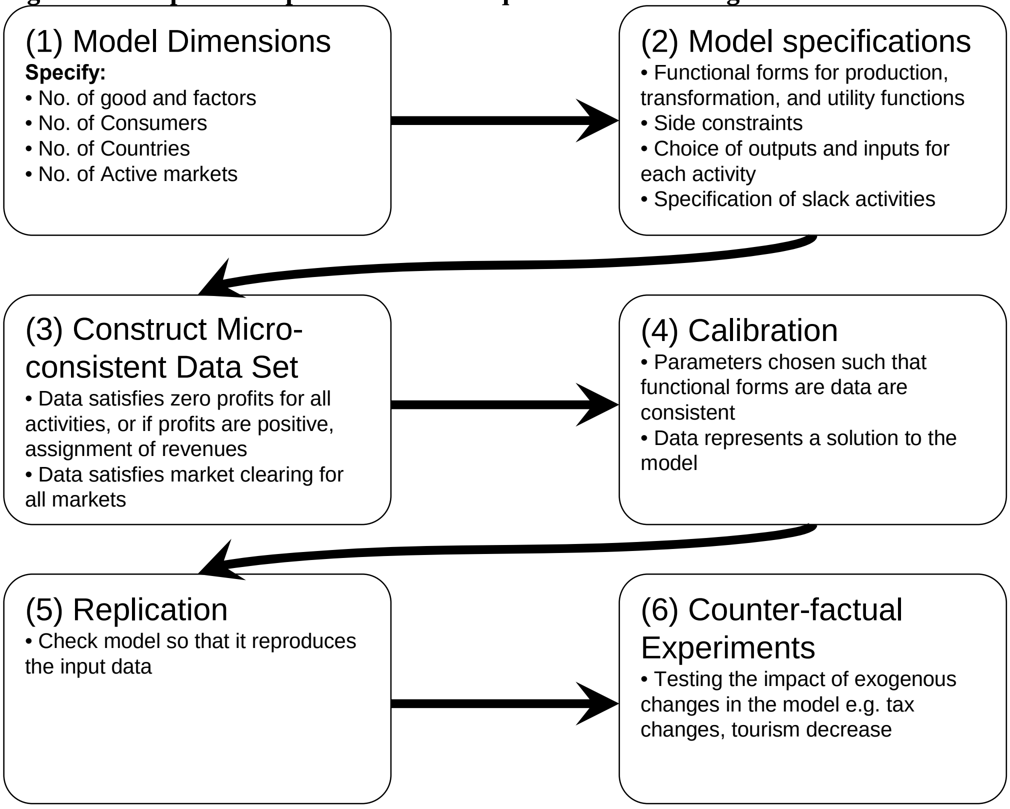
Having outlined generally the way the general equilibrium model is solved for prices, quantities and income levels, the next step is to show the steps in estimating an economic impact with computable general equilibrium models. Following Markusen (2002) and depicted in Figure 2.2, the standard steps are:

1. Specify the model dimensions. This involves designating the number of consumers, sectors and factors. To some extent this will be determined by how disaggregated the underlying IO table or SAM is. However, it is possible to aggregate certain sectors of interest.
2. The second step in CGE modelling involves specifying the functional forms of the underlying production and utility functions and including any model-specific constraints, such as making the small-country assumption by fixing world prices.

3. The next step involves imposing the profit maximisation and utility maximising conditions so that the zero profit condition, market clearance and income balance condition are satisfied.
4. In the fourth step the model is then calibrated to the base year data set. The share parameters are determined within the model so that the data is represented as a solution to the model.
5. The model is then run to see if it solves. When it does, the researcher can progress to the last stage.
6. Step 6 is the counterfactual experiment stage. After the model has been specified and calibrated, different scenarios can be tested where economic impacts can be measured.

This is a general overview of the way CGE modelling works. The next section reviews some empirical models, both IO and CGE, that have been developed over the last twenty years.

**Figure 2.2: Steps in Computable General Equilibrium Modelling**




## 2.4 Review of Applied Tourism Input-Output Models

This section reviews a set of empirical studies concerning the economic impact of tourism estimated using an IO methodology. While the review will not cover all studies ever completed, by the end of the section readers will have a good flavour of what has been completed for very different types of economies.

There is now extensive empirical literature on evaluating the economic impacts of tourism. This literature proceeds to show how the impact of changes in tourism expenditure can be evaluated in economic terms. The changes may come from a variety of sources such as a change in tourism demand based on tourists' tastes and preferences or an external shock such as a terrorist attack, or policy changes such as the implementation of a hotel tax. The impacts are often expressed in terms of changes in GDP (output or income) or some measure of welfare. It must be remembered though that a change in GDP is not the same as a change in benefits, since GDP is a gross amount. This economic activity imposes additional costs as well as benefits (Dwyer et al., 2002). While increased economic activity, as measured by an increase in GDP may be a positive impact, it does not necessarily mean that it is a desirable change – this is determined by what the costs of this extra activity are. Tourism impacts often measure gross, not net effects (Dwyer & Forsyth, 1997). The additional economic activity, measured by a change in GDP, will come with additional costs, such as additional labour that needs to be hired, additional capital that needs to be made available, more land that needs to be acquired and more natural resources used. So some policies or projects may increase GDP but may have overall negative net benefits. This holds true especially if the costs of achieving the additional growth are high, for example if there are negative externalities that have not been taken into account or if the project needs to be heavily subsidised.

IO analyses have been used widely over the past 50 years. IO models have been developed in a tourism context for a range of economies, from country level to state / province / region level to city level and even areas of cities / special events and attractions level.

IO models undertaken at a country level include Tanzania (Kweka, Morrissey, & Blake, 2001), Singapore (Heng & Low, 1990), Bermuda (Archer, 1995) and the Seychelles (Archer & Fletcher, 1996). As an example of how to interpret the multipliers and understand how tourism expenditure contributes to an economy, Heng and Low (1990) estimate the economic impact of tourism for Singapore. Earlier IO studies on Singapore were conducted by Diamond (1979, 1981), Seow (1981) and Khan *et al.* (1990). The income impact of one Singapore dollar of tourist expenditure is estimated at S$0.77 by Heng and Low (1990). For the overall output multiplier, every one Singapore dollar of tourist expenditure generates S$1.47 of output. In 1986, the employment impact per million dollars of tourist expenditure is 22 full time equivalent (FTE) employees.

Studies completed at a State/Province level include Queensland, Australia (West, 1993), Hawaii, USA (DBEDT, 2002), New Hampshire, USA (Wiersma, Morris, & Robertson, 2004). One such study conducted at this level of disaggregation is the Newark and Sherwood District Tourism Economic Impact Assessment 1998 (HeartofEnglandTouristBoard, 2001), a regional economic impact study. This study uses the 'Cambridge Model' which rather simplistically uses visitor surveys and economic / jobs ratios to calculate estimates. This study found that in 1998 3.6 million visitors came to the Newark and Sherwood District. During their visits to the district, a total of £96 million was spent by tourists across the year and tourism in the district supported 3,360 jobs, both for residents of the region and from outside.

Several regional economic impact studies have been carried out throughout the England in recent years. For example, one economic impact study for the North East region (TrendsBusinessResearch & cogentsi, 2002) estimated that tourism supports around 50,000 jobs directly and another 50,000 jobs are supported due to indirect and induced effects. In the region, tourism directly accounts for 3.5% of the North East's economy, and supports a further 6% by indirect and induced effects. The methodology used in estimating these impacts is via Tourism Satellite Accounts (TSA). TSAs seek to combine information from national visitor surveys with specially commissioned surveys conducted in the area of interest, which can be linked to National Accounts. In the study for the North East region of the England, it is estimated that for every £1 of direct sales spent by visitors, £1.80 is spent elsewhere in the economy. In terms of income, every £1 of direct tourism value added generates £1.67 of added value elsewhere. Lastly, with regard to employment, for each direct tourism job, another (1.07) is generated through indirect and induced effects. These estimates seem particularly high. A note in the methodology gives some indication why "without a full Input-Output model of the North East economy it is not possible to calculate the leakages from the North East (p45)" Imports from overseas are allowed for but not imports from other regions.

At a smaller spatial level, multipliers have been calculated for cities including Washington D.C. (Frechtling & Horvath, 1999) and Victoria, British Columbia, Canada (Juanita Liu & Var, 1982). Finally at a very local level, economic impacts have been estimated for areas of cities: the Old Town, Edinburgh, Scotland (Parlett, Fletcher, & Cooper, 1995) and a mega-multi-mall (Finn & Erdem, 1995). Most of the studies show output, income and employment multipliers while some also report tax and/or import multipliers.

In addition to measuring the overall value of tourism to an economy, tourism economic impact studies have been conducted for several events using IO analysis, such as the UK round of the 2004 World Rally Championship (Jones, 2008), the Olympic Games and the America's Cup Defence (MarketEconomicsLtd, 2003). A report prepared by Market Economics for the New Zealand Ministry of Tourism into the economic impact of the America's Cup defence in 2003 (MarketEconomicsLtd, 2003) estimated that $NZ523 million of net additional spending in the New Zealand economy was generated by the event over the 2000-2003 period, which would not have occurred otherwise. This expenditure generated $NZ529 million of value-added in the New Zealand economy, including $NZ450 million of value-added to the Auckland economy. The employment effects were estimated to be significant, with Cup-related expenditure sustaining the equivalent of 9,360 FTE jobs at the national level (8,180 FTE jobs in the Auckland economy).

Further, estimating the economic impact of tourism activities has also been attempted. Johnson and Moore (1993), estimate the economic impact of white-water recreation on the Klamath River in Oregon, USA using a combination of primary survey data on trip expenditure and the IMPLAN input-output system. Feeding the trip expenditures (final demand) obtained through a survey of white-water recreationists into an IO model, Johnson and Moore estimated the total output in Klamath and Jackson counties due to white-water recreation on the Upper Klamath River between $490,500 and $817,400 in 1982 dollars depending three alternative use levels. The corresponding figures for income estimates and the number of jobs created range from $245,300 to $408,900 and 16 to 26, respectively.

Table 2.1 reports the multipliers for selected studies over the last twenty years. In general, tourism output multipliers have a positive relationship with population size – economies with a larger population have a larger output/income multiplier but there is a negative relationship between employment multipliers and population - an observation noted by Fletcher (1989) and Wiersma *et al.* (2004). Generally, output multipliers for countries will be higher than output multipliers for States and cities. Nevertheless, higher multipliers do not necessarily mean better performance, nor do they necessarily indicate what is best for the economy.

**Table 2.1: Tourism Multiplier Estimates from Selected Studies**

| **Researcher(s)** | **Economy** | **Data Year** | **Multipliers*** | | | |
|---|---|---|---|---|---|---|
| | | | Sales | Income | Employment [a] | Imports |
| **Country** | | | | | | |
| Kweka *et al.*, 2001 | Tanzania | 1992 | 1.84 | 0.69 | 2,531[e] | 0.21 |
| Fleischer and Freeman, 1997 | Israel | X | 1.84 | 0.54 | X | X |
| Heng and Low, 1990 | Singapore | 1986 | 1.47 | 0.77 | 21.6 | 0.17 [g] |
| Khan *et al.,* 1990 | Singapore | 1983 | 1.48 | 0.94 | 24.8 | X |
| Henry and Deane, 1997 | Ireland | 1995 | X | 0.75 [d] | 41.9 | 0.25 |
| Archer, 1995 | Bermuda | 1992 | 1.26 | X | 21.6 | 0.95 |
| Archer and Fletcher, 1996 | Seychelles | 1991 | X | 0.88 [c] | X | 0.32 |
| National Tourism Organisation, 1999 | Malta | 1998 | 1.28/ 1.61 (GNP) | X | 60.6, 90.89, 94.68 | |
| **State/Province** | | | | | | |
| Wiersma *et al.*, 2004 | New Hampshire | 1999 | 1.51 [c] | X | 30 | X |
| DBEDT, 2002 | Hawaii | 1997 | 1.36 | 0.81 | 18.6 | 0.19 |
| Liu and Var, 1982 | Victoria, BC | X | 1.07 [b] | 0.37 [b] | X | X |
| **City** | | | | | | |
| Frechtling and Horvath, 1999 | Washington D.C. | 1994 | 1.18 [c] | 0.35 [c] | 18 | X |
| **Area of City** | | | | | | |
| Parlett *et al.*, 1995 | Old Town of Edinburgh | 1992 | 1.01 | 0.02 | 86.89[f] | X |

* =Direct and Indirect Effects unless otherwise specified

X = not reported

a. Employment multipliers show number of FTE jobs per $US million of output delivered to final demand.

b. Accommodation multipliers

c. Direct, Indirect and Induced Effects

d. Normal Multiplier

e. 1 million Tanzanian shilling = $US1,680.67 (1996)

f. 1 million GBP = $US1,872,500 (1992)

g. Tax multiplier makes up the remainder effect so that Income multiplier + Import multiplier sum to 1.

The summary in Table 2.1 closely matches Wanhill's tourist income multiplier table (Table 2.2)(Wanhill, 1994) replicated below, which summarises the mean and range of tourism income multiplier for different sized economies.

**Table 2.2: Comparison of Multipliers by Size of Economy**

| Area | Mean | Range | No. of Studies |
|---|---|---|---|
| National Economies | 1.67 | 1.23-1.98 | 4 |
| Island Economies | 0.85 | 0.39-1.59 | 18 |
| US States and Counties | 0.68 | 0.44-1.30 | 7 |
| UK Regions and Counties | 0.35 | 0.29-0.47 | 7 |
| UK Cities and Towns | 0.28 | 0.19-0.40 | 7 |

Source Wanhill, 1994

Several extensions of IO analyses, applied to tourism studies, appear in the literature. IO modelling and energy demand is an empirical extension of IO analysis undertaken by Tabatchnaia-Tamirisa *et al.* (1997). An energy matrix for Hawaii was developed in both absolute and coefficient form. In coefficient form, elements of the energy matrix represent intermediate and final energy and fuel requirements per dollar of industry output and final demand. Total energy and fuel use by tourists, $E_i$, was estimated as a sum of direct and indirect use, where indirect use is a product of the inverse Leontief matrix, vector of tourism expenditure and energy matrix:

$$E_i = (I - A)^{-1}.T.e_0 + e_f$$

where:

$E_i$ = Vector of total energy/fuel use by tourists by energy/fuel type;

$(I - A)^{-1}$ = Leontief inverse matrix;

$T$ = Vector of tourism expenditure;

$e_0$ = Energy matrix by sector; and

$e_f$ = Energy vector of final demand by tourists

The main finding of the study is that tourists account for a significant share of the total energy and fuel use in Hawaii. Differences exist in energy usage among the point of origin of tourist. Foreign tourists' indirect use of aviation fuel per dollar of tourist expenditures is about twice as high as that of domestic US tourists (not surprising given this type of tourist has to travel further to get to Hawaii) and indirect use of electricity per dollar of tourist expenditures is about 24% higher for foreign tourists than domestic tourists.

Table 2.3 shows the key findings for selected empirical IO analyses. There are several points to note from the table. Firstly, nearly all the IO model implemented were the standard model, estimating direct and indirect effects (Type I) and/or direct, indirect and induced effects (Type II) multipliers and their impacts. The literature does not include many examples of more sophisticated IO techniques outlined above. Second, the impact of tourism is seen as having solely beneficial impacts with few consequences on other sectors.

**Table 2.3: Summary of Selected Economic Impact of Tourism Studies**

| Researcher(s) | Economy | IO Analyses Used | Main Findings |
|---|---|---|---|
| Archer, 1995 | Bermuda | Standard IO for three different years | Tourism has major employment impacts. Income multiplier increasing over time due to efforts to increase the value added in sales. |
| Archer and Fletcher, 1996 | Seychelles | Standard IO incorporating multipliers by visitor point of origin | Tourism contributes approximately 24% to GDP. Impacts vary by visitor county of origin so that higher spending tourists have a greater economic impact. |
| Fleischer and Freeman, 1997 | Israel | Multi-regional IO model | Regional multipliers are smaller than the total multi-regional multipliers because regional multipliers include impact of leakages from the region, which are returned to it via interregional flows, and the impacts of other regions. |
| Frechtling and Horvath, 1999 | Washington D.C. | Standard IO both ratio and normal multipliers | Ratio multipliers are found to be more reliable than normal multipliers of total impact on earnings and employment. Multipliers were low relative to comparable U.S. localities. |
| Heng and Low, 1990 | Singapore | Standard IO incorporating multipliers by visitor point of origin | Tourism expenditure impact is quite uniform regardless of the tourist's country of origin and purpose of visit. Employment multipliers are relatively high. |
| Henry and Deane, 1997 | Ireland | Standard IO (Direct, Indirect and Induced Effects and Government induced effects) | Tourism accounts for 7-11% of national aggregates. International tourism shows a higher impact than aggregate exports of goods and services. |
| Liu and Var, 1982 | Victoria, BC | Standard IO (Direct, Indirect and Induced Effects) for the Accommodation sector by type of organisation (location, size, scale, affiliation and ownership) | Smaller multipliers were found for the central, the large, the affiliated, and the externally owned accommodation establishments because of smaller linkages in the local economy. |
| Parlett et al., 1995 | Old Town of Edinburgh | Standard IO (Direct, Indirect and Induced Effects) | Economic impact figures do not fully reflect the importance of the Old Town as a tourist destination. While tourists visit the Old Town much of their spending occurs outside of this area. Hence multiplier figures are extremely low. |
| West, 1993 | Queensland | Integrated Model: SAM and econometric analysis | Econometrics introduces a semi-dynamic structure to the model and the SAM adds detailed sectoral disaggregation. This provides superior analyses compared to the traditional IO techniques. |
| Wiersma et al., 2004 | New Hampshire | Standard IO (Direct, Indirect and Induced Effects) | Tourism output multipliers vary by region within a State. Multipliers are positively correlated with population size and the number of industries within a region. |

| Researcher(s) | Economy | IO Analyses Used | Main Findings |
|---|---|---|---|
| NZ Ministry of Tourism | America's Cup Defence 2003 | Regional IO (Direct, Indirect and Induced Effects) | America's Cup had a major positive economic impact for Auckland and New Zealand. |
| Wagner 1997 | Guaraquecaba, Brazil | Standard IO (Direct, Indirect and Induced Effects) and SAM | Tourism has a low impact on the economy due to the high import content. The greatest economic impacts are associated with rural farmers and subsistence households. There are relatively few linkages to other activities within the economy. |

## 2.5 Review of Applied CGE Modelling

Over the last three decades, with the increasing power and reliability of microcomputers and the development of sophisticated software, CGE models have been widely used in empirical economic policy analysis both for developed and increasingly for developing countries. This section first reviews a sample of applied CGE models investigating non-tourism issues. The purpose being to show the wide range of issues CGE models can address. The second part of this section reviews many of the applied tourism CGE modelling and compares IO model results with CGE model results. A summary of how these CGE models treat production, private consumption, external trade, sensitivity analysis and dynamics is found at the end of the section.

### 2.5.1 Review of Applied Non-Tourism CGE Modelling

This section briefly sketches out literature covering the wide range of economic issues that have been modelled using a CGE methodology. It showcases the wide range of topics including: international trade, public finance and taxes, energy and the environment including climate change, labour issues and economic development.

International trade has been a popular topic for research among CGE modellers. Trade policy analysis in developing countries is surveyed by de Melo (1988). Devarajan *et al.* (Devarajan, Lewis, & Robinson, 1990) specify, solve and draw policy lessons from small, two-sector, general equilibrium models of developing countries using a 1-2-3 model. Piermartini and Teh (Piermartini & Teh, 2005) survey and summarise the findings from five papers that examine the Uruguay Round and a further eight papers that examine the Doha Round.

There is a wealth of literature on the economic impacts of the trade policy analysis for different countries and trade blocs. Blake *et al.* (Blake, Rayner, & Reed, 1999) examines the effects of the Uruguay Round on agriculture, with special emphasis on the consequences for agriculture in the EU. Ines Terra *et al.* (Ines Terra, Bucheli, Laens, & Estrades, 2006) look at the impact of the labour market and poverty from the MERCOSUR trade bloc, a regional trade agreement among Brazil, Argentina, Uruguay and Paraguay.

Kitiwiwattanachai *et al.* (Kitiwiwattanachai, Nelson, & Reed, 2007) analyse the relative economic effects of four East Asian free trade agreement options. Hosoe examines the impact on the Jordanian economy of trade liberalization (Hosoe, 2001).

Another strand of literature focuses on the poverty alleviation aspects of trade policy modelled with CGE models. This is usually undertaken by reconciling and integrating results from a CGE model to a microsimulation studies using household surveys. For example Hertel *et al.* (Hertel, Ivanic, Preckel, & Cranfield, 2004) analyse the implications of multilateral trade liberalisation of poverty in Indonesia using this technique, whereby a modified version of the GTAP global trade model (Hertel, 1997) which generates price changes, are fed into a microsimulation analysis. Cororaton and Corong employ a similar methodology to examine the impact on poverty of substantial trade-policy reforms in the Philippines (Cororaton & Corong, 2006). Reimer (Reimer, 2002) reviews thirty-five studies examining the poverty impacts of trade liberalisation. Using a SAM, the calibrated data sets disaggregate the representative households into household groups specifying cohorts such as rural or urban, or by income deciles to analyse the impact on poor and non-poor segments. A study by Lofgren (Lofgren, 1999) is representative of how applied general equilibrium models have been used to analyse trade and poverty issues. Another example of this type of study involves estimating the welfare and poverty impacts of tariff reforms in Bangladesh (Khondker, Mujeri, & Raihan, 2006).

CGE modelling lends itself well to analysing public finance and taxation issues. Shoven and Whalley (1984) survey CGE applications on taxation and international trade. This review of nine applied general equilibrium tax models found that in general, efficiency costs of taxes may be more severe than had previously been supposed and that tax systems may be progressive in their distributional impact rather than proportional, the commonly held view. This same article (Shoven & Whalley, 1984) also reviewed applied general equilibrium models pertaining to international trade, finding that overall terms-of-trade effects associated with changes in trade policies can be significant.

A significant amount of research in the area of public finance and taxation looks at the marginal efficiency of different taxes and subsidies. Simulations involve changing tax rates on different sources and examining the efficiency and additional revenue yields from those taxes. This has been undertaken for various economies: Canada (Baylor & Beausejour, 2004), California (Berck, Golan, & Smith, 1996), Colombia (Rutherford & Light, 2001), the UK (Bhattarai, 1999) and the United States (Ballard & Medema, 1993).

Modelling energy and the environment has generated a large amount of CGE modelling literature. Early studies include research by Jorgenson and Wilcoxon (1990) and Whalley and Wigle (1990). Deverajan (1988) reviewed the literature on natural resources and taxation in developing countries using CGE models, finding that applications to natural resource questions fall into three categories: (1) energy management models, (2) "Dutch Disease" models that capture the effects of excess profits that accrue to exporters when the price of oil rises and (3) optimal deletion models that take into account the exhaustibility of the resource and the link between optimal extraction and investment decisions.

More recently, with the increasing focus on greenhouse gases and climate change, there is a growing literature examining energy / economic models. Among a myriad of other studies, Goulder (1995) looks at the effects of carbon taxes in an economy, Jensen and Rasmussen (2000) look at the effects of different ways of allocating $CO_2$ emissions permits under a tradable permit scheme and Arndt and Bacou (2000) examine the economy-wide effects of climate variability and climate prediction in Mozambique simulating the effects of a drought.

Weyant and Hill (1999) provide an introduction and overview to Energy Modelling Forum-16 (EMF-16), a comparative set of analyses of the economic and energy sector impacts of the Kyoto Protocol on climate change, undertaken by 13 modelling teams. Pinto and Harrison (2003) add a political dimension to climate change policy by added a political preference function to the CGE model to capture multilateral bargaining / negotiations. EMF-21 (Weyant, de la Chesnaye, & Blanford, 2006) continues where EMF-16 left off by including in the analyses the effects of including Non-Carbon Greenhouse Gases (NCGGs) and sinks (terrestrial sequestration) into short- and long-term mitigation targets.

Labour market issues, and specifically imperfections in the labour market, have been examined using CGE models by Annabi (Annabi, 2003), Kuster (Kuster, 2006) and Balistreri (Balistreri, 2002). These papers relax the assumptions of a neoclassical labour market and focus on endogenous labour supply, unions and efficiency wages and equilibrium unemployment.

The relevance of CGE modelling in the analysis for development policies is the subject of Dervis *et al.*'s book (Dervis, de Melo, & Robinson, 1982). Decaluwe and Martens (1988) review seventy-three applications of twenty-six developing country models while Cogneau and Robilliard use the previously mentioned CGE model / microsimulation model to look at growth, distribution and poverty in Madagascar (Cogneau & Robilliard, 2000).

### 2.5.2 Review of Applied Tourism CGE Modelling

It is only more recently that CGE modelling has also been undertaken specifically in the area of tourism. Adams and Parmenter (1992a, 1992b, 1995) first modelled the impact of tourism on the Australian economy. Since then, several authors have used CGE models to determine the effects of international tourism on Australia (Skene, 1993a, 1993b; Madden & Thapa, 2000) and the rest of the world: USA (Blake & Sinclair, 2002), Hawaii (Zhou, Yanagida, Chakravorty, & Leung, 1997), Spain (Blake, 2000) and the U.K. (Blake, Sinclair, & Sugiyarto, 2001b). A list of the CGE models applicable to tourism are presented in Table 2.4. As can be seen in the table, tourism impact studies have been carried out using CGE models in a variety of contexts. A variety of issues have been investigated and are reviewed below.

**Table 2.4: 18 Applications to 13 Economies**

| Study No. | Economy | Authors |
|---|---|---|
| 1 | Australia | Adams and Parmenter (1992a, 1992b, 1995); Dwyer *et al.* (2003b, 2006b) |
| 2 | Balearics | Polo and Valle (2004, 2008) |
| 3 | Brazil | Blake *et al.* (2005, 2008) |
| 4 | Cyprus | Blake *et al.* (2003b) |
| 5 | Fiji | Narayan (2004) |
| 6 | Hawaii | Zhou *et al.* (1997); Kim and Konan (2004) |
| 7 | Indonesia | Sugiyarto *et al.* (2002, 2003) |
| 8 | Malta | Blake *et al.* (2003b) |
| 9 | Mauritius | Gooroochurn and Milner (2004); Gooroochurn and Sinclair (2005) |
| 10 | Scotland | Blake *et al.*(2006); Yeoman *et al.* (2007) |
| 11 | Spain | Blake (2000) |
| 12 | UK | Blake *et al.* (2001b, 2003a) |
| 13 | USA | Blake *et al.* (2001a); Blake and Sinclair (2002, 2003) |

## Tourism Booms / Busts

Simulations using CGE models to estimate the economic impact of tourism have covered a range of different scenarios and policy possibilities. As such, these simulations could be categorised in a number of ways. The first category type examines tourism booms or adverse shocks. That is, an increase or decrease in tourism demand, for example 10%. Economic impacts are then estimated, examining the post-simulation economy compared to the base line economy. The second category type examines tourism and its relationship with other areas of economic interest, such as tourism and taxes (Gooroochurn & Milner, 2004; Gooroochurn & Sinclair, 2005), tourism and infrastructure demand (Kim & Konan, 2004) and tourism and trade (Sugiyarto et al., 2002; Blake et al., 2003b; Sugiyarto et al., 2003). Another way to segment the types of analyses that have been undertaken is to categorise the studies into 'generic' and 'contemporary issues' scenarios. The 'generic' studies would be those that examine the economic impact of a hypothetical tourism boom (for example, Zhou *et al.*, 1997), the other category being those scenarios that have attempted to replicate current events of the time and simulate alternative policies, such as the September 11, 2001 attacks in the US economy (Blake & Sinclair, 2002, 2003) and Foot and Mouth Disease in the UK (Blake et al., 2001b; Blake et al., 2003a). While these issues are contemporary, their applicability extends to other scenarios.

Reviewing the 'generic tourism boom' studies, Adams and Parmenter (1995) constructed a 117-sector general equilibrium model for Australia using the ORANI-F database. The effects of tourism were projected for key macroeconomic, sectoral and regional growth rates so the model is essentially static in nature, augmented with some simple dynamic relationships to examine medium-term effects.

The model simulates a 10 percent growth in tourism, so instead of tourist arrivals growing at seven percent, arrivals are assumed to grow at an average annual rate of 17% to simulate a tourism boom. The increase in tourism demand leads to an appreciation in the exchange rate, which leads to import substitution and the contraction of the traditional export sectors of mining and agriculture. This, together with the high import content of the tourism sector, leads to a worsening of the balance of trade. On the other hand, the tourism expansion helps to reduce the debt/GDP ratio. On an economy-wide basis, real GDP increases by 0.37%. Analysis on a regional level highlights interesting distributional effects of the simulated tourism boom. Queensland, the State which is more oriented towards servicing overseas tourists than the other states, was a net loser from an economy-wide expansion of tourism. While there were strong "first-round" effects for Queensland, this State was relatively hard hit by the crowding out of traditional export activities. Victoria, which does not rely heavily on traditional exports but has a large international airport, has the most to gain from a 10% annual increase in tourism (Gross State Product increase by 6.39%).

Blake (2000) undertakes a simulation of a ten percent increase in tourism for Spain as well as analysing the effects of tourism taxes. He found that national welfare increases by 0.05 percent of GDP, with a 0.61 percent appreciation of the real exchange rate, and that there are small increases in real private consumption, domestic tourism and investment. He further found that reductions in the value of non-tourism exports and increases in imports offset the increased revenues from tourism. Not unlike Adams and Parmenter, Blake found that while tourism and travel sectors grow by an average of

1.19% in output, agriculture and manufacturing experience reductions in output.

Another tourism economic impact study that simulates a ten percent increase in tourism expenditures is Narayan's Fijian model (Narayan, 2004). Tourism is Fiji's largest industry, with foreign tourism receipts earning the equivalent of 20% of GDP and employing around 40,000 people. A simulated ten percent increase in tourist expenditure results in an increase in total exports (1.65%) which outweighs the increase in total imports (1.09%), resulting in an improvement in the balance of payments. The additional tourism expenditure is estimated to have a positive impact on real GDP, which will grow by 0.5%, and the resultant increase in wages will contribute to a 1.9% increase in private disposable incomes leading to an increase in national welfare of 0.67%. An additional finding of this research is the estimated fall in Fiji's traditional export sectors of Kava and fish, and in manufacturing including processed food. This can be attributed to the fact that additional tourist expenditures induces a real appreciation of the exchange rate so the associated increases in domestic prices of goods and services and wage rates relative to foreign prices decrease Fiji's international competitiveness, especially for the traditional export sectors. This result has been noted by other researchers who model a tourist boom (Adams & Parmenter, 1992a, 1992b, 1995; Zhou et al., 1997; Blake et al., 2001a).

Dwyer *et al.* (2003b) employ a multi-regional general equilibrium model to estimate the effects of increased tourism on the economy of New South

Wales and the rest of Australia. Simulations were undertaken of the effects of an increase of 10% in world, interstate and intrastate tourism on the economy of New South Wales focussing on the assumptions that generate maximum impacts. Results show that intrastate and interstate tourism markets are potentially important generators of income and jobs for New South Wales. The impacts from intrastate markets depend on the extent to which intrastate tourism is substituted for tourism in the rest of Australia. Not surprisingly, international tourists generate the largest GDP and employment from an Australia-wide perspective as these represent net injections into the economy whereas for domestic tourists there is a degree of substitution between consumption in non-tourism goods and services.

Blake *et al.* (2008) simulate a 10% increase in tourism demand by foreign tourists to study the economic impacts and distributional effects of tourism expenditure. The results show that tourism benefits the lowest-income sections of the Brazilian population and has the potential to reduce income inequality. The welfare gain to Brazil is $0.45 for every $1 unit of additional spending. Yet the lowest-income households are not the main beneficiaries of an international tourism increase as next-to-low income households benefit to a greater degree due to earning and price channel effects of tourism expansion.

**Contemporary Issues**

Two studies that fall into the 'contemporary issues' category include Blake and Sinclair's analysis of the impacts of September 11 on the US economy

(Blake & Sinclair, 2002, 2003) and the research on the economy-wide effects of Foot and Mouth Disease in the UK economy (Blake et al., 2001b; Blake et al., 2003a). The September 11 study analyses not only the effects of the downturn in tourism but simulates the potential and actual policy responses to the crisis. These policy responses include the Air Transportation Safety and System Stabilization Act (ATSSSA) which the US Congress passed eleven days after the attacks and a six-point plan developed by the Travel Industry Recovery Coalition (TIRC), a group of industry members formed to lobby government for more action in response to September 11.

Blake and Sinclair categorise these policy responses in two ways. The first category involves policies of relatively low cost aimed at restoring confidence and increasing liquidity, such as the provision of credit or loans, low cost tax allowances and measures to limit the liability of businesses to acts of terrorism. The second category involves significant costs such as expenditure on compensation to airlines and measures to increase airline safety. As to the economic impact of this event, without any offsetting policy responses, the fall in tourism expenditures reduces Gross Domestic Product (GDP) by almost $US30 billion. With the implementation of these policies, the figure reduces to under $US10 billion. In terms of employment, the non-response unemployment figure is estimated to be 383,000 full-time equivalent (FTE) jobs lost because of the disaster. This is estimated to reduce to around 60% of that total with the policy interventions.

For the same tourism shock (September 11 terrorist attacks), Econtech, an independent economic consulting firm, estimated the economic effects on the Australian economy (Econtech, 2001). Around the same time of the attacks, Ansett Airlines, Australia's second domestic airline collapsed, reducing the capacity of the domestic aviation industry in Australia. Both these events are modelled separately and in combination using a CGE model. More specifically, the Ansett collapse was simulated through a four percent increase in the overall price of domestic travel packages due to higher domestic airfares as a result of lower competition. The 9/11 simulation involved a 15 percent decrease in inbound tourism arrivals for the Australian economy. The combined effects of these two simulations were estimated to incur a loss of travel exports of about 15% (A$500 million); a loss of transport GDP of about 3% ($A210 million); a loss of accommodation, cafes and restaurants GDP of about 4% ($A140 million); an overall GDP decrease of 0.6% ($A1 billion) and an employmenent decrease of 0.3% (28,000 jobs). The effects were forecast to be temporary in nature though, gradually fading away over the subsequent two years.

Continuing on the issue of crises, Dwyer *et al.* (Dwyer *et al.*, 2006b) explore the economic effects of the tourism crises of the Iraq War and SARS in 2003 on the Australian economy. They recognise that, while these events, resulted in less inbound tourism, they also resulted in less outbound tourism also so that the net effect on Austrlaia is not as severe as it might have been and depends to a certain extent on where the cancelled or postponed outbound travel is allocated to savings, domestic tourism or other non-tourism consumption.

The economic impact of Foot and Mouth Disease on the UK economy and its implications for tourism is modelled by Blake and Sinclair using a CGE model. The authors show that Foot and Mouth Disease (FMD) has considerable effects not only on agricultural production and farming industries but also on the tourism sector due to the inter-sectoral linkages and the effects of the ways in which the UK government handled the outbreak. The CGE model is linked to an econometric tourism demand model, the Micro-Regional Tourism Simulation (MRTS) model for the UK. The MRTS model estimates the direct effect of changes in tourism demand and these impacts are linked into the CGE model via a simulation of the estimated change in tourism demand (agricultural effects of FMD are simulated also through a reduction in exports of affected products). The MRTS results show that total tourism revenue in 2001 fell by almost £7.5 billion, which reduced GDP in 2001 by £1.93 billion as a direct result of tourism expenditure reductions. The total fall in GDP due to the FMD crisis for 2001 was £2.5 billion (around 0.28% of GDP). The fact that the fall in GDP is less than a quarter of the drop in tourism expenditures is due to "crowding in" – the opposite effect of the more familiar "crowding out" phenomenon. Labour and capital that was previously employed in industries satisfying tourism demand have substituted away to other forms of production. While the CGE model is not itself dynamic, the model is "advanced" annually from 2001 to 2004 with the simulated drop in international tourism expenditure falling as tourism rebounds after the crisis. The fall in international tourism expenditure is simulated to be 19% in 2001 and 2002 while in 2003 it is estimated to be 9.5% and in 2004, it will be a quarter of the level in 2001 (4.75% reduction). The corresponding fall in UK GDP due to the FMD crises is £1.46 billion, £0.49 billion and £0.25 billion for 2001/2, 2003 and 2004, respectively. Blake and Sinclair argue that the imposition of “restricted areas” that include historic sites and tourist attractions, closed countryside walking paths and waterways, and cancelled or postponed sports and public events had a larger impact on tourism than agriculture during the crisis.

Another economic impact study that was of ‘topical interest’ involves the CGE models of the Maltese and Cypriot economies and the impact of their accession to the European Union (EU) (Blake *et al.*, 2003b). The accession of Malta and Cyprus to the EU has a variety of effects on their respective economies. Nine effects of accession were simulated individually and as a collective. These effects were simulated for both the short-run and the long-run through varying the elasticity values in the models with long-run elasticities generally higher than the short-run model, because production technologies can be replaced over a long period of time. Overall, EU accession was found to be unambiguously and significantly beneficial to both the Maltese and Cypriot economies. In Malta, GDP will increase by almost four percent in the long-run because of accession. The welfare benefits of accession are 14% of incomes. In terms of employment, the EU accession of Malta is estimated to generate 3,559 FTE jobs in the long-run.  In Cyprus, GDP is estimated to increase by almost 3.5 percent in the long-run because of accession with welfare increasing by 6.2% of incomes. Significant job creation in Cyprus is attributed to accession, with 8,543 jobs being created. In terms of the impact on tourism, the effects of accession on tourism in Malta are negative but positive in Cyprus. The explanation for this is that the greater effects from trade and funding allocations lead to greater demand for factors of production in Malta that increase wages and divert resources away from tourism. In Cyprus, effects that benefit tourism outweigh the other general equilibrium trade-off effects.

**Tourism and Trade**

The issue of globalisation (trade) and tourism is investigated in the context of the Indonesian economy by Sugiyarto *et al.* (2002, 2003). A computable general equilibrium model of the Indonesian economy is developed to examine the effects of globalisation, specifically tariff reductions as a stand-alone policy and in conjunction with tourism growth. Tourism is a key sector for the Indonesian economy with the number of foreign visitor arrivals in 2005 estimated to be around 11 million, generating export receipts of $US15 billion. Three different scenarios as well as a combination of the scenarios are modelled. “Partial globalisation” is represented through a 20% reduction in the tariffs on imported commodities. “Far-reaching globalisation” is modelled through the previously mentioned tariff cuts as well as a 20% reduction in indirect taxation levied on domestic commodities. The increasing demand by foreign tourists is depicted by a 10% increase in foreign tourism demand.

The analysis concluded that the increase in foreign tourism demand will increase output (GDP increases by 0.1%) and employment (increases by 0.2%). When tourism growth is combined with increased globalisation, foreign tourism growth amplifies the positive effects of globalisation and, simultaneously reduces its adverse effects. The levels of GDP and employment are higher and, while the trade balance is in deficit, the deficit is lower than in the case of trade and tax liberalisation without tourism growth. The balance of payments deficit is also in a better position, owing to the increased income from foreign tourism.

**Tourism and Tax**

In the area of tourism tax, Blake (2000) examined the marginal impact of taxation across the whole Spanish economy and found that in Spain tourism and travel is relatively under-taxed compared to other sectors, mainly as a result of the large subsidies given to transportation sectors. Differences exist in the tax regime based on whether tourism is domestic or foreign in origin. Foreign tourism activities in Spain are highly taxed, relative to other sectors, but domestic activities are subsidised due to the lower rates of tax on tourism and the subsidised domestic travel. Via a simulation, Blake is able to show that raising the levels of taxation on foreign tourism may increase welfare because taxing foreign tourism effectively reduces some of the distortions created by the low levels of tax on domestic tourism.

Tourism tax is also the subject of research conducted for the Mauritian economy (Gooroochurn & Milner, 2004; Gooroochurn & Sinclair, 2005). Gooroochurn and Milner examine the effects of the reform of the current structure of indirect taxes in Mauritius, using a CGE model to explore the relative efficiency of changing rates of indirect taxation on tourist and non-tourist related sectors. The main finding is that for all simulated tax reforms, the tourism sectors are shown to be currently under-taxed. Given the current tax structure of that economy, taxation of tourism sectors is deemed to be the most socially-efficient means of raising additional tax revenue. The first simulation involves increasing production tax by 0.1% in each sector at a time and the second involves increasing sales tax by 0.1% in each sector at a time. To preserve fiscal neutrality, the additional tax revenue is transferred back to households. The authors find that the Marginal Excess Burden (MEB), the additional welfare cost of raising extra revenues from an already existing tax while holding other taxes constant, is lower for sales tax simulations than for the production tax simulations, for all sectors.

The results found by Gooroochurn and Milner (2004) are confirmed and extended by Gooroochurn and Sinclair (2005). Tourism taxes can increase domestic welfare since international tourists bear most of the welfare loss associated with the higher revenue. The two main tourism sectors (restaurants/hotels and transport/communications) have the highest MEB, resulting from the monopoly power associated with the differentiated tourism products, that is, tourist destinations and attractions are differentiated in terms of types and quality by destination.

The macroeconomic effects of taxation were examined through two simulations. One simulation involved the hotel and restaurant tax rate being increased and the second simulation, a broader policy, involved the sales tax rate of all five tourism sectors being increased simultaneously. While both simulations have a contractionary effect on GDP and increase inflation, the tax on the single industry (hotels and restaurants) results in more extreme results (larger decrease in GDP, higher increase in inflation). Unexpectedly, this single industry tax has larger welfare effects mainly because of the higher terms of trade effects. Higher terms of trade implies that the local economy can import and consume more for a given amount of exports and this fact outweighs the reduction in consumption as a result of the lower GDP.

**Tourism and the Environment**

The issue of sustainable tourism has grown as a research interest in recent years. Tourism and its impact on the environment has been the focus of several studies. Wattanakuljarus (2005) applied a CGE model of Thailand to look at the nationwide economic and environmental impacts of tourism. The expansion of tourism had predictable effects; an increase in real GDP, improvement in the current account deficit, an increase in the domestic inflation rate and an appreciation in the real exchange rate; but the tourism expansion resulted in extra water usage, relatively more piped water for non-agriculture sectors than for irrigated water for agriculture. Hence, net piped water usage and net wastewater discharges from the manufacturing sectors are higher than they otherwise would have been.

The issue of tourism and infrastructure demand has been examined by Kim and Konan (2004), contributing to the literature in the area of sustainable development. This research examines alternative scenarios for population growth and visitor spending in Hawaii in terms of the economic impact on urban infrastructure services (such as water, electricity, solid waste). The results are then projected into the future taking into account population, labour force and visitor expenditure growth rates (estimated exogenously from the CGE model). The key findings from this research include the result that economic activity and the resulting environmental consequences generated by residents are far greater than those generated by visitors. The impact of population growth is much more significant than visitor spending. This is a case where volume exceeds value, for while visitors consume more resources on a per day basis, there are approximately ten times the number of Hawaii residents as visitors present in Hawaii on any given day. These findings contrast with Tabatchnaia-Tamirisa *et al.* (1997) who estimated the derived demand for a primary input (energy) using input-output analysis and found that tourists account for a significant share (averaging 60%) of total energy and fuel use in Hawaii.

In a theoretical paper, Alavalapati and Adamowicz (2000) develop a simple two sector, two factor general equilibrium model to study the interactions between tourism, other sectors and the environment. The tourism sector is endogenised and modelled as a function of prices and environmental damage (both negative relationships – a rise in airfares and hotel rates will cause a decrease in tourism; a decrease in the environmental quality of a tourist destination will cause a decrease in tourism). The simulated imposition of a 1% environmental tax levied on each of the sectors of the regional economy shows contrasting results. If the tax is levied on the resource sector, the regional economy benefits if environmental damage is assumed to occur only from the resource sector activity. The reverse holds if the damage occurs from both resource and tourism sector activities.

Yeoman *et al.* (Yeoman *et al.*, 2007) considers the relationship of oil and the global economy and its relationship to Scottish tourism. Two scenarios are modelled. The first scenario, labelled 'energy inflation', includes a 500% increase in the price of oil, 300% increase in gases prices, 200% increase in electricity prices, all over 10 years and a 10% drop in capacity in Scottish petroleum due to falling oil reserves. The second scenario, labelled 'paying for climate change', includes a 250% increase in oil prices, 100% increase in gas and electricity prices, 20% sales tax (VAT) for the economy, 20% subsidy on rail transport and the same failing oil reserves assumption as the first scenario. At a macro level, the economic impact on overnight tourism is £1.3 billion for the 'energy inflation' scenario and £1 billion for the 'paying for climate change' scenario, reducing the growth rate for tourism from a 50% base line assumption to 28% in the first scenario and 22% in the second scenario.

**Tourism and Special Events**

It is now commonplace to conduct an economic impact study in conjunction with the bidding for sporting events (or other special events) to estimate the economic stimulus from the one-off event. The undertaking of an economic impact study can often be done to justify the governments' generous funding incentives and increased spending on games infrastructure. The general consensus is that hosting one-off games or international events brings social and economic benefits to a nation or region and hence these events are now highly sought after in many countries and regions internationally. Five examples of economic impact studies appearing in recent literature using CGE models are the 2003 South Pacific Games hosted by the Fiji Islands (Narayan, 2003), the 2012 London Olympics (Blake, 2005), the 2000 Sydney Olympics (Madden, 2002), the 2010 FIFA World Cup (Bohlmann & van Heerden, 2005) and the Qantas Australian Grand Prix 2000 (Dwyer, Forsyth, & Spurr, 2005). Dwyer *et al.* (2006a) show how CGE models can be adapted to estimate the displacement effects of events, their fiscal impacts, intraregional effects, event subsidies, and multistate effects – all of which are factors to consider when assessing the economic impact of events.

In general, the hosting of these large one-off events generates additional economic activity, bringing with it addition tourism. Narayan simulates the impact on the Fijian economy of 10,000 additional visitors. These additional visitors comprise 5,000 participants and officials and 5,000 spectators from outside Fiji. The simulation reveals a 0.36 percent increase in GDP with the increase in exports (1.21 percent) outweighing the increase in total imports

(0.89 percent) leading to a balance of payments surplus. The additional economic activity will generate additional tax revenue, government investment is likely to increase and these games are estimated to add to private disposable incomes and boost private savings. With real consumption increasing, an improvement in national welfare by 0.51 percent is expected. In sum, the tourism expansion brings about an appreciation of the exchange rate, coupled with increasing domestic prices and wages, the traditional export sectors experience a decline, leading to declining exports. Yet the decline in the traditional export sector is more than offset by the increase in tourism and non-traditional exports.

Blake (2005) examines the economic benefits and costs of hosting the 2012 Summer Olympics using a dynamic CGE model of the UK and London economies over a period of 12 years: 2005-2016. As a result of London hosting the 2012 Olympics, the total net UK GDP change is £1.9 billion. This impact can be separated into a pre-Games impact, during-Games impact and post-Games impact. The main GDP gain occurs in the Games year, 2012 (£1,067 million), with larger gains occurring in the post-Games period (£622 million) than the pre-Games period (£248 million). For the city of London itself, there will be a larger impact on GDP, with £925 million additional GDP in 2012, £3,362 million in the pre-Games period and £1,613 extra GDP post-Games. The increase in national welfare (as measured through Equivalent Valuation) attributed to hosting the Games is £736 million and for London, the same figure is £4,003 million. The regional impacts are larger than the national impacts for several reasons: spending in London by non-

London UK residents visiting for the Games and the movement of the labour and capital to the capital as higher wages and lottery funding attract workers and money to London.

Employment impacts are estimated to be an additional 8,164 FTE jobs nationally with 3,261 jobs created in the Games year. Not surprisingly, the impact of the Games will vary significantly across different sectors of the UK economy with those sectors not directly related to the Games growing at a slower rate than they would have had London not won the Games bid to host the 2012 Summer Games.

Madden (2002) assesses the economic impact of the Sydney Olympics on the NSW (New South Wales) and Australian economy. The effects of Olympics construction and operating expenditure and of spending by Games visitors and additional tourists are modelling over a 12 year period, under specific assumptions regarding the Australian labour market, capital supply constraints and Australian government policy on foreign debt. For the tourism simulation, the number of international visitors associated with the Olympics is 1.6 million over an eight-year period; 132,000 being Games and Games-related, the remaining 1.5 million being additional tourists visiting Australia as a result of the promotional effect of the Games. Extra tourism export receipts are estimated to be just over $A2.9 billion as a result of the Olympics with over $A2.7 billion being the induced effect. The macroeconomic effects of the Games include an estimated increase of almost $A490 million in NSW Gross State Product in an average year over the 12 years ending in 2005/06. Cumulatively, this has a present value of $A5.1 billion. Nationally, the present value impact of the Olympics on GDP was estimated at $A6.5 billion (0.12% on average over the 12 years). Hence, a large majority of the economic impact remained in the host State of NSW. Only around 40% of the increase in GSP comprised an increase in real household consumption. Most of the Olympics-induced increase in GSP/GDP went into increased investment and foreign borrowing for capital expenditures. The Olympics were estimated to have positive employment effects: an additional 5,300 and 7,500 jobs would be generated for NSW and Australia respectively, in an average year over the 12 years.

Bohlmann and van Heerden (2005) examine the impact of the pre-event phase expenditure attributable to the hosting of the 2010 FIFA World Cup on the South African economy. This phase is mainly geared towards the construction and improvement of infrastructure required to successfully host the event. The simulated shock to the capital stock in the construction and transport industries and a capital-augmenting technological change in these same industries is estimated to have a positive impact on most macroeconomic variables, including GDP and employment.

Several key issues arise for these economic impact studies on sporting events (or cultural events). Firstly, even for an event as large and complex as the Olympics Games, the overall economic impact is quite small (Madden, 2002). The overall estimated impact on Australian GDP is that it will be 0.12% higher over the 12 years than if the 2000 Games had not been held in Sydney.

For the 2012 London Olympics, the total economy-wide impact for the UK over the 2005-2016 period is only 0.119% of total UK GDP at 2004 prices. It is important not to make over-optimistic projections of the effects of mega-events. Secondly, leading on from the first point, there are a large number of smaller sporting and cultural events. Typically, event organisers tend to expect their events to be economic boons. While at a regional level, these events can boost the local economy; on a national level the events tend to attract resources to these activities, away from other activities.

**IO models and CGE models: Comparative Studies**

Several pieces of research have attempted to compare and contrast the results from IO analysis and a CGE model using the same IO table. These studies have compared the same simulated scenario using both an IO model and a CGE model with the same set of data. Used as a way of comparing the differing methods of analysis, studies of this nature have begun to highlight the advantages of CGE modelling over IO modelling. One such study was conducted by Zhou *et al.* (1997), who simulate a ten percent decrease in visitor spending in Hawaii using both a CGE model and an IO model. They find, not surprisingly, that output is reduced in the characteristically "tourism" sectors such as hotels, transportation and restaurants and bars more than in other sectors in the economy for both models. While output changes are generally of the same order of magnitude for each sector, the IO model results are larger in terms of percentage reductions. This, it is argued, is due the generated price effects in the CGE model (that are absent from the IO model). The CGE model allows for resource reallocation between sectors and allows greater modelling flexibility. It is deemed to have clear advantages over IO modelling for tourism.

IO modelling overestimates the total impact on GDP, underestimates the total effects on tourism sectors and completely misses the negative effects on non-tourism sectors (Blake et al., 2001a). In showing CGE modelling to be a superior methodology for analysing the economic impacts of tourism, Blake *et al.* (2001a) simulate a ten percent increase in foreign tourist expenditures for the US economy. This ten percent increase, $US 9.6 billion, results in a $US 5.8 billion (approximately 0.1% of GDP) increase in economic welfare, as measured by equivalent variation. This CGE-based result compares to a direct impact of $US 4.5 billion and an input-output-based estimate of $US9.4 billion. The reasons for the differences are three-fold: (1) a large proportion of the direct expenditures leads directly to purchases of intermediate inputs, giving a low direct expenditure impact figure; (2) the IO figure has no crowding out and there is little import leakage so almost all of the expenditure leads to increased GDP; (3) the CGE result includes significant levels of crowding-out and resource reallocation.

Another comparative study has been conducted by Polo and Valle (2004, 2008) who model a ten percent reduction in tourist expenditures on the Balearic economy using an IO model, a SAM model and a CGE model. As mentioned previously, the IO modelling and SAM modelling are similar in that they are linear models. The main difference between these two models is that in the IO model, only the production activities are endogenous to the model while for the SAM model, primary factors' income, residents' income and the capital account are endogenous. This results in higher feedback effects in the SAM model due to the links between productive activities and the generation, distribution and use of income. For the ten percent decline in tourism, total output (sales) of the Balearic economy in the SAM model would fall by 5.2% while for the IO model, the equivalent figure is 2.8%. This observation holds for other economic measures such as value added and employment. In contrast, the CGE model predicts that a ten percent drop in tourism will cause an increase in private investment of nearly 30% and that real GDP will increase by 0.3%, with the construction and machinery sectors seeing the largest expansions (19.2% and 11.7% respectively). Here, we see a "crowding-in" effect for other sectors when tourism declines. Interestingly, unemployment only decreases marginally, from 11% to 10.5%, as labour is reallocated throughout the economy.

All the CGE results contrast with the results of Input-Output studies which show that increased tourism leads to across-the-board expansion of activity.

**Treatment of the Production, Private Consumption, External Trade Blocks, Sensitivity Analysis and Dynamics**

This next section reviews the model specifications for the tourism CGE models, highlighting some of the common characteristics that these models exhibit.

**Production**

Reviewing the models listed in Table 2.4, there is a high degree of sectoral disaggregation in the tourism CGE models. This relates more to the detail contained in the underlying IO table or SAM, though, than choice by the modeller. Similarly, most of the studies surveyed are characterised by aggregated labour and capital as their factors of production, although several studies have disaggregated labour. In terms of the functional forms employed, nearly all of the studies specify nested production functions. At the top level of production, output is a Leontief fixed coefficients function of value added and intermediate inputs for each commodity. Value added is a Constant Elasticity of Substitution (CES) function of labour and capital inputs and the intermediate inputs are a CES function of domestically produced and imported commodities.

**Private Consumption**

The majority of studies surveyed only include one representative household, the exceptions being Indonesia (Sugiyarto et al., 2002; Sugiyarto et al., 2003), Mauritius (Gooroochurn & Milner, 2004; Gooroochurn & Sinclair, 2005) and Brazil (Blake *et al.*, 2008). Consumption tends to be treated as either a Linear Expenditure System (LES) or as a Cobb-Douglas function.

**External Trade**

An output transformation function, which is algebraically equivalent to the CES function, is used to transform output into domestic output and exports. The elasticity of transformation determines how readily suppliers can switch production between domestic and export markets. Generally, it is assumed that export goods and domestic goods are not identical (Armington, 1969). They may be of different quality or different grades for example.

Many of the studies rightly make the small-country assumption that world prices are taken as given. Nevertheless, for several studies, relative prices play a role so there is positive and finite foreign demand price elasticity. Other studies assume exogenous exports.

**Sensitivity Analysis**

One of the main limitations of CGE models in general is the dependence of the results on the estimated values of key parameters (Blake, Gillham, & Sinclair, 2006). This limitation means that it is difficult to choose appropriate elasticity and other parameter values. Very rarely are the elasticities to be used in the specific CGE model estimated econometrically for the same economy for the same time period (Shoven & Whalley, 1984). Hence it is prudent to conduct sensitivity analyses with regard to the value of the elasticities used in the models. Despite this, sensitivity analysis is the exception rather than the rule.

To determine how sensitive his findings are, Blake (2000) undertakes a limited sensitivity analysis where, for the six elasticities in the model, the parameters are doubled in value. Blake concludes that the results are reasonably insensitive to changes in these elasticity values. Sugiyarto *et al.* (2002, 2003) conduct a similar sensitivity analysis to test the robustness of their results. Export demand elasticities are doubled and the model is re-run. In general, the sensitivity analysis shows the robustness of the results, which are consistent with theoretical predictions; that is, higher export demand elasticities will produce larger impacts on the quantity variables, for any given policy changes. Blake *et al.* (2003b) add further analytical rigour to the Malta and Cyprus EU Accession research by implementing a systematic sensitivity analysis with regard to elasticity parameters, where a ‘Monte Carlo’ procedure was used to construct a range around the central estimate of the parameters used in the main model and 100 simulations were conducted.

**Dynamics**

Most of the studies reviewed are solely static in nature. In eight of the fifteen studies, some elements of a time dynamic occur. In all of these cases, however, the dynamic element is essentially practical and not based on the existence of intertemporal individual profit or utility functions but instead built around the adoption of greater values for production elasticities (Blake *et al.*, 2003b), internal mobility of capital (Zhou et al., 1997; Blake et al., 2003b) or exogenous changes in pre-determined variables such as population or visitor growth rates (Kim & Konan, 2004). For example, the dynamic structure of the model used by Adams and Parmenter (1992a, 1992b, 1995) does not allow for intertemporal optimisation by consumers. It is what might be termed an "integrated" model as opposed to a dynamic applied general equilibrium model. The model is "integrated" in terms of combining a static general equilibrium model with econometrically estimated growth rates. These growth rates are then used to project results into the future.

## 2.6 Discussion

> *"Input-output analysis is without question the most comprehensive method available for studying the economic impact of tourism."*
>
> Fletcher, 1989, p528

Tourism modelling has come a long way since 1989 and what may have been true back then, is not true today. In fact, the study of the economic contribution of tourism has recently "undergone a 'paradigm shift' as a result of the use of CGE models" (Dwyer, Forsyth, & Spurr, 2003a p117). This section outlines some of the problems with Input-Output modelling (see Briassoulis, 1991 for a review of the methodological issues surrounding IO analysis) and highlights some of the problem areas that CGE modelling can overcome. This will be followed by a discussion of where further developments can be made in the literature on estimating the economic impacts of tourism.

As was mentioned previously, one area of confusion with IO modelling is in the terminology. Archer (1984) points out the misunderstanding of the "ratio" approach, where the direct plus indirect income (in the case of Type I) is expressed as a ratio of the direct impact. This "ratio" multiplier expresses the degree of inter-linkage which exists between sectors within an economy. This is in contrast with the "normal" multiplier which is expressed as the amount of income generated in the economy by an additional unit of tourist expenditure. The IO multiplier research does not always make this distinction to the reader. This criticism is re-iterated by Hughes (1994) who goes on to cite other problems with IO modelling and multiplier analysis such as the occasional use of multiplier values from other study areas or from the same geographical area over different time periods. In the case of specific events or festivals where the tourist spending is event-induced, some trips would have occurred anyway, or the timing of events may have been switched so the expenditure is not a net addition. With regard to employment multipliers, jobs may be indivisible and discontinuous and the effects of tourism may be marginal. The implication of multiplier analysis is that without the expenditure, these jobs would not exist.

Another terminology issue, outlined by Wanhill (1994), is the treatment of income and whether or not direct taxes on income and social insurance contributions should be attributed to the household sector. One line of thinking suggests that they should be removed from income of the local economy as they are normally deducted at source and paid outside the area.

The other line of thought says that taxes are a leakage that is part of the national income accounting framework and hence should be included. Again, there remains confusion and often researchers do not specify which definition is being used.

Despite the aforementioned difficulties, it is the restrictive assumptions of IO modelling that are most problematic and lead to incorrect conclusions. This so-called 'Standard View', as Dwyer *et al.* (2000) classify IO modelling, sees increased tourism expenditure having direct, indirect and induced effects on a tourist destination, leading to increased output, income and employment. However, there are several downsides to IO analysis due to some of the analysis' restrictive assumptions. One limitation is that there are no constraints limiting the capacity of industry to expand production to meet the additional demands of tourists. In reality, an expanding tourism sector tends to 'crowd out' other sectors of economic activity, reducing the demand for traditional exports and import competing industries. Although the increased tourism demand may, in part, be met by a net increase in domestic output (if there is significant excess capacity in tourist-related industries, or in the economy as a whole), the principal outcome of an expansion in tourism is to change the composition of the economy (Dwyer *et al.*, 2003a). The extent of the crowding out depends on the characteristics of the labour market, changes in prices and the real exchange rate, and the macroeconomic policy context.

An IO model contains no pricing mechanism and hence it cannot incorporate the effects of changing factor costs within its framework. Further restrictions include:

- Constant technical coefficients ignore changes in input mix due to price-induced substitution between factors.
- Linear and additive input-output relationships ignore interactive effects between economic sectors.
- There is no distinction between gross output and employment effects of increased tourism and the net effects after taking into consideration general equilibrium effects.
- IO modelling does not take into account flow-on effects through the trade sector or impacts via the Public Sector Borrowing Requirement (PSBR).

The main difference between IO models and CGE models is that the former excludes key economic relationships. As outlined by Blake (2005), IO models impose no constraints on the amount of extra income that can be earned by labour and capital. CGE models impose constraints on the availability of these factors of production. Whether the supply of these factors is variable or fixed, the price of these factors will adjust so that the quantity supplied will satisfy demand. Further, CGE models impose constraints on income and expenditure so that income equals expenditure for the economic agents in the model, for example, government and households. This additional complexity contained in CGE models means that economic impacts can be measured more accurately. IO models can measure all the positive impacts but are unable to model most of the negative impacts. As such, they overestimate economic impacts (Dwyer & Forsyth, 1998). CGE models provide more realistic results, offering results that take account of the movement of prices and their interaction with real values.

In the empirical context, CGE models investigating the impact of an expansion in tourism demand result in the increased use of resources. Increases in prices attract resources into the tourism-related sectors, increasing the industries' costs and making the destination less competitive. The size of these increased costs depends on the supply of the factors of production and what proportion of the tourism-related industries' total production costs are accounted for by these factors. In the case where resources are drawn away from traditional export-oriented industries, increased production costs occur for these industries resulting in a loss of production and employment. If tourism growth increases investment, then pressure is exerted on the real exchange rate, increasing the feedback effects for the period of capital inflow (Dwyer et al., 2000). If tax increases or borrowing is used to finance any increased government consumption associated with tourism growth, then private consumption may be crowded out, limiting the positive effects on income and employment. The impacts outlined here can be simulated in CGE models but cannot be taken into account in IO models.

CGE modelling is not only a superior theoretical and empirical model of how tourism impacts an economy but has important implications for destination marketing organisations. Dwyer *et al.* (2000) outline three ways in which CGE models can make an impact on policy: tourism as a catalyst for growth, cooperative destination marketing, destination competitiveness.

Despite the clear advantages of CGE modelling over IO modelling, several objections to CGE models remain. Dwyer *et al.* (2004) outline both the objections and a response to the objections. When CGE models first started to be introduced into the literature, it was argued they were too time consuming to build and too complicated to use. In response to this, it should be noted that increasingly powerful personal computers and faster algorithms are now available. Moreover, much of the time needed to build the model can be due to the construction of the underlying IO table or SAM, which is used in both model methodologies. Further, the issue of a more realistic model should outweigh convenience.

Another line of argument is that CGE modelling and IO modelling produce very similar output so the additional complexity of CGE modelling is unjustified. However, as shown above with the comparative studies, the results can be very different. It can be true that if CGE modelling is specified with the same restrictive assumptions as an IO model, then the results may be similar but with more plausible assumptions, which recognise resource constraints and the ways in which the labour market works, IO models and CGE models will typically give very different results.

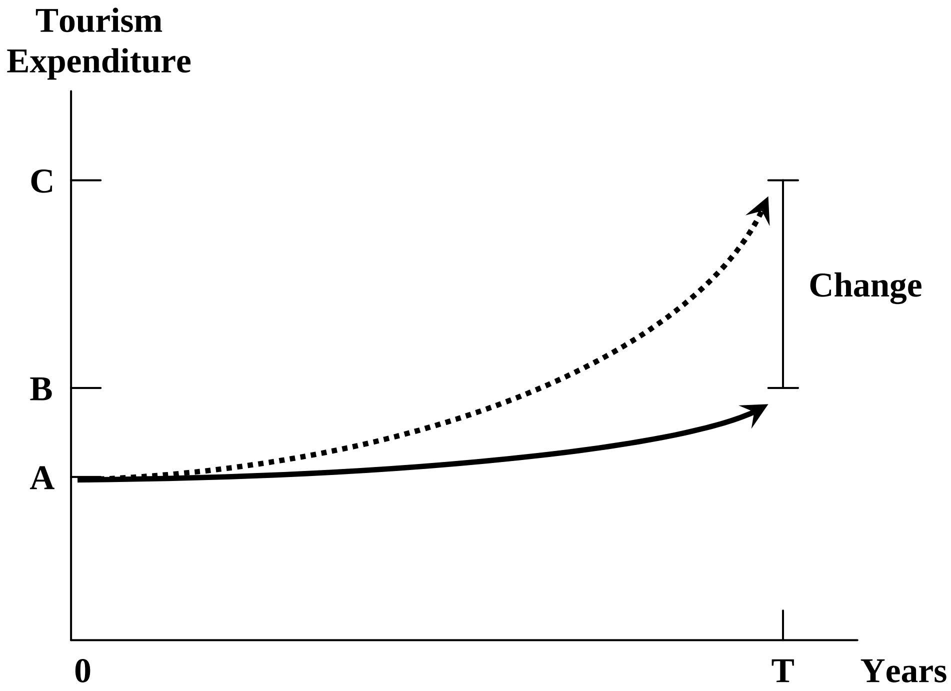
For analysing local impacts, though, there may be an argument for using IO modelling over CGE modelling. So if the research objective is to examine the economic impacts of a local event or project on the local area, then a local IO analysis could be undertaken. The reason for this is that the IO assumption of freely available resources is closer to reality in the local case, as labour and capital can flow into the area from other areas and the change in quantities supplied and demanded at the local level will not impact prices.

## 2.7 Future Research Requirements

As noted above, more recent analyses on the economic impact of tourism have examined not only the effects of tourism growth on an economy but also tourism's interaction with other economic variables of interest such as trade and globalisation, infrastructure, natural resources and taxation. However, there is very little research in these other areas. Many of these areas could be expanded and built upon. For example in the area of infrastructure, additional tourism will make use of public infrastructure, such as roads, imposing costs in providing and maintaining it. By making public spending a function of population and tourism, this area could be explicitly included in a model (Dwyer *et al.*, 2004). Other extensions pertaining to this area include congestion costs, environmental damage, and positive externalities from tourism such as gains from economies of density, for example more frequent flights between cities as a result of additional tourism. Conventional CGE modelling does not incorporate the costs of environmental degradation or loss of scenic attractions that are valued for their contribution to their standard of living, but do not appear in the industry cost of production. In principle, these issues could be included in a CGE model. Dwyer *et al.* (2000) then suggest that the CGE model output could then be utilised for cost-benefit analyses of such issues.

Dynamics and endogenous growth is another under-explored area in tourism economics. Several CGE models are dynamic, for example the MONASH model of the Australian economy, and as mentioned above, some form of dynamism exists. As Devarajan (1988) pointed out, in the context of CGE models in a natural resource allocation context, there is a need for more work on dynamic modelling. Many of the models reviewed above can be termed "comparative static" models. The model provides projections at only one point in time, which is the solution year (even though the model projection may be 'advanced' in time to allow for growth rates of exogenous variables). The model refers implicitly to the economy at some future period to ensure the economy adjusts after the initial shock. This can be portrayed visually in Figure 2.3, which graphs the values of a variable - tourism expenditures for example. Here, Point A is the level of tourism expenditures in the base period (period 0). Suppose there is an exogenous shock of a 10% increase in tourism demand in period 0. As a result of this shock, the level of tourism expenditures increases to Point C in T years time. Without the shock tourism expenditures would grow to Point B. The movement from Point A to Point B can be interpreted as the underlying growth path of tourism expenditures. Comparative statics is only concerned with the size of the gap between Point B and Point C. A dynamic simulation is concerned not only with this gap but also the economic path taken to reach Point B and Point C. There is little research in tourism economics that examines this process.

**Figure 2.3: Comparative Static Interpretation of Results**




Simply adding a time subscript to all variables is not sufficient. Intertemporal budget constraints must be added. Uncertainty about the future values of such variables as prices and wage rates has been an overriding concern among policymakers. Hence there appears to be a case for incorporating some form of stochastic decision-making in a CGE model's specifications. Dwyer *et al.* (2004) spell out the implication for tourism research:

> *..when there is an interest in the adjustment process, for example, how long it takes for a shift in tourism flows to influence other variables in the economy,*

> *then a dynamic framework is required"*
>
> Dwyer *et al.*, 2004, p314

Other areas for further exploration include the possibility of disaggregating tourists to examine their economic impact. Visitor surveys usually segment their samples by categories such as country of origin and by purpose of visit, length of stay and accommodation type used. Hence, the direct effects of the visitor impacts are calculated. More research could be conducted on the full impacts of different types of visitors as traced through a CGE model, given disaggregated source data.

The issue of investment and more specifically a tourism-related investment has not been examined in the literature. Analysis using a CGE model is one way to assess the economy-wide effects of more tourism-oriented investment, focussing attention on the advantages and disadvantages of domestic versus foreign investment. Dwyer and Forsyth (1994) argue that much confusion still exists about the impact of foreign direct investment in tourism on a host economy.

All of the simulated tourism shocks, be they positive or negative, have been deterministic in nature. Regardless of whether the simulations across the range of CGE models in the literature are hypothetical or sourced from real world policy decisions, no economy-wide models have explicitly included risk in the model. CGE models to date and their simulations to date have been deterministic in nature. By definition, a model of this type would be to be dynamic, in the sense that the path of the economy will need to evolve over time. As mentioned above, little CGE modelling work has been done for tourism in a dynamic framework. Risks and uncertainties need to be modelled over time, that is, uncertainty in tourism demand implies concern for the future and the process of adjustment is important.

## 2.8 Conclusions

The importance of tourism to economies is well recognised. Estimating the economic impact of tourism has traditionally been undertaken using IO models. IO models can estimate the direct, indirect and (if the household sector is assumed to be endogenous) induced effects of tourism. These types of studies invariably show that increased tourism leads to significant additional economy activity in excess of the initial spending increase. But IO models are essentially an interim measure. Due to their generally unrealistic assumptions and incomplete representation of the way an economy works, IO models may give misleading results. In reality, economies are general equilibrium systems. As such, indirect and feedback mechanisms as well as direct impacts are important. Any measures of the impact of a change, such as the expansion of tourism, must take into account the positive and negative impacts on economic activity. CGE models not only have an IO model embedded in them but also other markets, and the links between these markets are modelled explicitly. CGE models are underpinned by microeconomic theory of the consumer and firms. That is, consumers maximise their utility subject to their budget constraint while firms maximise their profits subject to their costs and given technology.

The key mechanisms which determine the size of the economic impacts as a result of increased tourism demand are factor supply constraints, exchange rate appreciation and current government economic policy (Dwyer *et al.*, 2000). In general, the economic impacts of a tourism boom, as modelled with a CGE model, sees an increase in economic activity or output as measured by GDP that is lower than IO model estimates, as well as a change in the composition of economic activity.

While the examination of a tourism boom has been the most common simulation, several studies are now starting to examine the role of tourism and its impact on other areas of the economy. Globalisation, taxation, infrastructure, sporting events and topical issues such as 9/11 and Foot and Mouth Disease in the UK are just a few of the ways in which research in the area of the economic impact of tourism has expanded in the last few years. There is scope for future developments in understanding the economic impacts of tourism. The environment, investment, the uncertainty of exogenous shocks and dynamic effects are all areas where further contributions can be made.

With several gaps in the literature, this thesis will focus on estimating the economic impact of tourism where there is risk or uncertainty regarding the size and timing of future tourism shocks to an economy. As mentioned in

Chapter 1, the context of this research will be the economy of Hawaii. The next chapter, Chapter three highlights some of the pertinent features of the economy in Hawaii and more specifically tourism in that destination.

# CHAPTER THREE

# HAWAII'S ECONOMY AND THE 2002 INPUT-OUTPUT TABLE

## 3.1 Introduction

The word 'Hawaii' conjures up images of white sandy beaches, crystal clear blue water, hula dancers in grass skirts and possibly volcanoes spewing lava into the air. As well as an idealised destination image, this economy provides a good stylised small island economy that is interesting as a context for research as it is also a region (State) of the USA, and thus has implications for regional analysis. It is geographically separated from the rest of the United States and exhibits characteristics of a small island tourism economy, not unlike Malta, Cyprus, Mauritius and many of the Caribbean islands where tourism is the primary industry. As such, it is well suited to testing economic models (Kim & Konan, 2004). This chapter describes the fundamental characteristics of the economy of the State of Hawaii and chronicles the underlying Input-Output table that will be used as a benchmark for the CGE modelling conducted in later chapters. The first section of this chapter will describe the trends of the main macroeconomic indices over the last few decades, showing how Hawaii has essentially shifted from an agricultural based economy to a tourism based economy. This section will note key features of the economy which will shape some of the assumptions made about the CGE model. For example, would it be more appropriate to incorporate a flexible labour supply into the CGE model or is the economy operating under the assumption of full employment? The answer to this question is an empirical one. The second section of this chapter will take an in-depth look at the role tourism has played in the Hawaiian economy. Tourism demand will be the source of the external shock to the economy. Hence it is important to understand the nature of tourism in Hawaii from both the demand and supply side. The last section of this chapter will outline the structure of the 2002 Hawaii Input-Output table, which will be used as a benchmark to calibrate the CGE models detailed in later chapters.

## 3.2 Hawaii's Economy

This section places the economy of Hawaii in context and examines the movement of several macroeconomic indices across time. Understanding some of the characteristics of the Hawaiian economy will aid interpretation of the CGE results.

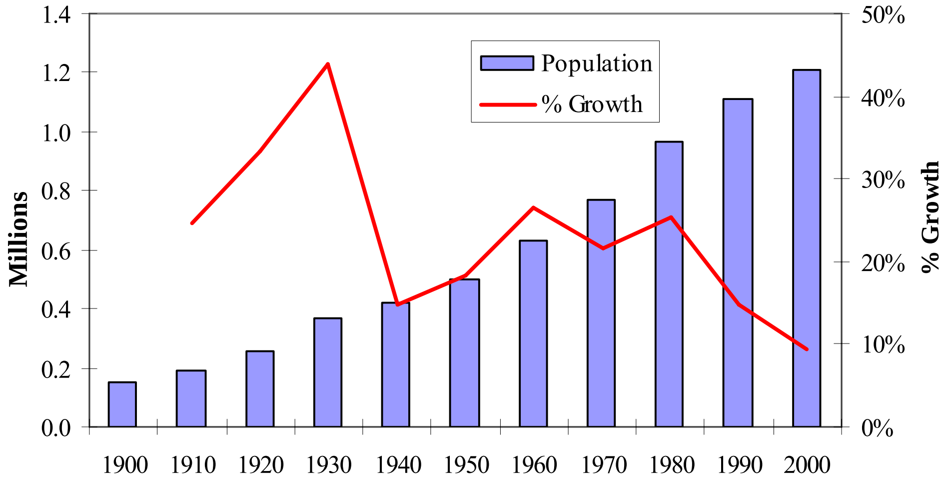
### 3.2.1 Historical Context

Hawaii was discovered by Polynesian settlers between the 3rd and 7th centuries A.D. Although several European traders had visited the islands in the mid 1700s, it was Captain James Cook, the British explorer, who landed in 1778 and established a semi-permanent Western presence there. Hawaii is a string of 137 islands encompassing a land area of 6,422.6 square miles in the north central Pacific Ocean about 2,400 miles from the west coast of the continental United States. Stretching from northwest to southeast, the major islands are: Ni'ihau, Kaua'i, O'ahu, Moloka'i, Lana'i, Kaho'olawe, Maui and Hawaii. Seven of these 8 islands are inhabited, Kaho'olawe being the exception. Honolulu, the capital city, is on the Island of O'ahu. Hawaii became the 50th State of the USA on August 21, 1959. From a governance point of view, there are four counties with mayors and councils, namely, City & County of Honolulu (the Island of O'ahu and the Northwest Hawaiian Islands excluding Midway), Hawaii County (Hawaii Island – also referred to as the Big Island), Maui County (Islands of Maui, Moloka'i, Lana'i and Kaho'olawe) and Kaua'i County (Islands of Kaua'i and Ni'ihau).

The two levels of government in Hawaii are state and county. Counties perform most services usually assigned to cities and towns (fire protection, police, refuse collection, construction and maintenance of streets and other public works).

In 2006, the State resident population was 1,285,498. Hawaii's resident population has experienced only modest growth between the last two US Censuses (0.9% per year between 1990 and 2000 – Figure 3.1). Over the course of the 20$^{th}$ Century, the average growth in the resident population of the State has been approximately 2.3% per year (US Census, Population Division, Table NST EST2004-01).

**Figure 3.1: Hawaii's Population Growth**

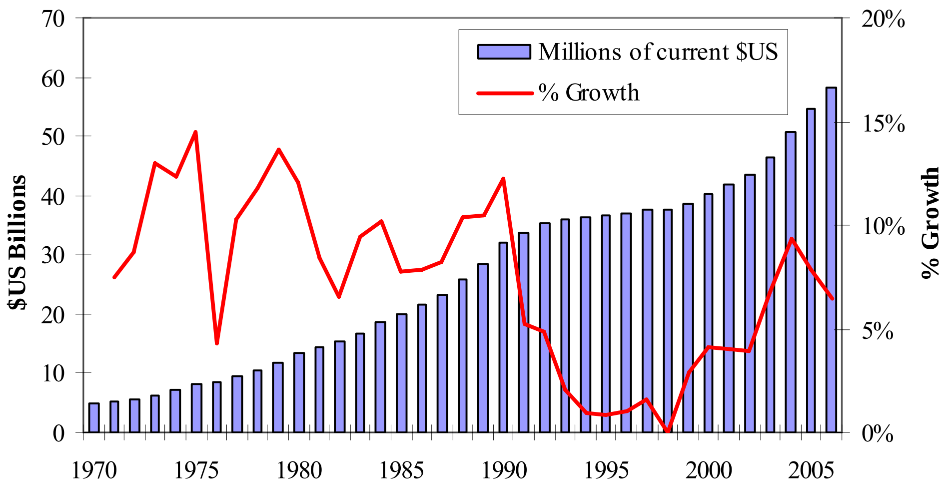



Just over 900,000 of the population reside on Oahu (City & County of Honolulu). This comprises 71% of the state-wide population. Hawaii County holds 13% of the resident population while the proportion of residents that reside in Maui County and Kaua'i County is 11% and 5% respectively (DBEDT, 2006). Over the last 16 years Oahu's share of the population has decreased gradually from 75.3% in 1990 to its present level. Over the same time period, Hawaii County's share has increased 2.4 percentage points. Kaua'i County's share has increased 0.3 points while Maui County's share of the total population has increased 1.9 percentage points.

### 3.2.2 Gross State Product and Income

In 2006, Hawaii's Gross State Product (GSP) stood at $58.387 billion in current US dollars. While the State economy has experienced an upswing since 1999, it has not always been this way. Through the 1980s, Gross State Product grew by an average of 9.1% per annum. Much of this growth can be attributed to strong tourism growth as well as the Japanese Bubble economy. In contrast, as can be seen in Figure 3.2, growth in Gross State Product only averaged 3.2% per annum throughout the period 1991-1999.

**Figure 3.2: Hawaii's Gross State Product**

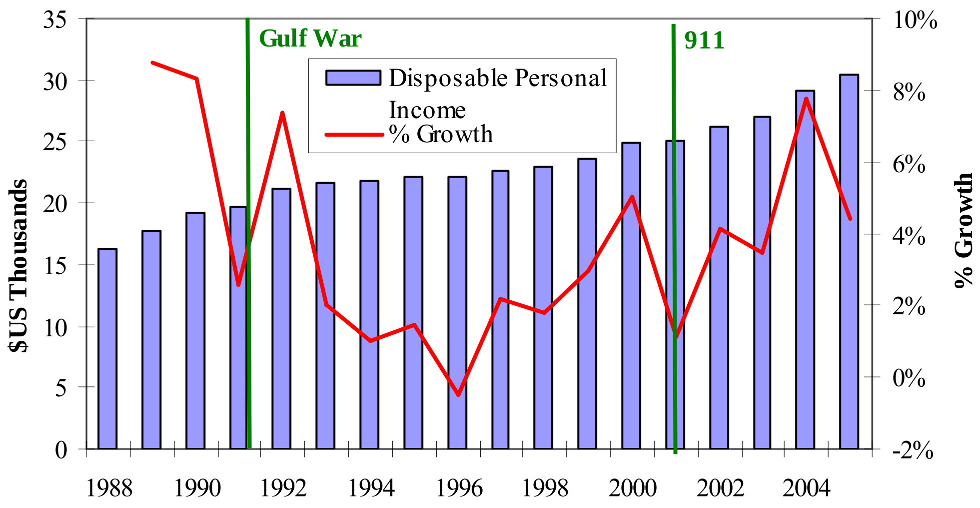



The Gulf War of 1991 followed by Hurricane Iniki exacerbated the slowdown in the domestic US economy. While Hawaii's economy started to turn around from 1999, the attacks of September 11 retarded growth coming out of this economic slump. From 2000, Gross State Product has grown at an average rate of 6.1%. In summary, the Hawaii economy at present is healthy, but is vulnerable to market conditions both at the national and international level.

The external shocks that impacted Hawaii's GSP have also had a notable impact on per capita disposable income. In Hawaii the per capita disposable personal income in 2005 was $US 30,487. The growth rate of per capita disposable income was 3.8% across the period 1989 to 2005.

Coinciding with the Gulf War in 1992 and the September 11 terrorist attacks in 2001, per capita disposable income decreased markedly. The median annual income for a four-person family for 2005 was $US 79,240. Hawaii was ranked 6th in this measure among the fifty states and District of Columbia.

**Figure 3.3: Per Capita Disposable Income**

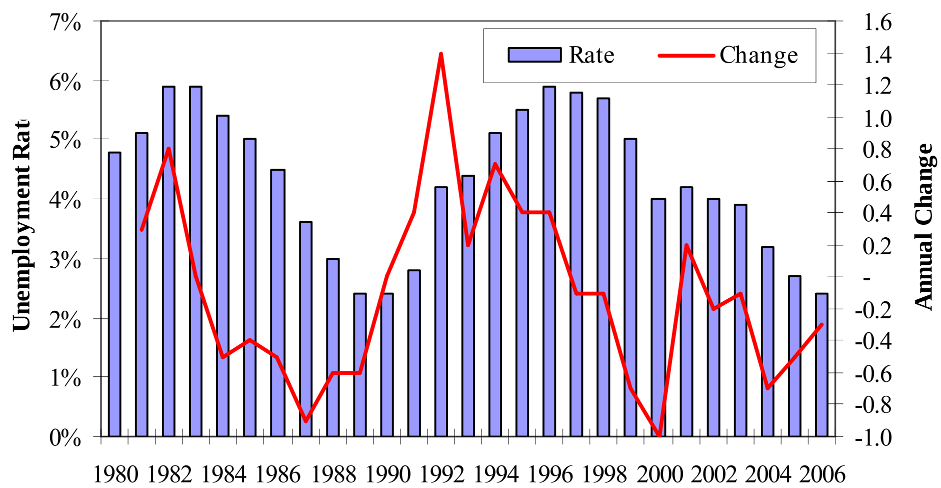



Hawaii is an expensive place to live. The cost of living for a family of four has been estimated to be roughly 25% higher than the U.S. average for a comparable standard of living. Part of the reason for the higher living costs is the housing situation. Housing is expensive in Hawaii due to limited availability and hence high price of land.

### 3.2.3 Labour

Three are various ways to model the labour market in CGE models. The way the labour market is treated in CGE model depends on the characteristics of the underlying economy. Specifically, there are different ways to model the economy in full employment versus an economy with excess capacity. In 2006, the civilian labour force was 643,500. Civilian employment in the same year was 628,300. Labour force growth has been positive over the last 25 years with the exception of 2002, just after 9/11. In 2006, the average annual unemployment rate was 2.4%. Since 1980 the labour force in Hawaii has grown at an average of 1.5% per year. Overall employment growth has tracked the labour force closely. The difference in these two measures, the number of persons unemployed, has followed the business cycles in the overall US economy.

**Figure 3.4: Hawaii's Unemployment Rate**




Unemployment, as shown in Figure 3.4, has been cyclical in Hawaii – rising to 5.9% in 1982 and 1983 before falling to 2.4% on average in both 1989 and 1990. 1996 saw another peak in unemployment, again returning to 5.9% before its gradual decline to 2.4% in 2004; the exception being the economy-wide employment response to the loss in tourism volume and export receipts from the September 11, 2001 terrorist attacks. Both labour force and employment experienced negative growth in that year. Unemployment increased by 0.2 percentage points to 4.2% (an increase of 5.0%) But this shock, although sharp, was more transitory than initially anticipated. Extended unemployment insurance benefits, "discouraged workers" (labour force exit), and the prevalence of multiple job-holding, meant that unemployment as a percentage of the labour force quickly returned to pre-9/11 rates. To accommodate fluctuations in the unemployment rate, there is a case to be made to include a flexible labour supply curve in this CGE model.

### 3.2.4 Public Sector

This section describes the taxation system in Hawaii and size and role of the State's public sector as well as the role and function the federal US government plays in Hawaii's economy. Like the labour market, key characteristics about the public sector can be modelled various ways in a CGE model and should reflect the benchmark economy.

Hawaii has a fairly large public sector in terms of employees and the large role that federal defence plays in Hawaii's economy. Historically this has been the case since pre-Pearl Harbor. The large military presence in Hawaii is both a boon and a potential vulnerability to the economy as increased political and global instability may lead to significant external shocks to the local economy.

In 2006, the State government hired the largest share of government workers across the State. Three in five government workers (59%) are employed at the state level with another quarter of the government workers (26%) working for the federal government.

The US federal government invests heavily in Hawaii specifically in the area of military and defence. USPACOM, the U.S. Pacific Command, based in Hawaii, is geographically the largest of the U.S. unified service commands. It covers more than 50% of the earth's surface from the U.S. West Coast to Africa's east coast and from the Arctic to the Antarctic.

By 2005, military personnel and dependents totalled 102,200 people, including 32,629 active duty personnel in the State. Since the annexation of Hawaii to the United States in 1898, Hawaii has had a strong military presence. The number of active duty personnel has remained stable since the end of the Vietnam War. Additionally, the federal government, specifically the Department of Defence, employ a significant number of civilian workers: a heavy investment in the economy of Hawaii.

Total tax collections across the three levels of government totalled $US 9.8 billion in 2003. The federal component comprises 53% of the total collections while the State part of the total is 38%. State government collections increased 4.4% in the 12 months to 2003. State revenue receipts in 2006 totalled over $US 7 billion, chiefly from taxes. A general excise tax (GET) of 4% is applied to retail sale of goods and services. The corporate tax rate is 4.4 percent of income up to $US 25,000, 5.4 percent of taxable income up to $US 100,000 and 6.4 percent of income exceeding $US 100,000. The capital gains tax rate is 4 percent for corporations.

The general excise and use tax ($US 2.3 billion) and individual income tax ($US 1.6 billion) are the major sources of tax revenue, comprising 34% and 24% respectively of total revenues. The four counties establish real property tax rates and assess and collect these taxes. Except for licenses, permits and fees, other tax collections are the responsibility of the State which operates a centralized tax system. Hawaii has no personal property or inventory taxes.

A key point to note in terms of tourism is that Hawaii imposes a transient accommodations tax – informally known as the 'hotel tax' - on all overnight stays in commercial places of accommodation. The tax rate for this is currently 7.25%. In 2006, the transient accommodations tax generated $US 124 million for the State.

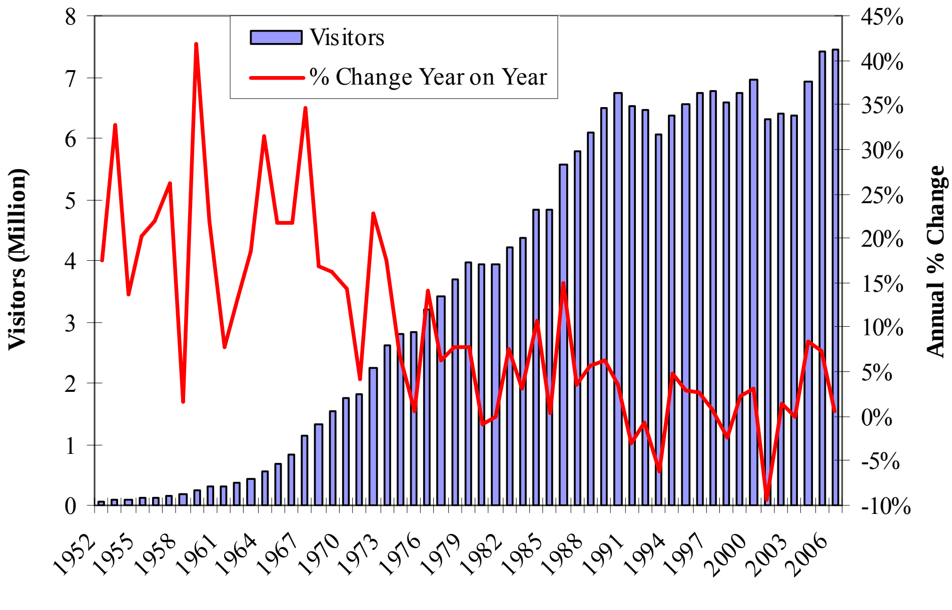
### 3.3 The Tourism Sector

This section examines some trends over the last few decades associated with both the demand and supply of tourism in the state of Hawaii. The supply issues will focus specifically on flights to Hawaii and the quantity of visitor accommodation available.

### 3.3.1 Tourism Demand

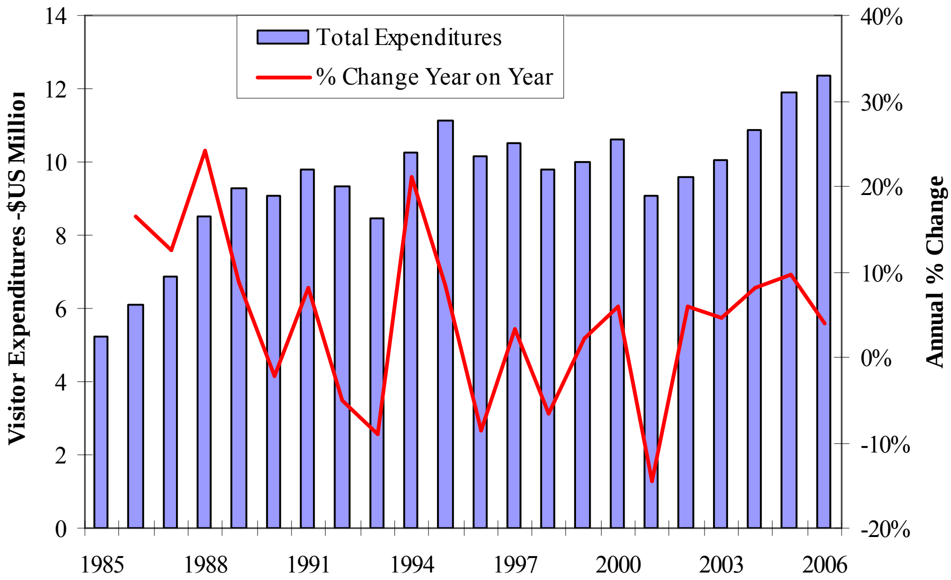
Tourism is a vital part of Hawaii's economy. From the 1950s until approximately 1990, the number of tourists visiting Hawaii grew almost exponentially. Figure 3.5 shows the massive growth in visitor numbers to Hawaii over the last half a century. Between 1970 and 1990, the volume of visitors visiting the Islands increased almost four-fold. From 1952 (when data became available) to 1959, visitor numbers grew an average of 22% per annum. The 1960s saw similar growth with average year-on-year increases averaging 20%. The 1970s saw more modest growth of 10% per year with the 1980s experiencing half as much growth again (5.2% per annum). By the 1990s growth in visitor arrivals tapered off. Average growth over this period was just 0.5%. While there was strong growth again in the beginning of the new millennium, the impact of several external shocks can be seen. The impact of the Gulf War is evident as is the large drop in visitor numbers in 2001 as a direct result of September 11. In 2006, 7.4 million visitors stayed in Hawaii overnight or longer.

**Figure 3.5: Hawaii's Visitor Arrivals**




The large influx of visitors to Hawaii is accompanied by a significant increase in visitor expenditures, an increase in export receipts to the island state. Total visitor expenditures in the year 2006 were $US 12.4 billion (Figure 3.6) compared to $US 5.2 billion in 1985. Like visitor arrivals, visitor expenditure grew strongly in the 1980s (15.5% per annum) with slow growth experienced in the 1990s (1.1% per annum) and more moderate growth since 2000 (3.4% per annum). In 2001, visitor expenditures decreased by 14% from the previous 12 month period, in part as a result of the September 11 terrorist attacks in New York. While other annual decreases have occurred throughout this 22-year period, it is reasonable to apportion some of the tourism decline to this exogenous shock.

**Figure 3.6: Visitor Expenditure in Hawaii**

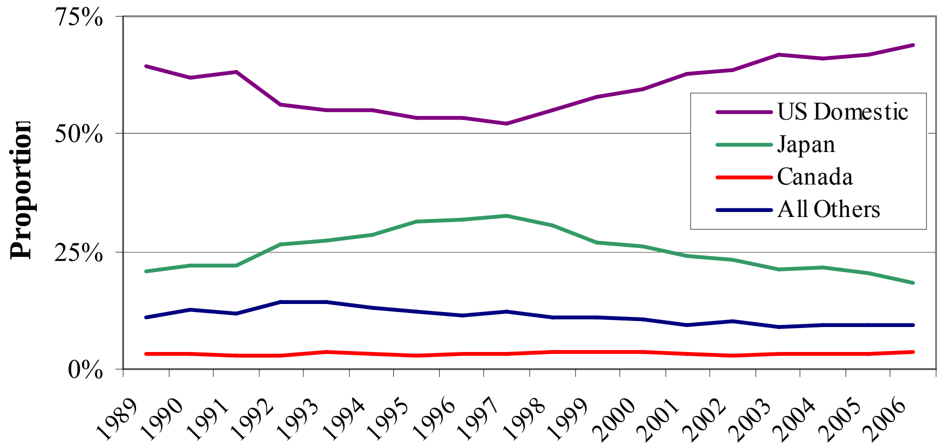



As visitor arrivals' and visitor expenditures' growth rates have waxed and waned over the past few decades, it is not surprising that the composition of visitors in terms of their point of origin have also changed. Tourism demand studies attempt to model these changes. Explanatory variables include economic factors such as income, and prices (exchange rates, consumer price indices) as well as qualitative variables such as marketing initiatives and perceived risks. The composition of visitors by point of origin affects the exposure to different sorts of shocks. For example, a larger proportion of domestic visitors would insulate the tourist destination in the case of sudden foreign exchange fluctuations.

By point of origin, there were 5.1 million Mainland U.S. visitors to Hawaii in 2006. This represents an increase of 3% on the previous 12 months. The second and third largest markets are Japanese visitors and Canadian visitors. These top three markets accounted for nearly 87 percent of visitor expenditures. Japanese visitors fell in absolute terms by 10% in the previous 12 months to 1.4 million visitors while Canadians increased 10% over the past year to 273,000.

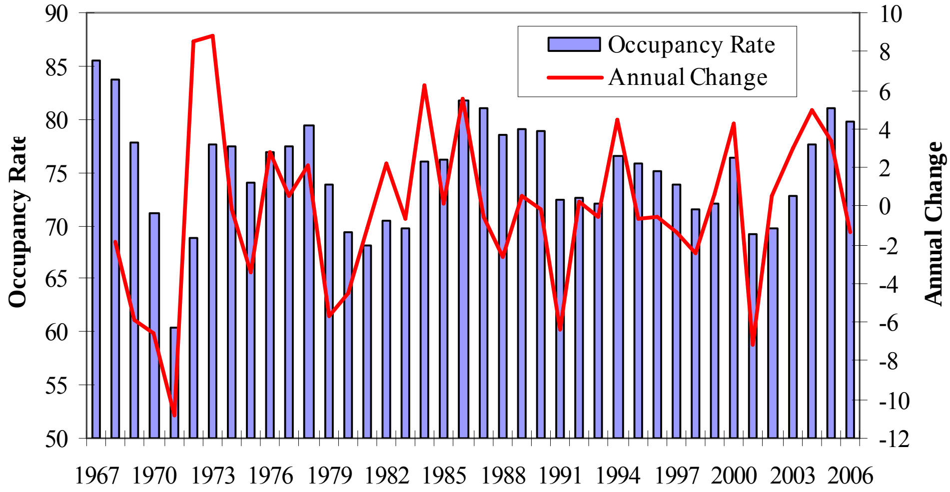
Yet Canadian visitors have always remained a small part of the Hawaii visitor market comprising 3-4% of total visitors from 1989 onwards. In contrast, US domestic visitors have increased their share up to a high in 2006 of 69%. US Domestic visitors' share has increased gradually since 1997 when it stood at 52%. Throughout the 1990s, with a strong Japanese economy and accompanying Yen, visitors to Hawaii from Japan comprised a third of all visitors to Hawaii.  This has declined to 18% in 2006.

**Figure 3.7: Hawaii Visitor Composition by Point of Origin**




The occupancy rate for visitor accommodation was 79.8% state-wide on average for the year 2006.  Since the year 2006, the average occupancy has been 75.2% for the decade, even allowing for a decrease of 7.2% in 2001. Corresponding with the relatively lower growth in visitor arrivals and visitor expenditures, occupancy rates in 1990s were lower than for the 1980s (74.1 compared to 75.0).

**Figure 3.8: Accommodation Occupancy Rates**

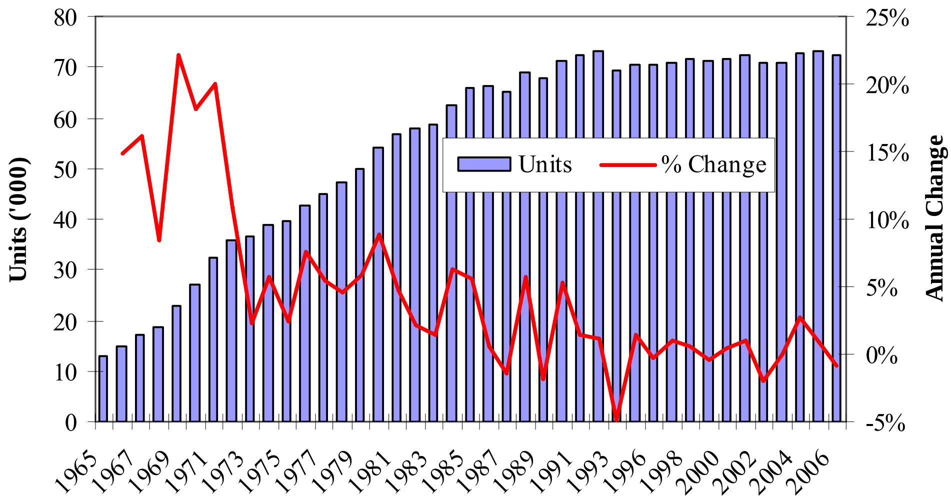



### 3.3.2 Tourism Supply

This section will review two features related to the supply of tourism services, namely, the trend in accommodation capacity and the availability of flights to Hawaii.

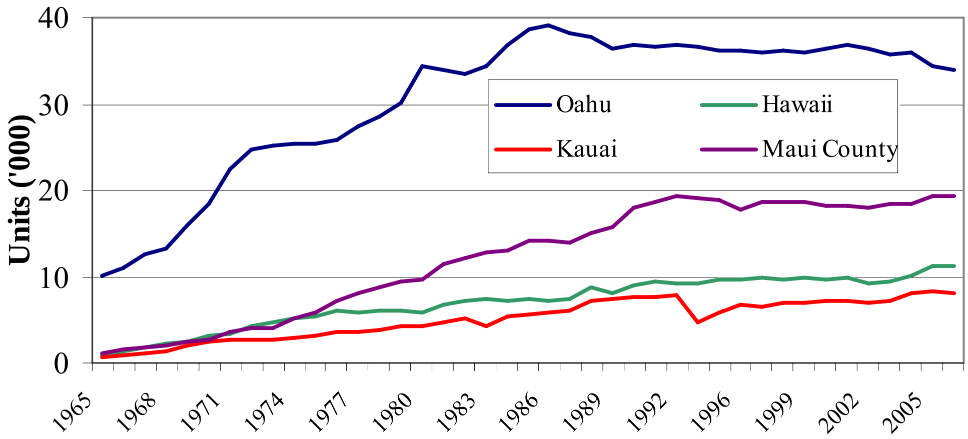
The number of accommodation units (hotels and condominiums) in 2006 summed to 72,614. From 1965 until 1986 there was significant growth year on year (8.3% annually) in the number of available accommodation units. Since 1987 there has only been incremental growth (0.5% per annum) as seen by the plateauing out of the time series in Figure 3.9.

**Figure 3.9: Total Available Accommodation Units**




Total state-wide visitor plant inventory reached 70,000 units in 1990. The growth in supply has not been uniform across the four counties in the State of Hawaii. The Neighbour Islands have seen the largest relative growth over the last few decades. In 1965, Oahu hosted 77% of all available accommodation units for the state while in 2006 just under half (47%) of the state-wide visitor units were located on Oahu in 2006 (Figure 3.10). By 1986, the number of units in Oahu had reached 39,000. Since then growth in the supply of accommodation has stagnated on Oahu. Maui County continues to have the second largest share of visitor units, followed by Hawaii and Kaua'i. The growth of units on Maui County as a proportion of the state-wide total can be seen in Figure 3.10. While Hawaii and Kaua'i have seen marginal growth in their share of state-wide units, Maui County's share has grown from 10.2% in the late 1960s to over a quarter of total units from 1990 onwards.

**Figure 3.10: Available Units by County**



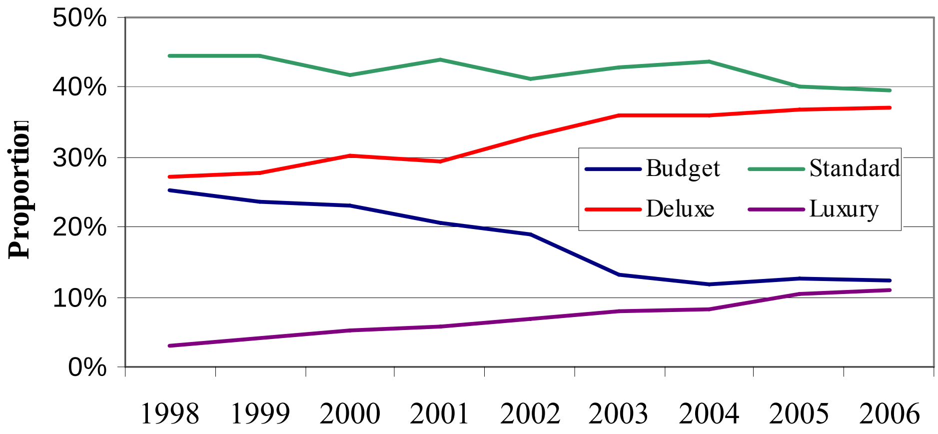

One point of interest is the significant drop in available units in Kaua'i for the year 1983 and the year 1993. The first significant decrease is attributable to Hurricane Iwa, which resulted in an 18.5% decrease in available units on Kaua'i for that year. More significant, however, was the 40.5% decrease in 1992 as a result of Hurricane Iniki. It was only in 2004 that available units in Kaua'i reached its pre-Hurricane Iniki levels, such was the devastation inflicted on that island.

By accommodation type, hotels continued to comprise the bulk (60.2%) of visitor units state-wide. This proportion has been decreasing over the last 8 years with the growth of timeshare apartments and condo/hotels. Bed & Breakfasts comprised less than 1 percent of total visitor units but made up 14.7% of the State's properties in 2006.

In the last seven years there has been a shift in the type of unit by class. Progressively, lodging in Hawaii is becoming more upscale. While the total volume of accommodation units has remained relatively static over the last

10 years, new builds have tended to be at the higher end of the accommodation class spectrum. Visitor units classified as "Standard" ($US 101 to $US 250 per night rack rate) still comprise the largest percentage of the total units state-wide in 2006 but there has been growth in the number of "Deluxe" ($US 251 to $US 500 per night) and "Luxury" (over $US 500 per night) units at the expense of "Budget" ($US 100 or less per night) accommodation.

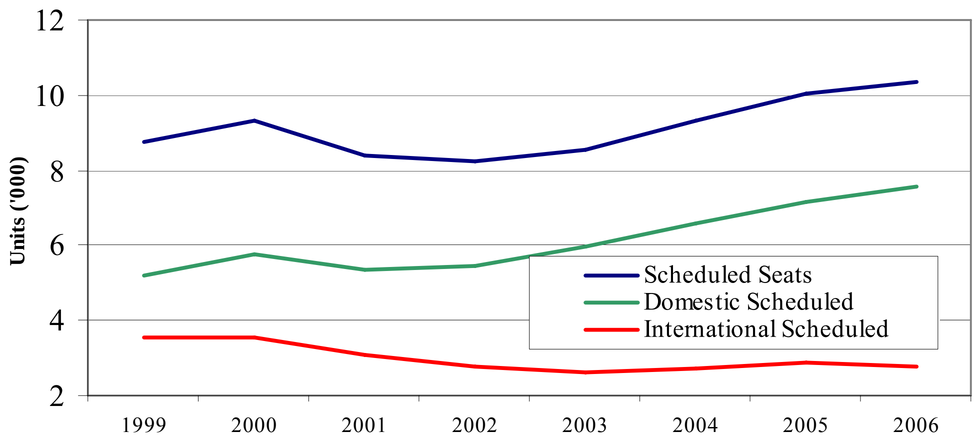
**Figure 3.11: Proportion of Accommodation by Class of Units**




Being an island, nearly all visitors arrive in Hawaii by air. With the introduction of Norwegian Cruise Lines having a permanent base in Hawaii, the cruise industry will grow significantly over the coming years but in terms of sheer volume of visitors, air travel carries the vast majority of visitors. In addition to external shocks such as 9/11, the airline industry is exposed to large changes in oil prices. Total air seats to Hawaii summed to 10.59 million seats in 2006 with approximately 7.73 million seats (73.0%) being Domestic (US) and the remainder being International seats. A large majority of these seats (98%) were on scheduled flights with around 2% being chartered flights.

Not surprisingly, as the airlines look to meet tourism demand, there are variations in the scheduled supply of flights to Hawaii. The supply of air seats on International flights is more variable than the supply of Domestic seats. This reflects the more inconsistent nature of tourism demand from this market. Further, it represents the changing mix of visitors to Hawaii with the US Domestic market increasing in size relative to International visitors.

**Figure 3.12: Air Seats to Hawaii**




Comparing total flights to Hawaii with overall visitor arrival numbers by air, the airlines are operating collectively at about 70% of their capacity. This figure has decreased in the last few years from 77% in 1999.

### 3.4 The 2002 Hawaii Input-Output Table

This section describes Hawaii's Input-Output table for the benchmark year of 2002. These tables are updated every five years and hence this is the latest available. The 2002 Hawaii Input-Output table provides a numerical snapshot of the economy in Hawaii for the calendar year, 2002. The benchmark economy will be used to calibrate the applied CGE models that follow in Chapters 4 and 6.

As explained in Chapter 2, the Input-Output table displays information on inter-relationships that exist among industries, final users (households, visitors, government, and exports), and factors of production within an economy. This information can be used to determine the role and relative importance of each sector in terms of its output, value added, income, and employment contributions and to analyze intersectoral linkages in the economy. Hawaii's Department of Business, Economic Development and Tourism (DBEDT) produce the Input-Output tables which can be found at the DBEDT website, www.hawaii.gov/dbedt/. The 2002 detailed Input-Output table has a total of 67 sectors. This has been condensed down to 20 sectors for this research for the purposes of tractability. A list of sectors included in the 2002 detailed and condensed tables is presented in Table 3.1. The sectors are associated with the North American Industry Classification Systems (NAICS) codes.

### 3.4.1 The Input-Output Block

The inter-industry transactions portion of the table, accounts for intermediate sales and purchases of goods and services among the producing industries in the economy. Reading across a row of the transactions table shows the inter-industry sales by the row sector to the various column sectors. Similarly, reading down a column shows the inter-industry purchases by the column sector from the various row sectors.

**Table 3.1: Sectors in the 2002 Input-Output Table**

| | **Detailed Sectors** | | **Aggregated Sectors** |
|---|---|---|---|
| 1 | Sugarcane | 1 | Agriculture |
| 2 | Vegetables | 1 | |
| 3 | Macadamia nuts, coffee, fruits | 1 | |
| 4 | Pineapples | 1 | |
| 5 | Flowers and nursery products | 1 | |
| 6 | Other crops | 1 | |
| 7 | Animal production | 1 | |
| 8 | Aquaculture | 1 | |
| 9 | Commercial fishing | 1 | |
| 10 | Forestry & logging | 1 | |
| 11 | Support activities for agriculture | 1 | |
| 12 | Mining | 2 | Construction |
| 13 | Single family construction | 2 | |
| 14 | Construction of other buildings | 2 | |
| 15 | Heavy and civil engineering construction | 2 | |
| 16 | Maintenance and construction repairs | 2 | |
| 17 | Food processing | 3 | Food processing |
| 18 | Beverage manufacturing | 4 | Other manufacturing |
| 19 | Apparel and textile manufacturing | 4 | |
| 20 | Petroleum manufacturing | 4 | |
| 21 | Other manufacturing | 4 | |
| 22 | Air transportation | 5 | Transportation |
| 23 | Water transportation | 5 | |
| 24 | Truck transportation | 5 | |
| 25 | Transit and ground passenger transportation | 5 | |
| 26 | Scenic and support activities for transportation | 5 | |
| 27 | Couriers and messengers | 5 | |
| 28 | Warehousing and storage | 5 | |
| 29 | Publishing (include Internet) | 6 | Information |
| 30 | Motion picture and sound recording industries | 6 | |
| 31 | Broadcasting (Radio, TV, Cable) | 6 | |
| 32 | Telecommunications | 6 | |
| 33 | Internet providers, web, and data processing | 6 | |
| 34 | Other information service | 6 | |
| 35 | Utilities | 7 | Utilities |
| 36 | Wholesale trade | 8 | Wholesale Trade |
| 37 | Retail trade | 9 | Retail Trade |
| 38 | Credit intermediation and related activities | 10 | Finance & Insurance |
| 39 | Insurance carriers and related activities | 10 | |
| 40 | Other finance and insurance | 10 | |
| 41 | Owner-occupied dwellings | 11 | Real Estate & Rentals |
| 42 | Real estate | 11 | |
| 43 | Rental & leasing and others | 11 | |
| 44 | Legal services | 12 | Professional Services |
| 45 | Architectural and engineering services | 12 | |
| 46 | Computer systems design services | 12 | |
| 47 | R&D in the physical, engineering, & life sciences | 12 | |
| 48 | Other professional services | 12 | |
| 49 | Management of companies and enterprises | 13 | Business Services |
| 50 | Travel arrangement and reservation services | 13 | |
| 51 | Administrative and support services | 13 | |
| 52 | Waste management and remediation services | 13 | |

| | Detailed Sectors | | Aggregated Sectors |
|---|---|---|---|
| 53 | Colleges, universities, and professional schools | 14 | Educational Services |
| 54 | Other Educational services | 14 | |
| 55 | Ambulatory health care services | 15 | Health Services |
| 56 | Hospitals | 15 | |
| 57 | Nursing and residential care facilities | 15 | |
| 58 | Social assistance | 15 | |
| 59 | Arts and entertainment | 16 | Arts & entertainment |
| 60 | Accommodation | 17 | Accommodation |
| 61 | Eating and drinking | 18 | Eating and drinking |
| 62 | Repair and maintenance services | 19 | Other service |
| 63 | Personal and laundry services | 19 | |
| 64 | Organizations | 19 | |
| 65 | Federal government: military | 20 | Government |
| 66 | Federal government: civilian | 20 | |
| 67 | State and local government | 20 | |

**Table 3.2: 2002 Condensed Input-Output Transactions Table for Hawaii (in $million): Inter-Industry Block**

| Industry | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | Interindustry Demand |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 56.7 | 4.6 | 175.8 | 8.3 | 0.2 | 0.0 | 0.0 | 0.3 | 0.3 | 0.0 | 40.1 | 0.4 | 0.8 | 0.0 | 5.0 | 0.6 | 0.1 | 39.3 | 1.2 | 1.5 | 335.2 |
| 2 | 7.1 | 13.0 | 1.7 | 2.8 | 76.0 | 3.7 | 60.2 | 4.5 | 16.4 | 11.2 | 257.6 | 8.4 | 10.1 | 24.0 | 16.9 | 3.5 | 90.8 | 43.8 | 16.2 | 63.4 | 731.5 |
| 3 | 4.7 | 0.0 | 33.5 | 13.9 | 1.1 | 0.4 | 0.0 | 0.6 | 0.4 | 0.0 | 0.0 | 0.9 | 0.0 | 0.0 | 20.7 | 0.3 | 2.1 | 150.3 | 1.7 | 2.0 | 232.7 |
| 4 | 32.0 | 279.6 | 19.7 | 109.9 | 342.7 | 5.3 | 296.8 | 33.7 | 68.9 | 16.4 | 106.4 | 45.1 | 47.8 | 14.1 | 62.3 | 3.5 | 11.8 | 63.9 | 41.4 | 35.5 | 1,636.9 |
| 5 | 16.0 | 72.3 | 17.3 | 48.6 | 203.9 | 8.9 | 5.9 | 14.2 | 21.6 | 22.2 | 47.6 | 58.1 | 28.2 | 6.5 | 35.4 | 3.7 | 26.3 | 21.2 | 22.7 | 32.1 | 712.8 |
| 6 | 1.5 | 31.5 | 4.2 | 16.3 | 44.9 | 154.1 | 1.7 | 55.9 | 76.4 | 122.3 | 85.3 | 79.4 | 84.9 | 26.1 | 61.9 | 7.7 | 78.3 | 36.1 | 44.8 | 37.7 | 1,051.1 |
| 7 | 10.2 | 22.3 | 15.3 | 32.9 | 9.6 | 6.8 | 0.9 | 12.2 | 66.9 | 7.7 | 94.2 | 19.0 | 37.1 | 7.2 | 73.4 | 13.8 | 134.7 | 68.7 | 63.7 | 62.0 | 758.6 |
| 8 | 24.4 | 226.2 | 45.1 | 77.0 | 89.9 | 16.3 | 6.7 | 52.8 | 19.3 | 4.4 | 51.8 | 38.7 | 28.0 | 6.3 | 78.9 | 4.3 | 50.1 | 122.6 | 36.7 | 43.6 | 1,023.1 |
| 9 | 4.4 | 277.5 | 15.4 | 24.8 | 6.0 | 20.2 | 8.5 | 20.8 | 56.1 | 4.6 | 96.9 | 56.5 | 46.6 | 0.9 | 53.1 | 0.9 | 11.9 | 13.1 | 33.8 | 0.2 | 751.9 |
| 10 | 7.0 | 47.3 | 3.9 | 17.5 | 56.3 | 24.6 | 12.6 | 27.8 | 72.9 | 635.3 | 427.9 | 37.6 | 31.6 | 4.9 | 39.3 | 4.4 | 97.6 | 32.9 | 24.3 | 13.1 | 1,618.7 |
| 11 | 25.6 | 85.2 | 11.3 | 22.5 | 60.0 | 32.4 | 4.8 | 62.5 | 515.7 | 170.7 | 827.3 | 270.2 | 119.4 | 88.5 | 337.7 | 28.1 | 131.6 | 159.3 | 197.7 | 41.1 | 3,191.5 |
| 12 | 2.7 | 317.3 | 11.3 | 26.5 | 75.5 | 45.6 | 17.8 | 45.6 | 81.3 | 153.6 | 192.7 | 228.7 | 177.9 | 14.2 | 161.9 | 19.6 | 108.6 | 82.2 | 81.3 | 74.6 | 1,918.9 |
| 13 | 4.4 | 67.1 | 64.0 | 75.7 | 248.2 | 28.2 | 13.2 | 114.6 | 180.5 | 96.4 | 288.8 | 60.3 | 132.2 | 32.8 | 317.5 | 17.2 | 302.6 | 71.1 | 123.0 | 70.3 | 2,308.0 |
| 14 | 0.0 | 0.6 | 0.2 | 3.3 | 15.3 | 5.7 | 8.1 | 2.3 | 3.1 | 11.3 | 2.3 | 11.1 | 5.1 | 6.1 | 15.9 | 2.7 | 1.0 | 0.5 | 3.2 | 8.1 | 105.8 |
| 15 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 0.0 | 0.7 | 33.0 | 0.2 | 0.0 | 0.0 | 0.5 | 2.5 | 37.3 |
| 16 | 0.2 | 2.0 | 1.0 | 1.3 | 1.1 | 3.4 | 0.1 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.4 | 0.2 | 16.0 | 2.5 | 7.0 | 0.9 | 0.1 | 36.2 |
| 17 | 0.3 | 3.7 | 2.2 | 3.1 | 1.8 | 1.9 | 3.6 | 4.2 | 6.9 | 9.2 | 17.8 | 16.7 | 4.6 | 1.0 | 12.4 | 0.4 | 5.6 | 3.8 | 3.4 | 5.2 | 107.8 |
| 18 | 0.6 | 22.1 | 9.6 | 12.6 | 49.2 | 10.7 | 3.9 | 14.0 | 19.5 | 27.2 | 29.6 | 24.0 | 16.8 | 12.6 | 46.5 | 7.1 | 24.7 | 27.9 | 8.1 | 12.4 | 378.9 |
| 19 | 3.4 | 28.4 | 9.5 | 20.4 | 32.3 | 15.7 | 0.7 | 20.8 | 24.4 | 32.4 | 424.5 | 30.6 | 27.6 | 4.3 | 28.4 | 7.3 | 44.7 | 21.7 | 19.2 | 22.6 | 819.1 |
| 20 | 3.6 | 6.7 | 3.3 | 9.3 | 178.0 | 5.5 | 3.6 | 10.5 | 35.3 | 22.7 | 50.5 | 15.6 | 17.7 | 2.1 | 41.6 | 7.6 | 35.3 | 15.4 | 14.3 | 15.4 | 494.0 |
| Total | 204.9 | 1,507.4 | 444.3 | 526.8 | 1,492.3 | 389.3 | 449.2 | 497.3 | 1,266.0 | 1,347.5 | 3,041.3 | 1,001.9 | 816.3 | 252.7 | 1,441.9 | 148.8 | 1,160.1 | 980.9 | 737.9 | 543.3 | 18,250.2 |

| | | | |
|---|---|---|---|
| 1 | Agriculture | 11 | Real estate and rentals |
| 2 | Mining and construction | 12 | Professional services |
| 3 | Food processing | 13 | Business services |
| 4 | Other manufacturing | 14 | Educational services |
| 5 | Transportation | 15 | Health services |
| 6 | Information | 16 | Arts and entertainment |
| 7 | Utilities | 17 | Accommodation |
| 8 | Wholesale trade | 18 | Eating and drinking |
| 9 | Retail trade | 19 | Other services |
| 10 | Finance and insurance | 20 | Government |

Hawaii's 2002 inter-industry block is shown in Table 3.2. Reading across a row of the inter-industry block shows sales by the row sector to the various column sectors in the economy. For example, in 2002, of total agricultural sales, total inter-industry sales to agriculture itself and other industries amounted to $US 335.2 million. Food processing accounted for the largest share ($US 175.8 million or 52%) of total inter-industry sales of agriculture. Reading down a column shows the purchases by the column sector from the various row sectors. For example, in 2002, total agriculture's purchases included $US 204.9 million from Hawaii's industries (including $US 56.7 million from agriculture itself and $US 148.2 million from other industries).

### 3.4.2 Final Demand

Final demand reflects the expenditure side of the GSP account. It consists of personal consumption expenditures (PCEs), visitors' expenditures (VEs), gross private investment (including change in inventories), state and local government consumption and investment, federal government consumption and investment (disaggregated by civilian and military consumption and investment), and exports. The 2002 Hawaii Final Demand block is shown in Table 3.4. The block shows the familiar national accounting income identity: $Y = C + I + G + (X - M)$. It shows that Hawaii's GSP for the year 2002 is $US 43.807 billion in current US dollars. Private consumption is $US 29.110 billion of which 78.8% or $US 22.944 billion is spent in Hawaii. Visitor expenditures for that year are $US 13.05 billion of which 86.4% are consumed in Hawaii. The higher proportion of visitors expenditures compared to residents' expenditures spent in Hawaii is partly due to the consumption of accommodation and eating and drinking places goods and services physically residing in state. The proportion of each final demand components' contribution to GSP is shown in Table 3.3. As mentioned earlier in this chapter, Federal government spending on military goods and services totals 15% of GSP. The federal government's role in the Hawaii economy will be modelled as an exogenous sector in the CGE models to follow while State and Local Government will be modelled as an active economic agent.

Hawaii is running a Balance of Payments deficit. Imports of goods and services used in the components of final demand total $US 10.39 billion and imports used in the production of intermediate goods and services total $US 8.56 billion.

**Table 3.3: Contribution to Hawaii's GSP**

| **$US Billion** | **Total** | **%** |
|---|---|---|
| PCE | $29.11 | 66% |
| Visitors' Expenditure | $13.05 | 30% |
| Gross Private Investment | $4.75 | 11% |
| State & Local Government | $5.85 | 13% |
| Federal Government: Military | $6.60 | 15% |
| Federal Government: Civilian | $0.58 | 1% |
| Non-Tourism Exports | $2.81 | 6% |
| Intermediate Imports | -$8.56 | -20% |
| Final Imports | -$10.39 | -24% |
| **GSP** | **$43.81** | **100%** |

**Table 3.4: 2002 Condensed Input-Output Transactions Table for Hawaii (in $million): Final Demand Block**

| Final Demand Component | PCE | Visitor's expenditures | Gross private investment | State & local government | Federal government: military | Federal government: civilian | Exports | Total Output |
|---|---|---|---|---|---|---|---|---|
| **Industry** | **A** | **B** | **C** | **D** | **E** | **F** | **G** | **H** |
| Agriculture | 135.6 | 15.3 | -1.1 | 1.8 | 1.1 | 0.2 | 193.6 | 681.8 |
| Mining and construction | 0.0 | 0.0 | 2,556.8 | 912.1 | 454.3 | 71.9 | 0.8 | 4,727.3 |
| Food processing | 357.3 | 38.4 | 0.2 | 7.0 | 8.5 | 2.5 | 335.8 | 982.3 |
| Other manufacturing | 363.5 | 37.2 | 89.9 | 45.6 | 130.8 | 0.1 | 410.4 | 2,714.4 |
| Transportation | 749.1 | 2,149.0 | 83.4 | 48.3 | 5.8 | 2.7 | 137.4 | 3,888.6 |
| Information | 774.6 | 41.2 | 0.0 | 21.1 | 9.4 | 2.5 | 166.1 | 2,066.0 |
| Utilities | 474.2 | 0.0 | 0.0 | 130.3 | 30.0 | 4.3 | 0.0 | 1,397.4 |
| Wholesale trade | 754.4 | 218.7 | 185.1 | 44.4 | 10.9 | 1.4 | 68.8 | 2,306.8 |
| Retail trade | 2,780.2 | 1,270.5 | 276.9 | 32.6 | 4.3 | 0.8 | 16.4 | 5,133.5 |
| Finance and insurance | 1,654.0 | 0.0 | 0.0 | 18.2 | 0.0 | 0.0 | 493.1 | 3,784.0 |
| Real estate and rentals | 5,708.1 | 1,597.7 | 29.5 | 56.9 | 1.6 | 4.4 | 171.0 | 10,760.7 |
| Professional services | 399.6 | 98.4 | 421.6 | 9.1 | 226.8 | 14.5 | 217.7 | 3,306.7 |
| Business services | 158.1 | 278.5 | 0.0 | 0.0 | 53.3 | 0.8 | 111.6 | 2,910.3 |
| Educational services | 527.4 | 97.7 | 0.0 | 0.0 | 4.5 | 0.0 | 0.0 | 735.4 |
| Health services | 4,831.5 | 101.6 | 0.0 | 0.0 | 7.2 | 12.0 | 0.0 | 4,989.6 |
| Arts and entertainment | 299.1 | 396.7 | 0.0 | 0.0 | 0.3 | 0.0 | 16.3 | 748.5 |
| Accommodation | 138.1 | 3,589.8 | 0.0 | 6.4 | 1.8 | 0.0 | 0.0 | 3,844.0 |
| Eating and drinking | 1,092.2 | 1,193.9 | 0.0 | 0.0 | 3.2 | 0.2 | 5.9 | 2,674.3 |
| Other services | 1,236.1 | 89.8 | 0.0 | 77.5 | 10.6 | 0.0 | 0.0 | 2,233.2 |
| Government | 510.4 | 57.1 | 0.0 | 4,179.0 | 5,054.2 | 438.4 | 0.0 | 10,733.1 |
| Intermediate input | 22,943.5 | 11,271.4 | 3,642.4 | 5,590.5 | 6,018.3 | 556.8 | 2,344.9 | 70,618.0 |
| Imports | 6,166.3 | 1,780.1 | 1,107.2 | 257.2 | 583.6 | 27.5 | 464.3 | 18,947.0 |
| Labor income | | | | | | | | 28,626.0 |
| Compensation of employees | | | | | | | | 26,222.0 |
| Proprietors' income | | | | | | | | 2,404.0 |
| TOPI | | | | | | | | 3,118.0 |
| Other capital costs | | | | | | | | 12,063.0 |
| Total value added | | | | | | | | 43,807.0 |
| Output | 29,109.7 | 13,051.5 | 4,749.6 | 5,847.6 | 6,602.0 | 584.3 | 2,809.2 | 133,372.0 |

**Table 3.5: Sectoral Proportion of Final Demand Components**

| Industry | PCE | Visitor's expenditures | Gross private investment | State & local government | Federal government: military | Federal government: civilian | Exports | Total Output |
|---|---|---|---|---|---|---|---|---|
| | **A** | **B** | **C** | **D** | **E** | **F** | **G** | **H** |
| Agriculture | 0.6% | 0.1% | 0.0% | 0.0% | 0.0% | 0.0% | 8.3% | 1.0% |
| Mining and construction | 0.0% | 0.0% | 70.2% | 16.3% | 7.5% | 12.9% | 0.0% | 6.7% |
| Food processing | 1.6% | 0.3% | 0.0% | 0.1% | 0.1% | 0.4% | 14.3% | 1.4% |
| Other manufacturing | 1.6% | 0.3% | 2.5% | 0.8% | 2.2% | 0.0% | 17.5% | 3.8% |
| Transportation | 3.3% | 19.1% | 2.3% | 0.9% | 0.1% | 0.5% | 5.9% | 5.5% |
| Information | 3.4% | 0.4% | 0.0% | 0.4% | 0.2% | 0.4% | 7.1% | 2.9% |
| Utilities | 2.1% | 0.0% | 0.0% | 2.3% | 0.5% | 0.8% | 0.0% | 2.0% |
| Wholesale trade | 3.3% | 1.9% | 5.1% | 0.8% | 0.2% | 0.3% | 2.9% | 3.3% |
| Retail trade | 12.1% | 11.3% | 7.6% | 0.6% | 0.1% | 0.1% | 0.7% | 7.3% |
| Finance and insurance | 7.2% | 0.0% | 0.0% | 0.3% | 0.0% | 0.0% | 21.0% | 5.4% |
| Real estate and rentals | 24.9% | 14.2% | 0.8% | 1.0% | 0.0% | 0.8% | 7.3% | 15.2% |
| Professional services | 1.7% | 0.9% | 11.6% | 0.2% | 3.8% | 2.6% | 9.3% | 4.7% |
| Business services | 0.7% | 2.5% | 0.0% | 0.0% | 0.9% | 0.1% | 4.8% | 4.1% |
| Educational services | 2.3% | 0.9% | 0.0% | 0.0% | 0.1% | 0.0% | 0.0% | 1.0% |
| Health services | 21.1% | 0.9% | 0.0% | 0.0% | 0.1% | 2.2% | 0.0% | 7.1% |
| Arts and entertainment | 1.3% | 3.5% | 0.0% | 0.0% | 0.0% | 0.0% | 0.7% | 1.1% |
| Accommodation | 0.6% | 31.8% | 0.0% | 0.1% | 0.0% | 0.0% | 0.0% | 5.4% |
| Eating and drinking | 4.8% | 10.6% | 0.0% | 0.0% | 0.1% | 0.0% | 0.3% | 3.8% |
| Other services | 5.4% | 0.8% | 0.0% | 1.4% | 0.2% | 0.0% | 0.0% | 3.2% |
| Government | 2.2% | 0.5% | 0.0% | 74.8% | 84.0% | 78.7% | 0.0% | 15.2% |
| Intermediate input | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% |

The sectoral breakdown of each component of final demand including total output is shown in Table 3.5. Examining the composition of the economy, as it relates to total output (Final demand + Intermediate demand); the largest industries are the real estate & rental sector and the government sector, both representing 15.2% of total output. The latter sector comprises not just local, state and federal government but also military spending that has a large presence in Hawaii. Of the industries that are heavily influenced by tourism, transportation amounts to $US 3.9 billion or 5.5% of total output and accommodation is 5.4% of total output. Eating and drinking places account for 3.8% of total output in Hawaii and the arts, entertainment and recreation industry, ranked 18th out of the 20 industries, makes up 1.1% of total output. Agriculture, once the largest industry in Hawaii and the livelihood of so many on the Islands now only amounts to 1.0% of total output.

In terms of visitors' expenditures (column B in Table 3.5), accommodation makes up 32% of total 'in-Hawaii' expenditure, followed by the transportation sector with 19% of total tourism demand. In terms of Gross Private Investment (Column C), not surprisingly, the construction industry comprises 70% of investment demand.

### 3.4.3 Value Added

Value added is the income side of the Hawaii Gross State Product account. This block shows primary payments to the owners of factors production. These include payments to the primary factors of production (labour, and capital), business tax payments to government, interest payments for business loans, and payments for imported goods and services for intermediate use. For the 2002 IO table, value added was divided into four components: (1) compensation of employees (COE), (2) proprietors' income, (3) taxes on production and imports less subsidies (TOPI), and (4) other capital costs (Table 3.6). Table 3.7 shows the sectoral breakdown of each component in the value added block.

Compensation of employees consists of wage and salary disbursements plus supplements to wages and salaries. The supplements to wages and salaries include employer contributions for employee pension and insurance funds, and employer contributions for government social insurance. In the CGE models that follow compensation to employees and proprietors' income will be aggregated to form labour demand and supply. Labour income totalled $US 28.626 billion in 2002 with compensation to employees comprising 92% of the total labour income. As mentioned earlier, government is a large employer of labour with 31% of labour income coming from the government sector. The next largest employer of labour is health services (9%) followed by the construction industry and retail trade (7% each).

### Table 3.6: 2002 Condensed Input-Output Table for Hawaii (in $US million) - Value Added Block

| Industry | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | Total Output |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Intermediate input** | 204.9 | 1507.4 | 444.3 | 526.8 | 1492.3 | 389.3 | 449.2 | 497.3 | 1266.0 | 1347.5 | 3041.3 | 1001.9 | 816.3 | 252.7 | 1441.9 | 148.8 | 1160.1 | 980.9 | 737.9 | 543.3 | 18250.2 |
| **Imports** | 105.0 | 1105.9 | 323.5 | 1618.1 | 756.3 | 392.7 | 129.3 | 279.6 | 565.5 | 374.5 | 385.4 | 321.8 | 206.0 | 39.8 | 562.7 | 47.7 | 301.8 | 437.4 | 339.3 | 268.8 | 8560.8 |
| **Labor income** | 286.8 | 1880.9 | 202.7 | 557.9 | 1174.8 | 717.9 | 240.7 | 837.4 | 1963.3 | 1142.9 | 647.3 | 1752.7 | 1610.2 | 400.6 | 2551.1 | 394.3 | 1432.1 | 918.0 | 938.4 | 8976.0 | 28626.0 |
| Compensation of employees | 260.0 | 1611.0 | 201.1 | 409.9 | 1095.0 | 613.0 | 229.0 | 769.0 | 1787.0 | 1012.0 | 467.0 | 1312.0 | 1502.0 | 390.0 | 2239.0 | 286.0 | 1376.0 | 893.0 | 794.0 | 8976.0 | 26222.0 |
| Proprietors' income | 26.8 | 269.9 | 1.6 | 148.0 | 79.8 | 104.9 | 11.7 | 68.4 | 176.3 | 130.9 | 180.3 | 440.7 | 108.2 | 10.6 | 312.1 | 108.3 | 56.1 | 25.0 | 144.4 | 0.0 | 2404.0 |
| **TOPI** | -33.0 | 44.0 | 6.7 | 10.3 | 239.0 | 84.0 | 132.0 | 460.0 | 820.0 | 109.0 | 516.0 | 63.0 | 57.0 | 27.0 | 118.0 | 53.0 | 300.0 | 117.0 | 72.0 | -77.0 | 3118.0 |
| **Other capital costs** | 118.2 | 189.1 | 5.1 | 1.3 | 226.2 | 482.1 | 446.3 | 232.6 | 518.7 | 810.1 | 6170.7 | 167.3 | 220.8 | 15.4 | 315.9 | 104.7 | 649.9 | 221.0 | 145.6 | 1022.0 | 12063.0 |
| **Total value added** | 372.0 | 2114.0 | 214.5 | 569.5 | 1640.0 | 1284.0 | 819.0 | 1530.0 | 3302.0 | 2062.0 | 7334.0 | 1983.0 | 1888.0 | 443.0 | 2985.0 | 552.0 | 2382.0 | 1256.0 | 1156.0 | 9921.0 | 43807.0 |
| **Output** | 681.8 | 4727.3 | 982.4 | 2714.4 | 3888.6 | 2066.0 | 1397.4 | 2306.8 | 5133.5 | 3784.0 | 10760.7 | 3306.7 | 2910.3 | 735.4 | 4989.6 | 748.5 | 3844.0 | 2674.3 | 2233.2 | 10733.1 | 70618.0 |

### Table 3.7: Sectoral Proportion of Value Added Component

| Industry | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | Total Output |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Intermediate input** | 1% | 8% | 2% | 3% | 8% | 2% | 2% | 3% | 7% | 7% | 17% | 5% | 4% | 1% | 8% | 1% | 6% | 5% | 4% | 3% | 100% |
| **Imports** | 1% | 13% | 4% | 19% | 9% | 5% | 2% | 3% | 7% | 4% | 5% | 4% | 2% | 0% | 7% | 1% | 4% | 5% | 4% | 3% | 100% |
| **Labor income** | 1% | 7% | 1% | 2% | 4% | 3% | 1% | 3% | 7% | 4% | 2% | 6% | 6% | 1% | 9% | 1% | 5% | 3% | 3% | 31% | 100% |
| Compensation of employees | 1% | 6% | 1% | 2% | 4% | 2% | 1% | 3% | 7% | 4% | 2% | 5% | 6% | 1% | 9% | 1% | 5% | 3% | 3% | 34% | 100% |
| Proprietors' income | 1% | 11% | 0% | 6% | 3% | 4% | 0% | 3% | 7% | 5% | 7% | 18% | 5% | 0% | 13% | 5% | 2% | 1% | 6% | 0% | 100% |
| **TOPI** | -1% | 1% | 0% | 0% | 8% | 3% | 4% | 15% | 26% | 3% | 17% | 2% | 2% | 1% | 4% | 2% | 10% | 4% | 2% | -2% | 100% |
| **Other capital costs** | 1% | 2% | 0% | 0% | 2% | 4% | 4% | 2% | 4% | 7% | 51% | 1% | 2% | 0% | 3% | 1% | 5% | 2% | 1% | 8% | 100% |
| **Total value added** | 1% | 5% | 0% | 1% | 4% | 3% | 2% | 3% | 8% | 5% | 17% | 5% | 4% | 1% | 7% | 1% | 5% | 3% | 3% | 23% | 100% |
| **Output** | 1% | 7% | 1% | 4% | 6% | 3% | 2% | 3% | 7% | 5% | 15% | 5% | 4% | 1% | 7% | 1% | 5% | 4% | 3% | 15% | 100% |

Taxes on production and imports (TOPI) consist of tax liabilities, such as general sales and property taxes that are chargeable to business expense in the calculation of profit-type incomes. Also included are special assessments. TOPI is the sum of business taxes and fees paid to the federal, state, and local governments. Components of TOPI include general excise taxes (GET), transient accommodations taxes (TAT), fuel taxes, property taxes, customs duties, and certain types of non-tax fees. Subsidies consist of the monetary grants paid by government agencies to private business or to government enterprises at another level of government. As mentioned earlier, the Transient Accommodation Tax (TAT) stands at 7.25%. This tax will be disaggregated from the remaining tax revenues and modelled explicitly in the CGE analysis that follows. Taxes totalled $US 3.12 billion in 2002. Net subsidies exist for the agriculture and government sectors. Retail Trade and Real Estate and Rentals have the largest tax bills at 26% and 17% respectively.

Other capital costs consist of several components, including corporate profits, consumption of fixed capital (i.e., depreciation), net interest paid, net rental income of individuals, and business transfers. Other capital costs by industry were computed by subtracting proprietors' income from gross operating surplus. This component will appear as the capital demand and supply in the CGE models. In 2002, the value of capital is $US 12.03 billion. The most capital intensive industries are Real Estate and Rentals and the Government sectors at 51% and 8% respectively.

## 3.5 Conclusions

This chapter reviews the economy of Hawaii and the role tourism plays in the economy. It outlines some of the key features of the economy in Hawaii, placing in context the modelling to be undertaken in later chapters. The chapter then describes salient features of the 2002 Input-Output Table.

Over the last fifty years Hawaii has transitioned from an agricultural based economy to a service-based economy with a focus on tourism. Tourism in Hawaii is an important component in the economy contributing to 30% of Gross State Product. Since the 1990s, the growth tourism arrivals to the state have been relatively stagnant. Similarly the supply of tourism services has plateaued. As buoyant and healthy as Hawaii's economy presently looks, over the past 15 years it has been subject to several large exogenous shocks. The Gulf War of 1991 and the terrorist attacks of September 11 impacted not only the sectors predominantly serving to tourism but the rest of the economy also. This chapter has shown the variability of visitor arrivals based on several external shocks. Shocks are not one-off events; they will keep occurring. There is still capacity in Hawaii's accommodation services but net increases have been marginal while the composition of the accommodation has changed. Recently, older and less expensive accommodation has been replaced with more upscale accommodation.

The original 2002 Hawaii Input-Output table consists of 67 sectors. These sectors have been aggregated to 20. The table consists of one representative household and explicitly delineates visitor expenditures from non-tourism export receipts. One of the main uses of the Input-Output table is to provide a benchmark for CGE models. Building an economic model to measure the impact of shocks will both aid destination marketing organisations to better market their products after such shocks and it will also add to the body of economic knowledge regarding how to incorporate such shocks into an applied economic model.

Chapter four, which follows, outlines the CGE methodology used to estimate the economic impact of tourism to Hawaii. The methodology describes the fundamental characteristics of the model. Step by step the basic CGE model is advanced culminating in a multi-sector dynamic forward-looking. From here, risk will be incorporated into the model.

# CHAPTER FOUR

# THE CGE MODEL FOR HAWAII: IMPACT OF A SIMULATED TOURISM CONTRACTION

## 4.1 Introduction

This chapter describes the formulation of the CGE model used in the analysis. The chapter outlines a CGE model that builds in increasing levels of sophistication. Starting with a relatively simple static version, this chapter outlines the features of the CGE model (Section 4.3). The model is then modified to incorporate more sophisticated features: moving from a full-employment static model to a static model that includes the possibility of unemployment. Incorporating a time dimension into the model, the static model is converted into a dynamic recursive model. This is reported in Section 4.3. The dynamic recursive model is solved one period at a time and then all the variables in the model are exogenously updated in the following time period, which again is solved for that single time period. This implies the behaviour of its agents is based on adaptive expectations, rather than on the forward-looking expectations that underlie inter-temporal optimisation models. Section 4.5 develops a dynamic forward-looking model, which can be interpreted as a simple neoclassical growth (Ramsey) model. The single sector dynamic forward-looking model will be explained, followed by the multi-sector equivalent (Section 4.6).

Using the Hawaii 2002 input-output table as a benchmark, at each increasing level of model sophistication, a simulated tourism bust of a 10% decrease in tourism demand for the economy of Hawaii will be simulated and analysed. The analysis will outline how changes in the models impact the economy compared to the benchmark. Explaining the models and providing some interim results in this chapter will lay the foundation for the introduction of risk on a conceptual level (introduced in Chapter Five) and the implications of the risk in a CGE model (explained in Chapter Six).

## 4.2 Economic Modelling

Economic models can be categorised with the following features: static versus dynamic models, equilibrium versus disequilibrium models and deterministic versus stochastic models. CGE models are a specific type of economic model. Defining these concepts in turn, a static model is one that does not account for time. It identifies the before and after outcomes but does not trace the path that the model takes to move from one equilibrium position to another. In contrast, a dynamic model incorporates time as a variable, which can be used to trace how the model moves from one equilibrium position to the next. Static models (by their nature) are equilibrium models as they analyse the before and after equilibrium positions. However, dynamic models can be either equilibrium or disequilibrium models. Economic models can either converge to a steady-state or not. A convergent model will tend, over time, to reach a stable equilibrium position. This is in contrast to the disequilibrium model where there is no tendency to equilibrium.

Models can also be distinguished by whether they are deterministic or stochastic. A deterministic model assumes that an outcome is certain. Therefore, a change to an exogenous variable will have a certain impact on the endogenous (dependent) variable. However, a stochastic model includes an unknown factor that will influence the endogenous variable. It is common for a stochastic model to include a random element. It can be argued that the stochastic model is more realistic as it can account for behavioural factors. Economic variables are difficult to measure; therefore, a more realistic model would include a random variable to account for these issues.

All of the CGE models examined in relation to tourism base their results on deterministic calibration procedure. They ignore the stochastic elements that may affect both the production and consumption sides of the economy.

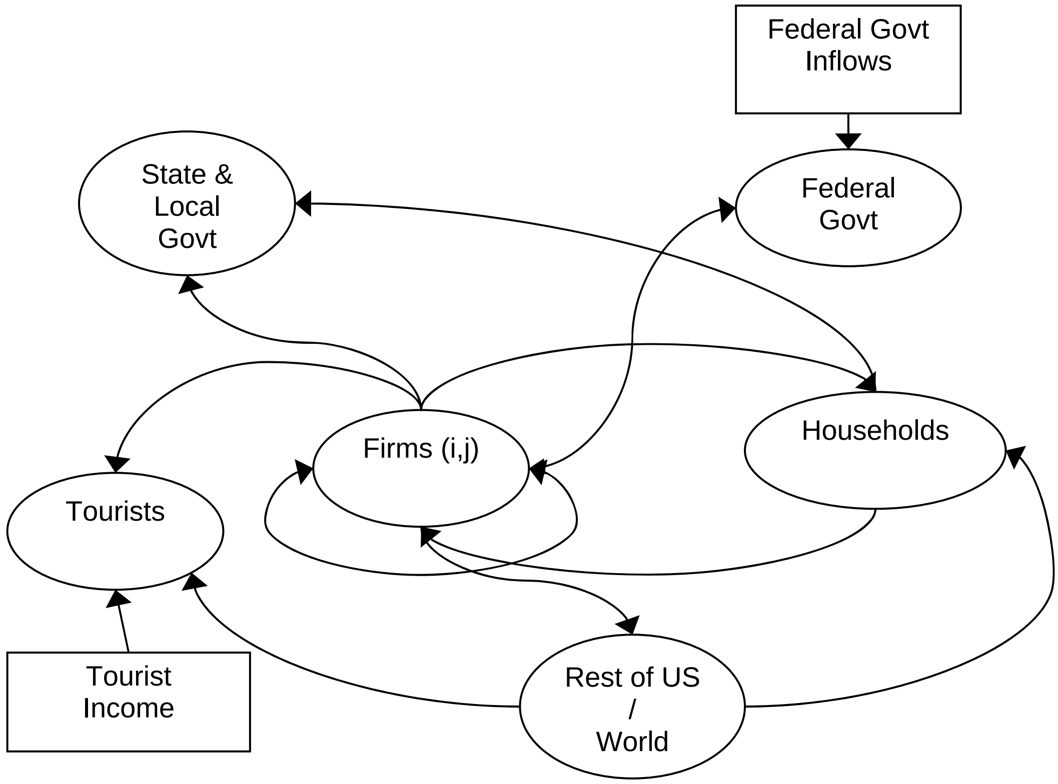
## 4.3 Static Model (Intra-temporal)

This section outlines the structure of the static model including the specification of the functional forms.

**4.3.1 Overview of the Structure of the Static Model**

The static CGE model follows the interactions and relationships of a market economy and solves for a set of prices including production prices, factor prices and exchange rate and levels of production that clear all markets. The static model recreates an Arrow-Debreu (1954) general economic equilibrium model. The model contains a representative consumer. Each consumer has an initial endowment of the 20 commodities and a set of preferences resulting in demand functions for each commodity. Market demands are the sum of all consumers' demands. Commodity market demands depend on all prices and satisfy Walras' law. That is, the total value of consumer expenditures equals consumer incomes, at any set of prices. Technology is described by constant returns to scale production functions. Each industry is assumed to be made of profit maximising firms which use two main factors, labour and capital in production function. The zero homogeneity of demand functions and the linear homogeneity of profits in prices (i.e. doubling all prices double money profits) imply that only relative prices are of any significance in such a model. The absolute price level has no impact on the equilibrium outcome (Rutherford, 1999; Rutherford & Paltsev, 1999). The flow between the sectors is shown in Figure 4.1.

**Figure 4.1: Inter-temporal flow of the CGE Model**




CGE models need to have the functional forms of utility and production functions specified. While CGE models need to be specific about the nature of production technology, it is important that the most appropriate functional forms are chosen. In econometric modelling, functional forms are used to estimate the local characteristics of technologies or preference ordering from a given data set. In applied general equilibrium models functional forms are used as a global representation of technologies and preferences. In "grossing up" the assumptions about the technologies and preferences, the global properties of these functional forms become important (Perroni & Rutherford, 1995). This is because, unlike econometric models, properties like third-order curvature of the functions can affect estimates of welfare impacts, both in total and at the margin, quite substantially. Perroni and Rutherford (1996) explore the properties of four flexible functional forms in order to assess their comparative performance and suitability for use in applied equilibrium modelling. "Performance" is evaluated by investigating the global regularity and third-order curvature properties of functional forms. The authors conclude globally regular functions like the Nonseparable Nested Constant Elasticity of Substitution (CES) are better at preserving local calibration information and hence better suited for equilibrium analysis than the Translog (Christensen, Jorgenson, & Lau, 1971), the Generalised Leontief (Diewert, 1971), and the Normalised Quadratic (Diewert & Wales, 1987). Nonseparable Nested CES functions will be incorporated into this dynamic general equilibrium model.

### 4.3.2 Production and Factor Markets

Firms have two decisions to make. Firms must first choose sectoral input demands, derived from profit maximising conditions and firms must allocate output between domestic sales and exports, based on revenue maximising conditions. Hence, firms are assumed to be price takers who choose variable inputs and its level of investment in order to maximise profits. Each industry is modelled using the constant elasticity of substitution (CES) family of functions, which includes Leontief, Cobb-Douglas and Constant Elasticity of Transformation (CET) functions. Each production sector $Y_i$ produces two types of commodities: domestic goods $D_i$ and goods for export $E_i$. These goods are assumed to be imperfect substitutes, and they have a constant elasticity of transformation. For production, each sector uses capital, labour, and intermediate goods. As such, the sector's *i* production function is

$Y_i = \mathrm{g}(\mathrm{D_i}, \mathrm{E_i}) = \mathrm{f}(\mathrm{K_i}, \mathrm{L_i}, \mathrm{A_{i,j}})$ where g is output transformation function, and f is input transformation function. Output transformation is assumed to be the constant elasticity of transformation (CET):

$Y_i = \Theta\left(\delta_i^e D_i^{\frac{\eta-1}{\eta}} + (1-\delta_i^e) E_i^{\frac{\eta-1}{\eta}}\right)^{\frac{\eta}{\eta-1}}$ where $Y_i$ = output; $E_i$ = exports; $D_i$ = domestic production; $\eta$ = the elasticity of transformation in total supply; $\delta_i^e$ = the calibrated share of exports; and $\Theta$ = the calibrated shift parameter in the transformation function. The value of gross supplies in the economy must equal the sum of the domestic supplies and exports:

$PY_iY_i = PD_iD_i + PE_iE_i$ where $PY_i$ is the price of domestic supplies of commodity *i*; $PE_i$ is the price of exported goods; and $PD_i$ is the price of domestic supplies.

An intermediate input to a sector *i* from a sector *j* is an Armington aggregate of domestic output and imports (Armington, 1969). Users regard these goods as imperfect substitutes, even though they are in the same sector. They are assumed to be qualitatively different and intra-industry trade can occur. These goods are assumed to have a constant elasticity of substitution (CES) between them.

$$A_i = \Omega\left(\delta_i^m D_i^{\frac{\gamma-1}{\gamma}} + (1-\delta_i^m) M_i^{\frac{\gamma-1}{\gamma}}\right)^{\frac{\gamma}{\gamma-1}}$$

where $A_i$ = the Armington CES aggregate of domestic supplies, $D_i$ and imported supplies, $M_i$ for each sector; $\gamma$ = the elasticity of substitution in the aggregate supply function; $\delta_i^m$ is the share of imported goods; and $\Omega$ = the calibrated shift parameter of the aggregated supply function.

The Armington specification treats imports and domestic goods produced in the same industry as distinct goods with a specified elasticity of substitution in demand. By differentiating exports, imports, and domestically produced goods sold on the domestic market, the CGE model increases the scope of the non-tradable sector. The effect of product differentiation allows domestic prices to be partially insulated from changes in the world prices of exports and imports and from changes in the exchange rate. The elasticity of substitution has been set to 4 between domestic and imported goods.

The aggregate value of supply in the economy must be equal to the sum of the values of domestic supplies and imports:

$PA_i A_i = PD_i D_i + PM_i M_i$ where $PD_i$ and $PM_i$ are the gross price of domestic and import supplies respectively; and $PA_i$ is the gross price of composite commodity *i*.

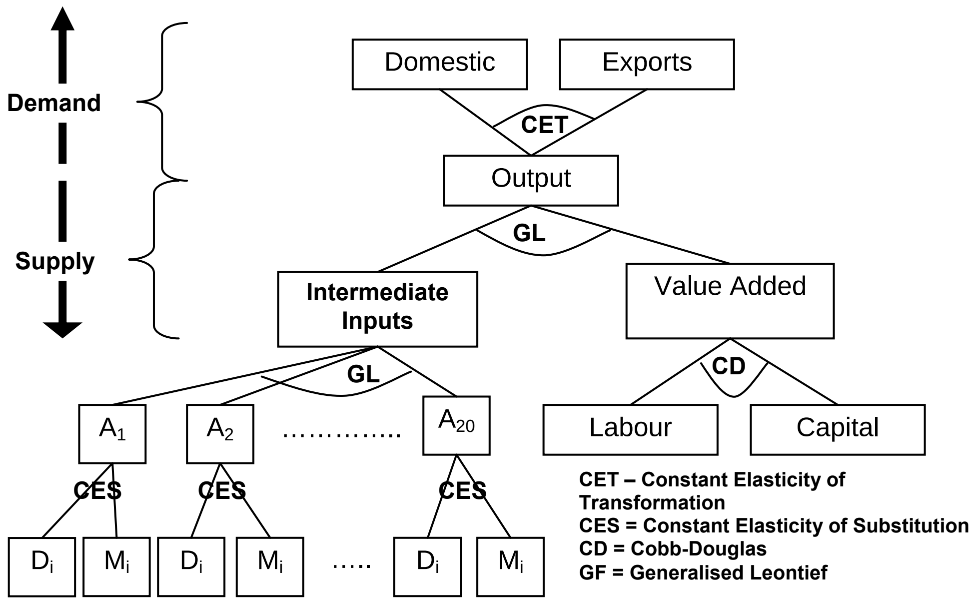
The production of goods follows from a nested Leontief-Cobb Douglas production function. Output is allocated to the domestic and export markets according to a constant-elasticity-of-transformation. Intermediate inputs are Leontief, while labour and capital enter as a Cobb-Douglas value-added aggregate.

The factors of production are combined via a Leontief aggregation. Capital and labour enters as a Cobb-Douglas value-added aggregate. Intermediate inputs from different sectors enter as a Leontief aggregate into a sector *i*'s production function:

$$\mathrm{f}(\mathrm{K}_{\mathrm{i}},\mathrm{L}_{\mathrm{i}},\mathrm{A}_{\mathrm{i,j}}) = \min\left\{B_i L_i^{\alpha_i} K_i^{(1-\alpha_i)}, \min\left\{\frac{A_{i,1}}{a_{i,1}}, \frac{A_{i,2}}{a_{i,2}}, \ldots, \frac{A_{i,j}}{a_{i,j}}\right\}\right\}$$

This is a constant returns to scale production function. Production can be depicted as in Figure 4.2.

**Figure 4.2: Production Schematic**




Armington aggregate is used for private consumption, government consumption, investment, and as an intermediate input for production. The three types of government consumption are Leontief aggregates across Armington composites of domestic goods and imports.

$$SLG_i = \min\left\{\frac{A_{i,1}}{a_{i,1}}, \frac{A_{i,2}}{a_{i,2}}, \ldots, \frac{A_{i,j}}{a_{i,j}}\right\}$$

$$FCG_i = \min\left\{\frac{A_{i,1}}{a_{i,1}}, \frac{A_{i,2}}{a_{i,2}}, \ldots, \frac{A_{i,j}}{a_{i,j}}\right\}$$

$$FMG_i = \min\left\{\frac{A_{i,1}}{a_{i,1}}, \frac{A_{i,2}}{a_{i,2}}, \ldots, \frac{A_{i,j}}{a_{i,j}}\right\}$$

where $SLG_i$ = state and local government consumption and investment; $FCG_i$ = federal government civilian consumption and investment; and $FMG_i$ = federal government military consumption and investment.

Overall market clearing in the product market means:

$$\mathrm{A}_{\mathrm{i,j}} = C_i + SLG_i + FCG_i + FMG_i + I_i + \sum_{j}^{n} DA_{i,j} + \sum_{j}^{n} MA_{i,j}$$

where $A_{i,j}$ = the Armington CES aggregate; $C_i$ = household consumption; $I_i$ = private investment; $DA_{i,j}$ = demand for domestically produced intermediate inputs; and $MA_{i,j}$ = demand for imported intermediate inputs.

### 4.3.3 The Demand Side

The demand side consists of the household sector, three types of governments, investment demand and tourism demand.

**Consumption**

A representative agent has an endowment of primary factors of production: capital and labour. They demand investment, private and government goods. The investment and the government sectors' output are exogenous while private demand is determined by utility maximizing behaviour. Consumer utility consists of a nested Cobb-Douglas utility index where the top level is a

Cobb-Douglas function of aggregate composite consumption and savings. The second level nest is defined over Armington aggregation of domestic and imported commodities.

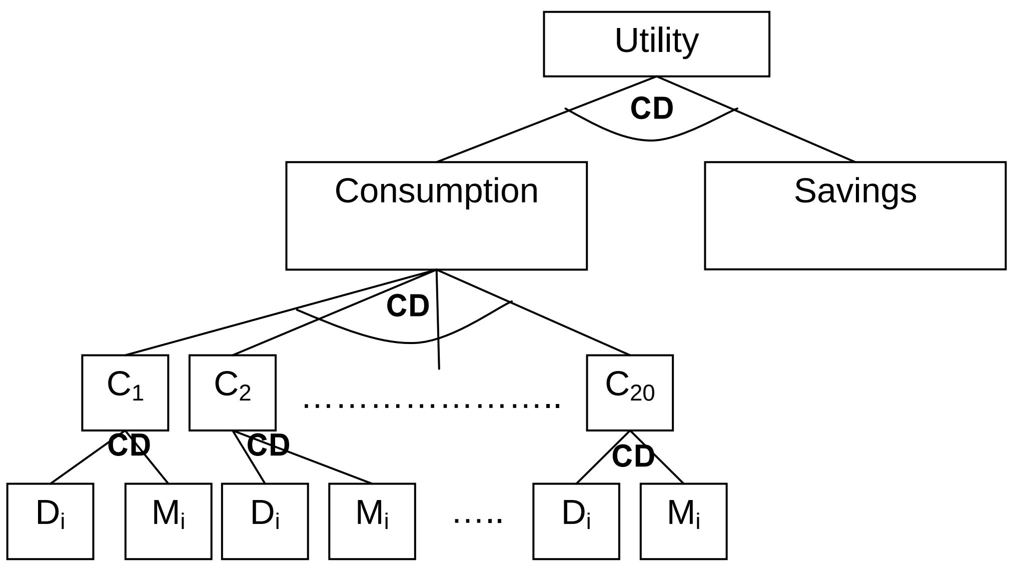
$$U = \kappa C^{\sigma} S^{1-\sigma}$$

where $U$ = utility; $C$ = aggregate consumption; $S$ = savings; $\kappa$ is a calibrated shift parameter; $C = \prod_{i=1}^{n} c_i^{\alpha_i}$ where $c_i$ = consumption by sector;

$$c_i = \mathrm{X}\left(\delta_i^c CD_i^{\frac{\gamma-1}{\gamma}} + (1-\delta_i^c) CM_i^{\frac{\gamma-1}{\gamma}}\right)^{\frac{\gamma}{\gamma-1}}$$

; $CM_i$ = imported production of consumption good; $CD_i$ = domestic production of consumption good; $\gamma$ = the elasticity of substitution between domestic goods and services and imported goods and services; $\delta_i^c$ = the calibrated share of consumed domestic goods; X = the calibrated shift parameter in the substitution function.

**Figure 4.3: Utility Composite**



**Government**

In this model, there are three types of government: the federal military government, federal civilian government and the State & Local government. The federal government agents are assumed to be exogenous in the model. The State & Local government in each region collects tax revenues to maximize social welfare function which represents the State's preferences. The role of taxes is to redistribute income, to finance State & Local government expenditures, to alter behaviour of the other economic agents, and to stabilize an economy. The State & Local government can use taxes to maximize social welfare. The aim of the optimal taxation is to balance efficiency losses from taxes with equity gains. The tax revenue that the State & Local Government receives is wholly expended on public consumption and transfers to the representative household. Like Blake (2000), this model is characterised by fiscal neutrality so that public consumption remains constant. Any changes in tax revenues or changes in the prices paid by the government for public consumption goods result in changes in the level of transfers. This is done so that welfare calculations are based solely on private utility. State & Local Government consumption is fixed in real terms. State & Local Government savings is a flexible residual.

**Tourism**

Tourism is modelled in the following way: a representative tourism household demands tourism in Hawaii (a certain quantity of a composite good and service) at an aggregated tourism price level, PT. It is assumed all tourists are homogeneous and that there is a representative tourist accounting for all tourists' consumption. As in the case of the domestic household, tourism demand is obtained by maximising the utility function of the representative tourist subject to their budget constraint. A constant elasticity of demand function is used, whereby demand varies according to the price of the appropriate bundle of tourism goods and services hence Hawaii faces a downward sloping demand curve for its tourism. Tourism consumption *TC* is related to a composite tourism price (akin to a tourism CPI), *PT* and the exchange rate, *PFX* in the following manner:

$$TC = \Theta \overline{TC} \left( \frac{PT}{PFX} \right)^{\varsigma}$$

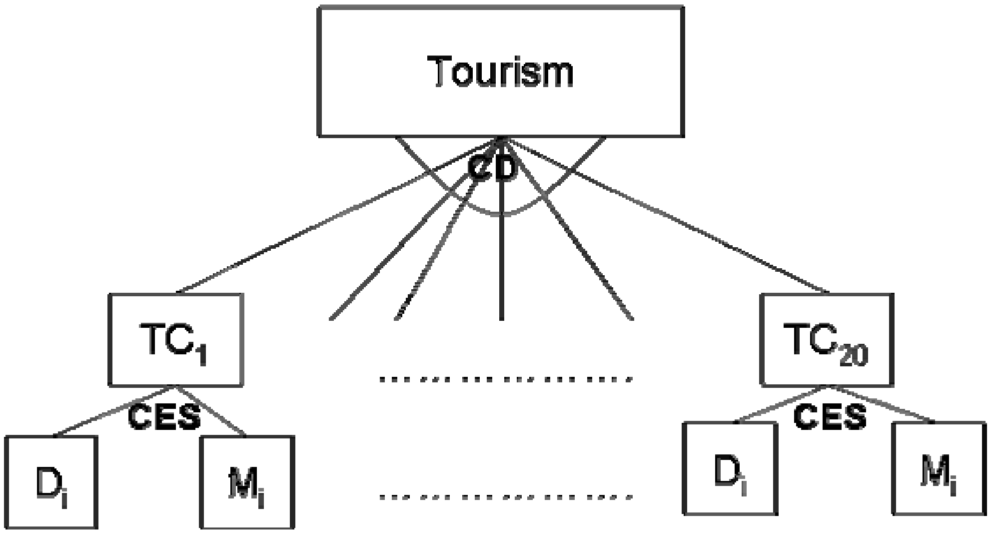
where $\overline{TC}$ is the base level of tourism consumption, $\varsigma$ is the price elasticity of demand for foreign tourism $(\zeta < 0)$ and $\Theta$ is a shift parameter ($\Theta = 1$ unless there is an increase in tourism demand being modelled, in which case $\Theta = 0.9$ simulates a 10% decrease in tourism demand). The elasticity of demand has been set at 0.5. Tourists are endowed with foreign exchange.

Tourism consumption is composed of the consumption of different commodities, with a Cobb-Douglas function determining how tourists substitute between commodities. The utility of the representative tourist is a Cobb-Douglas function of consumption of the composite goods

$$TC = T\prod_{i}^{n} tc_i^{\theta}$$

where $TC$ = aggregate tourism consumption; $T$ = a shift parameter, that is calibrated to ensure the model replicates the benchmark; $\theta$ = the share of commodity $i$ in tourism consumption; $tc_i$ = consumption by sector; $tc_i = \mathrm{X}\left(\delta_i^{tc} TCD_i^{\frac{\gamma-1}{\gamma}} + (1-\delta_i^{tc}) TCM_i^{\frac{\gamma-1}{\gamma}}\right)^{\frac{\gamma}{\gamma-1}}$; $TCM_i$ = imported production of a tourism consumption good; $TCD_i$ = domestic production of tourism consumption good; $\gamma$ = the elasticity of substitution between domestic goods and services and imported goods and services; $\delta_i^{tc}$ = the calibrated share of consumed tourism domestic goods; $\mathrm{X}$ = the calibrated shift parameter in the substitution function.

**Figure 4.4: Basic Structure of Tourism Consumption**




### 4.3.4 Model Solution and Closure

#### Model Solution

The model has been programmed using the software package, GAMS (Brooke, Kendrick, & Meeraus, 1988). GAMS, the "General Algebraic Modelling System", is a modelling language which was developed for linear, non-linear and integer programming. A GAMS subsystem, MPSGE, developed by Rutherford (Rutherford, 1999), is a language for the concise representation of Arrow-Debreu economic equilibrium models. MPSGE provides a shorthand representation for the complicated systems of non-linear inequalities that underlie general equilibrium models. One feature of a general equilibrium model developed in GAMS is that solution provides relative prices only and the modeller usually fixes one price. In this model, the consumer price index was chosen as the numeraire.

**Model Closure**

Regional CGE models differ from their national counterparts in several respects. These differences, and the nature of the economies, provide insights into the most appropriate closure rules to apply. Because of regional openness, commodity trade and resource migration are more important in regional CGE models (Vargas, Schreiner, Tembo, & Marcouiller, 1999). For example, regional households are unlikely to invest within the region if other regions offered higher rates of return. Thus, while national CGE models require that savings be equal to investment, some regional CGE models permit excess savings to flow out of the region and vice-versa. Further, while regional policymakers can influence rates of return to investments, it is at the national level that the components of monetary policy are mainly determined.

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Berck *et al.* (Berck et al., 1996) also note differences between national and regional CGE models. These differences include the fact that regional economies trade a larger share of their output; regional economies face larger and more volatile migration flows than nations; regional economies have no control over monetary policy; and regional CGE models do not require that regional savings equal regional investment.

The model needs to be closed in the sense that the modeller needs to designate which variables are exogenous and which variables are endogenous to the model. In theory, the economic model specified has more variables than number of equations. For a solution though, the number of endogenous variables must equal the number of equations. The model will not solve otherwise. Solving the model, then, requires an *a priori* allocation of some variables. This is achieved by assigning these variables numerical values based on the base year IO table. These variables are then known as the exogenous variables. The equations in the model are then solved for the endogenous variables.

The CGE model includes three closures:

1. The government closure
2. The external closure (the current account of the balance of payments, which includes the trade balance)
3. The Savings-Investment closure

While the choice of closure makes no difference to the calibrated base model, the closures do impact the results of the counterfactual simulations. The closure for production in this model follows the neoclassical characteristics where the quantity supplied of each factor is fixed at the original level. Holding quantities constant means prices change to bring about equilibrium. So in the labour market for example, an economy-wide wage can vary to ensure that total demand for labour equals total supply of labour. In this type of closure, the industry-specific wages are fixed.

The closure for the government sector allows the current fiscal stance (the difference between current government revenues and current government expenditures) to be a flexible residual while all tax rates are fixed (discussed above).

The model assumes a fixed trade balance for the state of Hawaii. Using this specification, then the exchange rate is the equilibrating variable. The role of the 'real' exchange rate in a state economy is to bring into equilibrium the external sector (Robinson, 1991). In the CGE model, the exchange rate is a well-defined relative price, usually designated in domestic currency per unit of foreign currency. The 'currency' is defined as units of domestic and world prices. No financial variables in the model (De Janvry & Kanbur, 2006). The model specifies a functional relationship between the balance of trade and the real exchange rate. The definition of the 'real' exchange rate is the relative prices of traded to non-tradables/ semi-tradables. This relationship is one of the crucial driving mechanisms determining how external shocks and stabilization policies will affect the real side of the economy. CGE models define only flow equilibria, and macro equilibria must be defined in flow terms (Ginsburgh & Keyzer, 1997). The external closure in this model requires the real exchange rate to vary while keeping foreign savings (the current account deficit) fixed. Foreign savings is the difference between foreign currency spending and receipts. The trade balance is fixed since all other items in the external balance such as transfer between the rest of the world and domestic institutions are fixed.

Regarding the Savings-Investment balance, the closure is termed "investment-driven" savings. For the closure that is investment driven, real investment quantities are fixed. In order for savings to balance, the savings rates of the non-government institutions are altered by the same number of percentage points; the implicit assumption being that government is able to put into action policies that generate the necessary private savings to finance the fixed real investment quantities. These three closures are the standard closures in CGE models.

**Measuring Welfare**

In terms of how to assess the impact of simulations on the economy, one way to do this is to measure the change in welfare from the simulated change. The change in welfare is calculated by comparing the existing equilibrium with the counterfactual equilibrium. The measures most widely used are Hicksian compensating and equivalent variations associated with equilibrium comparison. The compensating variation (CV) takes the new equilibrium income and prices, and computes how much income must be added or subtracted in order to return households to their pre-change utility levels. The equivalent variation (EV) takes the initial equilibrium income and prices and computes the change needed to achieve new equilibrium utilities. It is the amount of income necessary to get to the new level of utility. This means for a welfare improving change, the CV is negative and the EV is positive.

The expression for equivalent variation is given by EV = $E(U_1,P_0) - E(U_0,P_0)$

=> $EV = \frac{U1 - U0}{U0} Y0$ where U1 is the new level of utility, U0 is the benchmark utility and Y0 is benchmark income.

Another key measure of economic impact is Gross Value Added (GVA). GVA is measure of the net total output or income generated by an economy. Essentially it is the difference between the value of the goods and services produced in the economy and the cost of raw materials and other inputs which were used in their production. In this model, it is defined as labour payments plus gross operating surplus plus taxation payments made by an industry.

### 4.3.5 Impact of a Tourism Contraction

Having calibrated the CGE model to the base year of 2002, different scenarios (or counterfactuals) can be modelled to examine the impact on the economy. The objective of the calibration is to ensure that the solution to the model yields the appropriate model parameters and replicates the base year economic situation. The scenario to be modelled in this static CGE model is a 10% decrease in visitor expenditures. As expected, a 10% reduction in visitor expenditure impacts on welfare, domestic consumption output, trade, prices and factor demands.

**Table 4.1: Results from a 10% Decrease in Tourism Demand in a Static Model**

| Economic Indicators | Percentage Change from Benchmark |
|---|---|
| Welfare (EV) | -2.21 |
| Household Consumption | -2.26 |
| Tourism Consumption | -13.04 |
| Price of Tourism | -0.47 |
| Labour | 0.00 |
| Wage Rate | -0.49 |
| Capital | 0.00 |
| Return to Capital | -2.70 |
| Investment | -3.35 |
| Investment Price | 1.13 |
| Price of Foreign Exchange | 4.36 |
| State & Local Govt Goods Price | -0.35 |
| Federal Govt Military Goods Price | -0.43 |
| Federal Govt Civilian Goods Price | -0.42 |

A decline of 10% in tourism demand has resulted in decrease in welfare. The simulated negative tourism shock results in a decrease in welfare of 2.2%, as shown in Table 4.1. Hawaii residents' consumption also dropped 2.3% with the drop in investment marginally greater at 3.4%. Factor prices have decreased with the wage rate falling 0.5% and the return to capital falling by slightly more (2.7%). Real tourism fell by more than the simulated 10% decrease (13.0%) – the additional fall being attributed to the decrease in the real exchange rate, with the price of the tourism bundle falling half a percent but the price of foreign exchange increasing by 4.4%. The higher relative price paid by tourists leads to a further decrease in tourist demand – the terms of trade effect. For the three tiers of government, there was a decrease in the price of its public good with the State and Local Government public good price falling marginally and the Federal Government's military and civilian public good price decreasing by the same small amount (0.4%).

Examining the relationship between the tourism shock and welfare, as measured by equivalent variation, Table 4.2 shows that the 10% decrease in tourism demand, equivalent to a negative shock of $US 1,127 million, resulted in real tourism consumption decreasing by $US 1,470 million and real tourism expenditure decreasing by $US 1,515 million. Welfare, as measured by the change in Hawaii residents' consumption is estimated to fall by $US 506 million. Another indicator of the impact of simulated tourism bust is to calculate the ratio of the change in welfare to the change in tourism demand. This can be thought of as a kind of multiplier, akin to Input-Output Analysis where policy makers can examine the change in welfare for each $1 change in tourism demand. In this static CGE model of the economy in Hawaii, for every $US 1 decrease in tourism demand welfare decreases by $US 0.45. However, the difference between results obtained with Input-Output Analysis and CGE modelling is that CGE models are non-linear and hence these "multiplier" results will vary depending on magnitude of the counterfactual.

**Table 4.2: Simulated Change in Tourism Variables**

| | Change in Value ($US million) | Negative Tourism Shock |
|---|---|---|
| 1 | Tourism Demand (Simulation) | -1,127 |
| 2 | Real Tourism Consumption | -1,470 |
| 3 | Real Tourism Expenditure | -1,515 |
| 4 | Equivalent Variation | -506 |
| | Change in Welfare per $1 decrease in Tourism Demand (4/1) | 0.45 |
| | Change in Welfare per $1 decrease in Tourism Consumption (4/2) | 0.34 |
| | Change in Welfare per $1 decrease in Tourism Expenditure (4/3) | 0.33 |

Examining the impact of specific industries, Table 4.3 shows the tourism-related industries shrink as a result of the 10% decrease in tourism demand.

In terms of percentage change in GVA, the largest negative impact is in the accommodation industry (-10.7%), following by arts, entertainment & recreation (-6.6%), the transportation industry (-4.4%) and Eating and Drinking Places (-4.0%). One striking feature of the analysis is the estimated growth in the non-tourism exporting sectors, particularly in the food processing sector (+31.2%) as well as growth in the manufacturing and agriculture sectors (increases of 26.5% and 23.5% respectively). The reason for this relates to the exchange rate movements and the characteristics of these industries in the Hawaiian economy. In 2002, the total output for the manufacturing sector amounted to $US 2,714 million. Manufacturing sales to final demand totalled $US 1,077 million, including $US 410 million to non-tourism exports (38.1% of final demand). Non-tourism exports comprised 55.9% of final demand and 44.8% of final demand for agriculture and food processing sectors, respectively. Further, manufactured goods made up 17.5% of all non-tourism exports, the highest proportion of the 20 industry sectors after the Finance and Insurance sector. In terms of manufacturing purchases from other industries, in 2002, Hawaiian industries provided $US 526.8 million worth of production but a total of $US 1,618.1 million imports (over 3 times the amount from Hawaiian industries) fed into the manufacturing sector, representing over 60% of all purchases.

**Table 4.3: Percentage Change in Variables by Sector**

| | GVA | Labour | Capital | Exports | Imports |
|---|---|---|---|---|---|
| Accommodation | -10.7 | -11.3 | -9.3 | | -27.6 |
| Arts, Entertainment & Recreation | -6.6 | -7.0 | -4.9 | -1.7 | -24.5 |
| Transportation | -4.4 | -4.8 | -2.6 | 0.1 | -21.4 |
| Eating & Drinking Places | -4.0 | -4.5 | -2.3 | 1.0 | -21.8 |
| Educational Services | -2.6 | -2.6 | -0.4 | | -19.9 |
| Retail Trade | -2.1 | -2.5 | -0.3 | 3.2 | -20.6 |
| Real Estate & Rentals | -1.6 | -3.6 | -1.4 | 4.7 | -23.8 |
| Health Services | -0.9 | -1.1 | 1.1 | | -18.8 |
| Business Services | 0.0 | -0.3 | 2.0 | 5.1 | -19.0 |
| Government | 0.2 | 0.0 | 2.2 | | -17.8 |
| Other Services | 0.6 | 0.3 | 2.6 | | -17.7 |
| Utilities | 0.6 | -0.8 | 1.4 | | -17.5 |
| Professional Services | 1.5 | 1.3 | 3.6 | 6.7 | -18.5 |
| Construction | 2.1 | 1.8 | 4.2 | 7.0 | -15.4 |
| Wholesale Trade | 2.3 | 1.8 | 4.2 | 7.7 | -17.5 |
| Finance & Insurance | 3.6 | 2.6 | 5.0 | 9.5 | -21.4 |
| Information | 4.7 | 3.8 | 6.2 | 10.6 | -18.7 |
| Agriculture | 23.5 | 22.6 | 25.4 | 30.0 | -12.4 |
| Manufacturing | 26.5 | 26.5 | 29.4 | 32.3 | -8.9 |
| Food Processing | 31.2 | 31.3 | 34.3 | 38.4 | -21.7 |

In terms of the simulated impact on exports, only arts, entertainment & recreation shows a small percentage decreases. The other industries show modest increases with the exception of manufacturing (32.3%), food processing (38.4%) and agriculture (30.0%), which show large increases.

Demand for imports also decrease, on average by 19.2%. The tourism sectors display the largest decline with accommodation falling by 27.6% and arts, entertainment and recreation falling by 24.5%. The relatively inelastic demand for imports by the manufacturing sector, as evidenced by the high proportion of imports being purchased by the manufacturing sector, may have resulted in imports only decreasing by 8.9% in that sector.

The simulated effects impact prices and the impact on the aggregate prices has already been noted. Domestic prices decrease across all industries although these percentage decreases are small, again with the exception of the three high growth industries. A fall in prices in these industries would have simulated growth.

The effects from decreasing tourism demand on factors of production correspond closely with the effects on output (as can be seen from the 'Labour' and 'Capital' columns in Table 4.3. The industries with large output effects will generate large factor demand effects. For example, where output in the accommodation sector fell 10.7%, the corresponding decline in labour and capital in that industry of 11.3% and 9.3% respectively. This finding is a function of the model where the unique characteristic of the Cobb-Douglas production functions produces the strong correlation between the impacts on output and the factors of production, namely labour and capital.

**4.3.6 Unemployment**

The characteristics of the factor markets, labour and capital, can have a large impact of the results of the simulations. An increase in the demand for the factor of production will increase the rate of return of these factors, the wage rate and the interest rate, and therefore increase the wage rate and interest rates that firms need to pay for factor services. Although Hawaii's economy in the last several years has been close to full-employment, adding the possibility of unemployment in the labour market provides added realism to the model.

This section outlines how unemployment will be modelled. In the previous static model labour and capital move between sectors only in response to wage changes. Further, the degree of factor movement is determined by the extent to which the relative wage between sectors changes. The representative household decides on how much labour to supply at the given real wage rate. In order to maintain the flexibility to model unemployment in short-run situations, factor accumulation and labour supply responses in longer-run simulations, both unemployment and flexible labour supply are included in the model. The unemployment rate $u$ supplied by the household is a function of the real wage rate:

$$u = \bar{u}\left(\frac{p_c}{p_l}\right)^{\omega}$$

where $\bar{u}$ is the base rate of unemployment, $p_c$ is the price index for household consumption and $\omega$ is the elasticity of unemployment to real wages $(\omega < 0)$. This specification of unemployment says that an increase in relative wages, $p_l$, will increase the unemployment rate, $u$. Further, the larger in the elasticity of unemployment to real wages (more negative), $\omega$, the higher the increase the unemployment rate, $u$, all else being equal. This is a model of classical unemployment.

Factor supply is given by:

$$FY = (1-u)\overline{FY}\left(\frac{p_l}{p_c}\right)^{\eta}$$

where $\eta$ is the supply response elasticity. This specification says that an increase in relative wages will result in an increase in the labour supply, all else being equal. Workers will offer to work more hours at higher wages. Further, the larger the supply response elasticity, $\eta$, the larger the impact on labour supply, *FY*. When setting up the model to examine the short-run effects of an unanticipated shock, setting $\omega < 0, \eta = 0$ would be sensible, but to examine the long-run effects of a policy these elasticities would be $\omega = 0, \eta > 0$.

### 4.3.7 Impact of a Tourism Contraction with Unemployment

This section examines the results of 10% decrease in tourism demand in a static model with unemployment. The results will be contrasted with the full employment model results. In terms of the values assigned to the parameters related to the unemployment specification, the base unemployment rate in 2002 is 4.1% (DBEDT, 2004), the short run scenario is $\omega$= -0.5 and $\eta$= 0 (model denoted by SR) and the long run scenario is $\omega$= 0 and $\eta$= 0.1 (model denoted by LR) and $\omega$= -0.5 and $\eta$= 0.1 (model denoted by UN).

As can be seen from Table 4.4, the results of the model that incorporates unemployment are of the same direction and magnitude as the full employment model. The long run model where $\omega = 0$, labour is perfectly mobile across sectors but there is still unemployment incorporated in the model and where $\eta = 0$ there is a flexible labour supply but no unemployment. Welfare decreases as more assumptions are made about labour. A 10% decrease in tourism in the full employment model results in a 2.21% decrease in welfare whereas in the model with both unemployment and a flexible labour supply the same shock produces a 2.48% decrease in welfare. A similar trend can be seen for investment and household consumption. Wages still decrease but by a smaller amount in the unemployment model whereas the return to capital shows a larger decrease in the unemployment model.

**Table 4.4: Results of Unemployment Model**

| Economic Indicators | % Change from Benchmark | | | |
|---|---|---|---|---|
| | **FE** | **LR** | **SR** | **UN** |
| Welfare (EV) | -2.21 | -2.26 | -2.44 | -2.48 |
| Household Consumption | -2.26 | -2.31 | -2.50 | -2.55 |
| Tourism Consumption | -13.04 | -13.04 | -13.03 | -13.03 |
| Price of Tourism | -0.47 | -0.48 | -0.51 | -0.51 |
| Labour | 0.00 | -0.05 | -0.21 | -0.25 |
| Wage Rate | -0.49 | -0.47 | -0.42 | -0.41 |
| Capital | 0.00 | 0.00 | 0.00 | 0.00 |
| Return to Capital | -2.70 | -2.75 | -2.93 | -2.97 |
| Investment | -3.35 | -3.41 | -3.64 | -3.69 |
| Investment Price | 1.13 | 1.14 | 1.18 | 1.19 |
| Price of Foreign Exchange | 4.36 | 4.35 | 4.32 | 4.32 |
| State & Local Govt Goods Price | -0.35 | -0.35 | -0.33 | -0.33 |
| Federal Govt Military Goods Price | -0.43 | -0.42 | -0.41 | -0.40 |
| Federal Govt Civilian Goods Price | -0.42 | -0.41 | -0.40 | -0.40 |

The percentage change in Gross Value Added and Labour is shown in Table 4.5 for the four models. Again, the magnitude and direction of the impacts are similar to the full employment model. The simulation modelling unemployment displays lower decreases in the percentages change in GVA and labour by sector, that is, the percentages decreases are lower for the positive values or more negative for the negative decreases.

**Table 4.5: GVA and Labour Results of Unemployment Model**

| Percentage Change from Benchmark | Gross Value Added | | | | Labour | | | |
|---|---|---|---|---|---|---|---|---|
| | FE | LR | SR | UN | FE | LR | SR | UN |
| Accommodation | -10.7 | -10.7 | -10.7 | -10.7 | -11.3 | -11.3 | -11.4 | -11.4 |
| Arts, Entertainment & Recreation | -6.6 | -6.6 | -6.7 | -6.8 | -7.0 | -7.1 | -7.2 | -7.3 |
| Transportation | -4.4 | -4.5 | -4.6 | -4.6 | -4.8 | -4.8 | -5.0 | -5.0 |
| Eating & Drinking Places | -4.0 | -4.1 | -4.2 | -4.2 | -4.5 | -4.5 | -4.7 | -4.7 |
| Educational Services | -2.6 | -2.6 | -2.8 | -2.9 | -2.6 | -2.7 | -2.9 | -3.0 |
| Retail Trade | -2.1 | -2.1 | -2.3 | -2.3 | -2.5 | -2.6 | -2.8 | -2.8 |
| Real Estate & Rentals | -1.6 | -1.7 | -1.7 | -1.8 | -3.6 | -3.7 | -4.0 | -4.0 |
| Health Services | -0.9 | -0.9 | -1.2 | -1.2 | -1.1 | -1.2 | -1.5 | -1.5 |
| Business Services | 0.0 | -0.1 | -0.2 | -0.3 | -0.3 | -0.4 | -0.5 | -0.6 |
| Government | 0.2 | 0.2 | 0.2 | 0.2 | 0.0 | 0.0 | -0.1 | -0.1 |
| Other Services | 0.6 | 0.6 | 0.4 | 0.4 | 0.3 | 0.3 | 0.1 | 0.0 |
| Utilities | 0.6 | 0.6 | 0.5 | 0.5 | -0.8 | -0.9 | -1.2 | -1.2 |
| Professional Services | 1.5 | 1.5 | 1.3 | 1.3 | 1.3 | 1.3 | 1.1 | 1.0 |
| Construction | 2.1 | 2.0 | 1.8 | 1.8 | 1.8 | 1.8 | 1.6 | 1.6 |
| Wholesale Trade | 2.3 | 2.3 | 2.1 | 2.0 | 1.8 | 1.8 | 1.5 | 1.5 |
| Finance & Insurance | 3.6 | 3.5 | 3.4 | 3.4 | 2.6 | 2.6 | 2.3 | 2.3 |
| Information | 4.7 | 4.7 | 4.5 | 4.5 | 3.8 | 3.7 | 3.5 | 3.4 |
| Agriculture | 23.5 | 23.4 | 23.1 | 23.0 | 22.6 | 22.5 | 22.0 | 21.9 |
| Manufacturing | 26.5 | 26.3 | 25.8 | 25.7 | 26.5 | 26.3 | 25.8 | 25.7 |
| Food Processing | 31.2 | 31.1 | 30.6 | 30.5 | 31.3 | 31.1 | 30.6 | 30.5 |

This section has reported results for a 10% decrease in tourism demand for the state of Hawaii. Several assumptions regarding the nature of the labour market have been modelled from a perfectly competitively labour market at full employment to a model with a flexible labour supply and unemployment.

## 4.4. Dynamic Recursive Model

The simplest dynamic extension of the static model is a dynamic recursive model. A dynamic recursive model involves solving a model for period $t$ (the intra-temporal model) and then solves the model for $t+1$ and so on. After the first time period, $t$, the updated database for the initial year is used as the initial data for period $t+1$. After the model is solved for period $t+1$, the updated values of the variables in the model are used as the initial data for period $t+2$ and so on. In this way, a linked series of annual simulations can be calculated. The inter-temporal (between-period) model links the static (intra-temporal or within-period) models by updating the variables that are exogenous in the base year from one period to the next. What happens in future periods does not affect the current year's equilibrium. This means the model can be solved year by year, without having to solve the whole study period at once.

### 4.4.1 Model Structure

There are several features of the dynamic recursive model that differ from the static model. Firstly, a time index is introduced into the model. Secondly, the representative household derives utility from consumption only; savings / investment serve another purpose in this model. The modeller needs to specify several exogenous parameters: the steady state growth rate of the economy, $\gamma$ (set to 2%); and the depreciation rate, $\delta$ (set to 1%). Exogenous quantity variables, such as labour supply are assumed to grow at this exogenous rate. Productive capital can only disappear at the rate of depreciation. Investment has a one-year gestation period, meaning that investment in year *t* will affect the productive capital of year *t+1*. Hence setting the depreciation rate defines the speed for structural changes in the model.

Lastly, the intra-temporal models are linked together with a savings / investment rule. The dynamic recursive model needs to specify how the capital stock grows. In this case:

$$QCAP_{t-1}(1-\delta) = \frac{\overline{I0}}{\overline{K0}} INV_{t-1}$$

Where $QCAP$ = the capital stock; $\delta$ = the depreciation rate; $\overline{I0}$ = the benchmark level of investment; $\overline{K0}$ = the benchmark level of capital stock; and $INV$ = the level of investment.

Savings can be treated in several ways, according to different rules. For example savings can be assumed to be a fixed share of income (DR1); savings could be dependent on the rental rate of capital (DR2) or savings could be a weighted combination of the first two savings rules (DR3).

### 4.4.2 Impact of a Tourism Contraction

This section provides the key findings from a simulated 10% decrease in tourism demand for the economy of Hawaii using a dynamic recursive model. The section will highlight the differences in results based on the three different savings rules outlined above.

The scenarios being modelled in this dynamic recursive model are a persistent 10% decrease in tourism demand across the 50 time periods as well as a 10% decrease in tourism demand from the 10$^{th}$ time period to the end of the model horizon. All other parameters have the same values as in the static model.

All the results, shown in Table 4.6 below, are of the same direction and similar magnitude as for the static model. Welfare decreases are larger in these dynamic recursive models than the static model with welfare decreasing by 3.6% in the model where savings is assumed to be a fixed share of income (DR1) and 3.4% in the model where savings is dependent on the rental rate of capital (DR2): this is for a persistent shock. Of course, the shock starting in the 10$^{th}$ time period onwards is of a smaller magnitude than for a shock across all time periods. Further, the savings rule that is a combination of the DR1 and DR2 produces results that are a weighted average of the two components and hence lie within the two singular models. In general, results where savings is a fixed share of income are more negative than for the model where savings is dependent on the rental rate of capital, for example investment decreases 3.5% in the DR1 model and by 2.6% in the DR2 model. The exception to this is for the return to capital, which decreases by 2.5% in the DR1 model and 2.7% in the DR2 model.

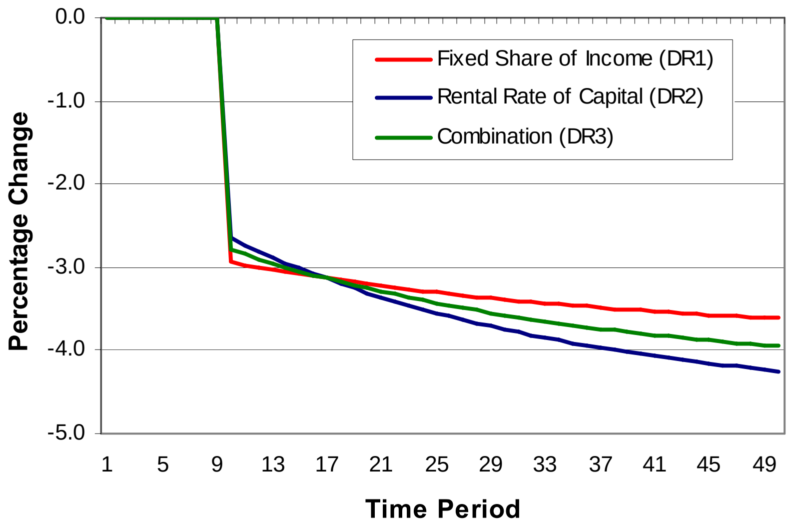
**Table 4.6: Results from a 10% Decrease in Tourism Demand in a Dynamic Recursive Model under Different Savings Rule Assumptions**

| Percentage Change in Variables from Benchmark across Model Time Horizon | Persistent Shock (10% Decrease in Tourism Demand from period t=1) | | | Delayed Shock (10% Decrease in tourism Demand from period t=10 onwards) | | |
|---|---|---|---|---|---|---|
| Economic Indicators | Savings Rule | | | Savings Rule | | |
| | DR1 | DR2 | DR3 | DR1 | DR2 | DR3 |
| Welfare (EV) | -3.58 | -3.41 | -3.49 | -2.48 | -2.70 | -2.60 |
| Household Consumption | -3.95 | -3.77 | -3.86 | -2.75 | -2.99 | -2.88 |
| Tourism Consumption | -13.23 | -13.16 | -13.19 | -10.68 | -10.78 | -10.73 |
| Price of Tourism | -0.72 | -0.68 | -0.70 | -0.45 | -0.49 | -0.47 |
| Labour | -0.62 | -0.53 | -0.57 | -0.28 | -0.41 | -0.35 |
| Wage Rate | -0.95 | -0.81 | -0.88 | -0.40 | -0.58 | -0.49 |
| Capital | -1.67 | -1.27 | -1.47 | -0.40 | -0.93 | -0.68 |
| Return to Capital | -2.48 | -2.66 | -2.57 | -2.22 | -1.99 | -2.10 |
| Investment | -3.48 | -2.61 | -3.04 | -0.94 | -2.17 | -1.60 |
| Investment Price | 0.99 | 1.05 | 1.02 | 0.87 | 0.79 | 0.83 |
| Price of Foreign Exchange | 3.97 | 4.05 | 4.01 | 3.13 | 3.02 | 3.07 |
| State & Local Govt Goods Price | -0.72 | -0.63 | -0.68 | -0.33 | -0.45 | -0.39 |
| Federal Govt Military Goods Price | -0.81 | -0.71 | -0.76 | -0.38 | -0.51 | -0.45 |
| Federal Govt Civilian Goods Price | -0.80 | -0.70 | -0.75 | -0.38 | -0.50 | -0.44 |

DR1= Savings Rule: Savings is assumed to be a fixed share of income
DR2= Savings Rule: Savings is dependent on the rental rate of capital
DR3= Savings Rule: Savings is both dependent on the rental rate of capital and a share of income

Figure 4.5 shows the percentage change in utility across time for a 10% decrease in tourism demand from period t=10 until the end of the model horizon (t=50). In the tenth time period, utility drops by 2.94% in the simulation where the level of savings is a fixed share of income. Utility drops by 2.65% in the simulation where the level of savings is tied to the rental rate of capital. Where the level of savings is tied to the rental rate of capital, utility decreases at a greater rate in the future than for the fixed share of income scenario.

**Figure 4.5: Utility by Savings Rule**




The reason for the above result (utility decreasing more in the DR2 scenario) can be seen in Figure 4.6 and Figure 4.7. Investment and the capital stock experience larger decreases in the scenario where the rental rate of capital is tied to the quantity of savings than in the scenario where the savings rule is a fixed share of income.

**Figure 4.6: Investment by Savings Rule**

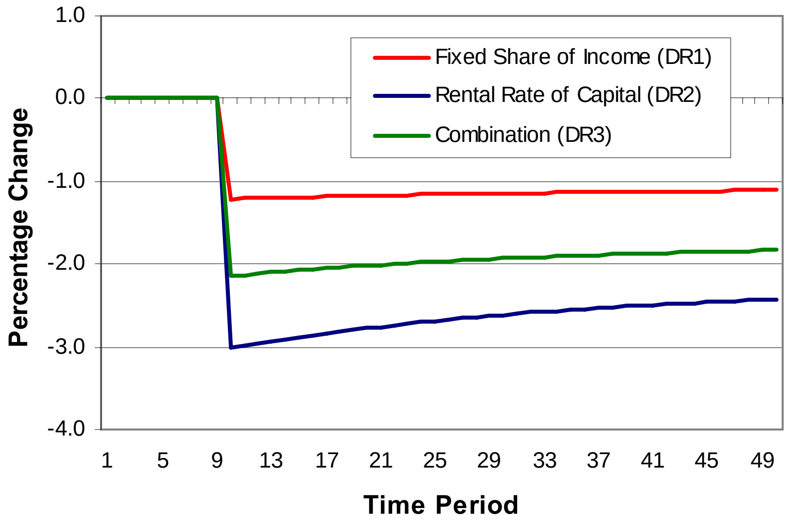
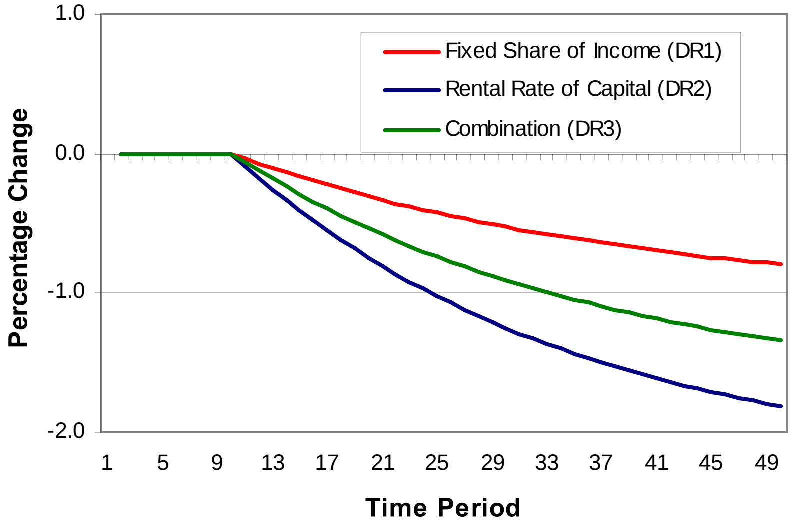



**Figure 4.7: Capital Stock by Savings Rule**




The percentage change in GVA (Table 4.7) also shows that DR1 model results are lower (more negative / less positive) than for the DR2 model. However all the dynamic recursive model results are lower (more negative / less positive) than the static model results.

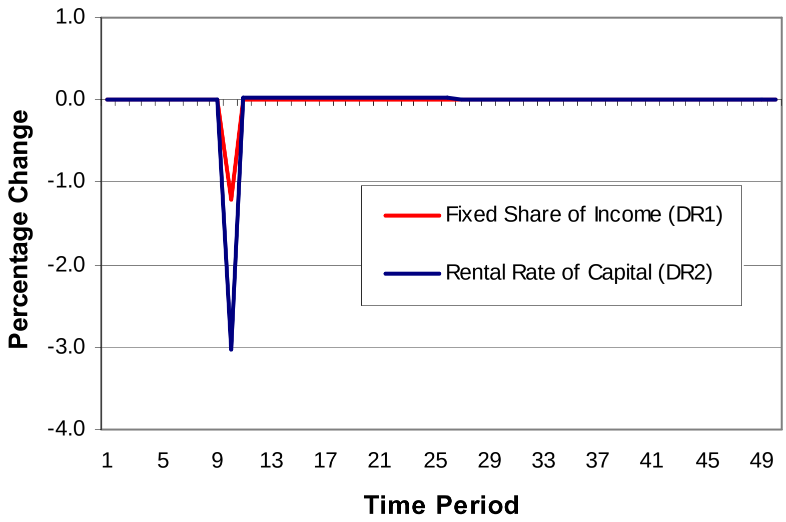
**Table 4.7: Percentage Change in GVA in a Dynamic Recursive Model under Different Savings Rule Assumptions**

| Percentage Change in Variables from Benchmark across Model Time Horizon | Persistent Shock (10% Decrease in Tourism Demand from period t=1) | | | Delayed Shock (10% Decrease in tourism Demand from period t=10 onwards) | | |
|---|---|---|---|---|---|---|
| **Gross Value Added** | **Savings Rule** | | | **Savings Rule** | | |
| | **DR1** | **DR2** | **DR3** | **DR1** | **DR2** | **DR3** |
| Accommodation | -11.0 | -10.9 | -10.9 | -8.81 | -8.92 | -8.87 |
| Arts, Entertainment & Recreation | -7.4 | -7.3 | -7.4 | -5.83 | -5.95 | -5.89 |
| Transportation | -5.0 | -4.9 | -5.0 | -3.86 | -4.00 | -3.93 |
| Eating & Drinking Places | -5.0 | -4.9 | -4.9 | -3.76 | -3.93 | -3.85 |
| Educational Services | -3.9 | -3.7 | -3.8 | -2.85 | -3.00 | -2.93 |
| Real Estate & Rentals | -3.3 | -3.0 | -3.1 | -1.92 | -2.33 | -2.13 |
| Retail Trade | -3.2 | -3.0 | -3.1 | -2.10 | -2.40 | -2.26 |
| Health Services | -2.4 | -2.3 | -2.4 | -1.64 | -1.80 | -1.73 |
| Business Services | -1.0 | -0.9 | -1.0 | -0.44 | -0.66 | -0.56 |
| Other Services | -0.8 | -0.6 | -0.7 | -0.18 | -0.42 | -0.31 |
| Utilities | -0.6 | -0.4 | -0.5 | 0.03 | -0.25 | -0.12 |
| Government | 0.1 | 0.1 | 0.1 | 0.10 | 0.08 | 0.09 |
| Professional Services | 0.7 | 1.0 | 0.8 | 1.24 | 0.82 | 1.02 |
| Wholesale Trade | 1.3 | 1.5 | 1.4 | 1.66 | 1.31 | 1.48 |
| Finance & Insurance | 1.8 | 2.1 | 1.9 | 2.22 | 1.81 | 2.00 |
| Construction | 1.8 | 2.3 | 2.1 | 2.62 | 1.89 | 2.23 |
| Information | 3.1 | 3.4 | 3.3 | 3.27 | 2.88 | 3.07 |
| Agriculture | 21.5 | 21.8 | 21.7 | 18.44 | 18.00 | 18.20 |
| Manufacturing | 25.6 | 25.7 | 25.6 | 21.30 | 21.09 | 21.19 |
| Food Processing | 29.3 | 29.6 | 29.4 | 24.63 | 24.32 | 24.47 |

DR1= Savings Rule: Savings is assumed to be a fixed share of income
DR2= Savings Rule: Savings is dependent on the rental rate of capital
DR3= Savings Rule: Savings is both dependent on the rental rate of capital and a share of income

The "problem" with dynamic recursive models is that expectations are not taken into account. For the most part, economic agents behave as in a one-shot example many times. In recursive models, agents lack a coherent representation of expectations. In reality, although economic agents do not have full information regarding the future, they behave as if the future matters. This can be seen clearly in the single period shock simulation (Figure 4.8). The period up until time period 10, there is no change in the level of investment, then in period 10, where the shock occurs, investment decreases 1.2% in the fixed share of income model (DR1) and 3.0% in the rate of return model (DR2) and then overshoots marginally to just above zero for the remaining periods in the model ($t \geq 10$).

**Figure 4.8: Investment in a Single Period Shock Model by Savings Rule**




Recursive models tend to be characterised by "overshoot and collapse" behaviour. Given the fact that these models are essentially static or "one-shot" model advanced one time period and updated with the values of the exogenous variables for the next time period, the assumptions regarding risk are similar to the intra-temporal model, that is, the interest rate (return to capital) and elasticities reflects all the inherent risk associated with saving and investing.

## 4.5 Single Sector Dynamic Forward-Looking Model

The Ramsey model is used as a base for the dynamic forward-looking CGE model. The description of a simple Ramsey model will be followed by a multi-sector equivalent.

The Ramsey model of optimal economic growth under certainty is a natural benchmark case for examining investment in a dynamic framework. The model was developed by Ramsey (Ramsey, 1928), Cass (Cass, 1965) and Koopmans (Koopmans, 1965). Competitive firms rent capital and hire labour to produce and sell output and a fixed number of infinitely lived households supply labour, hold capital, consume and save. This model is a good one to use as a base model given there are no market imperfections (with the exception of the unemployment specification outlined in the comparative static model), households are homogeneous and there is no overlapping generations. The model is a framework for studying the optimal intertemporal allocation of resources. It is based on neoclassical microfoundations, that is, the optimising behaviour of economic agents is explicit and savings is endogenous.

Lau *et al.* (Lau, Pahlke, & Rutherford, 2002) show that the Ramsey model can be represented in four different formulations; as a primal nonlinear program in quantities, and as two different mixed complementarity problems and as a dual nonlinear program in prices. The four representations all produce identical optimal allocation of resources given the same standard assumptions about technology, preferences and initial endowments.

### 4.5.1 Model Structure

The forward-looking CGE model depicts the circular flow of output, income and expenditure in the goods and factor markets accounting for price-based backward and forward linkages across various production sectors for the economy over the entire model horizon. In each time period, a representative household, who is endowed with labour and capital, supply these factors of production to firms. In turn, the firms use these inputs to produce goods and services. As owners of the factors of production, households are compensated according to their marginal contribution for each factor they provide to production. Income earned from work and/or from supplying capital is then either spent on current consumption of domestic or foreign products, or saved for future consumption. Firms, then, use those savings to purchase investment goods, which replace depleted capital, and add to their capital stock. Ex post total investment equals the ex-ante amount of savings in the economy.

Economic agents follow maximising behaviour, that is, households and firms make optimal choices given their intertemporal budget constraints. Net investment is determined by the profit maximising prospects across industries so more investment occurs in industries with higher marginal productivity of capital. Governments and investors also make choices consistent with dynamic optimisation. The government collects revenue, and either spends it on public consumption or make transfers to households. In every period, prices adjust to guarantee equilibrium in the model so that demand equals supply.

Labour is perfectly mobile across sectors in the model. Labour will flow to an industry with a higher marginal revenue product from one with a lower marginal revenue product until the demand and supply adjust from price changes, in this case, the price being the prevailing wage rate.

Demand for and supply of goods and services readjust until all excess demands and excess supplies are eliminated through changes in prices. Perfectly competitive markets operate to determine these equilibrium prices. Additionally, in equilibrium, no sector earns above-normal profits, markets clear for all factors and products, and the value of imports for intermediate use and final demand equals the value of export earnings. Any changes in taxes will change economic behaviour and eventually market prices via the model's equilibrium conditions.

In contrast to the dynamic recursive model, the dynamic forward-looking model does not just have a rule that links one time period to the next but capital is accumulated in each future time period. Further, firms maximise the net present value of their profits and consumers maximise the net present value of their utility. They have rational expectations about future time periods and can "see" the future. Decisions made in period t=1 (and subsequent time periods) take into consideration events that occur in future time periods. Economic agents can adjust to shocks before they occur.

The economic relationships can be expressed through the following equations. Aggregate output is characterised by constant returns to scale. Where inputs are capital and labour this can be represented as:

$$Y_t = F(\overline{L_t}, K_t)$$

A representative consumer maximises the present value of their lifetime utility:

$$\max \sum_{t=1}^{\infty} \left( \frac{1}{1+\rho} \right)^t U(c_t)$$

Where $t$ denotes the time period; $\rho$ denotes the discount factor or individual time-preference parameter; $U$ denotes the utility function; and $c_t$ denotes consumption in period $t$.

But the consumer faces two constraints. The first constraint is that total output produced in the economy can either be consumed or invested, $I$ (saved). The second constraint is that capital depreciates at the rate, $\delta$. Hence,

$$c_t = F(L_t, K_t) - I_t \quad \text{and}$$

$$K_{t+1} = K_t(1-\delta) + I_t$$

where $K$ denotes capital and $F(\bullet)$ is the production function.

As mentioned in the literature review section (Chapter 2), equilibrium in a general equilibrium model is characterised by three classes of equations:

1. Market clearance conditions and associated market prices

Output market (market price $p_t$): $Y_t = C_t(p, M) + I_t$

Labour market (wage rate $p_t^L$): $\overline{L}_t = a_L(r_t^K, p_t^L)Y_t$

Capital market (rental rate of capital $r_t^K$): $K_t = a_K(r_t^K, p_t^L)Y_t$

Capital stock (purchase price of capital $p_t^K$): $K_{t+1} = (1-\delta)K_t + I_t$

2. Zero profit conditions and associated activities are:

Output ($Y_t$): $p_t = c(r_t^K, p_t^L)$

Investment ($I_t \geq 0$): $p_t \geq p_{t+1}^K$

Capital stock ($K_t$): $p_t^K = r_t^K + (1-\delta)p_{t+1}^K$

3. Income balance:

$$M = p_0^K \overline{K}_0 + \sum_{t=0}^{\infty} p_t^L \overline{L}_t$$

Where $c(\bullet)$ = the unit cost; $C_t$ = consumption in year *t*; $C_t(p, M)$ = the demand for output in year *t* as a function of output prices and aggregate present value of income; $a_{L/K}$ = the compensated demand functions for labour and capital respectively; $M$ = the infinite lifetime full income.

### 4.5.2 Intertemporal preferences and household demand

Both consumers and producers are assumed to have perfect foresight with regard to their income, resources and prices of commodities in the economy. In the model, infinitely-lived households allocate their lifetime income to maximise lifetime utility, which is defined as:

$$\sum_{t=0}^{\infty} \beta^t \frac{U_t^{1-\sigma} - 1}{1-\sigma}$$

where $\beta$ is the discount factor, which depends on the rate of time preference;

$U_t$ is a composite commodity in the instantaneous utility function. This is the composite consumption commodity. The functional form of this utility function is a constant relative risk aversion (CRRA) CES function. As can be seen from the above equation, $\frac{1}{\sigma}$ measures the elasticity of substitution between the present and future composite commodity. A smaller $\sigma$ means marginal utility decreases more slowly as the quantity of the composite commodity increases, so households are more willing to allow changes in the composite commodity over time. Thus a smaller $\sigma$ implies a higher elasticity of substitution between current and future consumption. Put another way, a smaller $\sigma$ implies a higher degree of consumption smoothing and substitution over time.

Instantaneous utility is a function of composite consumption good, as per the comparative static model.

The representative household faces an intertemporal budget constraint where the present value of its consumption stream in all periods cannot exceed the present value of infinite full income. Life-time income in this model includes the value of the household's labour endowment and other income:

$$\sum_{t=0}^{\infty} R_t^{-1} P_t C_t = W$$

where $R_t^{-1} = \prod_{s=0}^{t-1} \frac{1}{1+r_s}$ is a discount factor; $r_s$ represents the real interest rate on assets at time *s*; $P_t$ is the price of composite consumption; and $C_t$ is composite consumption, which is composed of sectoral consumption goods, that is, $P_t = \vartheta \prod_{i=1}^{n} p_{i,t}^{\alpha_i}$ , and $C_t = \prod_{i=1}^{n} C_{i,t}^{\alpha_i}$ where $\alpha_i$ is the share of spending on good i by the representative household, $C_{i,t}$ is a composite of domestic and foreign sector j products and $p_{i,t}$ its gross-of-tax price, and $\vartheta$ is a constant price index in the base year. $W$ is the life time wealth of the household, defined as:

$$W = \frac{J_0}{1+r_0^c} + \frac{J_1}{(1+r_0^c)(1+r_1^c)} + ... + \frac{J_2}{\prod_s^t (1+r_s^c)} + ... = \sum_{t=0}^{\infty} R_t^{-1} J_t$$

where $J_t$ is disposable household income in period *t*, which includes the value of labour endowments and capital income plus transfers:

$$J_t = w_t L_t + r_t K_t + TR_t$$

where $w_t$ is the wage rate; $L_t$ is the amount of labour supplied; $r_t$ is the rental rate of capital; $K_t$ is the capital stock; and $TR_t$ is the transfer from the government to the household.

The representative's intertemporal problem can be represented in the following Lagrangian:

$$\zeta = \sum_{t=0}^{\infty}\left(\frac{1}{1+\rho}\right)^{t}\frac{U_t^{1-\sigma}}{1-\sigma} + \lambda\sum_{t=0}^{\infty} R_t^{-1}P_tC_t - W_t$$

Where $\sigma$ is the intertemporal elasticity of substitution between consumption in different time periods, $\lambda$ is the Lagrangian multiplier, also known as the shadow price of income in terms of the present value of utility, and $\beta$ in the lifetime utility equation is now $\frac{1}{1+\rho}$, where $\rho > 0$ is the rate of time preference. It signifies the degree to which the household prefers consumption earlier rather than later in the model. The larger the value of $\rho$, the more households are willing to spend their resources earlier in their life. This parameter is most important in terming the level of savings and consumption that the household wants to carry out in each time period. It is assumed that preferences are not satiated so that the intertemporal budget constraint will hold with equality at an optimum.

The instantaneous utility function used to model intratemporal substitution choices is the same as in the static model.

### 4.5.3 Investment and Tobin's q

Firms face a perfectly elastic supply of capital goods and can adjust their capital stocks effortlessly, in this model. Firms rent capital up to the point where its marginal revenue product equals its rental price. Romer shows (Romer, 1996) that for both the continuous time and discrete time version the firm's objective function in choosing its investment and capital stock. It can be shown that the first derivative of the current-value Hamiltonian gives: $1+C'(I_t)=q_t$ in the discrete time version and $1+C'(I(t))=q(t)$ in the continuous time version where q is the value to the firm of an additional unit of capital at time *t+1* in time-t dollars; $C(I_t)$ are the adjustment costs; and the purchase price of capital is normalised to 1. Hence, firms invest up to the point where the cost of acquiring capital equals the value of capital, the neoclassical behaviour. If adjustment costs are zero, then q =1.

Further, *q* (Tobin, 1969) summarises all the information about the future that is relevant to the firm's investment decision. *q* shows how an additional dollar of capital affects the present value of profits. A one unit increase in the firm's capital stock increases the present value of the firm's profit's by *q* and raises the value of the firm by *q*. Thus q is the market value of a unit of capital.

### 4.5.4 Terminal condition

The implementation of a dynamic general equilibrium involves three steps. These steps are the calibration of model parameters, replication of the benchmark economy, and computation of transitional dynamics in relation to external shocks or policy changes in the model economy (the counterfactual). Numerical models can only be solved for a finite number of periods. An adjustment needs to be made to produce a model which approximates over the infinite horizon. If there was no adjustment process then all capital would be consumed in the last period and nothing would be invested. Lau *et al.* (Lau et al., 2002) propose a method for approximating the infinite horizon equilibria with endogenous capital accumulation. This method has become the standard way of approximating infinite horizon general equilibrium models. Their central idea is to split the intertemporal utility function into two parts. This can be written as:

$$U = \sum_{t=1}^{T} \beta^t U(C_t) + \sum_{t=T+1}^{\infty} \beta^t (C_t)$$

The second term in this utility function collapses into a constant term. For a Cobb-Douglas utility function and a constant consumption growth rate of $\gamma$ from periods T to $\infty$, the utility function can be written as:

$$U = \sum_{t=1}^{\infty} \left(\frac{1}{1+\rho}\right)^t \log(C_t)$$

$$U = \sum_{t=1}^{T} \left(\frac{1}{1+\rho}\right)^t \log(C_t) + \sum_{t=T+1}^{\infty} \left(\frac{1}{1+\rho}\right)^t \log(C_{T+1}(1+\gamma)^{t-T+1})$$

$$U = \sum_{t=1}^{T} \left(\frac{1}{1+\rho}\right)^t \log(C_t) + \left(\frac{1}{1+\rho}\right)^{T+1} \left[ \log(C_{T+1}) \sum_{\tau=1}^{\infty} \left(\frac{1}{1+\rho}\right)^{\tau} + \log(1+\gamma) \sum_{\tau=1}^{\infty} \tau \left(\frac{1}{1+\rho}\right)^{\tau} \right]$$

$$U = \sum_{t=1}^{T} \left(\frac{1}{1+\rho}\right)^t \log(C_t) + \left(\frac{1}{1+\rho}\right)^{T+1} \left[ \log(C_{T+1}) \frac{1+\rho}{\rho} + \log(1+\gamma) \sum_{\tau=1}^{\infty} \tau \left(\frac{1}{1+\rho}\right)^{\tau} \right]$$

This last equation can be summarized as:

$$U = \sum_{t=1}^{T+1} \beta_t \log(C_t) + \kappa \text{ where}$$

$$\beta_t = \begin{cases} \left(\frac{1}{1+\rho}\right)^t \ldots t < T+1 \\ \left(\frac{1}{1+\rho}\right)^{T+1} \ldots t = T+1 \end{cases} \quad \text{and}$$

$$\kappa = \left(\frac{1}{1+\rho}\right)^{T+1} \sum_{\tau=1}^{\infty} \left(\frac{1}{1+\rho}\right)^{\tau}$$

For modelling purposes, often the steady-state growth rates and interest rates are more readily observable than the discount factor. If the steady-state growth rate is denoted by $\gamma$ and the steady-state interest rate is $r$, then the discount rate is given by:

$$\rho = \frac{1+r}{1+\gamma} - 1 = \frac{r-\gamma}{1+r} \text{ and then}$$

$$\beta_t = \begin{cases} \left(\frac{1+\gamma}{1+r}\right)^{t} \ldots t < T+1 \\ \left(\frac{1+\gamma}{1+r}\right)^{T+1} \frac{1+r}{r-\gamma} \ldots t = T+1 \end{cases}$$

(see Rutherford, 2005 for the case where there is a CES utility function).

Differing from the dynamic forward-looking infinite horizon model, the finite horizon model is solved for a certain number of time periods after which the terminal condition then is operationalised. This method gives the model tractability.

In a single sector model, the two sub-problems are linked through the capital stock in period T+1. Having decomposed the model, a good terminal approximation occurs where the capital stock in period T+1 is close to the optimal value in the infinite-horizon part of the model. If the "true" value of the capital stock in the post-terminal period is known then the true consumption and saving paths can be calculated in the interim transitional period. After an external shock, however, the "true" value of the capital stock in the post-terminal period may not be known. In this case, what Lau *et al.* (2002) recommend is, rather than to impose the long-run steady-state value of capital stock (where the model horizon may be extraordinarily long for it to converge to the steady state), the state variable, $K_{T+1}$, can be determined as part of the equilibrium calculation by targeting the associated control variable, $I_T$. This is done by imposing a constraint that defines how terminal investment grows. Gross investment in the terminal period is therefore determined by the size of the capital stock in the terminal period, the steady state growth rate, and the rate of capital depreciation. Rutherford (Rutherford, 2004) has suggested the following:

Terminal investment growth set equal to the long-run steady-state growth rate:

$$\frac{I_T}{I_{T-1}} = 1 + \gamma$$

Terminal investment growth rate set equal to the growth rate of consumption:

$$\frac{I_T}{I_{T-1}} = \frac{C_T}{C_{T-1}}$$

Terminal investment growth rate set equal to the growth rate of aggregate output:

$$\frac{I_T}{I_{T-1}} = \frac{Y_T}{Y_{T-1}}$$

Lau *et al.* (2002) argue that this state-variable targeting method is a superior method to the one outlined by Barr and Manne (1967). The latter method involves an increased weight on utility of consumption in the terminal period, and a constraint on investment in the terminal period. However the state variable targeting method has two advantages over the techniques based on optimisation methods. State variable targeting provides a more precise approximation of the infinite horizon equilibria. In other words, the model is more efficient (takes fewer periods to approximate the infinite horizon saddle path) when the state variable targeting method is used. Further, state variable targeting does not require ex ante specification of the growth rate of the terminal period or impose a specific capital stock in the post-terminal period. This research will follow this method as it is suitable for models with endogenous growth where the terminal stock is not determined ex ante.

### 4.5.5 Model Calibration

Having calibrated the CGE model to the base year of 2002, different scenarios (or counterfactuals) can be modelled to examine the impact on the economy. The objective of the calibration is to ensure that the solution to the model yields the appropriate model parameters and replicates the base year economic situation.

In a dynamic model, the interest rate is exogenous to the model so model parameters need to be selected so that, starting from current levels of capital stock and prices, the model yields a dynamic solution path which is consistent with balanced growth. Using the relationship between the current and future prices of capital and investment goods, the following holds true:

$$P_t^k = r_t^k + (1-\delta)P_{t+1}^k \qquad \textbf{(a)}$$

where $P_t^k$ is the price of capital good at the end of period $t$.

This equation states that one unit of investment in period $t$ must produce one unit of capital stock in period $t+1$ from one unit of output of the investment goods in period $t$. One unit of capital at the beginning of period $t$ earns a return of $r_t^k$ in the current period and provides $(1-\delta)$ units of capital for the beginning of the $t+1$ period. This is the zero profit condition for $K_t$. The gross return sufficiently covers depreciation and the interest earned for each unit of investment so:

$$r_t^k = (r+\delta)P_{t+1}^k \qquad \textbf{(b)}$$

where $r$ is the real rate of interest. Substituting Equation (b) into (a) gives:

$$\frac{P_{t+1}^k}{P_t^k} = \frac{1}{1+r}$$

This can be interpreted as the ratio of price of capital in the next period to its current price is equal to the market discount factor in the model. Base period investment, $I_0$, can be calculated on the basis of growth and depreciation of the base year capital stock:

$I_0 = K_0(\gamma+\delta)$. Further, the market clearance condition for capital in the first period is:

$$K_1 = K_0(1-\delta) + I_0 = (1+\gamma)K_0$$

Substituting in and using the fact that $r_t^k$ determines $K_0$ the base period, the investment equation is given by:

$$I_0 = \overline{VK}\frac{\gamma+\delta}{r+\delta}$$

Where $\overline{VK}$ is the value of the base period capital earnings

Rutherford (2004) points out that in applied models these calculations do not satisfy this relation for arbitrary values of $\gamma$, $r$ and $\delta$. In this model, the real rate of return adjusts to calibrate the benchmark dataset with the baseline grow path.

### 4.5.6 Impact of a Tourism Contraction (Results)

This section displays the results of a 10% decline in tourism demand in the state of Hawaii using a single sector dynamic forward-looking model. For comparability, all parameters in this model have been set to the values outlines in previous models. The terminal condition implemented for the results below is a balanced growth path at an endogenous rate (now that capital is endogenous to the model), that is,

$$\frac{I_T}{I_{T-1}} = \frac{K_T}{K_{T-1}}.$$

Alternative terminal conditions will be explored in subsequent chapters.

**Table 4.8: Results from a 10% Decrease in Tourism Demand in a Single-Sector Dynamic Forward-Looking Model**

| Economic Indicators | Persistent Shock | Delayed Shock | Temporary Shock |
|---|---|---|---|
| **Percentage Change in Variables from Benchmark across Model Time Horizon** | **(10% Decrease in Tourism Demand from period t=1)** | **(10% Decrease in Tourism Demand from period t=10 onwards)** | **(10% Decrease in Tourism Demand in period t=10 only** |
| Welfare (EV) | -3.65 | -1.63 | -0.14 |
| Household Consumption | -5.62 | -3.90 | -0.16 |
| Tourism Consumption | -14.03 | -11.41 | -0.29 |
| Price of Tourism | 1.46 | 0.62 | 0.05 |
| Labour | -1.67 | -1.20 | -0.04 |
| Wage Rate | 0.70 | 0.55 | 0.03 |
| Capital | -5.85 | -4.03 | -0.15 |
| Return to Capital | 0.76 | -0.08 | 0.00 |
| Investment | -15.20 | -12.93 | -0.21 |
| Investment Price | 2.94 | 1.23 | 0.10 |
| Price of Foreign Exchange | 5.95 | 2.35 | 0.22 |
| State & Local Govt Goods Price | 1.16 | 0.63 | 0.04 |
| Federal Govt Military Goods Price | 1.04 | 0.59 | 0.03 |
| Federal Govt Civilian Goods Price | 1.07 | 0.60 | 0.04 |

The results for three scenarios are displayed in Table 4.8 above: A persistent 10% decrease in tourism demand across the model time horizon, a 10% decrease in tourism demand starting in period t=10 and continuing until the end of the model (t=50) and a single period shock in period t=10. In the first simulation, welfare is estimated to decrease by 3.7% as a result of the tourism demand decrease with household consumption estimated to decrease by 5.6% and tourism consumption decreases by 14.0%. With both investment and capital endogenous in the model, there are significant decreases in these variables with capital falling by 5.9% and investment decreasing by 15.2% as a result of the tourism bust. Naturally, smaller percentage decreases are estimated for negative tourism demand shocks that occur later in the model and / or for a limited time period.

Table 4.9 shows the percentage change in gross value added for the three simulations. The persistent shock results in percentage decreases in 15 of the 20 sectors in the economy of Hawaii. As expected the largest decreases arise in the tourism-related sectors with the Accommodation sector expected to experience a 12.0% in gross value added and the arts, entertainment and recreation sector expected to experience an 8.3% fall in gross value added. As has been shown in the static and dynamic recursive a significant amount of substitution between sectors occurs as economic agents respond to changes in factor prices so the agriculture, manufacturing and food processing sectors benefit from the downturn in tourism.

**Table 4.9: Percentage Change in GVA in a Single-Sector Dynamic Forward-Looking Model**

| Gross Value Added | Persistent Shock | Delayed Shock | Temporary Shock |
|---|---|---|---|
| **Percentage Change in Variables from Benchmark across Model Time Horizon** | **(10% Decrease in Tourism Demand from period t=1)** | **(10% Decrease in Tourism Demand from period t=10 onwards)** | **(10% Decrease in Tourism Demand in period t=10 only** |
| Accommodation | -12.0 | -9.7 | -0.25 |
| Arts, Entertainment & Recreation | -8.3 | -6.5 | -0.19 |
| Real Estate & Rentals | -6.4 | -4.5 | -0.17 |
| Eating & Drinking Places | -6.2 | -4.7 | -0.15 |
| Transportation | -6.2 | -4.9 | -0.13 |
| Retail Trade | -5.6 | -4.2 | -0.13 |
| Construction | -5.1 | -4.4 | -0.06 |
| Educational Services | -4.8 | -3.5 | -0.13 |
| Health Services | -3.4 | -2.2 | -0.11 |
| Professional Services | -3.0 | -2.3 | -0.06 |
| Business Services | -2.8 | -1.9 | -0.07 |
| Utilities | -2.7 | -1.7 | -0.08 |
| Other Services | -2.6 | -1.6 | -0.08 |
| Wholesale Trade | -1.7 | -1.1 | -0.04 |
| Finance & Insurance | -1.3 | -0.3 | -0.06 |
| Government | 0.0 | 0.0 | 0.00 |
| Information | 0.1 | 0.8 | -0.03 |
| Agriculture | 18.2 | 15.6 | 0.35 |
| Manufacturing | 23.7 | 19.5 | 0.47 |
| Food Processing | 27.0 | 22.8 | 0.53 |

In contrast with the dynamic recursive model, the dynamic forward-looking model is characterized by economic agents with perfect foresight. This means they are able to "see" future shocks and adjust their behaviour accordingly. This can be seen graphically in Figure 4.9 and Figure 4.10 for the scenario where the shock occurs in period t=10 and continues until the end of the model horizon. The economy is assumed to grow at 2% (green line), however in period t=10, the economy experiences a negative tourism shock so investment drops sharply and then continues to grow, albeit at a lower level than before the shock. However, in the first nine time periods, the firms anticipate the shock and build up their investment. Further, as agents see the end of the model approaching, they run down their investment.

**Figure 4.9: Investment and Capital (Levels) in a Single-Sector Dynamic Forward-Looking Model**

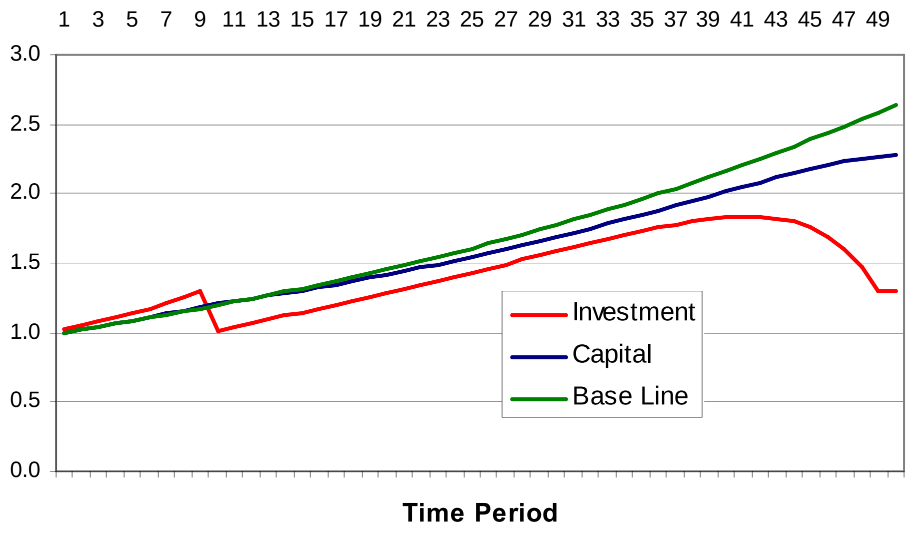
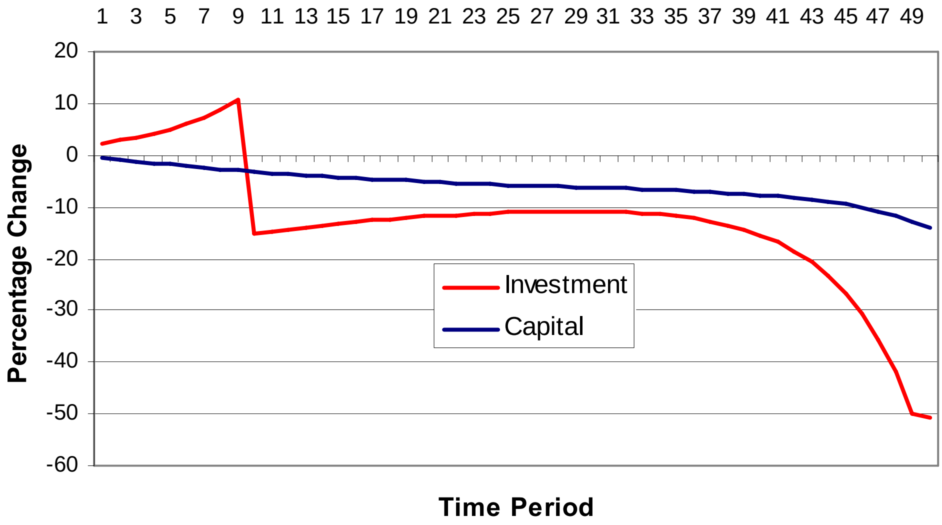


**Figure 4.10: % Change in Investment and Capital in a Single-Sector Dynamic Forward-Looking Model**




### 4.5.7 Timing of "on-line" Investment

In the previous section, the single sector dynamic forward-looking model assumed that investment came 'on-line' in the same time period as capital. To be more realistic, the model can include a parameter, S, to allow the proportion of investment that comes on-line to be decided by the modeller. When S=0, capital in period t=1 comes on-line as investment in period t=2 and when S=1, capital in period t=1 comes on-line as investment in the same period, t=1. When is set at S=0.5, half of the capital invested in period t=1 comes on-line in the same period and half comes on-line in the next period. The inclusion of this parameter has implications for both the calibration of the model and model results.

The calibrated base capital stock, K0, is: $K0 = \frac{I0.(1 - S.\delta)}{\gamma + \delta}$ where I0 is the base level of investment, δ is the depreciation rate, and γ is the exogenous growth rate of the economy. The calibrated net rate of return, R0, is now: $R0 = \frac{KS0}{K0 + (S.I0)}$ where KS0 is the initial capital supply, and K0 is the base capital stock. The reference path of prices, PREF(t), is formulated as:

$$PREF(t) = \left[ \frac{(1 - (S.R0)}{(1 + R0(1 - S) - \delta)} \right]^{t-1}.$$

### 4.5.8 Impact of a Tourism Contraction (Results)

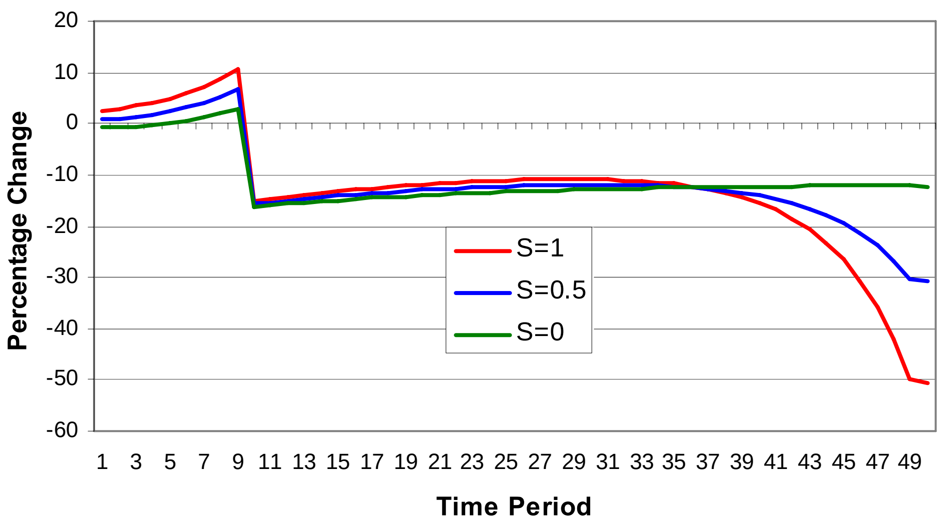
Simulating a negative tourism demand shock of 10% from period t=10 until the end of the model horizon (t=50), three different scenarios are compared and contrasted in this section with the values of S being set to 1, 0.5 and 0.

**Table 4.10: Results from Impact of 'on-line' Investment Timing**

| Economic Indicators | Delayed Shock (10% Decrease in Tourism Demand from period t=10 onwards) | | |
|---|---|---|---|
| **Percentage Change from Benchmark across Model Time Horizon** | **Investment on-line in current period (S=1)** | **Half of Investment on-line next period (S=0.5)** | **Investment on-line next period (S=0)** |
| Welfare (EV) | -1.63 | -1.82 | -2.03 |
| Household Consumption | -3.90 | -3.61 | -3.37 |
| Tourism Consumption | -12.52 | -12.43 | -12.33 |
| Price of Tourism | 0.62 | -0.10 | -0.83 |
| Labour | -1.20 | -1.08 | -0.98 |
| Wage Rate | 0.55 | -0.39 | -1.33 |
| Capital | -4.07 | -3.51 | -2.99 |
| Return to Capital | -0.08 | -0.29 | -0.54 |
| Investment | -17.84 | -16.40 | -14.94 |
| Investment Price | 1.23 | 0.25 | -0.73 |
| Price of Foreign Exchange | 2.35 | 1.50 | 0.64 |
| State & Local Govt Goods Price | 0.63 | -0.21 | -1.06 |
| Federal Govt Military Goods Price | 0.59 | -0.26 | -1.12 |
| Federal Govt Civilian Goods Price | 0.60 | -0.25 | -1.10 |

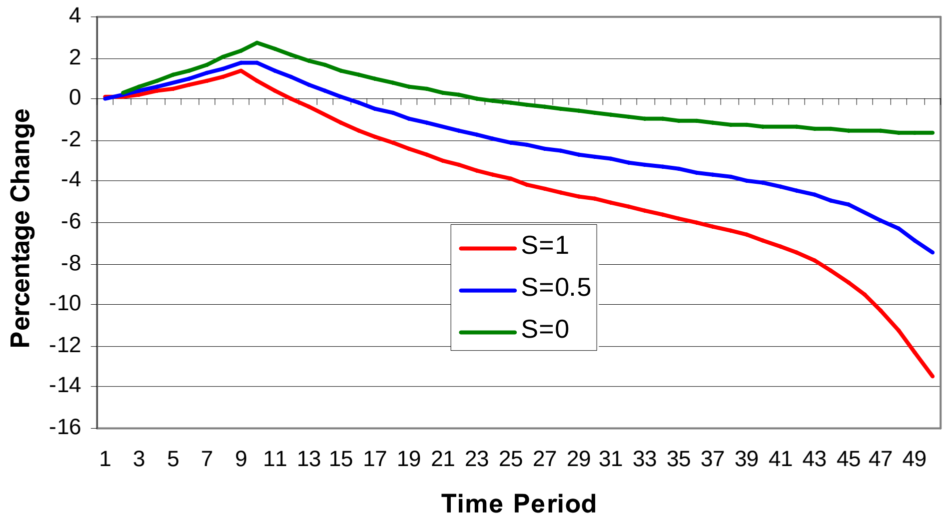
When there is a lag between capital and the production of investment from one period to the next, both capital and investment fluctuate less in response to a negative tourism demand shock. Table 4.10 shows that investment decreases 17.8% when investment comes on-line in the same period as capital but decreases by only 14.9% when investment comes on-line in the next time period as capital. The return to capital decreases less when investment comes on-line in the same period as capital. Tellingly, there is an investment price increase when investment comes on-line in the same period as capital but an investment price decrease when investment comes on-line in the next period to capital. The delay in converting capital to investment results in smaller impacts for household consumption, tourism consumption, and labour. The increased variability of same-period new capital coming on-line can be seen in a Figure 4.11 below, in the percentage change in investment across the model time horizon. When S=1, the model shows that investment increases at a higher rate in the lead up to the shock than for the case where half of all capital is converted to investment in the same time period (S=0.5) and more so for when all of capital in the current time period is converted to investment in the next time period (S=0). Further, as the model reaches the terminal path, investment in the case where S=1 decreases at a faster rate then for the other two scenarios.

**Figure 4.11: % Change in Investment with Different Timing Assumptions**



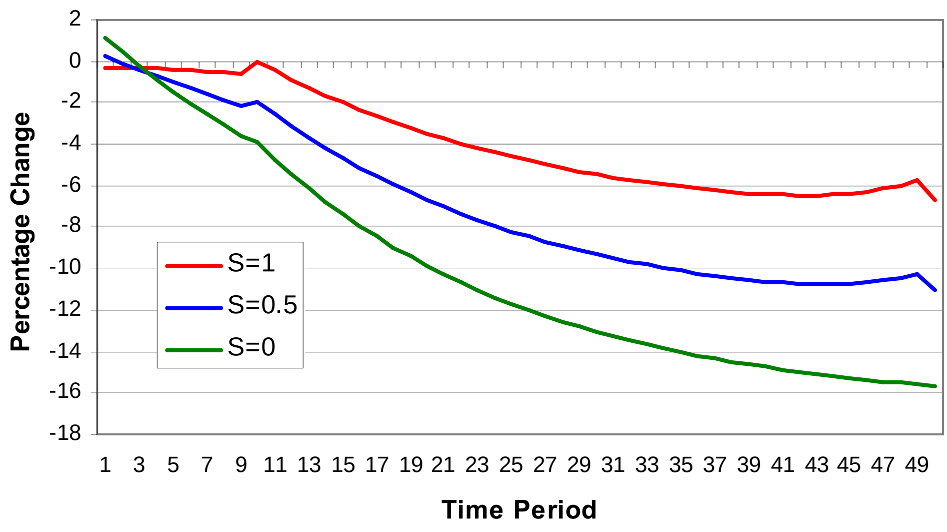

Similarly with capital (Figure 4.12), the build up of capital peaks earlier but at a lower level when investment comes on-line in the same period as capital compared to when investment coming on-line in the next time period. Over time, capital decreases at a lower rate when investment comes on-line in the same period as capital.

**Figure 4.12: % Change in Capital with Different Timing Assumptions**




Utility decreases less when investment comes on-line in the same period as new capital. This is due to the rise prices including the wage rate and investment price.

**Figure 4.13: % Change in Utility with Different Timing Assumptions**



## 4.6 Multi-sector Equivalent of Ramsey Model

This section explains the difference between the single-sector and multiple-sector dynamic intertemporal model and will be the last model developed before explaining how risk came be included in the CGE model to model uncertainty in tourism demand in Chapter 5.

### 4.6.1 Model Structure

This section outlines the differences in the single sector dynamic forward-looking model to the multi sector equivalent. The change from homogeneous capital to heterogeneous capital has more implications than just adding a sector-specific subscript to capital.

Firms invest, using savings. The market rental rate of capital is determined by market forces, the supply of and demand for capital. Total investment demand equals the use of investment goods from domestic and imported sources. Economy-wide, a composite investment good is derived from the final investment demand column from the Input-Output table. The composite investment good is allocated to sector-specific investment so that the marginal productivity of capital is equal across sectors. Investment opportunities are arbitraged when the net rate of return from each sectorally differentiated investment does not exceed the rate of interest. When investment is undertaken in a particular sector the net rate of return in that sector will equal the rate of interest. These relationships can be expressed in the following equations:

$$R_{i,t} - \delta_i \le r_t$$

$$I_{i,t} \ge 0$$

$$I_{i,t}(R_{i,t} - \delta_i - r_t) = 0$$

where $R_{i,t}$ = gross of depreciation rate of return in sector $i$ at time $t$; $\delta_i$ = sector-specific depreciation rate; $r_t$ = rate of interest at time $t$. For simplicity, the depreciation rate will be constant across sectors in this model. However, with available data, it is possible to add this feature.

This arbitraging condition means that sectors with high gross returns and lower depreciation rates generate more gross investment demand. In the steady-state, investment will grow at the same rate in all sectors, and the return to capital will be equalised across all sectors. However, during the transitional phase, it is possible for the net return in one sector to fall below that of another. As a result, investment can be shut down in the low return sector. Similar to the single-sector model, assets depreciate. Gross sectoral investment increases the capital stock as well as replaced depreciated capital.

$$K_{i,t+1} = K_{i,t}(1 - \delta_i) + I_{i,t}$$

As can be seen from the results section above, when such models are solved numerically, there is a tendency for the economy to jump as fast as possible to this level of capital; the models exhibit “bang-bang” behaviour. Since such behaviour is not observed in the real world, and could make the model results implausible, modellers tend to impose an adjustment cost function that dampens the bang-bang behaviour. A common cost function employed is to assume a quadratic cost function (Uzawa, 1969). Such a specification leads to the economy adjusting to the desired capital stock in a smooth fashion over time. Again, this added level of sophistication will not be added to this model.

### 4.6.2 Impact of a Tourism Contraction (Results)

This section reports the results for a 10% decrease in tourism demand in a multi-sector forward-looking dynamic model. With investment and capital disaggregated by sector, the terminal condition used in this model now becomes a balanced growth path at a weighted average endogenous rate, that is,

$$\frac{\sum_i I_{i,t}}{\sum_i I_{t-1}} = \frac{\sum_i K_{i,t}}{\sum_i K_{t-1}}.$$

This ensures at the final time period in the model the growth rate by sector are equalised and all sectors are growing at the same rate.

Table 4.11 shows the summarised results for a 10% decrease in tourism demand in a multi-sector forward-looking dynamic model. Two scenarios are modelled: a persistent 10% shock across the model horizon and a shock from period t=10 until the end of the model horizon. Welfare is estimated to decrease by 3.72% in the first scenario and 1.65% in the second scenario. This decrease in welfare is marginally more for both scenarios compared to the same simulations in the single-sector forward-looking dynamic model (3.64% and 1.63% respectively). This is due to the nature of capital and investment now being sector-specific. There is less substitutability as capital and investment are required to be sector specific. As an average across the model time horizon, household consumption decreases 5.9% as a result of the persistent shock in tourism demand, tourism consumption decreases by 15.1%, labour decreases 1.5% and capital, across time and sectors, decreases by 6.2% on average.

**Table 4.11: Results from a 10% Decrease in Tourism Demand in a Multi-Sector Forward-Looking Dynamic Model**

| Percentage Change from Benchmark across Model Time Horizon | (10% Decrease in Tourism Demand from period t=1) | (10% Decrease in tourism Demand from period t=10 onwards) |
|---|---|---|
| Welfare (EV) | -3.72 | -1.65 |
| Household Consumption | -5.87 | -4.11 |
| Tourism Consumption | -15.09 | -12.25 |
| Price of Tourism | 1.43 | 0.85 |
| Labour | -1.47 | -1.00 |
| Wage Rate | 0.69 | 0.73 |
| Capital | -6.17 | -4.00 |
| Return to Capital | 0.93 | 0.14 |
| Investment | 2.23 | 1.76 |
| Investment Price | 3.00 | 1.56 |
| Price of Foreign Exchange | 5.98 | 2.88 |
| State & Local Govt Goods Price | 1.19 | 0.84 |
| Federal Govt Military Goods Price | 1.07 | 0.80 |
| Federal Govt Civilian Goods Price | 1.10 | 0.81 |

Table 4.12 shows the % change in GVA by sector averaged across time. As with the other CGE model results outlined earlier in the chapter, a decrease in tourism demand is associated with the shifting of resources from the tourism-oriented sectors, such as accommodation, arts, entertainment & recreation, and eating and drinking places towards sectors such as agriculture, manufacturing and food processing. A comparison between the two tables reveals that the magnitude of the percentage changes in GVA is very similar between the single-sector and multi-sector model. The construction sector is an interesting exception where GVA is estimated to decrease by 5.1% in the

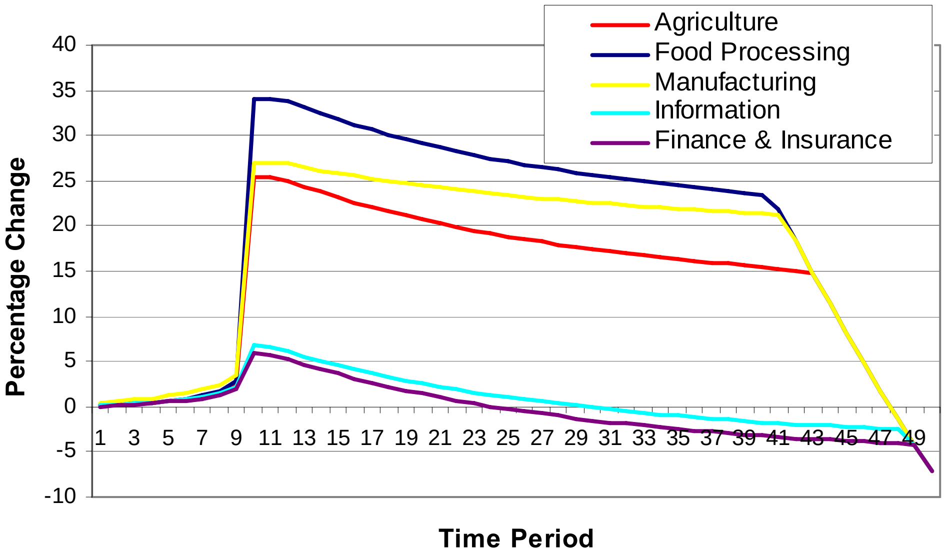
single sector model for a permanent shock but is estimated to decrease by only 2.1% in the multi-sector equivalent.

**Table 4.12: Percentage Change in GVA in a Multi-Sector Forward-Looking Dynamic Model**

| Gross Value Added | Persistent Shock | Delayed Shock |
|---|---|---|
| **Percentage Change in Variables from Benchmark across Model Time Horizon** | **(10% Decrease in Tourism Demand from period t=1)** | **(10% Decrease in Tourism Demand from period t=1)** |
| Accommodation | -11.6 | -9.4 |
| Arts, Entertainment & Recreation | -8.3 | -6.5 |
| Eating & Drinking Places | -6.2 | -4.7 |
| Real Estate & Rentals | -6.1 | -4.2 |
| Transportation | -5.9 | -4.6 |
| Retail Trade | -5.2 | -3.7 |
| Educational Services | -5.1 | -3.7 |
| Health Services | -3.8 | -2.5 |
| Other Services | -2.6 | -1.5 |
| Business Services | -2.6 | -1.7 |
| Utilities | -2.5 | -1.5 |
| Construction | -2.1 | -1.5 |
| Professional Services | -1.9 | -1.1 |
| Finance & Insurance | -1.0 | 0.0 |
| Wholesale Trade | -1.0 | -0.4 |
| Government | 0.0 | 0.0 |
| Information | 0.4 | 1.1 |
| Agriculture | 17.6 | 15.1 |
| Manufacturing | 24.4 | 20.1 |
| Food Processing | 26.3 | 22.2 |

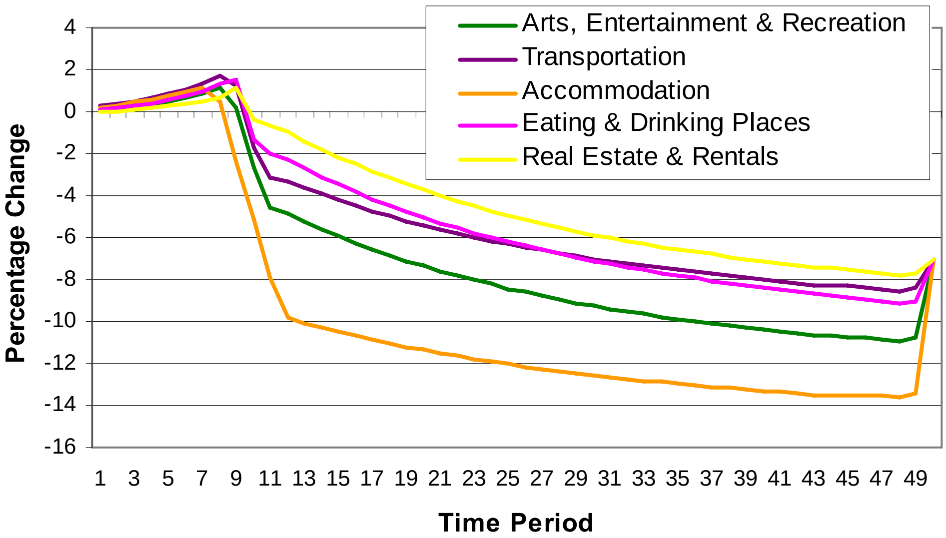
The growth trajectory for capital in each sector can be seen in Figure 4.14 to Figure 4.17.

**Figure 4.14: % Change in Capital in a Multi-Sector Dynamic Forward-Looking Model (1)**



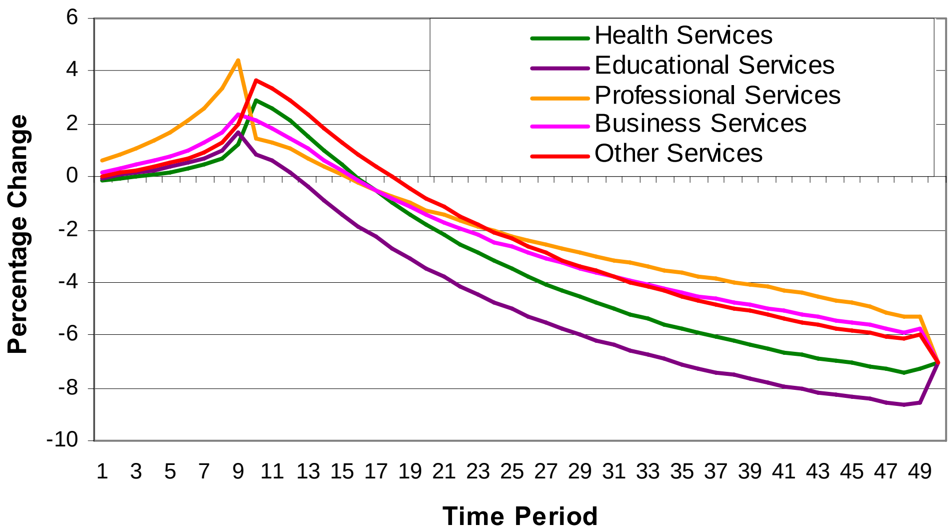

As can be seen in Figure 4.14, the traditional exporting sectors are the ones that experience the largest percentage change in capital in the 10th time period. In about the 40th time period then sectors growth rate start to converge to meet the terminal condition by the 50th time period.

**Figure 4.15: % Change in Capital in a Multi-Sector Dynamic Forward-Looking Model (2)**



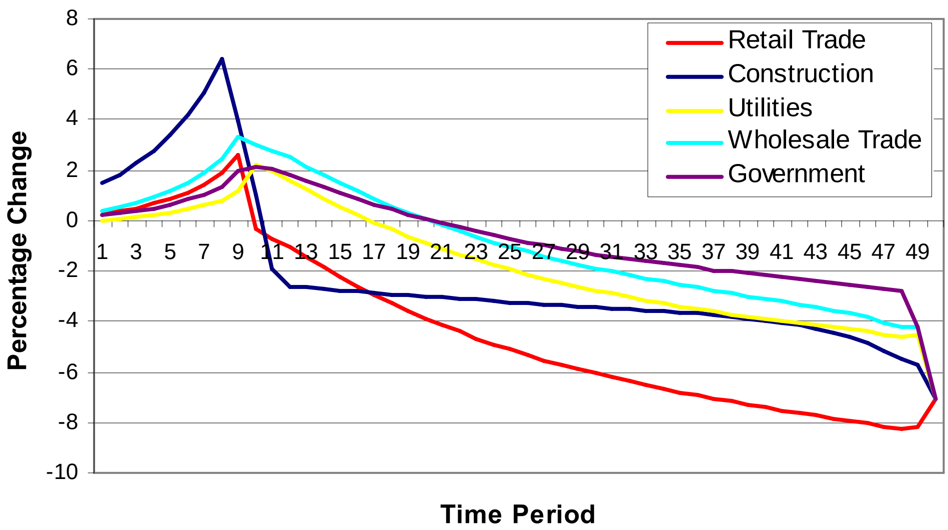
The tourism-oriented sectors experience negative growth in capital to the period of the shock (t≥10) (Figure 4.15).

**Figure 4.16; % Change in Capital in a Multi-Sector Dynamic Forward-Looking Model (3)**




Interestingly, the change in capital in the construction sector peaks at 6.4% in the 8th time period, pre-empting the shock that will commence in the 10th time period.

**Figure 4.17: % Change in Capital in a Multi-Sector Dynamic Forward-Looking Model (4)**



With investment now specified by sector, there is large variability in several sectors. These sectors now display typical 'bang-bang' behaviour. The percentage change in investment by sector across time is shown in Figure 4.18 to Figure 4.21. As can be seen in Figure 4.18, in the 10$^{th}$ time period – the first period of the shock – investment in the agriculture, food processing and manufacturing sectors increase by 770.8%, 1,057.9% and 792.6% respectively. Even though percentage changes can be misleading with relatively small sectors (as noted in Chapter 3), these percentage changes are of unrealistic magnitude.

**Figure 4.18: % Change in Investment in a Multi-Sector Dynamic Forward-Looking Model (1)**

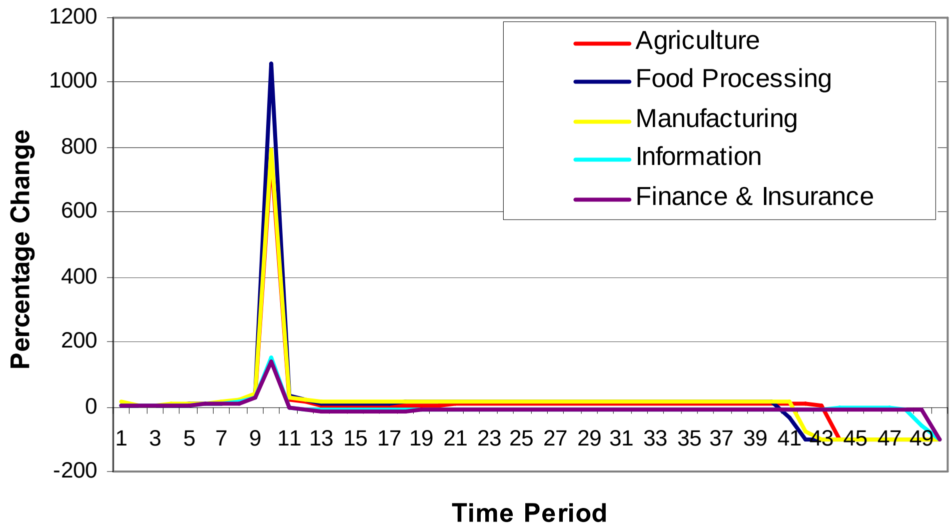



Figure 4.19 shows the more tourism-oriented sectors. These sectors experience relatively large decreases in investment associated with the onset of the negative tourism demand shock. While the eating and drinking places and arts, entertainment & recreation sectors' spike in the 10$^{th}$ time period, the large decrease in the accommodation sector is sustained from 9$^{th}$ to the 11$^{th}$ time period.

**Figure 4.19: % Change in Investment in a Multi-Sector Dynamic Forward-Looking Model (2)**

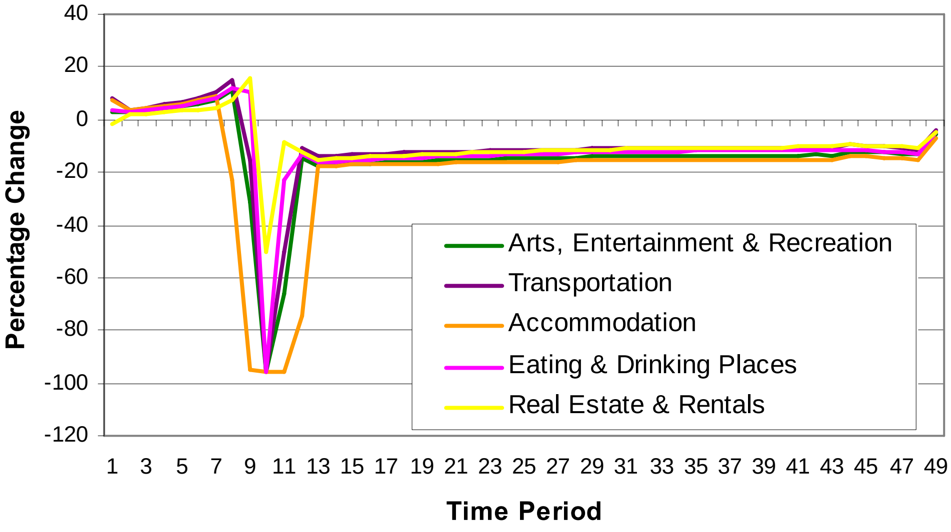



**Figure 4.20: % Change in Investment in a Multi-Sector Dynamic Forward-Looking Model (3)**

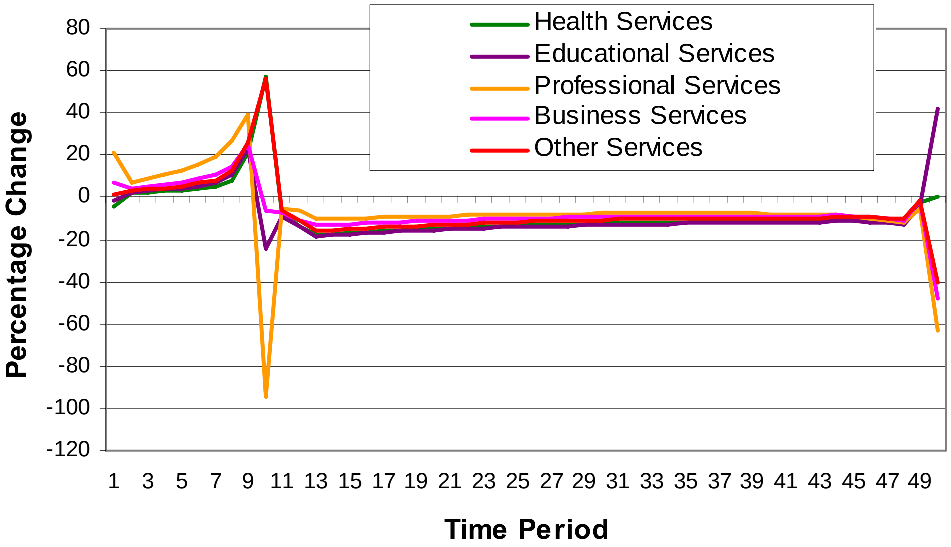
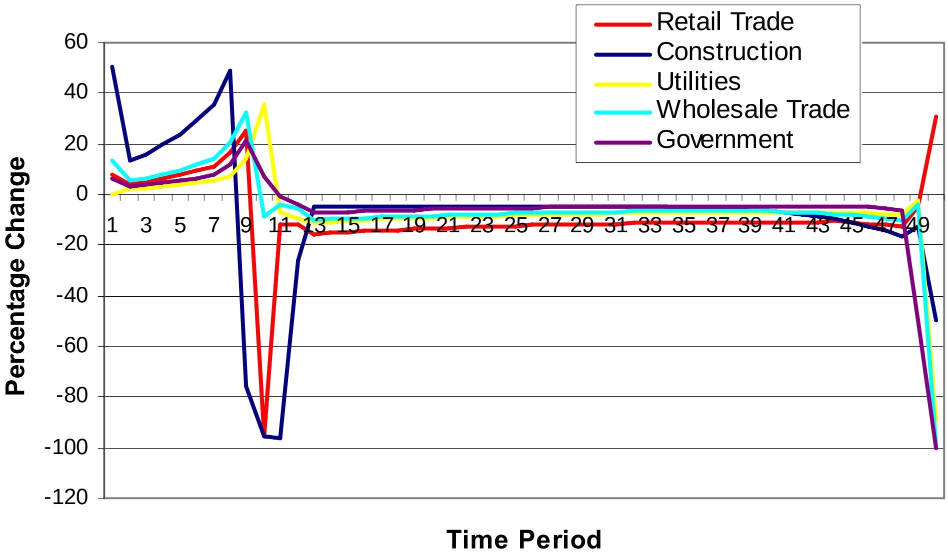


**Figure 4.21: % Change in Investment in a Multi-Sector Dynamic Forward-Looking Model (4)**




## 4.7 Conclusions

This chapter described the features of the CGE model used to model the economy of Hawaii. A comparative static model is initially developed, moving to a dynamic recursive model to a single sector dynamic forward-looking model to a multi-sector equivalent. At each major phase in the model building stage, a 10% decrease in tourism demand is simulated (a permanent shock as well as a shock starting 10 periods into the model) and the key results described.

In sum, with a negative tourism demand shock, some sectors benefit and some sectors lose. Overall, the net effect is a decrease in welfare, as measured by equivalent variation. The tourism-oriented sectors experience decreases in GVA while traditional export-oriented sectors, such as agriculture, manufacturing and food processing, experience increases in GVA. Further, the less substitutability between factors of production and production between sectors, the more welfare decreases.

Up until now, the models have not explicitly included risk. The next chapter outlines what assumptions are made regarding risk in the models explained in this chapter and develops a methodology which explicitly incorporates risk into a CGE model.

# CHAPTER FIVE

# CGE MODELLING AND RISK

## 5.1 Introduction

In the large majority of CGE models, the concept of risk is only implicitly specified in the model. In forward-looking dynamic CGE models economic agents are endowed with perfect foresight, so both consumers and firms anticipate any exogenous shocks and adjust their maximising behaviour from the first time period onwards. Perfect foresight then would appear to negate any uncertain response to a shock. More recently, several studies had incorporated risk and uncertainty into CGE models. This chapter outlined the implicit assumptions made in CGE models regarding risk (Section 5.2) then goes on to review previous work of applied studies of CGE models where risk is explicitly modelled (Section 5.3). Section 5.4 outlines the conceptualisation of another method of how to incorporate risk (or uncertainty) into CGE models. Taking a simple model with Ramsey economic growth dynamics, this section illustrates a frame work that incorporates uncertainty by allowing alternative future time paths resulting in uncertainty in the model and section 5.5 concludes.

### 5.2 Risk in Standard CGE Models: Behaviour of Microeconomic Agents

The section outlines the basic characteristics of the different types of CGE models: the static model, the dynamic recursive model, the single sector dynamic forward-looking model and the multi-sector dynamic forward-looking model. For each type of model, the implicit assumptions of risk are outlined.

#### 5.2.1. Risk in a Comparative Static CGE Model

As explained in the previous chapter, the comparative static (within period) CGE model follows the interactions and relationships of a market economy and solves for a set of prices including production prices, factor prices and exchange rate and levels of production that clear all markets.

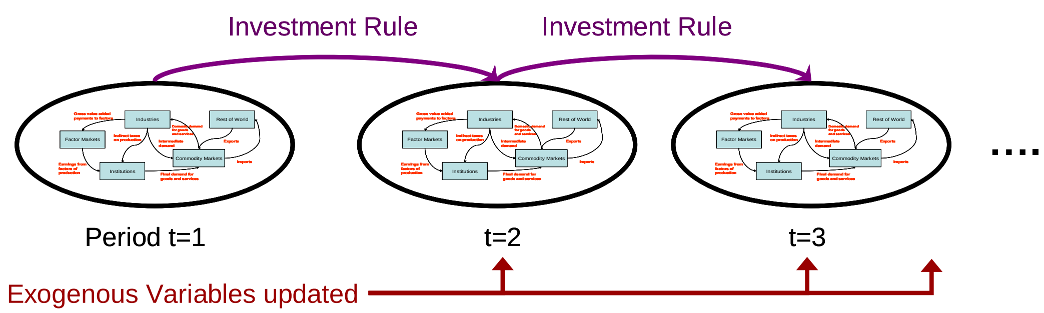
Equilibrium in this model is characterized by a set of prices and levels of production in each industry such that the market demand equals supply for all commodities. Since producers are assumed to maximize profits, and production exhibits constant returns to scale, this implies that no activity (or cost-minimizing technique for production functions) does any better than break even at the equilibrium prices. Demand for and supply of goods and services readjust until all excess demands and excess supplies are eliminated through changes in prices. The production function is specified into terms of labour and capital and the amount of each type of these inputs employed by a producer in a particular sector is based on the sector specific production technology and input prices. Perfectly competitive markets operate to determine these equilibrium prices. Additionally, in equilibrium, no sector earns above-normal profits, markets clear for all factors and products, and, in an open economy, the value of imports for intermediate use and final demand equals the value of export earnings. As described above, consumers or representative households maximise their income-constrained utility and firms maximise their cost-constrained profits. The microeconomic underpinnings of economic agents in a CGE framework follow the traditional neoclassical approach. Agents have rational preferences among outcomes that can be identified and associated with a value. Individuals exhibit maximising behaviour and act independently on the basis of full and relevant information.

In terms of implicit risk, the return on capital captures all the inherent risk associated with the investment and owners of capital are paid an appropriate return, given the level of risk. Elasticities capture the trade-off between the choice of various products and of the inherent risk associated with the curvature of the utility functions. In such models, risk or uncertainty is not explicitly factored into the model.

### 5.2.2 Risk in a Dynamic Recursive CGE Model

As outlined in Chapter 4, a dynamic recursive model is backward-looking by nature: what happens in future periods does not affect the current year's equilibrium. The model is solved year by year without having to solve the whole study period at once. Agents in these models exhibit myopic behaviour. These sequential dynamic models are basically a series of static CGE models that are linked between periods by behavioural equations for endogenous variables and by updating procedures for exogenous variables. Capital stock is updated endogenously with a capital accumulation equation, whereas exogenous variables such as total labour supply are updated between periods. This process can be seen in Figure 5.1. The intra-temporal model is represented by the circular flow diagram within the black ovals in Figure 5.1. The updating of the exogenous variables flow chronologically from left to right, that is, the with-in period model solves and then advances to the next time period.

**Figure 5.1: Graphical Representation of a Dynamic Recursive Model**



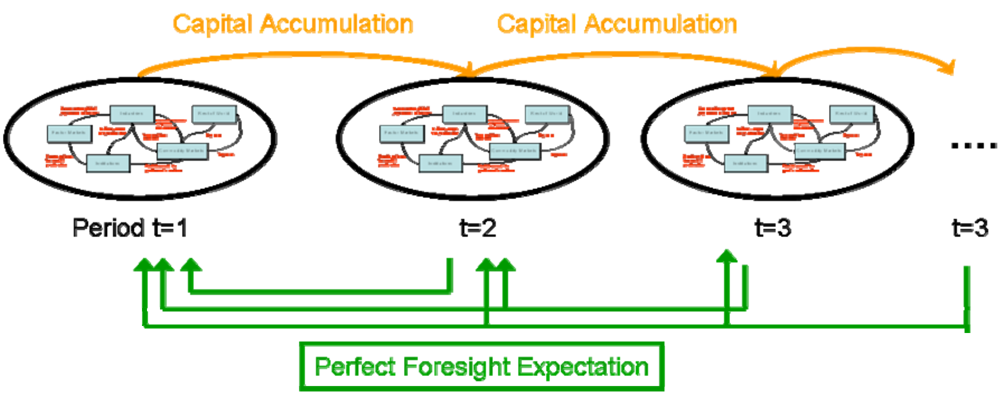
The models are linked together by the savings / investment rule. However, other research has shown that the savings / investment rule can determine to a large extent, the results of the model. The concept of risk in the dynamic recursive model is the same as the treatment of risk in a static model. The 'new' elements in the dynamic recursive model are deterministic in nature and again, the risk is implicitly modelled through the interest rate and in the elasticities.

### 5.2.3 Risk in a Single-Sector Dynamic Forward-Looking CGE Model

As outlined in Chapter 4.5, the dynamic forward-looking computable general equilibrium model assumes that consumers' and producers' behaviour is derived from both intra- and intertemporal optimization. These models incorporate some form of life-cycle behaviour. The household maximizes an additive separable time-invariant intertemporal utility function, while the producer's optimal behaviour is determined by the maximization of the market value of the firm or by the maximization of the present discounted value of net cash flows. The market value of the firm is usually represented as the present discounted value of the future steam of dividends. The model is based upon the perfect foresight hypothesis and describes the transition path to the new equilibrium point. Households and firms make optimal choices given their intertemporal budget constraints. Households maximises the present value of their lifetime utility and firms maximise the value of their profits. In every period, prices adjust to guarantee equilibrium in the model so that demand equals supply.

As with the comparative static model, demand for and supply of goods and services re-adjust until all excess demands and excess supplies are eliminated through changes in prices. Perfectly competitive markets operate to determine these equilibrium prices. Additionally, in equilibrium, no sector earns above-normal profits, markets clear for all factors and products.

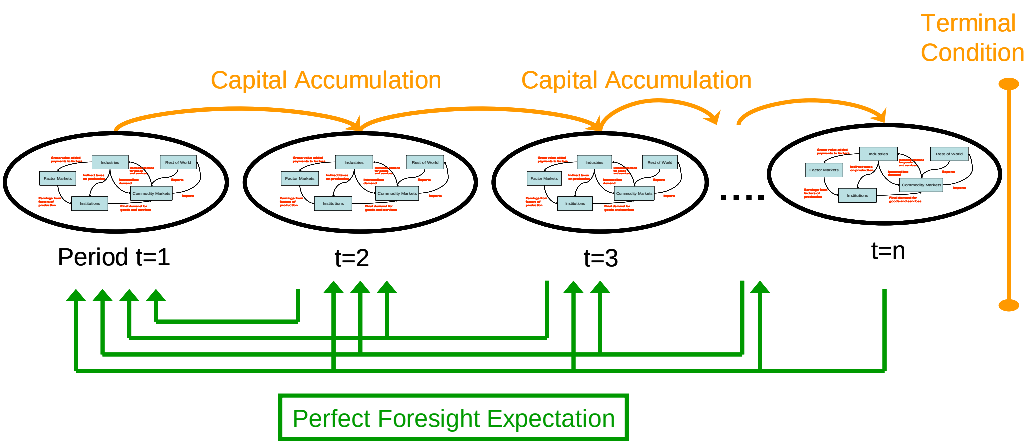
**Figure 5.2: Graphical Representation of a Dynamic Forward-Looking Model: Infinite Horizon**




In contrast to the dynamic recursive model, the dynamic forward-looking model does not just have a rule that links one time period to the next but capital is accumulated in each future time period (represented by the orange links between the intra-temporal models in Figure 5.2). Further, firms maximise the net present value of their profits and consumers maximise their net present value of their utility. They have rational expectations about future time periods and can "see" the future. Decisions made in period, *t* (and subsequent time periods) take into consideration events that occur in future time periods. Economic agents can adjust to shocks before they occur. As represented in Figure 5.2, the expectations are made for each time period considering what has happened before and what will happen after the current time period so in period t=2, the representative consumer optimises their utility given what has happened in period t=1 and given what will happen in the future time periods.

Differing from the dynamic forward-looking infinite horizon model, the finite horizon model is solved for a certain number of time periods after which the terminal condition then is operationalised. This method gives the model tractability. Figure 5.3 depicts this graphically so that the model solves up until t=n at which the terminal condition is enacted.

**Figure 5.3: Graphical Representation of a Dynamic Forward-Looking Model: Finite Horizon**




For both the single-sector dynamic forward-looking model with the infinite and finite horizon versions, risk is implicit as it is with the static and dynamic recursive models.

### 5.2.4 Risk in a Multi-Sector Dynamic Forward-Looking CGE Model

This section explains the difference between the single-sector and multiple-sector dynamic intertemporal model and the implications this has for risk in the model. The change from homogeneous capital to heterogeneous capital has more implications than just adding a sector-specific subscript. In models of this type, heterogeneous capital can introduce exogenous risk premia.

As mentioned in Chapter 4, the market rental rate of capital is determined by market forces, the supply of and demand for capital. Total investment demand equals the use of investment goods from domestic and imported sources. Economy-wide, a composite investment good is derived from the final investment demand column from the Input-Output table. The composite investment good is allocated to sector-specific investment so that the marginal productivity of capital is equal across sectors. Investment opportunities are arbitraged when the net rate of return from each sectorally differentiated investment does not exceed the rate of interest. When investment is undertaken in that sector the net rate of return in that sector will equal the rate of interest.

This arbitraging condition means that sectors with high gross return and lower depreciation rate generate more gross investment demand. In the steady-state, investment will grow at the same rate in all sectors, and the return to capital will be equalised across all sectors. However, during the transitional phase, it is possible for the net return in one sector to fall below that of another. As a result, investment can be shut down in the low return sector. Similar to the single-sector model, assets depreciate. Gross sectoral investment increases the capital stock as well as replaced depreciated capital.

Different from the other models; the multi-sector dynamic forward-looking model can introduce a risk premia between the different rates of return on sector-specific investment. Examples of applied models where this has been introduced can be found in Section 5.3 of this chapter. Nevertheless, this neoclassical risk is exogenous.

Based on these limitations it might be argued that there is no room for risk to be incorporated into a CGE model. The CGE methodology does not allow it. The next section reviews a selection of instances where elements of risk have been incorporated into applied models.

## 5.3 Review of CGE Models incorporating Risk

This section reviews and evaluates a selected number of applied CGE models found in the literature that have explicitly incorporated risk into the model. The way risk has been incorporated into the models can be categorised in two ways: modeller uncertainty (including uncertainty about model parameters and uncertainty about model results); and economic risk (including risk premia and incomplete information).

### 5.3.1 Modeller Uncertainty

There have been several ways to the issue of risk and uncertainty has been addressed concerning CGE modelling. Uncertainty can originate within the economic system or uncertainty can occur as part of the modelling process, that is, modeller uncertainty. Modeller uncertainty relates to the risk of reporting incorrect results or the uncertainty relating to exogenous parameters which have been inputted into the model. The modelling process may involve uncertainty regarding the true value of the model parameters, such as elasticities. Elasticities are sometimes applied to CGE models from one region or points in time that have been estimated econometrically from datasets from different regions or different time periods, that is, there is a mismatch between the data sample and the source of variation in the econometrics and the policy experiment explored in the CGE model (Hertel, Hummels, Ivanic, & Keeney, 2004). Systematic sensitivity analysis, via Monte Carlo analysis or Guassian Quadrature procedure (DeVuyst & Preckel, 1997) is a way to account for this type of uncertainty in CGE models. This technique has been used by Blake (2005), for example.

Modellers may also been uncertain about the results obtained in their CGE model simulations. There is a risk of reporting inaccurate results. Because the source data for CGE models are usually Input-Output tables and Social Accounting Matrices (SAMs) from a particular benchmark year, the assumed production functions and consumer preference functions are calculated deterministically by a process of calibration rather than being estimated econometrically. As such, t-ratios and confidence intervals that can be used for statistical testing do not exist hence there is uncertainty over the accuracy of results. Research exists that attempts to validate results usually through econometric techniques. Valenzuela, Hertel, Keeney and Reimer (2005), in an attempt to validate results from the global CGE model, GTAP, employ the method of stochastic simulation to reflect random production variability for the commodity, wheat. They model uncertainty in wheat output using shocks derived from a times-series (ARMA) model of wheat production to measure the randomness inherent in annual output. Repeatedly solving a CGE model, while sampling from the residuals of the times-series model, creates a distribution that imitates the corresponding market price changes for wheat, by region.  The standard deviations based on these model results are compared to the observed outcomes for annual wheat price changes in order to validate the model.  They find that the simulated outcomes for some regions are remarkably close to the observed outcomes but for other regions the model does not perform as well. Two other pieces of research to employ similar methods: Gehlhar (1997) and Liu, Arndt and Hertel (2004), where the former uses a backcasting simulation to evaluate the validity of GTAP model results versus observed outcomes concerning East Asian economic growth in the 1980s. Gehlhar finds that the CGE model performs adequately at the qualitative level (direction of change in trade share), but is weak in its predictive power. Liu *et al.* build on Gehlar's approach and develop an approximate likelihood function to assess the quality of model performance over a 6 year period, 1986 to 1992.

### 5.3.2 Economic Risk

In economic theory, there has been an attempt to incorporate risk into the economic system in a CGE model in two ways: through the introduction of risk premia and through assumption regarding economic agents' expectations.

#### 5.3.2.1 Risk Premia

McKibbin and Wilcoxon (1999), in their G-Cubed model, incorporate exogenous risk premiums in their inter-temporal dynamic multi-sector multi-region CGE model. They do this through the full integration of real and financial markets. With the assumption of perfectly integrated asset markets across regions, the expected returns on loans (interest rates plus risk premiums) denominated in one region (currency) is equal to the expected returns in another region (currency) adjusted by the exchange rate so there is no arbitrage. Within each economy, the expected returns to each type of asset are equalized by arbitrage, adjusting for adjustment costs of physical capital stock and exogenous risk premiums. In long run equilibrium the return of capital across sectors is the same, yet in the short run, simulations can allow for arbitrage and hence risk premiums across different capital assets. This can be notated algebraically as: $r_k + \mu_k = r_l + \mu_l + XR_l^k$ where $r_k$ and $r_l$ are the rates of interest in countries *k* and *l* and $\mu_k$ and $\mu_l$ are the risk premia in countries *k* and *l* and $XR_l^k$ is the exchange rate between the two countries.

McKibbin & Vines find that in the analysing the rise in US equity prices in the 1980s the change in the equity risk premium is the most important of the three factors (the other factors being a rise in global and US public sector saving and productivity growth in the US computer sector) (McKibbin & Vines, 2000).

Country risk has also been modelled through exogenous risk premiums using a dynamic CGE model (Malcolm, 1998). The standard GTAP model assumes that the global bank equalizes risk-adjusted rates of return so that the risk-adjusted rates for all regions are equal to a weighted average of returns around the world. Malcolm (1998) explicitly defines this risk premia and hence examines the effects of changes in these risk premia. In these multi-sector models, the risk premiums are exogenous.

One method of endogenising risk into a CGE model has been developed by Arndt and Tarp (2000). They employ a CGE model to analyse the interactions between agricultural technology improvement, risk, and gender roles in agricultural production in Mozambique. They introduce a particular type of "technology" risk into the model, assuming that a safety first strategy is pursued, that is, they assume that households aim to produce a certain exogenous amount of cassava (the crop of interest in the study) for risk reduction purposes only. Once resources have been allocated to produce a minimum amount of cassava, resources are then distributed to other agricultural and non-agricultural activities according to the market. The safety first risk-aversion strategy is applied by adding an endogenous variable which serves as a risk premium. This risk variable enters in two functions in the model: the factor demand function and the factor income equation with the risk premium in the numerator of the factor demand function and the risk premium is in the denominator of the factor income equation. This means that if a risk premium exists (>1), factor demand for the commodity will be higher than in the risk-less pure profit maximizing position and factor income will be lower than in the risk-less scenario. Arndt and Tarp conclude there are considerable differences in production and price movements for cassava between the risk and no risk scenarios.

#### 5.3.2.2 Incomplete Information

Uncertainty can be viewed in the context of incomplete information – market inefficiency. The lack of information regarding the future may give producers an incentive to supply too much of some products and too little of others. Alternatively, consumers may not purchase a product even though they would benefit. One method of simulating incomplete information has been to contrast static expectation (incomplete information), where consumer and producers have full information in each current time period but know nothing of the future, to rational expectations (perfect information) where consumers and producers have perfect knowledge of both current and future market conditions.

The issue of uncertainty with regard to future information is explored by Arndt and Bacou (2000). Taking a relatively standard CGE model of Mozambique, these authors explore the value of climate forecast information that operates and interacts at a farm level, at a marketing system level and at a full economy level. Under the premise that predictable droughts are less damaging than randomly occurring droughts, three simulations are modelled. This first simulation involves an unanticipated drought (droughts being simulated by a Hicks-neutral technology decline), where agricultural activity is fixed and can not be adjusted based on realized climate outcomes. The second and third simulation allow farmers and both farmers and marketing agents, respectively, to react to a received perfect climate forecast. Results show that reduction in risk associated with a perfect forecast results in lower decreases in real GDP and welfare as resources are reallocated from drought intolerant to more drought tolerant activities.

Along the same lines but in a different context Adams, Hansen and Jacobsen (2001) explore the issue of timing and announcement of policy changes within a dynamic CGE model. The two scenarios modelled involve, first, the introduction of a once-off quota without any previous announcement on the production of pigs in the Danish economy and the second scenario involves an announced gradual phased in production quota. Not surprisingly, the adjustment path of the economy is smoother when the policy is announced compared to the surprise policy implementation. The key factor is the relationship between investment and expectations. In the 'announced' scenario investors correctly anticipate future adjustments in prices and rental rates on capital when making investment decisions and the capital stock starts to adjust from the start of the simulation. In the 'surprise' scenario, expectations are static and investors adjust fully only when the quota is implemented (rather than announced). With the announced policy, scenarios that contract the economy occur earlier and more gradually so whether the announcement or surprise implementation is preferable depends on agent's attitude to risk and their implicit discount rate. The more risk averse they are or the lower they discount future consumption, the more likely it is they prefer an announced policy.

Focusing on international capital mobility, Ianchovichina, McDougall and Hertel (1999) develop a disequilibrium approach for a dynamic multi-sector multi-region general equilibrium model. As well as modelling exogenous risk premia as McKibbin and Wilcoxon do (McKibbin & Wilcoxon, 1998), the key feature of this model is that there are errors in investors' assessment of potential returns to capital. They argue that investors' expectations are "sticky" and that when the observed rates of return change, investors are uncertain whether this change is temporary or permanent. It is only with a lag that they adjust their expectations. Initially, investors make small adjustments, and if the change in the rate of return persists, they make further changes in their expectations until the expected rate equals the observed rate of return.

This was the explanation for the Asian financial crisis of 1997. The authors argue that the developments in East Asia reflect the fact that investors have not foreseen correctly returns to capital. They argue that this can be represented through a simple recursive solution procedure to mimic investment theory of adaptive expectations. They argue that the limitation of forward-looking inter-temporal models is the assumption of perfect foresight of returns to capital. In this case, the financial crisis would imply investors did not have perfect foresight.

Boussard, Gerard, Piketty, Christensen and Voituriez (2002), as well as allowing for imperfect expectations, examine the issue of agricultural trade liberalization, adding instability in the model by endogenising risk through lags in delivery, and risk aversion. Uncertainty is introduced into the model through a production lag in the agricultural sector. Picking up the work done by Ezekiel (1938), who developed cobweb theorem, the researchers specify a lag between the production and consumption decision for the agricultural sector. The market equilibrium occurs between the previous year's production and the current year's consumption. Production decisions are taken on the basis of expected prices, rather than equilibrium prices. Equilibrium prices are used as inputs, expectations are important, in this model, only for next year's production. In turn, income in the current year depends heavily on expectations for the future year; implying firms can gain or lose. As such, firms bear risks. In sum, Boussard *et al.* introduce risk, imperfect information and production lag in the agricultural sector in a standard CGE model to model uncertainty. They find, in contrast to the classical perfect foresight model where global gains are associated with trade liberalization, the model with risk aversion, imperfect information and a production lag in the agricultural sector shows negative changes in real income. Imperfect information constrains the economy from reaching its optimum. In a later piece of work, Boussard, Gerard, Piketty, Ayouz and Voituriez (2004) explain how the endogenous risk differs from exogenous risk. Neoclassical risk is exogenous, it is delivered from above, outside the model. The behaviour of agents has no relationship to the level of risk involved and cannot influence the degree of risk. Endogenous risk is a consequence of expectation errors. These errors are inconsistent with the rational expectations hypothesis.

In the CGE risk literature, a dynamic recursive model is implemented to replicate incomplete information about the future. However, one weakness with this research is that the dynamic recursive model has some inherent problems. While the researchers cited above argue that a dynamic forward-looking model does not allow the existence of imperfect information or errors in expectations, to argue economic agents do not make any decisions based on what they know about the future and / or attempt to, say smooth consumption or production is to err in the other direction. In the next section, an alternative method is outlined that treats risk explicitly through creating multiple future paths for the model, with agents able to predict each path and make decisions in the presence of this uncertainty.

As CGE models have become more sophisticated, there have been efforts to model elements of risk and uncertainty. There have been two main categories: modeller uncertainty, where there is uncertainty regarding exogenous parameters and results in general and attempts to allow for uncertainty in these cases; and uncertainty regarding future expectations where agents' behaviour under static expectations is contrasted with expectations with perfect foresight. The next section describes a different way to incorporate uncertainty into a CGE model.

## 5.4 Uncertainty Regarding the Future Path of the Economy

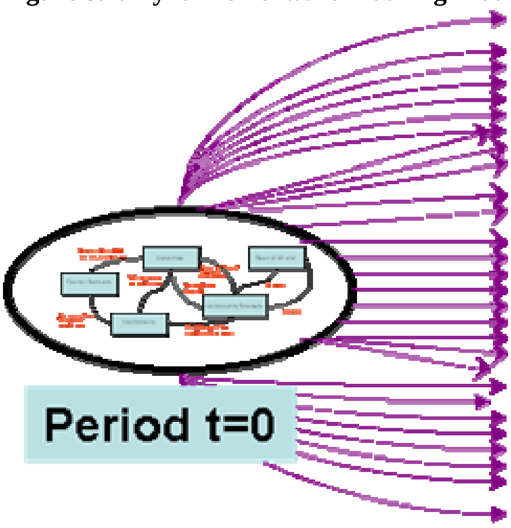
This section outlines how risk can be incorporated into a dynamic forward-looking CGE model through the uncertainty of the future path of the economy. The thesis uses the terminology 'paths' to refer to what is commonly known the economic literature as 'states' or 'states of the world'. This has been chosen to reduce any confusion over terminology due to the homonym 'state' can also refer to a geographical region, of which, Hawaii is one.

The general equilibrium framework has been developed to economic situations involving the exchange and allocation of resources under conditions of uncertainty (Mas-Colell, Winston, & Green, 1995). In these theoretical models, the concept of uncertainty is formalised by means of different states of the world. That is, technologies, endowments, and preferences depend on the state of world. A contingent commodity is a commodity whose delivery is conditional on the realised state of the world. This “state-preference” approach to uncertainty, introduced by Arrow (Arrow, 1964) and further detailed by Debreu (Debreu, 1959 Chapter 7) assumes there is a market for every contingent commodity. The introduction of contingent commodities then sees the concept of a Walrasian equilibrium become an Arrow-Debreu equilibrium. Arrow-Debreu equilibrium results in a Pareto optimal allocation of risk. The Arrow-Debreu framework then moves into the creation of spot markets and forward markets, arriving at the Radner equilibrium (Radner, 1972) where economic agents form expectations of spot prices in future states, purchase present goods and securities on the basis of those expectations. Current and future spot prices of goods and assets adjust so that all "markets" clear and these price expectations must be fulfilled. This now the foundation of finance theory (for an introduction see Huang & Litzenberger, 1988; Duffie, 1992).

Applied CGE models have also integrated financial flows and assets with the neoclassical CGE model. Robinson surveys these ‘micro-macro’ CGE models that incorporate asset markets and product and factor markets (Robinson, 1991). The distinguishing feature of these models is “in their specification of the loanable funds markets, with a variety of different assets including currency, demand deposits, time deposits, government debt, domestic bonds, foreign bonds, equity real capital, and working capital.” (Robinson, 1991 p. 1517). Typically, the underlying SAM will disaggregate the capital account to include different types of assets from the different economic agents.

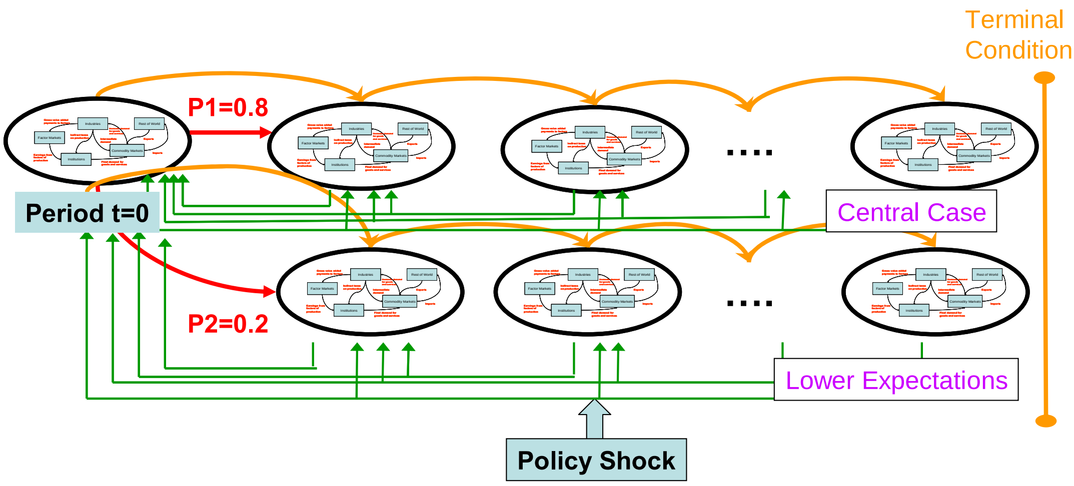
The model outlined in this thesis does not include a loanable funds market but several features of the theoretical Arrow-Debreu framework are implemented. Uncertainty in the model means different states of the world or paths that the economy might take (Figure 5.4). Due to the different states of the world, risk is created but the uncertainty of which paths will occur –one or more paths will contain a shock which may be realised. An exogenous variable, for example tourism demand, can be simulated to vary on any or all of the possible paths the economy might take. Economic agents have perfect sight across all the possible paths the economy might take. The assumption of rational expectations will hold so that the representative consumer, firms, and government are endowed with perfect foresight, and so anticipate any exogenous shocks and adjust their maximising behaviour from the second time period (the period in which the uncertainty, but not necessarily the shock, will occur).

**Figure 5.4: Dynamic Forward-Looking Model with Multiple Future Paths**



Given this uncertainty, how do consumers and firms change their behaviour? For example, in the partial equilibrium literature, firms will under-invest in sectors where there is uncertainty (Marschak, 1949; Hartman, 1972; Cuikerman, 1980; Pindyck, 1982; Bernanke, 1983; Majd & Pindyck, 1987). Do these results hold in the general equilibrium context? It may even be that the uncertainty may be so high as to stifle investment such that, it may be unprofitable to invest in the current time period. The economic impacts of the timing (when the shock occurs and how long the shock lasts) as well as the magnitude of the exogenous shocks will also be analysed in the next chapter.

**Figure 5.5: Dynamic Forward-Looking Model: With Uncertainty**




A graphical representation of the conceptual model is shown in Figure 5.5. In this example, two paths are possible. One path follows the baseline growth, while the other path experiences a policy shock. These impacts are then followed through to the *n*th time period. Expectations are consistent throughout so that economic agents have lower expectations under the negative shock path from the first time period, even though the negative shock does not take place until period *t=2*. Further, the probability that a path may take is set objectively, as an exogenous parameter. In the model above (Figure 5.5), the benchmark case (P1) is assumed to continue with a probability of 80% and the case with the negative policy shock is assumed to occur with a probability of 20%. Policy makers can use the model to investigate the economic impact of a shock to the economy with a particular certainty.

In the initial time period, *t=0*, the model is solves and calibrated as if it were a comparative static model. In period *t = 1*, there is uncertainty on which path the economy might follow. The next step is to introduce a number of different paths that the economy might take as well as the probability that each path might take along a certain path. Let $p$ be the number of possible path, then $\Phi(p)$ is the probability that a specific path is taken. It is a necessary condition that $\sum_{1}^{P}\Phi(p)$, that is, that the probability of the sum of the paths sum to 1. To calibrate the model: from the second time period onwards (t=1), all the sectors and benchmark quantities need to be multiplied by the probability that this particular path occurs. The relationships described above (Section 4.1) exist for the first time period and in each path, *p*. The capital accumulation links the *t=0* no-uncertainty part of the model to the dynamic uncertainty part of the model (*t≥1*). Hence, where $K^*$ indicates the first time period and $K_{p,t}$ indicates capital in period *t* for path, *p*. The capital accumulation equation now becomes:

$$K_{p,t=1} = K^{*}(1-\delta) + I^{*} \quad \textbf{(15)}$$

$$K_{p,t+1} = K_{p,t}(1-\delta) + I_{p,t} \quad \textbf{(16)}$$

where * in Equation 15 denotes first-year values (*t=0*) and Equation 16 represents the capital accumulation equation from the second period onwards (*t≥1*).

Production can be decomposed in this model for the time period *t=0* and for *t*≥1. As in Section 4.3.2, in the initial period sectors *i*'s production function is

$Y_i = \mathrm{g(D_i, E_i) = f(K_i, L_i, A_{i,j})}$ . For the dynamic component of the model, sector *i*'s production function is dependent on time and the path the economy takes hence: $Y_{i,t,p} = \mathrm{g(D_{i,t,p}, E_{i,t,p}) = f(K_{i,t,p}, L_{i,t,p}, A_{i,j,t,p})}$ where g is output transformation function, and f is input transformation function. Specifically, the initial output transformation takes the form of a constant elasticity of transformation (CET):

$Y_i = \Theta\left(\delta_i^e D_i^{\frac{\eta-1}{\eta}} + (1-\delta_i^e)E_i^{\frac{\eta-1}{\eta}}\right)^{\frac{\eta}{\eta-1}}$ and the multi-path dynamic output is

expressed as $Y_{i,t,p} = \Theta\left(\delta_{i,t,p}^e D_{i,t,p}^{\frac{\eta-1}{\eta}} + (1-\delta_{i,t,p}^e)E_{i,t,p}^{\frac{\eta-1}{\eta}}\right)^{\frac{\eta}{\eta-1}}$ where $Y$ = output; $E$ = exports; $D$ = domestic production; $\eta$ = the elasticity of transformation in total supply; $\delta_{i,t,p}^e$ = the calibrated share of exports; and $\Theta$ = the calibrated shift parameter in the transformation function.

Similarly, the Armington aggregate of domestic output and imports in the initial time period is specified as a constant elasticity of substitution (CES) function:

$$A_i = \Omega\left(\delta_i^m D_i^{\frac{\gamma-1}{\gamma}} + (1-\delta_i^m)M_i^{\frac{\gamma-1}{\gamma}}\right)^{\frac{\gamma}{\gamma-1}}$$

while the multi-path dynamic CES function of the Armington aggregate is given by

$$A_{i,t,p} = \Omega\left(\delta_{i,t,p}^m D_{i,t,p}^{\frac{\gamma-1}{\gamma}} + (1-\delta_{i,t,p}^m)M_{i,t,p}^{\frac{\gamma-1}{\gamma}}\right)^{\frac{\gamma}{\gamma-1}}$$

where $A$ = the Armington CES aggregate of domestic supplies, $D$ and imported supplies, $M$ for each sector; $\gamma$ = the elasticity of substitution in the aggregate supply function; $\delta_{i,t,p}^m$ is the share of imported goods; and $\Omega$ = the calibrated shift parameter of the aggregated supply function.

As with other sections of the economy, the production of goods follows a nested Leontief-Cobb Douglas production function with the *t=0* intratemporal model being specified as in Section 4.3.2 and the multi-path dynamic part of the model being a function of time and path. Hence, in the initial period, *t=0*, output is allocated to the domestic and export markets according to a constant-elasticity-of-transformation and intermediate inputs are Leontief, while labour and capital enter as a Cobb-Douglas value-added aggregate:

$$\mathrm{f}(\mathrm{K_i}, \mathrm{L_i}, \mathrm{A_{i,j}}) = \min\left\{B_i L_i^{\alpha_i} K_i^{(1-\alpha_i)}, \min\left\{\frac{A_{i,1}}{a_{i,1}}, \frac{A_{i,2}}{a_{i,2}}, \ldots, \frac{A_{i,j}}{a_{i,j}}\right\}\right\}$$

In the dynamic section of the model, from t≥1, the production of goods is denoted by a nested Leontief-Cobb Douglas production function in every time period and on every path:

$$\mathrm{f}(\mathrm{K}_{\mathrm{i,t,p}}, \mathrm{L}_{\mathrm{i,t,p}}, \mathrm{A}_{\mathrm{i,j,t,p}}) = \min\left\{ B_{i,t,p} L_{i,t,p}^{\alpha_i} K_{i,t,p}^{(1-\alpha_i)}, \min\left\{ \frac{A_{i,j,t,p}}{a_{i,j,t,p}} \right\} \right\}$$

The representative household maximises the present value of their lifetime utility across paths. Utility, now dependent on the time path chosen, is represented by:

$$U_p = \sum_{t=1}^{\infty} \left( \frac{1}{1+\rho} \right)^t C_{p,t} \qquad \textbf{(17)}$$

Total utility across all paths is given by

$$U^* = \left[ \sum_{1}^{P} \Phi(p) U_p^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} \qquad \textbf{(18)}$$

Where $U^*$ is total utility

$C_{t,p}$ is consumption in each time period and on each path

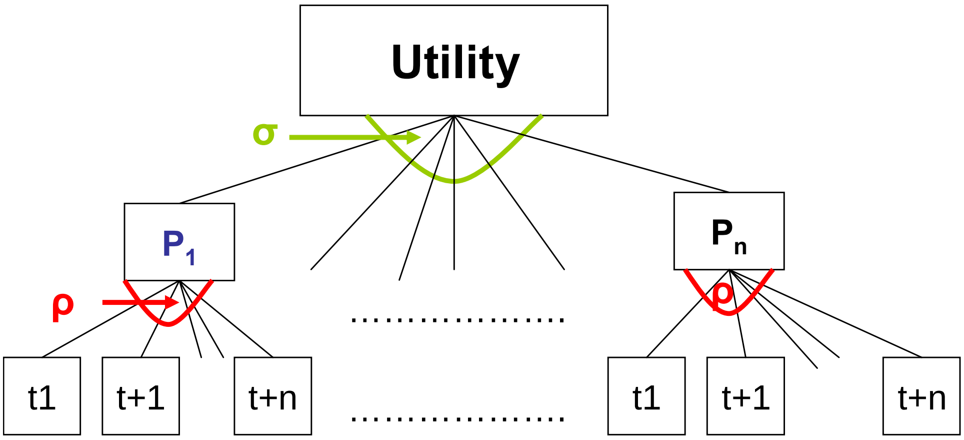
$\rho$ is the discount factor or individual time-preference parameter

$U_p$ is discounted utility on each path,

$\Phi(p)$ is the probability of each path occurring, and

$\sigma$ is the risk aversion parameter

**Figure 5.6: Multiple Path Utility Schematic**




As shown in Figure 5.6, utility is a nested function across paths and across time. At the top level, total utility is a composition of utility in each path with the elasticity of substitution between paths – the risk aversion parameter denoted by σ, as in Equation 18. At the next level down, utility on path, p, is a composite of utility in each time period with the elasticity of substitution between time periods denoted by ρ.

Welfare is measured by the equivalent variation metric (EV). EV at time period 0 is given by: $\frac{C_1 - C_0}{C_0}.C0$ where $C_1$ is consumption after the counterfactual; $C_0$ is consumption in the benchmark (normalised to 1) and; C0 is the benchmark level of consumption. EV in each path is given by $EV(p) = \frac{UP_1(p) - UP_0(p)}{UP_0(p)}.\sum_t$ (QRef(t).PRef(t).C0) where $UP_1(p)$ is utility after the counterfactual; $UP_0(p)$ is utility in the benchmark (normalised to 1); QRef(t) is the reference growth path for the economy given by $(1+\gamma)^t$; PRef(t) is the reference growth path for prices in the economy given by

$PREF(t) = \left[ \frac{(1-(S.R0)}{(1+R0(1-S)-\delta)} \right]^t$ and C0 is the benchmark level of consumption. Pref(t) is the same variable discussed in Section 4.5.7, however due to the initial time period (t=0), PRef(t) in the Risk Model is advanced one time period (raised to the power t, rather than raised to the power t-1). EV for the whole model is given by $EV = \frac{U_1 - U_0}{U_0}.\sum_t \sum_p \Phi(p).U^*$

## 5.5. Conclusion

CGE models have traditionally tended to be deterministic in nature. This chapter describes how risk is treated in standard CGE models and reviews how other researchers have attempted to model risk explicitly. In this chapter, another way to model risk and uncertainty in a CGE model has been demonstrated. The risk is incorporated into the model through the introduction of uncertainty regarding the future path of the economy. The probability and timing of a shock to the model economy is the underlying source of uncertainty. Understandably, there are limitations to modelling uncertainty in this way. It is not possible to model all future possible future time paths. The number of possible paths chosen and the probability of travelling along each path will need to be specified to span a feasible solution.

This model explicitly includes risk and agents' reaction to risk. Further, this chapter outlines one way to add uncertainty into a dynamic forward-looking model. The purpose of the next chapter is to show the impact of risk and reports the results of various scenarios using the model of the Hawaiian economy developed in Chapter 4. A dynamic forward-looking CGE model with and without uncertainty will be compared. The parameters of interest will be the numbers of different paths the economy can take, the probability that each paths takes given a negative tourism demand shock on one path and value of the risk aversion parameter.

# CHAPTER SIX

# IMPLICATIONS OF UNCERTAINTY IN A FORWARD-LOOKING CGE MODEL: AN APPLICATION TO HAWAII

## 6.1 Introduction

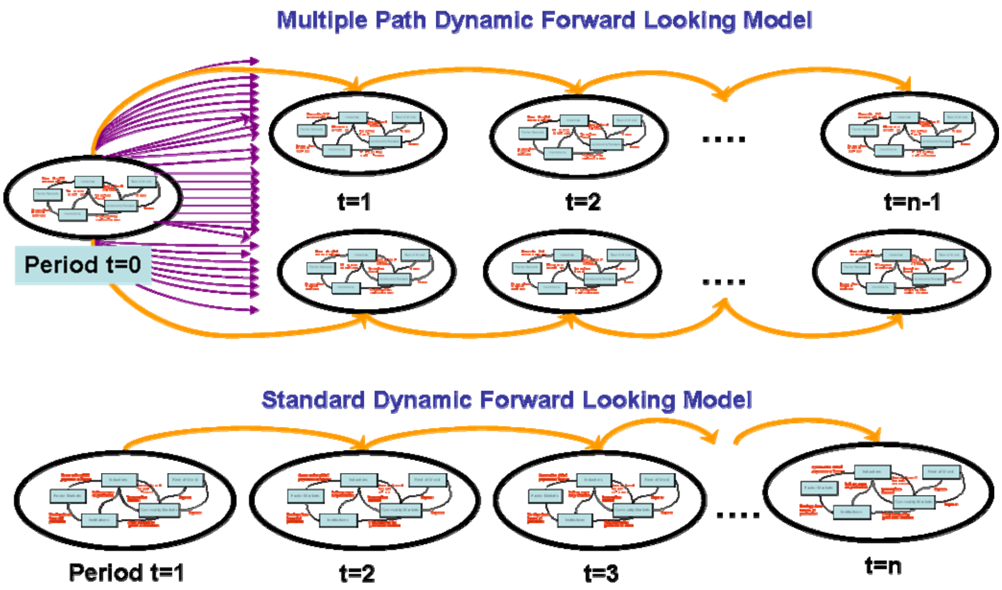
This chapter shows the results of incorporating risk, as described in Chapter 5, into the dynamic forward-looking CGE model of the Hawaii economy. It shows the results of how modelling risk using a CGE model works in practice. The various results are shown for varying number of possible paths the economy might take, different values of the magnitude of the shock, different timings of the shock and different probabilities of travelling along the path with the shock will be simulated. Moreover, the value of key parameters of the model will be tested. These parameters include the elasticity between paths: the risk aversion parameter and the elasticity between time periods: time preference elasticity. Lastly, the chapter will report the addition of several policy initiatives that government might implement in light of the uncertainty of tourism demand.

## 6.2. Model Structure

As outlined at the end of Chapter 4, the multi-sector dynamic forward-looking model produced somewhat unrealistic results in terms of the behaviour of sector-specific investment. Therefore, for the purposes of modelling risk, the single sector dynamic forward-looking CGE model will be used. For comparison to the risk-free model, all other parameters and features of the model have been kept constant: there are twenty productive sectors; unemployment and a flexible labour supply are included in the model; the benchmark unemployment rate = 4.1%, the supply response elasticity ($\eta$) = -0.1 and the elasticity of unemployment to real wages ($\omega$) = -0.5; the steady state growth rate of the economy ($\gamma$) = 2%; the depreciation rate ($\delta$) = 1%; the closure rules are the same as in the comparative static model; and investment comes 'on-line' in the next time period (s=1).

The model time horizon will also be the same but by specifying different paths the economy can take, the nomenclature will be different. In a standard dynamic forward-looking model across 50 time periods, the model runs from *t=1* to *t=50*. In a multi-path dynamic forward-looking model, the 'first' period calibrates the model and does not contain the option of multi-paths. This 'first' period is modelled like a comparative static model. Like the standard dynamic forward-looking version, the accumulation of capital links this 'comparative static' model to the ensuing multi-path dynamic model. For comparability, the last time period, will be one period less than the standard model. In the above example the dynamic part of the multi-path model would be *t=49* time periods. This can be seen pictorially in Figure 6.1. As a check the standard t=50 period model was benchmarked against the static t=0, multi-path dynamic t=49 model and the benchmark values were equivalent.

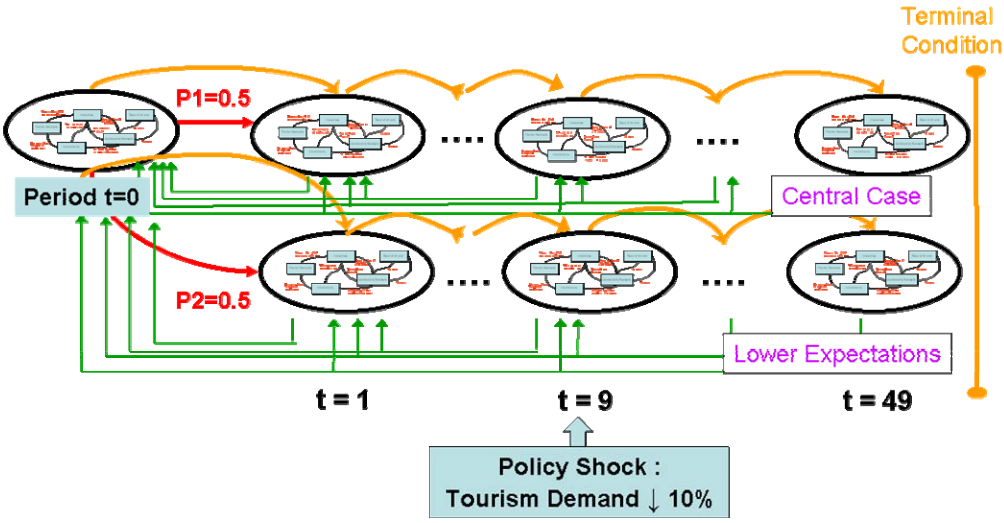
**Figure 6.1: Comparison of Time Periods**




## 6.3. Uncertainty Regarding Future Tourism Demand

Operationalising this CGE model with risk, a natural counterfactual would be to assume the economy continues on the business as usual growth path with a probability of 50% (path 1) and to model a 10% decrease in tourism demand from the 9$^{th}$ time period onwards with a probability of 50% (path 2). This counterfactual is shown pictorially in Figure 6.2. The value of the risk aversion parameter, σ, has been set to 0.5. This specification (σ <1) implies the representative household is risk averse. When σ =1, the representative household is risk neutral and when the σ >1, the representative household is risk seeking. The elasticity between time periods: time preference elasticity, ρ has been set to 1, implying the representative household's utility is a Cobb-Douglas function (fixed proportions) across time.

**Figure 6.2: Possibility of a Negative 10% Tourism Demand Shock from t=9 onwards**




In a model of this sort, welfare can be decomposed into welfare from path 1, welfare from path 2 and welfare from the initial time period (*t=0*). The sum of these three components will not usually equal total welfare across the model due to the non-linear nature of the model. The results tables will display the decomposed welfare changes as well as the overall change in welfare.

**Table 6.1: Results: 2 Path 10% Negative Shock on 1 Path in t=9 onwards**

| Time Period | t=0 | Path 1 | Path 2 | Total |
|---|---|---|---|---|
| EV | $150.3m | $372.4m | -$3,713.5m | -$ 1,537.7m |
| % EV (% Change from Benchmark) | 0.66% | 0.13% | -1.26% | -0.48% |
| Terms of Trade | $5.1m | -$2,587.3m | -$17,143.3m | -$9,860.2m |
| Tourism Demand Shift | - | - | -$84,337.9m | - |
| Tourism Price (% Change from Benchmark) | 0.045% | -0.24% | -1.79% | - |

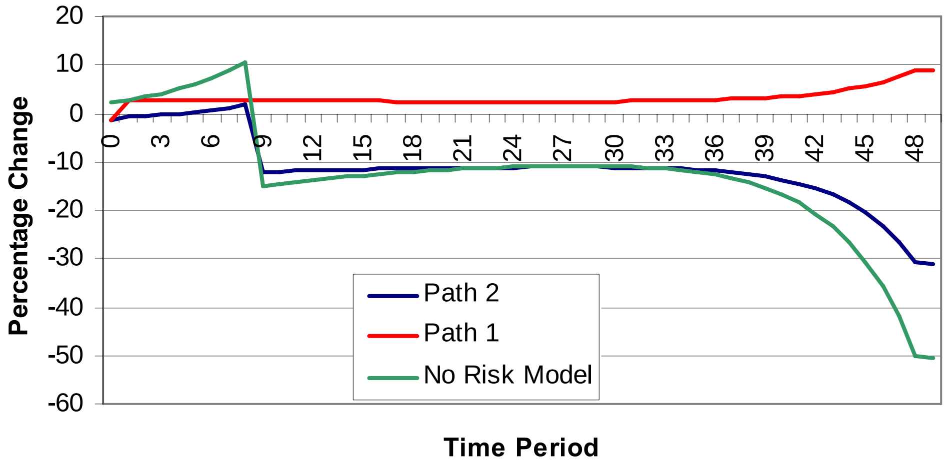
Table 6.1 shows the decomposition of several variables across the three time dimensions: the initial period (*t=0*), path 1 and path 2. The rows in the table are Equivalent Variation (EV) in $US million, the percentage change in EV,

the terms of trade in $US million (this shows the amount changed due to the change in prices), the amount in $US million of the tourism demand shift being simulated and the percentage change in the tourism price.

The table shows some interesting results. Firstly, the consumers start adjusting their behaviour from the period *t=0*, that is, even before the model splits into the two paths. This observation is standard in rational expectations models and should be expected but it is significant nonetheless as consumer behaviour of this kind marks a significant departure from the consumer behaviour in dynamic cursive models. Secondly, in the path where there is no tourism demand shock, travelling along this path increases welfare. Along this path, welfare increases by $US 372.4 million across the model horizon, equating to a slight increase in welfare of 0.13%. As expected, welfare in path 2, where the simulated shock occurs decreases by 1.3%. In total, welfare decreases by 0.48%. This stands in contrast to the definitive case where tourism demand is simulated to fall 10% with certainty from t=10 onwards (the equivalent of t=9 in the risk model), which reported a decrease of 1.63% in welfare.

Figure 6.3 to Figure 6.6 shows the transition paths of investment, capital, residents' consumption and tourism consumption respectively for the no-risk model, and paths 1 and 2 for the risk model for a 10% decrease in tourism demand starting from period *t=9* onwards.

**Figure 6.3: Investment in the Risk vs. No-Risk Model**




Investment, capital and residents' consumption on path 1 (the path with no counterfactual) grow at a positive rate above the baseline benchmark growth rate. Path 2 investment does not fall as far as investment in the 'no-risk model'. This is to be expected as there is only a 50% probability of a tourism demand shock along path 2.

**Figure 6.4: Capital in the Risk vs. No-Risk Model**

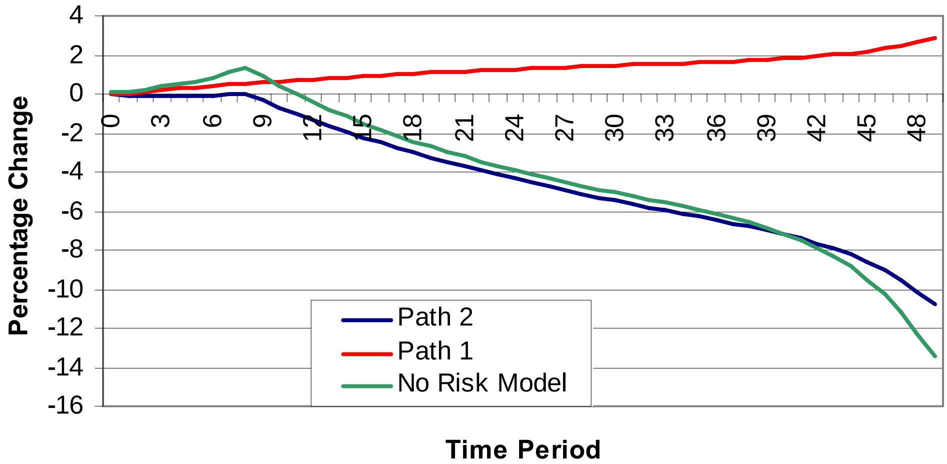
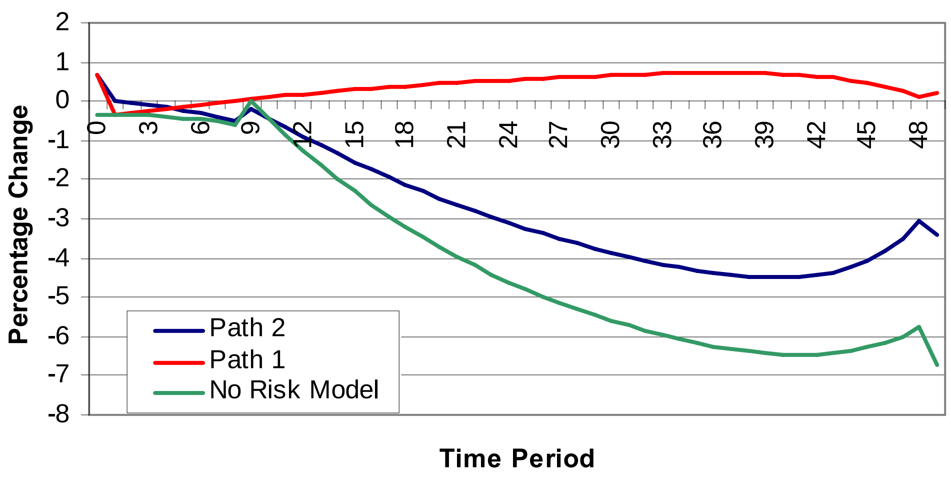
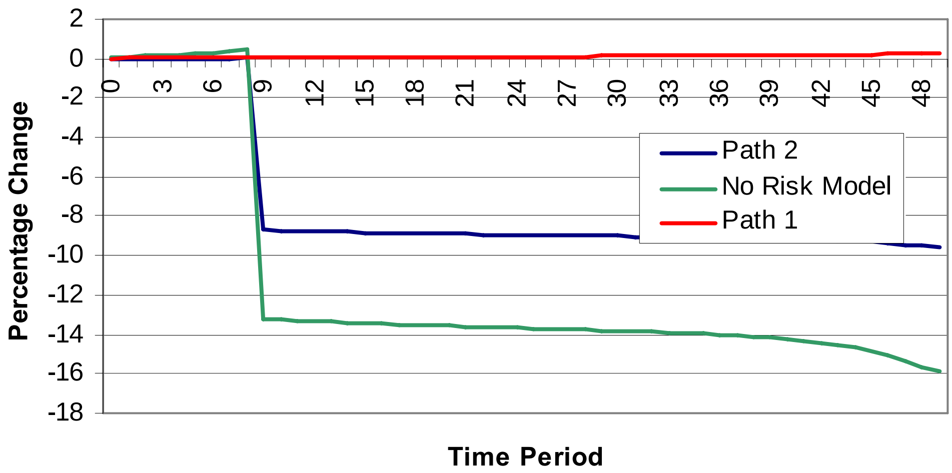


**Figure 6.5: Consumption in the Risk vs. No-Risk Model**



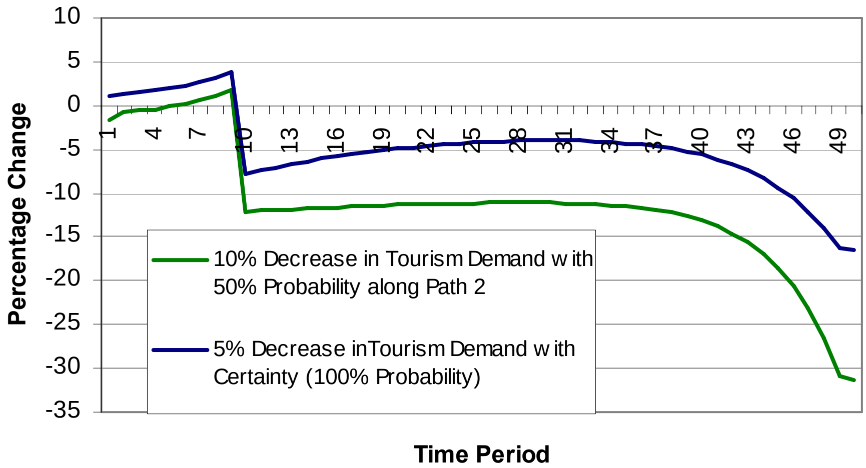

Further, with the counterfactual on path 2 being only likely to occur with a probability of 50%, the percentage change in investment, capital, resident's consumption and tourism consumption is only a proportion of 'no-risk' model rate.

**Figure 6.6: Tourism Consumption in the Risk vs. No-Risk Model**



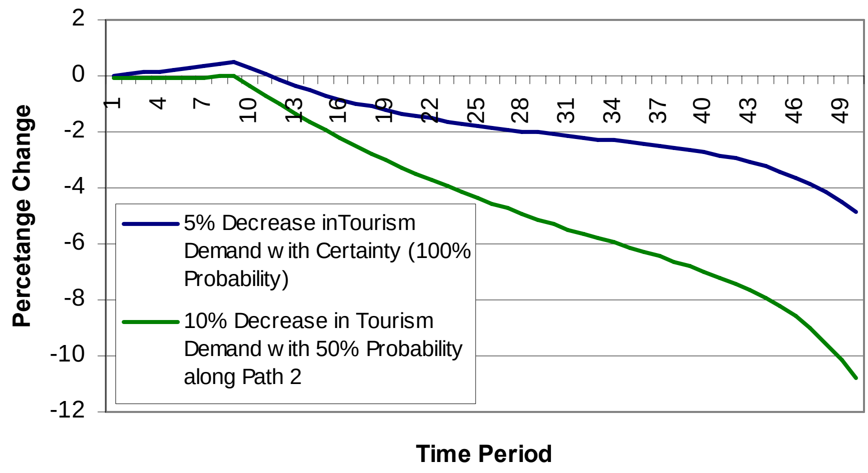

It could be argued then that a two path model with a 10% decrease in tourism demand occurring along one path with a 50% probability is really just the equivalent of single path standard model with a 5% decrease in tourism demand occurring with 100% certainty. However, this is not the case. Figure 6.7 compares the investment in the two different models described above and Figure 6.8 shows the comparison for capital. As can be seen from the graphs, the models with risk exhibit much sharper declines in both capital and investment than in the model with twice as large decrease in tourism demand modelled with certainty.

**Figure 6.7: Investment in the Risk vs. No-Risk Model: Comparing a 5% shock with certainty with a 10% shock with 50% probability**




As outlined in Section 4.5.8, a 10% decrease in tourism demand with the certainty is estimated to decrease welfare by 1.63%. Using the same standard single-sector forward-looking CGE model but simulating a 5% decrease in tourism demand with certainty is estimated to decrease welfare by 0.67%. A 10% decrease in tourism demand with a 50% probability and 50% probability that the economy will remain on its steady state growth rate is estimated to decrease welfare by 0.48% (Table 6.1). Thus, modelling uncertainty this way is not the same as proportioning the shock. Other factors such as the degree of risk aversion and substitutability between paths are involved.

**Figure 6.8: Capital in the Risk vs. No-Risk Model: Comparing a 5% shock with certainty with a 10% shock with 50% probability**




A second scenario of interest would be to model both a hypothetical tourism boom and tourism bust with the same probability occurring in the same time period. This scenario is shown pictorially in Figure 6.9.

**Figure 6.9: Possibility of a Positive & Negative Tourism Demand Shock from t=9 onwards**

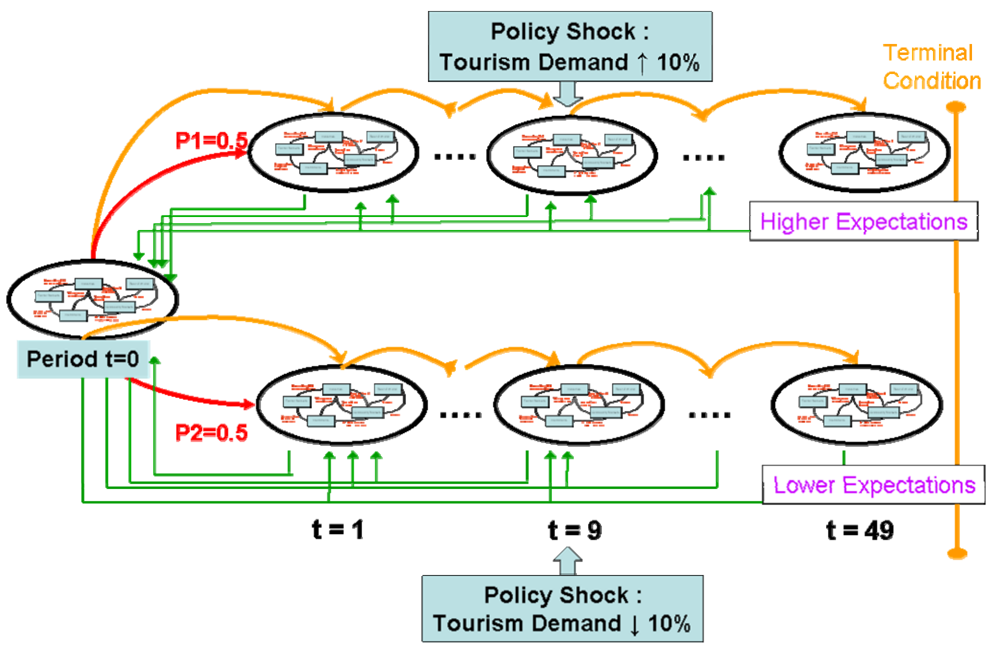


Table 6.2 shows that the absolute value of the equivalent variation from path 1 is greater than the absolute value of the equivalent variation from path 2. This is because the tourism price in path 1 increases more than the tourism price in path 2 decreases. This is due to the risk aversion of the representative consumer. The increase in EV for the total model is $US 2.7 million, again reflecting the non-linear nature of the model – the negative shock is not the equivalent of the opposite of a positive shock. The difference in the absolute value of path 1 and path 2's equivalent variation can be interpreted as the value of risk – in this scenario – it is worth $US 166.6 million.

**Table 6.2: Results: 2 Path 10% Positive & Negative Shock on Both Paths in t=9 onwards**

| Time Period | t=0 | Path 1 | Path 2 | Total |
|---|---|---|---|---|
| EV | -$19.0m | $4,343.0m | -$4,176.5m | $2.7m |
| % EV (% Change from Benchmark) | -0.08% | 1.47% | -1.42% | 0.00% |
| Terms of Trade | -$0.9m | $15,270.9m | -$14,465.8m | $401.7m |
| Tourism Demand Shift | - | $93,708.7m | -$84,337.9m | - |
| Tourism Price (% Change from Benchmark) | -0.008% | 1.62% | -1.54% | - |

## 6.4 Varying Model Parameters

Having implemented a CGE model with risk and highlighted some of the salient results from several simulations, this section examines the impact of changing several model parameters that are integral to the risk version of the CGE model.

### 6.4.1 Magnitude of Shocks

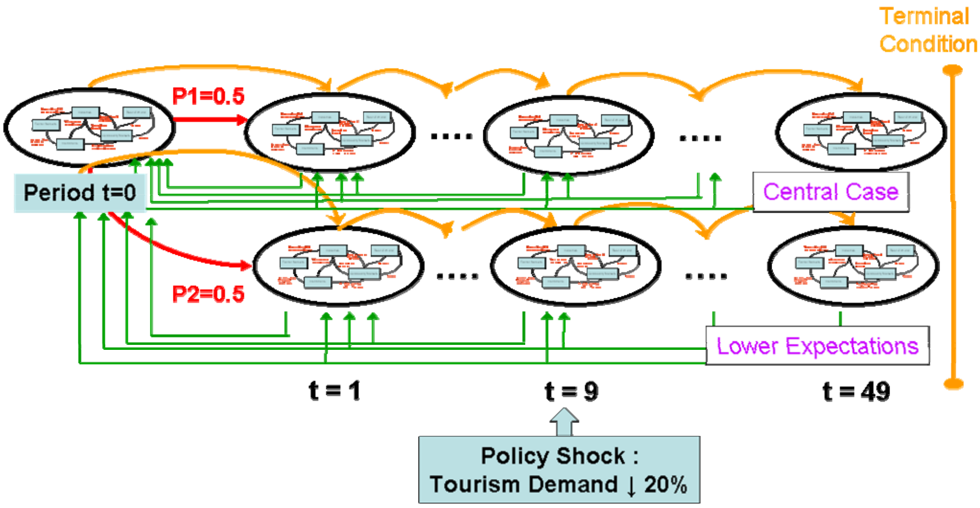
By altering the magnitude of the tourism demand shock in one of the paths, as in Figure 6.10, while leaving one path unshocked, it can be seen that the opportunity cost of travelling down the negative tourism demand path increases so that the percentage change in EV increases in Path 1 as the shock on Path 2 at period *t=9* onward increases in magnitude (but remains at the same likelihood – p=50%).

**Table 6.3: % Change in Welfare - Increasing Negative Tourism Demand Shock**

| | EV % Change | | | |
|---|---|---|---|---|
| **Path 2 Negative Shock** | **t=0** | **Path 1** | **Path 2** | **Total** |
| 10% | 0.66 | 0.13 | -1.26 | -0.48 |
| 20% | 1.31 | 0.25 | -2.53 | -0.98 |
| 30% | 1.93 | 0.37 | -3.77 | -1.49 |
| 40% | 2.55 | 0.48 | -4.96 | -1.98 |

Table 6.3 shows that as the shock on Path 2 increases, welfare for the three distinctive time dimensions, *t=0*, path 1 and path 2, increase at a decreasing rate so that doubling of the magnitude of the shock from 10% to 20% produces a larger decrease in welfare than a doubling of the magnitude of the shock from 20% to 40%. For example, welfare decreases by 100% in path 2 when changing the shock from 10% to 20% but decreases by 96% when changing the shock from a 20% decrease in tourism demand to a 40% decrease in tourism demand.

**Figure 6.10: Possibility of a Negative 20% Tourism Demand Shock from t=9 onwards**



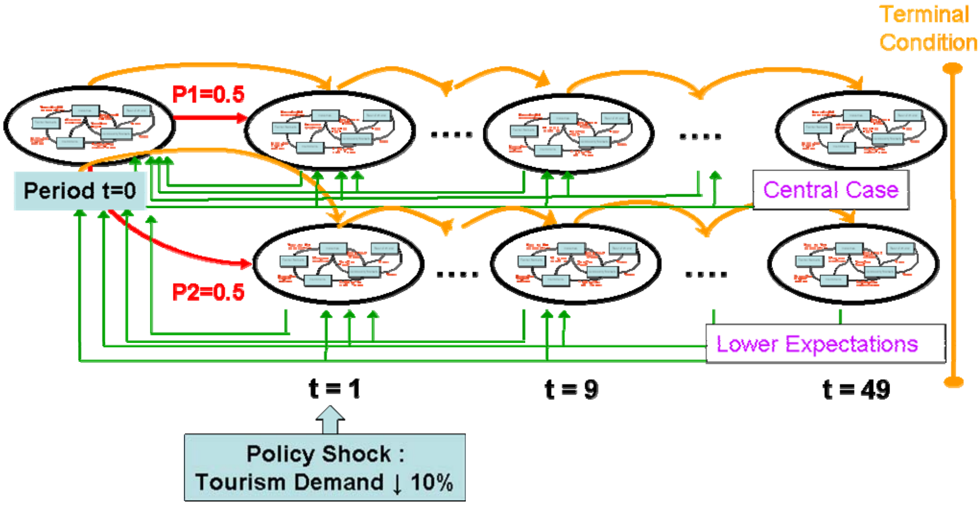

### 6.4.2 Timing of Shocks

As with standard dynamic forward-looking CGE models, the later in the model the negative shock occurs, the lower the loss in welfare. Table 6.4 shows the percentage change in EV for a negative 10% tourism demand shock when the period in which the shock commences is altered. A diagram of the shock that occurs in *t=1* on path 2 is depicted in Figure 6.11. As noted in earlier simulations, path 1, which contains no shock, exhibits positive welfare from *t=1*, that is, once there is the possibility of alternative paths the economy can take. In this scenario, when the shock occurs from period *t=0* onwards, the loss in welfare overall is the largest since the shock is maintained for the longest length of time. When the shock occurs in period *t=1* onwards, the EV for path 1 is the largest. The reason for this is that in period *t=1*, there is a path can make the representative consumer better off (path 1) and hence the shock on path 2 is worse in terms of decreasing welfare. As expected, when the shock occurs in the period *t=0* only, the EV for paths 1 and 2 are equivalent (-0.37%).

**Table 6.4: Results: % Change in Welfare altering the shock period**

| | EV % Change | | | |
|---|---|---|---|---|
| **Path 2 Negative 10% Shock** | **t=0** | **Path 1** | **Path 2** | **Total** |
| t=0 only | 2.84 | -0.37 | -0.37 | -0.14 |
| t=0 onwards | 2.10 | 0.01 | -2.65 | -1.09 |
| t=1 onwards | -0.73 | 0.37 | -2.26 | -0.95 |
| t=9 onwards | 0.66 | 0.13 | -1.26 | -0.48 |
| t=19 onwards | 0.40 | 0.04 | -0.53 | -0.20 |
| t=29 onwards | 0.13 | 0.01 | -0.18 | -0.07 |
| t=39 onwards | 0.02 | 0.00 | -0.03 | -0.01 |
| t=49 only | 0.019 | 0.001 | -0.012 | -0.004 |

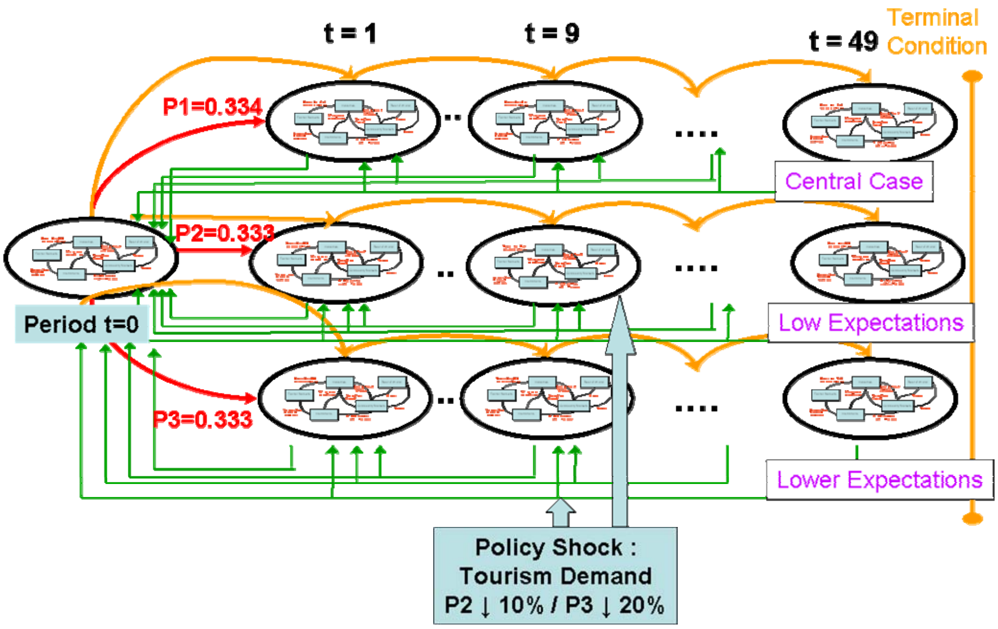
**Figure 6.11: Possibility of a Negative 10% Tourism Demand Shock from t=1 onwards**




### 6.4.3 Number of Paths

The model can be extended to include multiple paths. Suppose that policy makers analysing current affairs wanted to predict the economic impact of a tourism demand shock in the future (say in ten years time, *t=9*). These policy makers were not sure of the magnitude of the shock but predicted that a 10% and 20% decrease in tourism demand might occur with equal probability as well as predicting with an equal probability that economy would continue on its current trajectory. This scenario could be modelled as in Figure 6.12.

**Figure 6.12: Two Possible Negative Tourism Demand Shocks from t=9**




The model is additive in the sense that a shock of a 10% decrease in tourism demand on one path with the probability of the shock occurring set at 50% is identical to a shock of a 10% decrease in tourism demand on two paths with the probability of the shock occurring set at 25% on each path. Table 6.5 shows that even with two thirds of possible paths (path 2 and path 3) and probability that the economy might take (prob.(path 2) = prob.(path 3) = 0.333), path 1, the path without any possible tourism bust will generate positive EV as investment and capital is diverted to this path.

**Table 6.5: Results: 3 Path Model**

| Time Period | t=0 | Path 1 | Path 2 | Path 3 | Total |
|---|---|---|---|---|---|
| EV ($US million) | 300.9 | 728.1 | -7,458.9 | -3,273.5 | -3,080.9 |
| EV % Change | 1.31 | 0.25 | -2.53 | -1.11 | -0.97 |
| Terms of Trade | 10 | -5146 | -34,864 | -19,716 | -19,884 |
| Tourism Demand Shift | | | -168,676 | -84,338 | |
| Tourism Price % Change | 0.09 | -0.48 | -3.62 | -2.03 | |

### 6.4.4 Path Probabilities

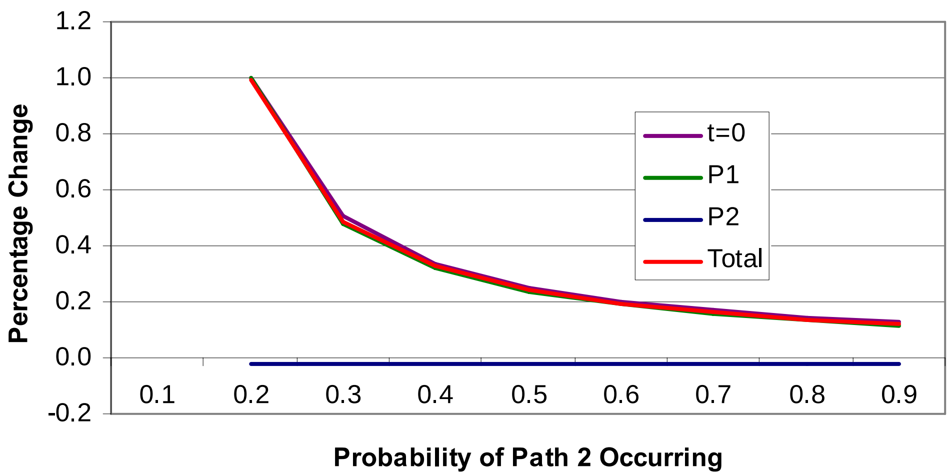
The next set of simulations involve changing the likelihood of each path occurring. Again, using the two-path model where tourism demand is simulated to decrease 10% from period *t=9* onwards, the percentage change in equivalent variation is shown in Table 6.6. If path 2 occurs with a 10% probability, welfare decreases by 1.38% along that path and by 0.1% overall. At the other end of the spectrum, if path 2 (where the shock occurs) occurs with a 90% probability, welfare decreases by 1.15% along that path and by 0.86% overall. The overall welfare figures produce expected results: the higher the probability of a decrease in tourism demand, the lower the welfare. Yet, path 1 welfare increases as the probability of a decrease in tourism demand increases. Additionally, path 2 welfare increases (becomes less negative) as the probability of a negative tourism demand shock increases.

Further, as the probability of a negative tourism demand shock increases, welfare increases at a decreasing rate for *t=0*, path 1 and total welfare but remains constant for path 2. This is shown by the percentage change in the percentage change in welfare (Figure 6.13).

**Table 6.6: Results: % Change in Welfare with different Probabilities of Path 2**

| Probability of Path 2 occurring with a 10% decrease in Tourism Demand on Path 2 | % Change in EV | | | |
|---|---|---|---|---|
| **P2** | **t=0** | **P1** | **P2** | **Total** |
| 0.1 | 0.13 | 0.03 | -1.38 | -0.10 |
| 0.2 | 0.26 | 0.05 | -1.35 | -0.20 |
| 0.3 | 0.39 | 0.08 | -1.32 | -0.29 |
| 0.4 | 0.52 | 0.10 | -1.29 | -0.39 |
| 0.5 | 0.66 | 0.13 | -1.26 | -0.48 |
| 0.6 | 0.79 | 0.15 | -1.23 | -0.58 |
| 0.7 | 0.92 | 0.17 | -1.20 | -0.67 |
| 0.8 | 1.06 | 0.20 | -1.17 | -0.76 |
| 0.9 | 1.19 | 0.22 | -1.15 | -0.86 |

**Figure 6.13: % Change in the % Change in Welfare**




### 6.4.5 Elasticities

In a dynamic forward-looking model, when the representative consumer maximises his/ her utility over the model horizon, one key parameter is the rate of time preference. It signifies the degree to which the household prefers consumption earlier rather than later in the model. This section examines the impact different values of this parameter has on a model with risk. Table 6.7 shows the change in equivalent variation across the time paths with values of the time preference parameter ranging from 0 to 3 in 0.5 increments. Apart from providing insight in how consumers deal with risk across time, varying a parameter in this way serves as a form of sensitivity analysis.

**Table 6.7: Results: % Change in Welfare with different values of the Time Preference Parameter**

| Time Preference Parameter Elasticity | % Change in EV | | | |
|---|---|---|---|---|
| | t=0 | Path 1 | Path 2 | Total |
| 0 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.5 | 1.73 | 0.03 | -1.27 | -0.46 |
| 1.0 | 0.66 | 0.13 | -1.26 | -0.48 |
| 1.5 | 0.15 | 0.17 | -1.24 | -0.49 |
| 2.0 | -0.15 | 0.19 | -1.23 | -0.50 |
| 2.5 | -0.35 | 0.20 | -1.22 | -0.50 |
| 3.0 | -0.49 | 0.21 | -1.21 | -0.50 |

In theory, larger values of this elasticity mean households are more willing to spend their resources earlier in their life. Not surprisingly, when the elasticity is 0 (Leontief function), there is no substitution that can take place across time – the level of utility in each period is fixed. Hence the percentage change in EV is 0 across both paths and in total.

The table shows that in path 2 (where the shock occurs), lower elasticity values result in a larger welfare losses. In total, welfare decreases marginally as the elasticities take higher values. While on path 1, higher elasticity values are associated with larger positive change in welfare. Thus, the larger elasticity values result in households are consuming more in the earlier time periods of the model – before the shock takes place. This is born out in the following figures (Figure 6.14 to Figure 6.17). This parameter is important in determining the level of savings/ investment and consumption that the household wants to carry out in each time period. Higher elasticities are associated with higher levels of earlier consumption after the shock and higher levels of earlier investment before the shock for the non-shocked path.

**Figure 6.14: % Change in Investment on Non-Shocked Path by Time Pereference Elasticity**

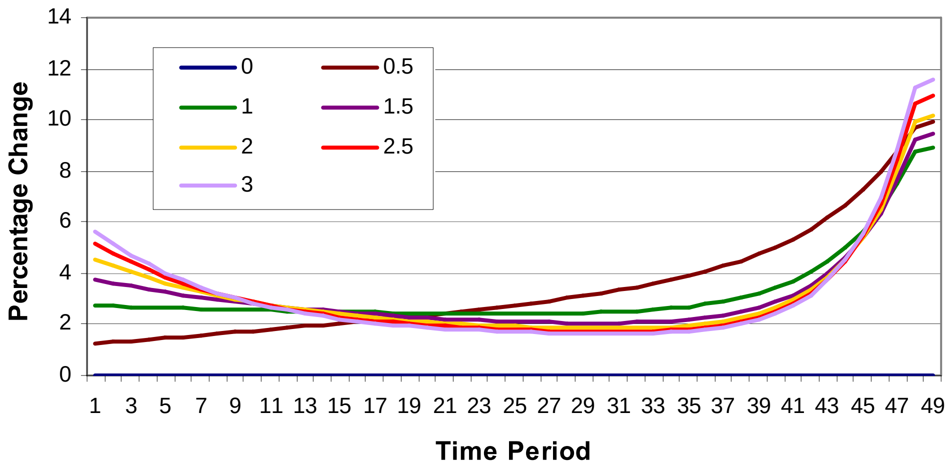
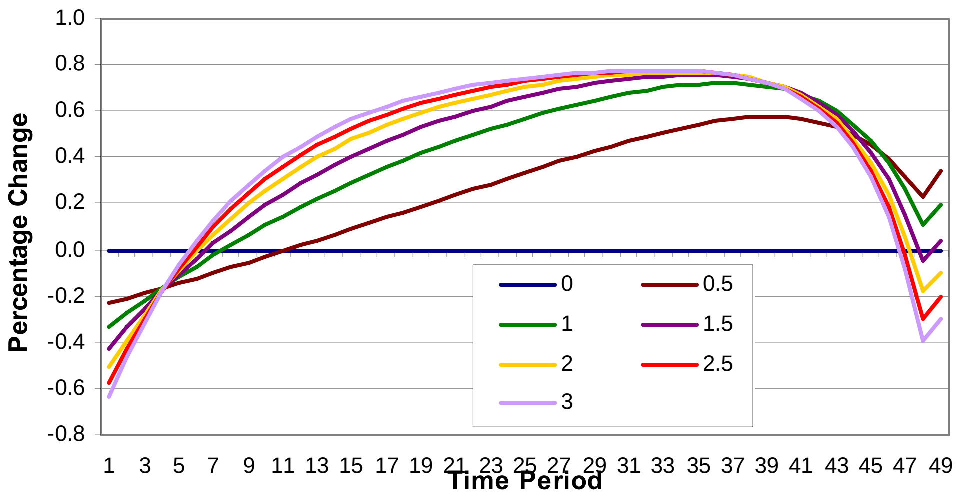



**Figure 6.15: % Change in Consumption on Non-Shocked Path by Time Preference Elasticity**




In the shocked path, higher elasticities are associated with high rates of consumption before the shock but lower rates of consumption immediately after the shock. Conversely, higher elasticities correspond with lower (more negative) investment / savings growth before the shock but higher (less negative) growth after the shock.

**Figure 6.16: % Change in Investment on Shocked Path by Time Preference Elasticity**

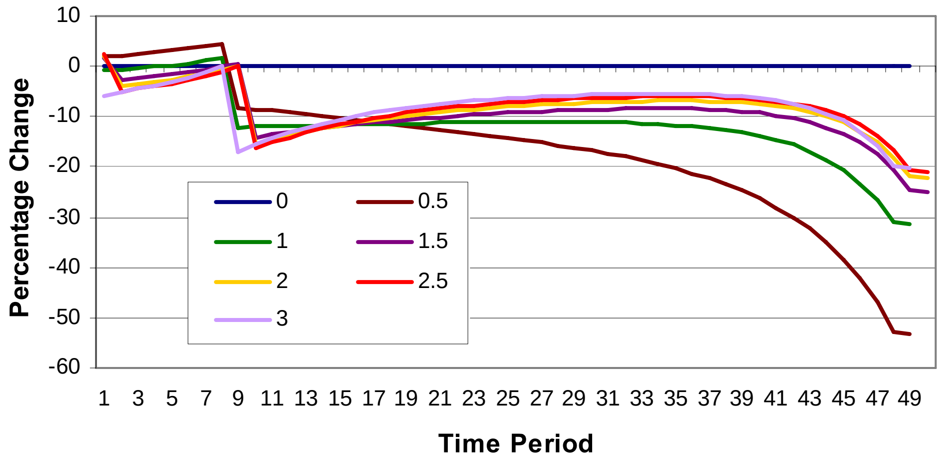
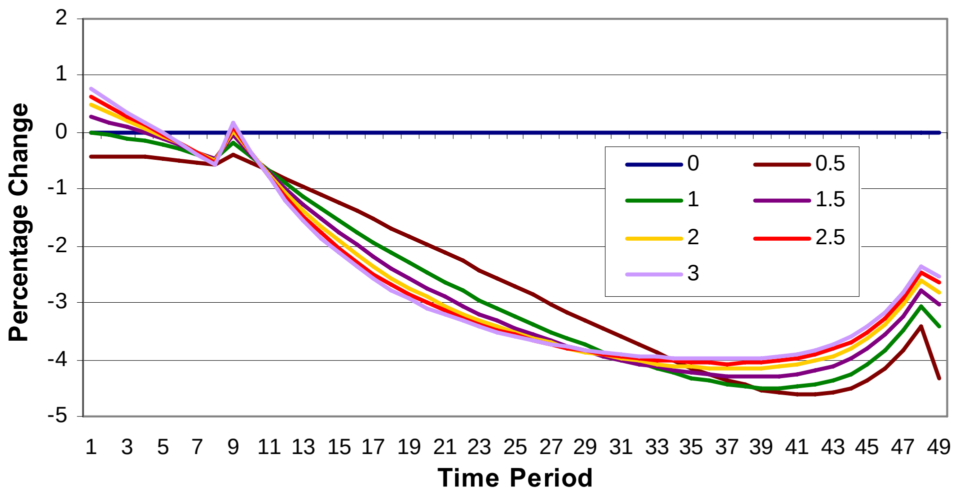



**Figure 6.17: % Change in Consumption on Shocked Path by Time Preference Elasticity**



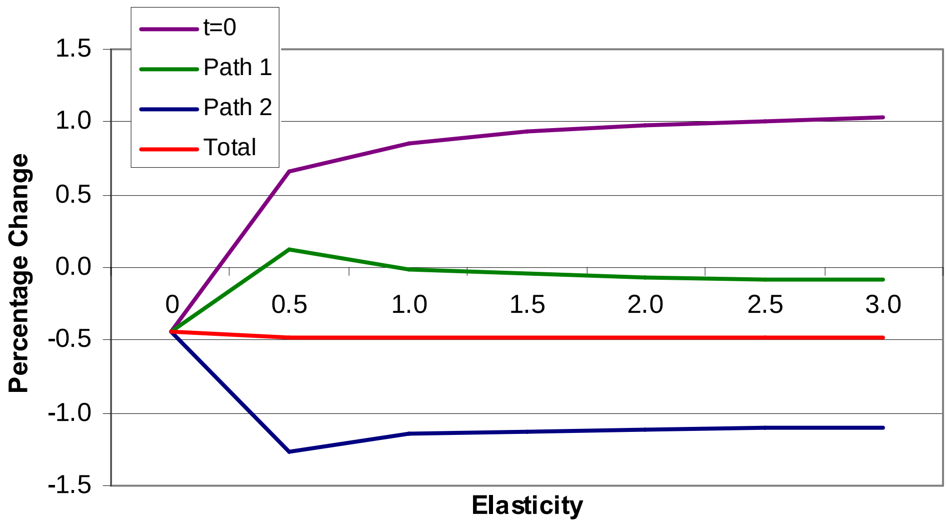

Another elasticity of interest for this model is the value of the risk aversion parameter, σ. Investigating the impact that different values of this parameter will provide insight into how the household's risk aversion impacts their welfare in this model. Table 6.8 shows the percentage change in equivalent variation for each path as well as the total by the risk aversion parameter, ranging from 0 to 3. There are several things to note in this table – firstly when the elasticity is zero and there is no substitution between paths, the percentage change in welfare for $t=0$, paths 1 and 2 and for total welfare is -

0.44%. Secondly, the more elastic the aversion to risk, the lower the percentage change in welfare along the shocked path (path 2) but the higher the change in welfare in the initial time period (t=0). Apart from elasticities close to zero, the weighted total percentage change in welfare is consistently estimated at a loss of 0.48%. On the non-shocked path (path 1), as the representative household becomes less risk averse, welfare decreases. This can be seen graphically in Figure 6.18.

**Table 6.8: Results: % Change in Welfare with different values of the Risk Aversion Parameter**

| Risk Aversion Parameter Elasticity | % Change in EV | | | |
|---|---|---|---|---|
| | t=0 | Path 1 | Path 2 | Total |
| 0 | -0.44 | -0.44 | -0.44 | -0.44 |
| 0.2 | 0.03 | 1.24 | -2.67 | -0.75 |
| 0.4 | 0.57 | 0.21 | -1.34 | -0.49 |
| 0.6 | 0.72 | 0.08 | -1.22 | -0.48 |
| 0.8 | 0.80 | 0.02 | -1.17 | -0.48 |
| 1.0 | 0.85 | -0.01 | -1.15 | -0.48 |
| 1.5 | 0.93 | -0.05 | -1.12 | -0.48 |
| 2.0 | 0.98 | -0.07 | -1.11 | -0.48 |
| 2.5 | 1.01 | -0.08 | -1.11 | -0.48 |
| 3.0 | 1.03 | -0.08 | -1.10 | -0.48 |

**Figure 6.18: % Change in Welfare by Risk Aversion Parameter**



### 6.4.6 Terminal Conditions

An important characteristic of the dynamic problem is a treatment of capital in the last period of modelling. As outlined in Chapter 4, the model cannot solve numerically for an infinite number of periods, hence, some adjustments are needed for approximation to a finite horizon model from the infinite horizon choices. If a terminal condition is not specified all capital would be consumed in the last period and nothing would be invested (end of the world scenario).

As in the single sector dynamic forward-looking model in Chapter 4, this model with risk has a terminal condition for each path. As with the other CGE literature (Harrison, Rutherford, & Tarr, 1997), the model contains a variable that controls the level of post-terminal capital with a constraint on the growth rate of investment in the terminal period. Several constraints were tested such as:

$$\frac{I_t}{I_{t-1}} = \frac{K_t}{K_{t-1}}, \quad \frac{I_t}{I_{t-1}} = \frac{C_t}{C_{t-1}}, \quad \frac{I_t}{I_{t-1}} = \frac{Y_t}{Y_{t-1}} \text{ and } \frac{I_t}{I_{t-1}} = 1+\gamma$$

The advantage of using this constraint is that it imposes balanced growth in the terminal period but does not require that the model achieve steady-state growth. The meaning of the constraint is that investment in a terminal period should grow at the same rate as capital / consumption / output or the exogenously set growth rate of the economy.

However, because all quantities grow at the same rate in the terminal period, it is possible to use any of these specifications. The model produced identical results with various terminal condition specifications.

## 6.5 Government Intervention to offset Risk

Given the possibility of uncertainty regarding the future tourism demand shocks and the resulting decrease in welfare, the issue arises of whether the government can take any intervention to offset the existence of risk. The tourism literature identifies two main reasons for the inevitability of governmental intervention in the tourism product. The first is the suboptimal level of tourism production due to market distortions and the second is the presence of non-priced goods in the production of the tourism good (Croes & Severt, 2007). For this research, the market distortion would include imperfect information. One fundamental way in which the government interacts with the tourism sectors is via the implementation of tourism taxes. Tourism taxes have proliferated around the world as governments have viewed the expanding tourism sector as a ready source of tax revenue (Gooroochurn & Sinclair, 2005). As mentioned in Chapter 3, Hawaii has a tourism tax in the form of a transient accommodation tax, widely known as a hotel room tax or bed tax in some countries. Tourism taxes can help to generate revenue to finance the provision of public goods, to contribute towards the costs of using environmental assets and to decrease negative externalities such as congestion. For Hawaii, tourism tax revenues were used for tourism promotion and to build a convention centre to diversify sources of visitors and to fill empty hotel rooms during the slack periods (Mak, 2008).

Arguments against levying a tourism tax include the argument that a hotel room tax would discourage tourists from visiting the destination and hurt the tourism-oriented industries, as well as the imposition of tourism taxes may generate retaliatory measures by other governments, significant costs may be involved in the collection of the taxes and an increase in the tax rate may even result in lower tax revenue, depending on the elasticity of tourism demand.

For comparison, several simulations need to be conducted using the standard dynamic forward-looking model. Five scenarios have been run: the removal of the hotel tax (the benchmark hotel tax is set at 7.5%); increasing the hotel tax to 18.75% (benchmark x 2.5); a negative 10% tourism demand shock; a negative tourism demand shock with the removal of the hotel tax and a negative tourism demand shock with a hotel tax increase to 18.75%.

**Table 6.9: Results: Tourism Demand and Hotel Tax Simulations**

| **Percentage Change** | | | **Tourism Demand -10%** | | |
|---|---|---|---|---|---|
| **Economic Indicators** | **Hotel Tax = 0%** | **Hotel Tax = 18.75%** | **Bench-mark** | **Hotel Tax = 0%** | **Hotel Tax = 18.75%** |
| **Simulation** | **1** | **2** | **3** | **4** | **5** |
| Welfare (EV) | -0.53 | 0.73 | -1.31 | -1.79 | -0.62 |
| Household Consumption | -0.94 | 1.15 | -2.82 | -3.71 | -1.64 |
| Tourism Consumption | 2.57 | -4.09 | -12.38 | -10.05 | -16.13 |
| Price of Tourism | -0.97 | 1.68 | 0.47 | -0.50 | 2.15 |
| Labour | -0.22 | 0.35 | -0.28 | -0.48 | 0.02 |
| Wage Rate | -0.09 | 0.15 | 0.32 | 0.25 | 0.45 |
| Capital | -1.58 | 2.68 | -3.30 | -4.56 | -1.25 |
| Return to Capital | 0.00 | -0.01 | -0.05 | -0.06 | -0.06 |
| Investment | -8.79 | 15.83 | -13.12 | -20.02 | -1.43 |
| Investment Price | 0.30 | -0.41 | 1.01 | 1.30 | 0.61 |
| Price of Foreign Exchange | -0.22 | 0.36 | 2.18 | 1.98 | 2.50 |
| State & Local Govt Goods Price | -0.09 | 0.16 | 0.43 | 0.35 | 0.57 |
| Federal Govt Military Goods Price | -0.09 | 0.15 | 0.40 | 0.32 | 0.53 |
| Federal Govt Civilian Goods Price | -0.089 | 0.15 | 0.40 | 0.33 | 0.53 |

The results presented in Table 6.9 for the changes in the hotel tax could be thought of as counter-intuitive as a decrease in tax is associated with lower welfare (-0.53%) and an increase in the hotel tax is associated with an increase in welfare (0.73%). This goes against the partial equilibrium analysis, which would suggest that taxes are ‘bad’ for the economy. The hotel tax is ‘exported’ to the tourist since the tourist bears the major burden of the taxation. The welfare loss, corresponding to a tax increase, is not reflected in domestic welfare since utility of tourists is not included in the welfare function. In the simulation (Simulation 5) where tourism demand decreases by 10% in conjunction with a hotel tax increase, both investment and capital fall but by far less than in the case where there is a tourism demand decrease but no changes in taxation (Simulation 3). This scenario is welfare improving compared to Simulation 3. Alternatively, removing the tax (with no change in tourism demand – Simulation 1) results in tourism consumption increasing by 2.6%, other changes in the economy (to the detriment of Hawaii residents) offset the changes in tourism consumption. These offsetting effects include decreases in investment, capital and labour.

Table 6.10 shows the percentage changes in GVA by sector for the same simulations. In the first two simulations, the accommodation sector, where the tax is imposed, increases its GVA when the tax is removed and this sector's GVA falls when the tax increases but the other sectors experience changes in the opposite direction.

**Table 6.10: Percentage Change in GVA: tourism demand & hotel tax simulations**

| | | | **Tourism Demand -10%** | | |
|---|---|---|---|---|---|
| **% Change in GVA** | **Hotel Tax = 0%** | **Hotel Tax = 18.75%** | **Bench-mark** | **Hotel Tax = 0%** | **Hotel Tax = 18.75%** |
| Agriculture | -2.4 | 3.9 | 17.7 | 15.0 | 22.0 |
| Construction | -3.7 | 6.6 | -2.2 | -5.2 | 2.8 |
| Food Processing | -2.2 | 3.5 | 25.3 | 22.6 | 29.7 |
| Manufacturing | -2.0 | 3.3 | 22.0 | 19.9 | 25.5 |
| Transportation | -0.4 | 0.7 | -4.1 | -4.4 | -3.7 |
| Information | -1.4 | 2.3 | 1.9 | 0.7 | 3.9 |
| Utilities | -0.5 | 0.8 | -0.8 | -1.2 | -0.2 |
| Wholesale Trade | -1.6 | 2.6 | 0.3 | -1.0 | 2.5 |
| Retail Trade | -1.2 | 2.0 | -3.0 | -4.1 | -1.5 |
| Finance & Insurance | -1.5 | 2.3 | 0.9 | -0.4 | 2.9 |
| Real Estate & Rentals | -1.5 | 2.3 | -3.7 | -4.9 | -1.8 |
| Professional Services | -1.7 | 3.0 | -0.8 | -2.2 | 1.5 |
| Business Services | -0.2 | 0.3 | -0.9 | -1.1 | -0.7 |
| Educational Services | -0.6 | 0.6 | -2.4 | -3.0 | -1.8 |
| Health Services | -0.8 | 0.8 | -1.0 | -1.7 | -0.1 |
| Arts, Entertainment & Recreation | -0.2 | 0.3 | -5.9 | -6.0 | -5.7 |
| Accommodation | 6.5 | -9.7 | -9.4 | -3.5 | -18.3 |
| Eating & Drinking Places | -0.5 | 0.6 | -4.0 | -4.3 | -3.5 |
| Other Services | -0.9 | 1.3 | -0.5 | -1.3 | 0.7 |
| Government | -0.1 | 0.1 | 0.2 | 0.1 | 0.2 |

When welfare is measured as the change in resident households' consumption, and the burden of a hotel tax falls on foreign tourists then it is reasonable to expect that an increase in taxes might be associated with an increase in welfare especially when if tourism demand is price inelastic relative to domestic demand. Further, in a fiscal neutral CGE model, additional tax revenues are transferred back to the representative household in a fixed proportion.

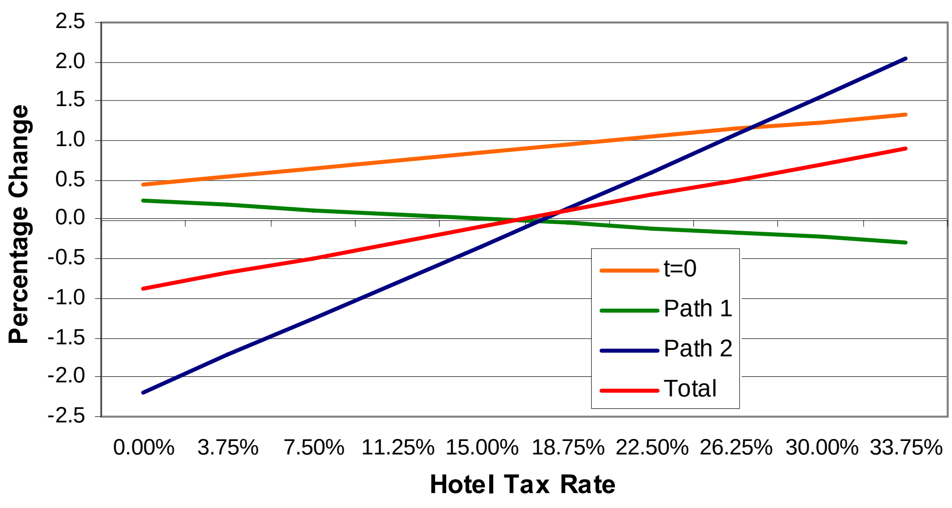
When the taxes are changed in conjunction with a negative tourism demand shock, the offsetting government intervention (an increase in the hotel tax would be the offsetting policy) is not enough to compensate the decrease in welfare caused by the tourism demand shock. With the size (10% decrease) and timing (9th period onwards) of this simulated tourism demand shock, the hotel tax would need to increased to 33.7% (x 4.5 times the benchmark) to achieve a positive welfare increase (+0.2%) across the model horizon. An increase in the hotel tax of this magnitude would certainly be controversial and be politically difficult to implement.

With uncertainty in the model, path 1 – the non-shocked path – decreases in welfare as the hotel tax rate increases at the same time as the negative tourism demand shock in path. When the tax is removed, welfare increases by 0.24% along path 1. Welfare decreases by 0.29% along path 1 when the hotel tax rate is 33.75% (4.5 times its benchmark rate). Conversely, along the shocked path, the removal of the tax worsens welfare by 2.18% in conjunction with a negative tourism demand shock. Along the shocked path, welfare increases as the tax rate increases. Total welfare shows the same pattern. The trajectory of the each path is shown in Figure 6.19. What is interesting is that the cross over point in welfare (path 1 moving from welfare gain to welfare loss and path 2 moving from welfare loss to welfare gain) occurs at a much lower hotel tax rate (18.75%) than in the standard CGE model where the counterfactual is modelled with certainty (30.0%). Again, this is the effect of the possibility that the risk will not be realised.

**Table 6.11: % Change in Welfare - Tourism Demand Shock, Hotel Tax and Risk**

| Hotel Tax | | % EV | | | |
|---|---|---|---|---|---|
| **Multiple of Benchmark** | **Hotel Tax Rate** | **t=0** | **Path 1** | **Path 2** | **Total** |
| 0.0 | 0.00% | 0.44 | 0.24 | -2.18 | -0.88 |
| 0.5 | 3.75% | 0.55 | 0.18 | -1.72 | -0.68 |
| 1.0 | 7.50% | 0.66 | 0.13 | -1.26 | -0.48 |
| 1.5 | 11.25% | 0.76 | 0.07 | -0.80 | -0.29 |
| 2.0 | 15.00% | 0.86 | 0.01 | -0.33 | -0.09 |
| 2.5 | 18.75% | 0.96 | -0.05 | 0.14 | 0.11 |
| 3.0 | 22.50% | 1.06 | -0.11 | 0.61 | 0.31 |
| 3.5 | 26.25% | 1.15 | -0.17 | 1.08 | 0.50 |
| 4.0 | 30.00% | 1.24 | -0.23 | 1.56 | 0.70 |
| 4.5 | 33.75% | 1.33 | -0.29 | 2.04 | 0.90 |

**Figure 6.19: % Change in Welfare by Hotel Tax Rate**



## 6.6 Conclusions

This chapter summarises the economic impact of uncertain tourism demand in Hawaii by incorporating risk in a dynamic forward-looking CGE model. The possibility of a negative tourism demand shock induces welfare losses. The magnitude of the losses depends upon several factors. While the economy might take many trajectories, for tractability this research primarily examines a two-path model. In the scenario where there is an asymmetric shock (50% probability of benchmark growth on path 1, 50% probability of a 10% negative tourism demand shock on path 2), on the non-shocked path, there are welfare gains while, as expected, on the shocked path welfare decreases. The percentage change in overall welfare across all paths is negative. The non-shocked path experiences welfare gains as investment and capital increases at a positive rate on this trajectory, above the benchmark where the representative household is assumed to be risk averse.

The values of several key parameters in the risk model were tested. The conclusions being: as the probability of the shocked path increases, the welfare gain on the non-shocked path increases, the welfare loss on the shocked path decreases (becomes less negative). In contrast, the overall welfare decreases as the probability of the shocked path increased. Additionally, the more consumers value the present, the larger the welfare losses on the shocked path and the lower the welfare gains on the non-shocked path. The more risk averse the representative household, the larger the welfare gains on the non-shocked path and the larger welfare losses on the shocked path. Welfare across the total model remained constant regardless of the degree of risk version. When the representative household became risk seeking, welfare losses were experienced even on the non-shocked path.

In a two-path model with symmetric shocks (50% probability of a 10% tourism boom and 50% probability of a 10% tourism bust), the total welfare increases marginally by $US 2.7 million but the welfare gain on the tourism boom path is larger than the welfare loss on the tourism bust path. This is due to the risk aversion characteristic of the representative household. Further, the difference in the absolute value between the welfare gain and the welfare loss on the two paths can be interpreted as the cost of the information regarding which path economy will travel. Another way to look at it would be the cost of the uncertainty or the monetary value of the risk in the model.

## 6.7 Policy Implications

The research findings have policy implications for businesses, policy makers and governments. One purpose of this research is to understand how uncertainty over future negative tourism demand shocks affects the economy. The results presented earlier in the chapter showed that the possibility of a future negative shock will have negative consequences. Risk is inevitable and cannot be totally eliminated. Tourism destinations in every corner of the globe face the virtual certainty of experiencing a disaster of one form or another at some point in their history. Despite this, few destinations have properly developed disaster management plans in place to help them cope with such eventualities (Faulkner, 2001). Given this risk, the key stakeholders in the host economy (Government and the Destination Marketing Organisations, for example) may wish to examine several risk management strategies that can be implemented. Faulkner (2001) develops a tourism disaster framework as a means for minimising the damage of, and accelerating the recovering from, such events through the development of disaster management strategies. Another way to examine risk management is by borrowing terminology from financial markets, these risk management strategies include:

1. Risk retention and risk avoidance – this strategy involves tolerating the risk. Exposure to risk may be planned or unplanned, but the decision to retain the risk is a conscious one. In situations like these, the cost of risk reduction may exceed the benefits. The decision to retain the risk is a form of specialisation as well as an implicit decision to avoid other forms of risk. Retaining the risk may be part of a larger strategic vision where a destination believes it is qualified to handle that risk.

2. Risk consolidation – A destination may aggregate multiple sources of uncertainty into a single "portfolio" of outcomes. Consolidation can be achieved by increasing the scale at which planning and management are focussed and concentrated resulting in economies of scale. At the destination level, open communication between the DMO, information gathering

agencies and government agencies may share information and coordinate strategies for dealing with negative tourism demand shocks.

3. Risk transfer – risk can be transferred from one destination to another, either intentionally or by accident. This strategy may not be applicable at the destination level as many tourism demand shocks have cross border implications.

4. Risk reduction – risk may be reduced by decreasing the uncertainty, controlling losses, or lowering hazard exposure. There are several initiatives a destination might undertake to decrease the uncertainty regarding travelling ex ante. The results in Table 6.6 showed that overall welfare improved with a decrease in the probability of a tourism demand shock. Safety and physical security are fundamental conditions for tourism development of a destination. Research has shown that safety and security is a key issue in deciding if and when to go on vacation. Sonmez, Apostolopoulos and Tarlow (Sonmez, Apostolopoulos, & Tarlow, 1999) showed that, based on worldwide tourism data, higher risk is associated with decreased visitation. Further, many authors have researched risk perceptions among tourists (Moutinho, 1987; Yavas, 1987). Risk perceptions are important in determining destination choice, reflecting such beliefs as ''travel is unsafe'' and ''tourists are likely to be targets of terrorism'' (Sonmez & Graefe, 1998). Perceptions of risk will depend on tourists' characteristics (Roehl & Fesenmaier, 1992), on the tourists' role and tourists' preferences for familiarity or novelty (Lepp & Gibson, 2003), on their personality type (Carr, 2001), on their nationality (Seddighi, Nuttall, & Theochaous, 2001) and on their cultural orientation and psychographic factors (Reisinger & Mavondo, 2005). Hall (Hall, 1989)

suggests that risk can be reduced through diversification of product that the destination offers and through diversification of tourist.

In terms of diversification of tourist, the challenge is for DMOs to understand the perceptions of travel risk and react to the tourists' need for safety and security. DMOs should target those visitor segments that are less risk-averse. These groups can be targeted with marketing campaigns to motivate them to commence / recommence travelling again after a crisis such as a natural disaster or act of terrorism, for example.

DMOs need to target their advertising to the cultural background of tourists. Figure 3.7 in Chapter 3 showed the changing mix of tourists to Hawaii with an increase in the proportion of US mainland tourists and a corresponding decrease in the proportion of Japanese tourists to Hawaii. Domestic tourism is perceived to be less risky than international travel. Moreover, strategies could be developed to appeal to risk-avoiding cultures such as group travel, travelling shorter distances, promoting shorter stays at familiar and closer-to-home destinations. Group Inclusive Travel could be offered because they provide comfort and the services of a professionally trained guide who has the knowledge of local resources and safety procedures and who can create an atmosphere of reassurance and being in control (Reisinger & Mavondo, 2005). One initiative implemented in Hawaii is the Visitor Aloha Society of Hawaii (VASH). VASH's role is to provide assistance and support to visitors traumatized by crime or other adversities in an effort to create a positive memory of their stay in Hawaii.

Diversifying the product involves offering a range of different product offerings in the one destination. In contrast to marketing to tourists who are more sensitive to risk, research has uncovered another segment of travellers who exhibit a higher tolerance to risk. Lepp and Gibson (2003) suggest that novelty seekers tolerate higher levels of risk. Realising there is a segment of tourists like this; DMOs can tailor products such as rock climbing, white-water rafting or parachuting to attract these types of tourists, given that they have a higher propensity to travel anyway in the context of a world-wide crisis.

Tourists should be encourage to seek information for a wide range of sources to avoid tourists being susceptible to any one news story regarding the risk associated with a destination. Reducing the risk of a shock in tourism demand may include a broad media campaign to emphasize the safety and security of this destination. In the case of Hawaii, this might include undertaking advertising in international and national media highlighting the existence of the National Oceanic and Atmospheric Administration's Pacific Tsunami Warning Center and its website where tourists can examine the likelihood of a possible tsunami.

Ex post, there are policy implications for the host economy also. With the existence of risk in the model, policy makers may need to undertake counter measures to offset the possible welfare losses due to the uncertainty. Given the possibility of a tourism bust, the main policy instruments that the Government has at its disposal is its fiscal policy and to a lesser extent monetary policy tools. A regional destination such as Hawaii has no control over US monetary policy, however for other island nation economies, the opportunity of increasing / decreasing interest rates in response to changes in tourism demand is an option.

One common policy tool used around the world in relation to tourism is tourism taxes / tax credits. To offset the loss of income due to the uncertainty of future tourism demand, the imposition of an additionally tourism tax would generate tax revenues, which would eventually be distributed back to residential households by the State and Local Government in Hawaii. Hence, the revenue generated by the additional taxes would need to be as great as the income lost as a result of the tourism bust. For simulations where a permanent slump is tourism demand is simulated to occur from the 9$^{th}$ time period onwards, the increase in the tourism tax would need to be significantly large as to be politically infeasible. An increase in tourism taxes in the context of inelastic demand for tourism, as well as elastic supply, can give rise to welfare gains. Another way of think of this situation is that Hawaii is assumed to have implied market power. With the assumption that the elasticity of tourism demand for Hawaii is inelastic, an increase in the price of tourism in the form of an export tax results in a less than proportionate decrease in tourism demand 'consumed'. Hence Hawaii can increase the price of their 'product' without losing a significant amount of tourists to competitive destinations. It is for this reason that such an ‘export tax’ is welfare improving.

However, the preceding analysis suggests that the issue of introducing or changing tourism taxes is somewhat complicated and policy makers should pay explicit attention to the welfare effects that are likely to arise from them.

It may also be that the tourism-oriented sectors (accommodation, eating and drinking places, for example) are under-taxed, as found by Gooroochurn and Milner (Gooroochurn & Milner, 2004). Further empirical investigation would be needed to understand the relationship between tourism demand and tourism taxes in a general equilibrium context.

Another policy initiative that could be used by the host economy is tax credits. Mak (2008) points out that incentives may not be necessary to induce tourism investment, at least in the case of Hawaii. Tax credits can be used as a way to attract out-of-state investment. In Hawaii, incentives did exist to induce hotel remodelling and new construction. Evidence suggests that these tax credits did work to increase hotel investment as seen from the shift to more upmarket accommodation stock (see Figure 3.11). Opponents argue that tax credits given now only move up inevitable investment in the future – an increase in investment now will result in a decrease in investment in the future.

The scenarios examining the impact of the resident household's risk aversion parameter on welfare showed that while the expected value of welfare across the two paths remained the approximately the same (-0.48% change in welfare) regardless of the value of the parameter, if the risk was not realised (the economy travelled along path 1), households experienced welfare gains while they were risk averse and welfare losses when they were risk seeking. So, the DMO desires tourists to be risk seeking and keep travelling to their destination but want their own residents to be risk averse. These two states may not be mutually exclusive. Risk aversion in resident households might look like the framework laid out by Faulkner (2001) where the ingredients of the tourism disaster management planning process and its outcomes would include risk assessment; prioritisation; protocols; community capabilities audit; disaster management command centre; media and monitoring activities; warning systems; flexibility; and involvement, education and review. Not all tourism disasters and risks will need all these processes but through residents' awareness of them, they will be better prepared to deal with uncertainty.

# CHAPTER SEVEN

# CONCLUSIONS

## 7.1 Introduction

This chapter sums up the main findings developed in this thesis. The key contributions to the body of knowledge will be highlighted. In the final section, several suggestions are made for further areas of enquiry that have arisen from the research so far. This section also includes some of the limitations of this research.

## 7.2 Key Contributions

This research makes original contributions toward the current body of knowledge both methodologically and from a policy perspective. The thesis investigates the economic impact of uncertain tourism demand in Hawaii. It does this by incorporating risk into a computable general equilibrium model. More specifically, the thesis answers the following questions: how does uncertainty regarding future tourism demand impact on an economy? What is the cost of uncertainty; and what, if anything, can policy makers do to offset the effects of uncertainty on an economy?

Chapter one addresses three main issues. Assessing the economic impact of changes in tourism demand requires an economy-wide model. The most appropriate type of economy-wide modelling is computable general equilibrium modelling. Further, tourism is a multi-sector industry, that is, there is no one sector labelled 'tourism' – tourism demand impacts several sectors directly and more sectors indirectly hence the need for a disaggregated method of modelling. Secondly, risk has been studied across a range of disciplines, from an economic perspective, from a technological perspective, from a psychological perspective and from a financial perspective. Risks are unavoidable and the impact of risks is felt across economies due to the interrelationships between different economies and different sectors of economies. Chapter one limits the scope of the research in terms of the study of risk. Uncertainty in this thesis is characterised by different states of the world or paths that the economy may take. Risk is the possibility that on one or more of the paths (states of the world), a negative tourism demand shock may occur. While there has been some research into the theory of general equilibrium under uncertainty, as yet there is little, if any, computable general equilibrium models of this nature. The last issue addressed in chapter one moves the general discussion of risk and uncertainty and places them within the context of tourism demand in Hawaii. The state of Hawaii is heavily dependent on tourism as a source of income and generator of employment. Recently, several crises have had a negative impact on Hawaii. The origins of these shocks have occurred many thousands of miles away. Yet, visitor arrivals to Hawaii fell approximately 13.5% overall year-on-year as a result of the September 11, 2001 terrorist strikes and 3.1% overall year-on-year as a result of the Gulf War in 1991. This highlights the importance of understanding how shocks and even the possibility of shocks can impact an economy.

Historically, the academic study of tourism economics has tended to analyse economic impacts using Input-Output analysis. In recent years, tourism applications of CGE models have become increasingly more common. Chapter two in this thesis surveys the literature, both theoretical and applied, on estimating economic impacts using economy-wide models, namely IO analysis and CGE models. CGE models are the most appropriate way to estimate the economic impacts of tourism. IO analysis is shown to be sub-optimal due to its restrictive assumptions regarding fixed coefficients and the fact prices play no role in IO analysis. In contrast, CGE models are characterised by multiple interacting economic agents where firms and consumers exhibit optimising behaviour and equilibrium is achieve through the adjustment of prices so that supply equals demand in each market.

Chapter two also reviews many of the CGE models applied to tourism found in the literature. This literature is expanding with research examining tourisms interaction with trade, tax policies, the environment, and special events in addition to the more generic issues of the impact of tourism booms and busts on an economy. The chapter also recognises the volume of research issues that have been conducted using CGE models outside of the tourism field. Importantly, estimating economic impacts using a CGE model in conjunction with simulating uncertainty regarding the future path of the economy has, until now, yet to be explored. This research fills this gap.

The research needs a context and chapter three has the dual purpose of reviewing some of the key features of the Hawaiian economy as well as describing some of the key features of the 2002 Hawaii Input-Output table – the benchmark data used to calibrate the models in Chapters 4 and 6. The economy in Hawaii has shifted over the last 50 years from an agricultural-based economy to a service-based tourism-driven economy. In 2006, Hawaii's GSP stood at $US 58.387 billion. The 1980s saw strong growth in the economy followed by much weaker growth in the 1990s and a recovery after 2001. Tourism is a vital part of Hawaii's economy. Between 1970 and 1990, the volume of visitors to Hawaii grew four-fold. In 2006, 7.4 million visitors came to Hawaii, which generated $US 12.4 billion. The 2002 Hawaii Input-Output table, for the purposes for this research, has been aggregated to 20 sectors.

Chapter four in the thesis, the methodology chapter, describes how this particular CGE model works. In building up to a CGE model that contains the possibility of risk, the thesis starts with a comparative static model of the Hawaiian economy and simulates a 10% decrease in tourism demand. The negative shock to the economy results in a decrease in welfare, measured using equivalent variation. Welfare decreases by 2.2%, Hawaii residents' consumption decreases by 2.3%, investment drops by 3.4% and wage rates decrease, as a result of the simulation. Tourism consumption decreases by 13.0%, more than the simulated 10% decrease due to the terms of trade effect caused by the depreciation of the exchange rate. In contrast to IO analysis results, the change in prices (wages and exchange rate) results in competition for resources among sectors and therefore substitution effects occur whereby some sectors gain and some sectors lose. A depreciation of the exchange rate, in parallel with falling domestic prices and wage rates sees traditional export sectors, such as agriculture, manufacturing and food processing experience an increase in their export competitiveness, leading to increasing exports. However, the increase in traditional exports does not outweigh the decrease in tourism and non-traditional exports. These findings are consistent with other studies that have modelled changes in tourism (Copeland, 1991; Adams & Parmenter, 1992b, 1995; Zhou et al., 1997).

The comparative static model is then modified to include a flexible labour supply and unemployment. Dynamics are then introduced with the construction of a dynamic recursive model followed by a single-sector dynamic forward-looking model and then a multi-sector dynamic forward-looking model. With each adaptation of the model, a 10% decrease in tourism demand is simulated. The results in terms of the impact on welfare are presented in Table 7.1 below.

**Table 7.1: Summary: % Change in Welfare across Models**

| Model Description & Simulation | % Change in EV |
|---|---|
| **Static Models / 10% Decrease in Tourism Demand** | |
| Full Employment & Fixed Labour Supply | -2.21 |
| Full Employment & Flexible Labour Supply | -2.26 |
| Unemployment & Fixed Labour Supply | -2.44 |
| Unemployment & Flexible Labour Supply | -2.48 |
| **Dynamic Models / Shock in period t=10 onwards** | |
| Recursive: Savings is a Fixed Share of Income | -2.48 |
| Recursive: Savings is Weighted Combination | -2.60 |
| Recursive: Savings is dependent on Rental Rate of Capital | -2.70 |
| Single-sector Forward-looking: Investment comes on-line in Same Period | -1.63 |
| Single-sector Forward-looking: Half of Investment comes on-line in Same Period | -1.82 |
| Single-sector Forward-looking: Investment comes on-line in Next Period | -2.03 |
| Multi-sector Forward-looking: Investment comes on-line in Same Period | -1.65 |

In standard CGE models characterised by neoclassical microeconomics, risk is only implicitly defined in the model through the interest rate and return to capital and through elasticities. When economic agents are endowed with perfect foresight, the anticipation of future events and shocks are taken into account. Chapter five outlines risk in the standard CGE models and survey the CGE modelling literature where attempts have been made to account for risk in CGE models. The literature reveals two main areas of research: modelling uncertainty and economic risk, namely the introduction of risk premia and the inclusion of imperfect information.

Chapter five presents the conceptualisation of the uncertainty in the dynamic forward looking model. Uncertainty is built into the model through the introduction of different states of the world or paths that the economy might take. The risk experienced by the economic agents is the possibility that on one of these paths the economy will experience a negative tourism demand shock. For the representative household with rational expectations and perfect foresight, the possibility of this risk will influence their optimising behaviour. Firm minimise their expected costs across time and across states of the world subject to their technology constraints. Similarly, the representative household maximises the expected value of their utility subject to their budget constraint across time and given the possible paths that the economy might take.

The penultimate chapter operationalised the CGE model described in chapter five. Various scenarios were simulated. For example, one what-if scenario was to model a 50% probability of 10% negative tourism demand shock from time period *t=9* until the end of the model horizon along with a 50% probability that the economy would continue along its usual growth path. In this scenario, the expected value of welfare decreases by $US 1,537.7 million or 0.48%. If the risk is realised and shock occurs, welfare decreases by $US 3,713.5 million or 1.26%. If the economy were to follow the non-shocked path, households would receive $US 372.4 million in welfare or 0.13%, above the baseline. The welfare gains along the non-shocked path are a result of household's risk aversion and their substituting resources away from the shocked path. The difference in the monetary values of the welfare on either path can be interpreted as the 'price' of the risk – in this case $US 4,085.9 million. It is the price households would be willing to pay to guarantee no tourism shock. Another scenario was to model a 50% probability of 10% negative tourism demand shock from the time period *t=9* until the end of the model horizon in conjunction with a 50% probability that the economy would experience a positive tourism demand shock from the same point in time. Overall, the expected value of welfare increased marginally meaning the welfare gain from the tourism boom is greater than the welfare loss from the tourism bust. Therefore, this research was able to quantify the monetary cost of the risk. This value can be interpreted as the cost of imperfect information.

Chapter six goes on to examine several policy actions that the active government agent might undertake to offset the negative impact of the tourism demand shock. With welfare measured as a change in the representative household's consumption, a tourism tax in the form of a hotel tax would be welfare-improving and hence offset the decline in the tourism demand since the tax burden is levied on the tourist rather than the resident. Simulations showed that to off-set a decrease in tourism demand from the time period $t=9$ onwards, the tax would need to be increased from its benchmark rate of 7.5% to 18.75% to off-set the loss of income due to the decrease in tourism demand. This policy action would achieve a positive welfare gain.

## 7.3 Areas for Future Research

While this thesis has made several important contributions to the body of knowledge in several areas there are more avenues that could be explored further.

The analysis of tourism demand is only one area where an exogenous shock can be modelled with risk due to external factors such as global political and health situations. The area of agricultural economics lends itself to this type of analysis. For example, the introduction of cash crops in an economy reduces poverty and is generally seen as welfare enhancing but, due to the vagaries of climate and weather, agriculture can be a riskier activity than other sectors. Cash crops entail an even higher level of exposure to risk from global commodity markets. Poverty includes dimensions of risk, and the additional exposure to risk for poor households can be modelled using the techniques developed in this thesis. Modelling risk may be an important task to undertake for the agricultural sector. Noting the inherent uncertainty in the weather and the implications it has for the agricultural sector, leads questions of how this type of modelling might be used to model climate change, where uncertainties about future impacts of climate change can be included in a model to show the effects of this uncertainty. This is another area where this methodology could be implemented.

Another interesting branch of research could be to investigate what other policy actions the State & Local government might to do, if anything, to decrease the amount of uncertainty in order to increase long term growth in the economy. The counterfactuals reported in Chapter 6 are only are small subset of counterfactuals that might be implemented to better understand the role of risk in an economy using a CGE model. The benchmark data set, to some extent, determines what kind of simulations can be undertaken. For instance, taxes in this model are reported in the aggregate as one row in the

Hawaii 2002 Input-Output table. Further disaggregation of taxes into corporation tax, sales tax, and income tax may be of interest to policy makers to understand the relationship between risk and tax efficiency.

Another area where this type of modelling can be extended is in the spatial nature of the CGE model described. A multi-region model could be developed by disaggregating the state of Hawaii into a county level model. This is now achievable with available data. In March 2007, the State of Hawaii's Department of Business, Economic Development and Tourism (DBEDT) produced the 2002 Inter-County Input-Output table, an extension of the 2002 State Input-Output table. In addition to showing the flows of goods and services among various economic sectors within each county, the Inter-County Input-Output table also accounts for flows that occur among the various sectors between counties. By accounting for differences in consumption and production among counties, the Inter-County Input-Output table, used as a benchmark data set for a multi-region CGE model, can be used to better assess impacts of county-specific economic activities. The Inter-County Input-Output table can provide a useful tool in assessing rural-urban linkages in the State economy and in identifying appropriate policies to promote economic growth in less-developed areas. However, constructing this model would come with additional demands on computing resources as a four-region, 20-sector, 50-time period, multiple-path dynamic forward-looking model would result in an extremely large model.

The other way to make the model multi-regional is to include the rest of the U.S.A as a region as well as the Rest of the World. Again, this would add increasing complexity to the model but may be useful to model tourism demand flows in and out of Hawaii with its major markets.

Further, this research is not without limitations. As with any methodology there are strengths and weaknesses and CGE modelling is not exempt. Croes and Severt (2007) list two such shortcomings, namely, the assumption of rational economic agents and the assumption of constant economic equilibrium. Even though the models developed in this thesis have relaxed several of the neoclassical microeconomic underpinnings, there are still further assumptions that might be relaxed. Alluded to at the end of Chapter 4, the issue of market failure versus perfect competition in investment would be an issue to explore. In the multi-sector model developed Section 4.5, investment in several sectors did not behave as observed in the real world. Modellers tend to impose an adjustment cost function that dampens the bang-bang behaviour. Many CGE model keep this neoclassical assumption that firms rent capital up to the point where its marginal revenue product equals its rental price. In reality this is not the case. Frictions prevent instantaneous and costless adjustment of the capital stock. Investment literature from the 1970s to the present has focussed on two frictions: adjustment costs and the irreversibility.

Most firms have limited output flexibility in the short run at least, and capacity changes involve significant adjustment costs. The existence of inventories can reduce the need to make short-term capacity adjustment but inventories are costly. Most firms then need to decide how much to invest allowing for the likelihood of future capacity adjustments in response to unpredictable fluctuations in demand and costs. Moreover, technology and market structure make it costly for firms to adjust their capital stock. The standard investment (partial equilibrium) models now recognise and incorporate variations in capital inputs with adjustment costs. However, several studies are now incorporating adjustment costs into CGE models (Ianchovichina *et al.*, 1999; McKibbin & Wilcoxon, 1999). These CGE modellers have followed Uzawa (Uzawa, 1969) who assumes that capital installation costs depend on the rate of gross investment relative to the existing capital stock. Given the level of investment, the cost of new capital decreases as the capital stock increases and vice versa. The installation cost function relating net to gross investment is given by

$J_t = I_t(1+\varphi\frac{I_t}{2K_t})$ where $\varphi$ is the adjustment cost parameter. When $\varphi = 0$, there are no adjustment costs, and the model reduces to the neoclassical (Ramsey) model. When $\varphi$ is large, rapid changes in the capital stock are costly and the speed of adjustment is reduced when installation costs increase (Rutherford, 2002). Using this specification, net investment is included in the intertemporal market clearance condition for capital and gross investment is included in the market clearance condition for output.

Along a balanced growth path with growth rate, $\gamma$, and depreciation rate, $\delta$, $I = (\delta + \gamma)K$, and the marginal cost of investment = $1 + \varphi(\gamma + \delta)$, and with a one period investment lag the base year capital price is

$P_k = (1 + r)[1 + \varphi(\gamma + \delta)]$.

As a result of adjustment costs, a marginal increase in the capital stock both increases the supply of productive capital services and decreases the cost of new investment. The marginal return associated with the decreased investment cost can be found by:

$$\frac{\partial J}{\partial K} = -\frac{\varphi I^2}{2K^2}$$

From this, the baseline investment cost premium for capital is :

$$\rho = \frac{\varphi(\gamma + \delta)^2}{2}$$

Under perfect competition assumed in capital markets, the value of capital at the start of a period equals the return to productive services in that period, $r_k$, the premium associated with investment, $\rho$, and the salvage value of capital in the subsequent period:

$$p_k = r_k + \rho + (1 - \delta)\frac{p_k}{1 + r}$$

Solving for $r_k$ and substituting in for $p_k$ and $\rho$:

$$r_k = r + \delta + \varphi(\delta + \gamma)\left[r + \frac{\delta - \gamma}{2}\right]$$

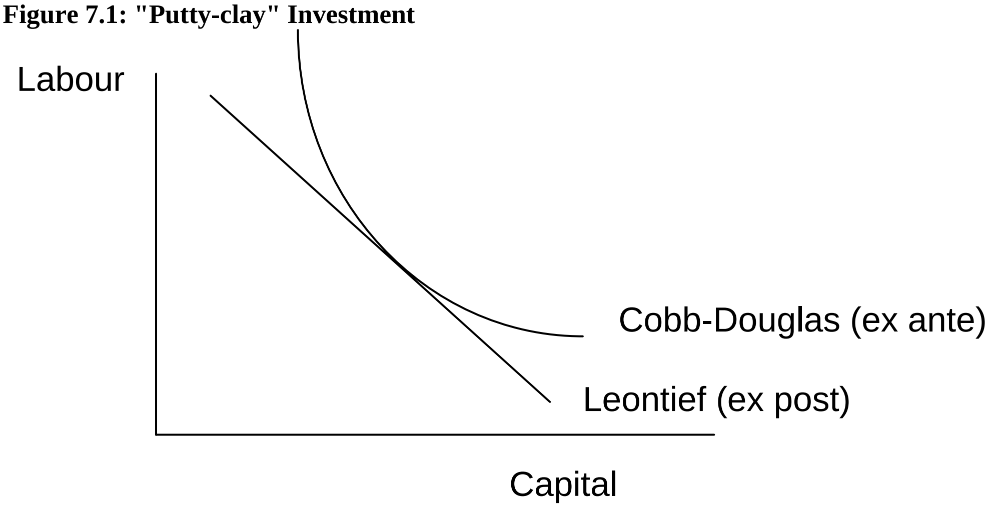
Thus the rental price of capital is dependent on the real interest rate, the depreciation cost and the adjustment premium.

Another issue related to investment is the irreversibility of investment. Most major investment expenditures are at least partly irreversible: the firm cannot disinvest, so these expenditures are sunk costs. Irreversibility arises because capital is heterogeneous. It is usually firm or industry-specific. It cannot be used in a different industry or sometimes even by a different firm in the same industry. For example, a hotel is industry-specific. It can only be used to accommodate visitors, so if the demand for tourism falls, the market value of that hotel will fall. And although the hotel could be sold to another hotel chain, there is little value in doing so; the investment in the hotel can be viewed as a sunk cost.

While a significant amount of research has been conducted in the partial equilibrium context, the literature of the firm's decision to invest under uncertainty especially when investing or investment is irreversible, has rarely been explored in the general equilibrium context. Research into irreversibility in a general equilibrium context is somewhat scarce. Little is known about the consequences of investment irreversibility in a general equilibrium context. A better understanding of the economy-wide consequences for investment irreversibility will aid several areas of research interest: economic growth, the business cycle, and asset pricing (Faig, 2001).

Another way to view irreversible investment taps into the literature on putty-clay investment. Capital, before it is built, is "putty" and can be put anywhere. Once in place it hardens like clay; it is fixed in that form to perform a specific function. "Putty-clay" refers to the substitutability of two factors: when investment occurs, it is possible to choose the degree of capital-intensive technologies that are available (this can be represented as movement along the Cobb-Douglas production function isoquant). Ex-post, once investment is sunk, the technology is Leontief. Investment is assumed to be irreversible, so that the economy has no way of eliminating capital that now has an inefficient capital intensity ratio.

**Figure 7.1: "Putty-clay" Investment**




Before capital is put in place, a firm can choose form a wide variety of different ratios of labour to capital. This ‘putty’ stage of capital is known as ex ante variable proportions. For example, a tour operator can choose from a range of different tour bus sizes. Since there is only one tour bus driver at once, a more expensive tour bus implicitly means a higher ratio of capital to labour. Once that capital is put in place (the clay part of the process), the ratio of capital to labour embodied in that asset remains the same for as long as it is in use. Ex post variable proportions is known as putty-putty, because firms are free to remould and reshape existing capital in order to vary its labour requirement as needed. This is the older and more common neoclassical assumption. Under this assumption if the price of capital relative to the wage rate falls, firms can take new investment and combine it with existing capital in order to hold constant the ratio of the wage rate per hour to the cost of capital being operated by that worker. Firms will increase the capital one percent, every time the cost of capital falls one percent relative to the cost of labour. With putty-clay capital (ex post fixed proportions), changes in the cost of capital only affect the labour intensity of new capital. Firms cannot change the labour requirements of existing capital.

The assumption of putty-clay capital has implications for production. With the production function in a standard neoclassical model, output is a function of total workers and of the total capital stock. This implies any investment affects the marginal productivity of all labour and of all existing capital. In a putty-clay world, capital cannot be pulled apart and reformed but is made up of plant, equipment and buildings, for example, which are used by many workers. The purchase of new capital only affects the productivity of the labour using that new capital. The productivity of labour using the existing capital is left unchanged. Further, the new capital does not reduce the productivity of existing capital.

Adjustment costs, irreversibility of investment and putty-clay investment are three areas regarding the treatment of investment where extensions to the dynamic forward-looking model can be explored.

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