Economic Growth and the Role of Taxation

Prepared for the OECD

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Summary

The development of endogenous growth theory has provided many new insights into the sources of economic growth. The essence of the new theory is that growth is a consequence of rational economic decisions. Firms expend resources on research and development to secure profitable innovations. Consumers invest in education to develop human capital and increase lifetime earning. Governments increase growth by providing public inputs, encouraging foreign direct investment, and enhancing educational opportunities. Through the aggregation of these individual decisions the rate of growth becomes a variable of choice, and hence a variable that can be affected by the tax policies of governments.

Viewed from an endogenous growth perspective the link between taxation and growth seems self-evident. Corporate taxation affects the return to innovation and hence must affect the optimal amount of research and development. Personal income taxation reduces the returns to education so must reduce the accumulation of human capital. In simulations of economic growth models the effect of taxation on growth has frequently been demonstrated to be considerable. A clear presumption exists that data on economic activity must reveal a strong correlation between taxation and growth.

It is therefore surprising to discover that aggregate data provides no convincing of this correlation. There are numerous explanations for this finding, including the difficulty of disentangling the positive effect of government expenditure from the negative effect of the taxes used for financing. Whatever the explanation may be, the implication is that the tax effect must be sought in the micro data on individual decisions.

The econometric analysis of individual decisions has made major advances in recent years. The availability of detailed data sets and developments in methodology, not least the exploitation of natural experiments, has allowed for much refined estimates of behavioral responses. Empirical estimates of the responsiveness of decisions to government policies, typically summarized in elasticities, can now be accepted with a degree of confidence. In all of the decisions relevant for growth - such as physical and human capital investment, and research and development - published studies are returning statistically significant estimates which are consistent in their values.

A summary of the current position is that the elasticities of each of the individual components of growth are known with a degree of certainty. What is not clear is how these individual elasticities aggregate into an overall effect. Theoretical models predict that they should be significant but the effects are not apparent in the aggregate data. To confirm the link between taxation and growth future research must integrate the individual effects into an overall picture. This appears to be a considerable challenge.

Part 1
Preliminaries

Chapter 1: Introduction

- Importance of economic growth
- Organization of report
- Policy and economic growth
- The algebra of growth

1.1 Economic Growth

Economic growth is the basis of increased prosperity. Growth comes from the accumulation of capital (both human and physical) and from innovations which lead to technical progress. Accumulation and innovation raise the productivity of inputs into production and increase the potential level of output.

The rate of growth can be affected by policy through the effect that taxation has upon economic decisions. An increase in taxation reduces the returns to investment (in both physical and human capital) and Research and Development (R&D). Lower returns mean less accumulation and innovation and hence a lower rate of growth. This is the negative aspect of taxation. Taxation also has a positive aspect. Some public expenditure can enhance productivity, such as the provision of infrastructure, public education, and health care. Taxation provides the means to finance these expenditures and indirectly can contribute to an increase in the growth rate.

In most developed countries the level of taxes rose steadily over the course of the twentieth century: an increase from about 5%-10% of gross domestic product (GDP) at the turn of the century to 30% - 40% at the end is typical. Such significant increases raise serious questions about the effect taxation has upon economic growth. This does not imply that it is straightforward to infer the effects of taxation from aggregate economic data. The positive and negative effects of taxation will be mutually offsetting and only the net effect (which may be very small) will be observed.

Until recently, economic models that could offer insight into how to proceed beyond aggregate data were lacking. Much of the literature on economic growth focused on the long-run equilibrium where output per head was constant or modelled growth through exogenous technical progress. By definition, when technical progress is exogenous it cannot be affected by policy. The development of endogenous growth theory has overcome these limitations by explicitly modelling the process through which growth is generated. This allows the effects of taxation to be traced through the economy and predictions made about its effects on growth. This report describes these models and the recent empirical evidence on the size of the tax effect.

1.2 Structure of Report

The question upon which this report focuses is how tax policy affects growth. To answer this it is first necessary to understand what determines the rate of growth. As a consequence this review takes several approaches to answering this question. Not all of them are directly connected with taxation but they are all connected with obtaining insights into the growth process. Sometimes to understand the details (*i.e.* taxes) it is necessary to understand the generalities first.

This report is divided into four main parts. Following this introduction Part 2 describes the key models of economic growth. These are included to make the report self-contained and to provide a context in which to locate the review of empirical research. Exogenous growth models are reviewed in Chapter 2 and endogenous growth models in Chapter 3. Particular emphasis is given to the channels through which endogenous growth can arise. Identifying these is essential to tracing the numerous routes through which the tax system can interact with the growth process. This part also notes the influential result that in the long-run it is optimal to have a zero tax on capital. This result plays a key role in understanding the motivation for the tax reform simulations that have been conducted in endogenous growth models. A summary of this line of analysis is provided in Chapter 4. The chapter first reviews the simulation of basic endogenous growth models with human capital accumulation and then proceeds to simulation results in a wide range of models. This analysis is intended to clarify the effect that taxation may have and to provide a point of reference for the empirical research.

The next two parts focus upon empirical research and are the central components of the report. Part 3 focuses on the analysis of growth using aggregate economic data. Chapter 5 provides a review and discussion of the extensive literature on growth regressions that flourished following the influential work of Barro (1991). These regressions aim to identify the correlation of growth with a wide range of economic, political, and social variables. The interpretation of the results proved fairly controversial though the ultimate message of this line of work now seems clear. Chapter 6 then reviews regressions that focus upon taxation and measures of government size as explanatory variables in growth regression. Again there has been much contention concerning the interpretation of these results. Ultimately, it can only be concluded that these growth regressions have provided little in the way of insight into the sources of economic growth or the link between taxation and growth. Chapter 7 reports the results of exercises in growth accounting. This is a method for evaluating the contribution of each of the growth components to total growth. It has been used to provide interesting insights into the extent to which countries have differed in their paths to growth. Growth accounting also provides guidance on the elements that are likely to be most important when the effect of taxation is considered.

The failure of the aggregate analysis to produce results provides the motivation for considering disaggregate analysis of the individual components of the growth process. The economic literature contains an extensive range of endogenous growth models that describe a variety of components of the growth process. Part 4 of the report reviews the empirical literature using disaggregated data. Chapter 8 then reviews empirical research that has studied the effect of policy on a range of personal choices that are related to growth. Chapter 9 analyzes the relation between corporate choices and taxation. This part is concluded with Chapter 10 that brings together some observations from country studies of tax reform and economic growth.

Part 5 gathers together some reflections on the material surveyed and discusses possible future research directions. More importantly it provides a discussion of what seem to be the most important areas for policy given the empirical research that is reviewed.

1.3 Taxation and Growth

It is worth making a simple but important observation at the outset. This observation is that the effect of a tax upon the growth rate of output is determined by two separate components.

Let the growth rate of output, g_Y, be defined by

$$g_Y = g_Y\left(a_1(t_1), a_2(t_2)\right), \tag{1}$$

where a_1 and a_2 are two actions (*e.g.,* R&D expenditure and education) and the t_i, $i = 1,2$ are two taxes (or the levels of some other policy instrument). Then the effect of the tax is

$$\frac{dg_Y}{dt_i} = \frac{\partial g_Y}{\partial a_i}\frac{da_i}{dt_i}. \tag{2}$$

Now even if the tax has a significant effect on the action, so that da_i / dt_i is large, it need not have a significant effect on growth if $\partial g_Y / \partial a_i$ is small. Conversely, even if the effect on the action is small, the growth effect can still be large if $\partial g_Y / \partial a_i$ is large.

The consequence of this is that countries need not be alike in the response to taxation. Even if the economic agents behave in the same way (*i.e.*, all reduce their human capital investment in the same way when income tax is raised) the effect on growth may not be the same. If countries are structurally different - perhaps some rely on human capital accumulation for growth whereas others focus on R&D - then the same tax policy may have very different growth consequences.

Hence understanding the effect of taxation requires understanding both of these components. Looking at the tax responses is not enough. The tax elasticity is only one part of the story. This is the reason why it is important to understand the channels through which growth originates and why it is not enough to just study components individually.

This report will conclude that fairly firm estimates of the tax effects da_i / dt_i are available in the literature and, where they do not exist, there is an established and successful methodology for obtaining them. What does not seem to exist is knowledge of the growth effects $\partial g_Y / \partial a_i$. There are numerous theoretical predictions but the empirical literature has been unsuccessful in obtaining convincing estimates.

Appendix on Calculating Growth Rates

A number of results concerning the definition of growth rates and the manipulation of growth rates are used in this report. This appendix provides a self-contained summary of these results.

The growth rate of GDP can be measured in either discrete time or in continuous time. In discrete time the level of output at time t is denoted Y_t. In continuous time the level of output at t is $Y(t)$.

In discrete time the change in output between times t and $t+1$ is $\Delta Y = Y_{t+1} - Y_t$. This can be used to define the proportional rate of growth of output as

$$g_Y \equiv \frac{Y_{t+1} - Y}{Y_t} = \frac{\Delta Y}{Y_t}. \tag{3}$$

In continuous time the rate of change is

$$\dot{Y} \equiv \frac{dY}{dt}, \tag{4}$$

so the proportional rate of growth is

$$g_Y \equiv \frac{dY / dt}{Y} = \frac{\dot{Y}}{Y}. \tag{5}$$

Observe that by the chain rule of differentiation

$$\frac{d \ln(Y)}{dt} = \frac{1}{Y}\frac{dY}{dt} = g_Y. \tag{6}$$

This result is useful for two reasons. First, it allows development of expressions for per capita growth levels. GDP per capita is given by *Y/L*, where *L* is population size, so

$$\begin{aligned} g_{Y/L} &= \frac{d \ln(Y / L)}{dt} \\ &= \frac{d(\ln(Y) - \ln(L))}{dt} \\ &= \frac{1}{Y}\frac{dY}{dt} - \frac{1}{L}\frac{dL}{dt} \\ &= g_Y - g_L. \end{aligned} \tag{7}$$

Hence the growth rate of GDP per capita is equal to the growth rate of GDP less the growth rate of population. Second, it allows decomposition of aggregate growth into a set of contributory factors. Let the aggregate production function have the Cobb-Douglas form

$$Y = AK^{\alpha}L^{1-\alpha}. \tag{8}$$

Then

$$\ln(Y) = \ln(A) + \alpha \ln(K) + (1-\alpha)\ln(L), \tag{9}$$

so

$$g_Y = g_A + \alpha g_K + (1-\alpha)g_L. \tag{10}$$

The factors K and L contribute to growth according to their shares in the Cobb-Douglas production function.

The division of aggregate growth into the contributions from different factors generalizes to any production function of the form

$$Y = AF(K,L). \tag{11}$$

Differentiating both sides and dividing by gives

$$\frac{1}{Y}\frac{dY}{dt} = \frac{A}{Y}\frac{\partial F}{\partial A}\frac{1}{A}\frac{dA}{dt} + \frac{K}{Y}\frac{\partial F}{\partial K}\frac{1}{K}\frac{dK}{dt} + \frac{L}{Y}\frac{\partial F}{\partial L}\frac{1}{L}\frac{dL}{dt}, \tag{12}$$

or

$$g_Y = \alpha_A g_A + \alpha_K g_K + \alpha_L g_L, \tag{13}$$

where

$$\alpha_z = \frac{z}{Y}\frac{\partial F}{\partial z}. \tag{14}$$

The analogue of the continuous growth rate can be calculated from data by using

$$g_Y = \frac{1}{t}\left(\ln(Y_t) - \ln(Y_0)\right), \tag{15}$$

where Y_0 is a base year and t is the time from 0 to t. Finally, the annual percentage growth rate (AGR) averaged over a period of years is defined by

$$AGR = \left[\exp\left(\frac{1}{t}\left(\ln(Y_t) - \ln(Y_0)\right)\right) - 1\right] \times 100. \tag{16}$$

This is the growth rate used in many of the growth regression.

Part 2
Modelling Growth

Chapter 2: Exogenous Growth

- The Solow model describes growth through capital accumulation
- The model predicts convergence to a steady state
- Output per capita in the steady state is determined by the saving rate
- Increases in output are obtained only through technological innovation
- The development of technology is not explained by the model
- The taxation of capital is inefficient

2.1 Introduction

The exogenous growth theory that developed in the 1950s and 1960s viewed growth as being achieved by the accumulation of capital, and increases in productivity achieved via technical progress. The theory generally placed its emphasis upon capital accumulation, so the source of the technical progress was not investigated by the theory. It was assumed instead to arise from some outside or exogenous factors.

The standard form of these growth models was based upon a production function that had capital and labour (with labour measured in man-hours) as the inputs into production. Constant returns to scale were assumed, as was diminishing marginal productivity of both inputs. Given that the emphasis was upon the level and growth of economic variables, rather than their distribution, the consumption side was modelled by either a representative consumer or a steadily growing population of identical consumers.

The simplest of these growth models assumes that both the rate of saving and the supply of labour are constant. This model is a special case of the general Solow growth model. Although the assumption of a constant saving rate eliminates issues of consumer choice, the model still reveals important lessons about the limits to growth and the potential for efficiency of the long-run equilibrium. The key finding is that if growth occurs only through the accumulation of capital, there has to be a limit to the growth process if there is no technical progress.

The fact that there are limits to growth in an economy when there is no technical progress can be most easily demonstrated in a setting in which consumer optimization plays no role. Instead, it is assumed that a constant fraction of output is invested in new capital goods. This assumption may seem restrictive but it allows a precise derivation of the growth path of the economy. The basic model has also been used to motivate much empirical work. In addition the main conclusions relating to limits on growth are little modified even when an optimizing consumer is introduced.

2.2 Solow Growth Model

Consider an economy with a population that is growing at a constant rate. Each person works a fixed number of hours and capital depreciates partially when used. There is a single good in the economy which can be consumed or saved. The only source of saving is investment in capital. Under these assumptions, the output that is produced at time *t*, Y_t, must be divided between consumption, C_t, and investment, I_t. In equilibrium, the level of investment must be equal to the level of saving.

With inputs of capital K_t and labour L_t employed in production, the level of output is

$$Y_t = F(K_t, L_t). \tag{2.1}$$

It is assumed that there are constant returns to scale in production. Output can be either consumed or saved. The fundamental assumption of the model is that the level of saving is a fixed proportion s, $0 < s < 1$, of output. As saving must equal investment in equilibrium, at time t investment in new capital is given by

$$I_t = sF(K_t, L_t). \tag{2.2}$$

The use of capital in production results in its partial depreciation. Assume that this depreciation is a constant fraction δ, so the capital available in period $t+1$ is given by new investment plus the undepreciated capital, or

$$\begin{aligned} K_{t+1} &= I_t + \delta K_t \\ &= sF(K_t, L_t) + (1-\delta)K_t . \end{aligned} \tag{2.3}$$

This equation is the basic capital accumulation relationship that determines how the capital stock evolves through time.

The fact that the population is growing makes it preferable to express variables in per capita terms. This can be done by exploiting the assumption of constant returns to scale in the production function to write $Y_t = L_t F(K_t / L_t, 1) = L_t f(k_t)$ where $k_t \equiv K_t / L_t$. Dividing (2.3) through by L_t, the capital accumulation relation becomes

$$\frac{K_{t+1}}{L_t} = sf(k_t) + \frac{(1-\delta)K_t}{L_t}. \tag{2.4}$$

Denoting the constant population growth rate by n, labour supply grows according to $L_{t+1} = (1+n)L_t$. Using this growth relationship, the capital accumulation relation shows that the dynamics of the capital/labour ratio are governed by

$$(1+n)k_{t+1} = sf(k_t) + (1-\delta)k_t . \tag{2.5}$$

The relation in (2.5) will trace the development of the capital stock over time from an initial stock $k_0 = K_0 / L_0$. To see what this implies, consider an example where the production function has the form $f(k_t) = k_t^{\alpha}$. The capital/labour ratio must then satisfy

$$k_{t+1} = \frac{sk_t^{\alpha} + (1-\delta)k_t}{1+n}. \tag{2.6}$$

For $k_0 = 1$, $n = 0.05$, $\delta = 0.05$, $s = 0.2$ and $\alpha = 0.5$, Figure 2.1 plots the first 50 values of the capital stock. It can be seen that starting from the initial value of $k_0 = 1$ the capital stock doubles in 13 years. After this the rate of growth slows noticeably and even by the 50th year it has not yet doubled again. The figure also shows that the capital stock is tending to a long-run equilibrium level which is called the steady state. For the parameters chosen, the steady state level is $k = 4$ which is virtually achieved at $t = 328$, though the economy does reach a capital stock of 3.9 at $t = 77$. It is the final part of the adjustment that takes a long time.

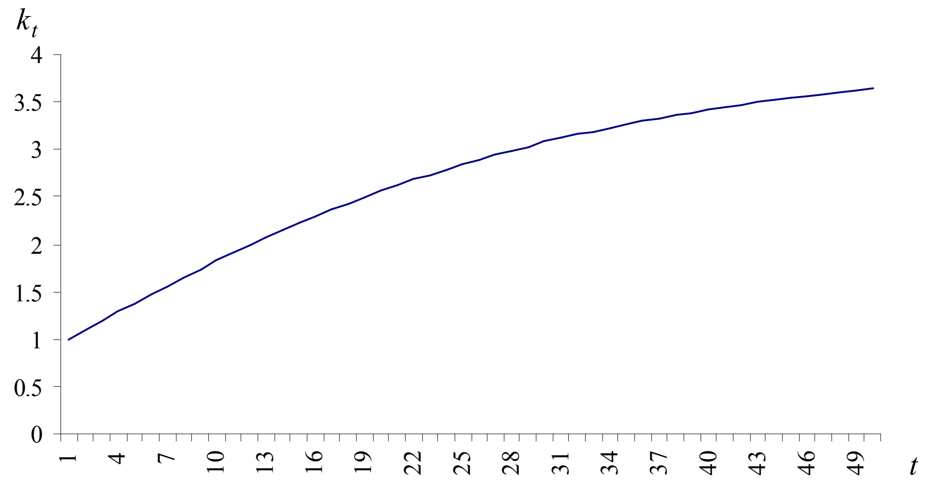

Figure 2.1: Dynamics of the Capital Stock

The steady state is achieved when the capital stock is constant with $k_{t+1} = k_t$. Denoting the steady state value of the capital/labour ratio by k, the capital accumulation condition shows that k must satisfy

$$(1+n)k = sf(k) + (1-\delta)k, \tag{2.7}$$

or

$$sf(k) - (n+\delta)k = 0. \tag{2.8}$$

The solution to this equation is called the steady state capital/labour ratio and can be interpreted as the economy's long-run equilibrium value of k.

The solution of this equation is illustrated in Figure 2.2. The steady state occurs where the curves $sf(k)$ and $(n+\delta)k$ intersect. If this point is achieved by the economy, the capital/labour ratio will remain constant. Since *k* is constant, it follows from the production function that Y_t / L_t will remain constant as will C_t / L_t, where C_t is aggregate consumption at time *t*. (However, it should be noted that as *L* is growing at rate *n*, then the values of *Y*, *K* and *C* will also grow at rate *n* in the steady state.) It is the constancy of these variables that shows there is a limit to the growth achievable by this economy. Once C_t / L_t is constant, the level of consumption per capita will remain constant over time. In this sense, a limit is placed upon the growth in living standards that can be achieved. The explanation for this limit is that capital suffers from decreasing returns when added to the exogenous supply of labour. If excessive capital is employed the return will fall so low that the capital stock is unable to reproduce itself.

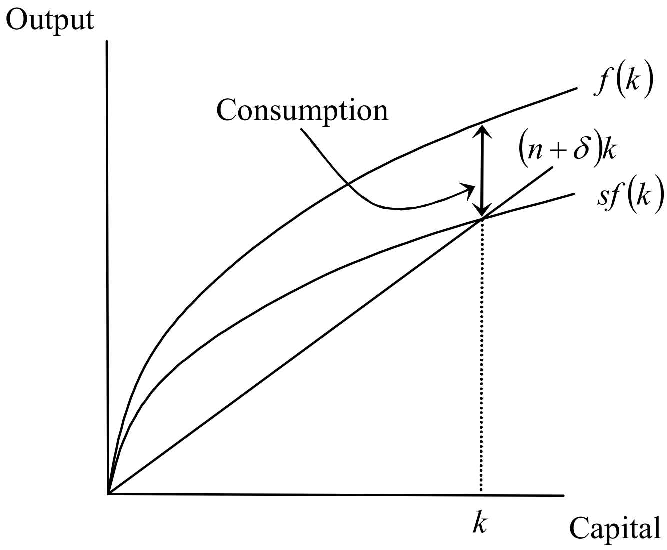

Figure 2.2: The Steady State

Although no policy variables have yet been included, this analysis of the steady state can be used to reflect on the potential for economic policy to affect the equilibrium. Studying Figure 2.2 reveals that the equilibrium level of *k* can be raised by any policy that engineers an increase in the saving rate, *s*, or an upward shift in the production function, $f(k)$. However, any policy that leads only to a one-off change in *s* or $f(k)$ cannot affect the long-run growth rate of consumption or output. By definition, once the new steady state is achieved after the policy change, the growth rates of the per capita variables will return to zero. Furthermore, any policy that only increases *s* cannot sustain growth since *s* has an upper limit of 1 which must eventually be reached. If policy intervention is to result in sustained growth it has to produce a continuous upward movement in the production function. A mechanism through which policy can achieve this is studied in Section 3.4.

2.3 Technical Progress

A means for growth to be sustained without policy intervention is to assume that output increases over time for any given levels of the inputs. This can be achieved through labour or capital (or both) becoming more productive over time for exogenous reasons summarized as "technical progress". A way to incorporate this in the model is to write the production function as $f(k,t)$, where the dependence upon t captures the technical progress which allows increased output. Technical progress results in the curve $f(k,t)$ in Figure 2.2 continuously shifting upwards over time, thus raising the steady state levels of capital and output. The drawback of this approach is that the mechanism for growth, the "growth engine", is exogenous so preventing the model from explaining the most fundamental factor of what determines the rate of growth. This deficiency is addressed by the endogenous growth models of the next chapter that explore the mechanisms that can drive technical progress.

Returning to the basic model without technical progress, condition (2.8) shows the steady state capital/labour ratio is dependent upon the saving rate s. This raises the question as to whether some saving rates are better than others. To address this question, it is noted first that for each value of s there is a corresponding steady-state capital/labour ratio at the intersection of $sf(k)$ and $(n+\delta)k$. It is clear from Figure 2.2 that for low values of *s*, the curve $sf(k)$ will intersect the curve $(n+\delta)k$ at low values of *k*. As s is increased, $sf(k)$ shifts upwards and the steady state level of *k* will rise. The relationship between the capital/labour ratio and the saving rate implied by this construction is denoted by $k = k(s)$. The construction shows that $k = k(s)$ is an increasing function of *s* up until the maximum value of $s = 1$.

Taking account of the link between *s* and *k*, the level of consumption per capita can be written

$$c(s) = (1-s)f(k(s)) = f(k(s)) - (n+\delta)k(s), \tag{2.9}$$

where the second equality follows from definition (2.8) of a steady state. What is of interest are the properties of the saving rate that maximizes consumption. The first-order condition for defining this saving rate can be found by differentiating $c(s)$ with respect to *s*. Doing so gives

$$\frac{dc(s)}{ds} = [f'(k(s)) - (n+\delta)]k'(s) = 0. \tag{2.10}$$

Since $k'(s)$ is positive, the saving rate, s^*, that maximizes consumption is defined by

$$f'\left(k\left(s^*\right)\right) = (n+\delta). \tag{2.11}$$

The saving rate s^* determines a level of capital $k^* = k\left(s^*\right)$ which is called the Golden Rule capital/labour ratio. If the economy achieves this capital/labour ratio at its steady state it is maximizing consumption per capita.

The nature of the Golden Rule is illustrated in Figure 2.3. For any level of the capital/labour ratio, the steady state level of consumption per capita is given by the vertical distance between the curve $(n+\delta)k$ and the curve $f(k)$. This distance is maximized when the gradient of the production function is equal to $(n+\delta)$ which gives the Golden Rule condition. The figure also shows that consumption will fall if the capital/labour ratio is either raised or lowered from the Golden Rule level. An economy with a steady-state capital stock below the Golden Rule level, k^*, is dynamically efficient - it requires a sacrifice of consumption now in order to raise k so a Pareto-improvement cannot be found. An economy with a capital stock in excess of k^* is dynamically inefficient since immediate consumption of the excess would raise current welfare and place the economy on a path with higher consumption.

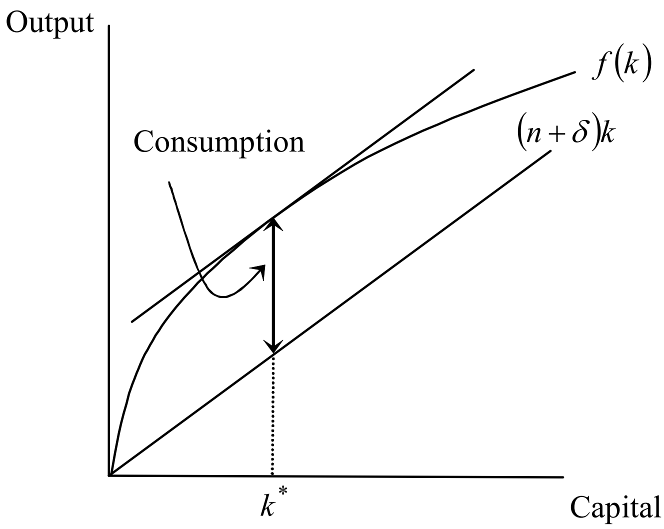

Figure 2.3: The Golden rule

As an example of these calculations, let the production function be given by $y = k^{\alpha}$, with $\alpha < 1$. For a given saving rate s the steady state is defined by the solution to

$$sk^{\alpha} = (n+\delta)k. \tag{2.12}$$

Solving this equation determines the steady state capital/labour ratio as $k^* = \left(\frac{s}{n+\delta}\right)^{1/(1-\alpha)}$. Using this solution, the per capita level of consumption follows as

$$c(s^*) = (k^*)^{\alpha} - (n+\delta)k^*$$

$$= \left(\frac{s}{n+\delta}\right)^{\alpha/(1-\alpha)} - (n+\delta)\left(\frac{s}{n+\delta}\right)^{1/(1-\alpha)}. \tag{2.13}$$

Adopting the parameter values $n = 0.025$, $\delta = 0.025$ and $\alpha = 0.75$, the level of consumption is plotted in Figure 2.4 as a function of *s*. The figure shows that consumption rises with s until the saving rate is reached at which the equilibrium capital stock is equal to the Golden Rule level and then falls again for higher values.

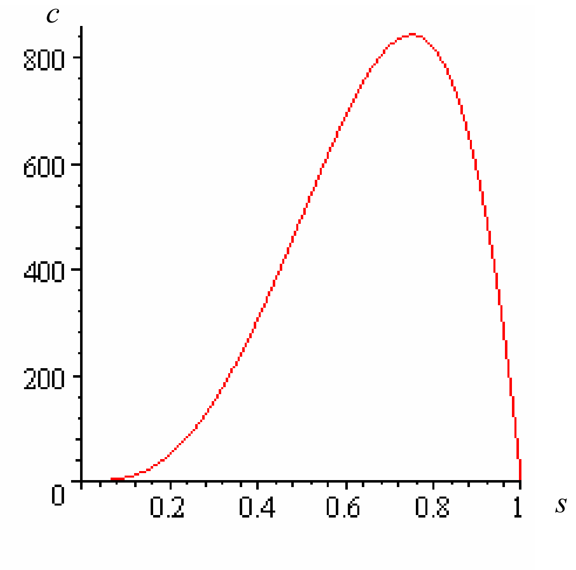

Figure 2.4: Consumption and the saving rate

Formally, the fact that the saving rate is fixed leaves little scope for the analysis of policy. However, studying the effect of changes in the saving rate reveals the factors that would be at work in a more general model in which the level of saving is a choice variable that can be affected by policy variables. By definition, the per capita levels of the variables are constant once the steady state has been achieved. The living standards in the economy reach a limit and then cannot grow any further unless the production function is continually raised. Changes in the saving rate affect the level of consumption but not its growth rate.

2.4 Convergence

The Solow model has a further implication that is important for understanding the outcome of the growth regressions described in Chapter 5. This is the property of *convergence* between countries.

The steady-state level of per capita income depends only upon the saving rate. As a consequence, two countries that have access to the same production technology and have the same saving rate must eventually converge to the same steady-state level of per capita income. Since there are decreasing returns to the accumulation of capital an additional unit of capital added to the stock of a low-capital country will lead to a greater increase in output than an additional unit added to the stock of a high-capital country. Along the transition path to the steady state countries with low capital-labour ratios must grow faster than countries with high capital-labour ratios. This is the only way in which they can ultimately arrive at the same steady state. Hence, cross-country data on growth and output levels can be expected to show that the rate of growth is inversely related to the capital-labour ratio. If there is trade between economies the rate of convergence should be faster than without. A country with a low capital-labour ratio will offer a higher return to capital so should attract investment. This will cause quicker growth in the capital stock and hence faster convergence.

A formal demonstration of convergence can be given as follows. The change in the capital stock with respect to time in the Solow growth model is

$$\dot{k} = sf(k) - (n+\delta)k\,, \tag{2.14}$$

so the growth rate of the capital stock is

$$g_k = \frac{\dot{k}}{k} = \frac{sf(k)}{k} - (n+\delta). \tag{2.15}$$

Therefore

$$\frac{\partial g_k}{\partial k} = \frac{s}{k}\left(f'(k) - \frac{f(k)}{k} \right) < 0\,. \tag{2.16}$$

This result shows that the higher the level of capital the slower is the rate of growth.

Consider two countries that differ in their capital stocks but are otherwise identical. From (2.16) the country with the lower capital stock – and consequently lower output - will grow faster. This is termed *absolute convergence* (or absolute β convergence). The data suggest that absolute convergence does not apply when a large number of heterogeneous countries are considered but is a characteristic for a more homogeneous set of countries or regions (see Barro and Sala-i-Martin, 1995).

A weaker concept of convergence is *conditional convergence* (or conditional β convergence). If countries differ in underlying parameters then their steady states will also be different. Conditional convergence is the proposition that countries further from their own steady state grow faster.

2.5 Tax Policy

The Solow model with a constant saving rate leaves little role for tax policy to affect the rate of growth. The saving rate could be made variable but there would still be a limited number of economic choices that can be taxed in the Solow framework. Consequently the appendix to this chapter analyses optimal taxation in the more general Ramsey model of growth. This model assumes a single consumer but endogenizes the choice of consumption, labour supply, and investment. This permits taxation to distort the decisions on consumption (hence saving), labour, and investment.

The central result of the tax analysis is the Chamley (1986) and Judd (1985) finding that in the long-run the optimal tax on capital income should be zero. This result is easily interpreted. Firstly, note that the result does not say that the tax should be zero along the growth path to the steady state - it is derived assuming the economy is in the steady state so applies only to that situation. This does not prevent the tax being positive (or negative) along the growth path. Secondly, the zero tax on capital income implies that all taxation must fall upon labour income. If labour were a fixed factor this conclusion would not be a surprise, but here labour is a variable factor. Finally, the reason for avoiding the taxation of capital is that the return on capital is fundamental to the intertemporal allocation of resources by the consumer and because of the intertemporal structure the consequences of the distortion accumulate over time. The result shows that it is optimal to leave this allocation undistorted to focus distortions upon the choice between consumption and labour within periods.

Since the optimal tax rate is zero, any other value of the tax rate must lead to a reduction in welfare compared to what is achievable. An insight into the extent of the welfare cost of deviating from the optimal solution is given in Table 2.1. These results are derived from a model with a Cobb-Douglas production function and a utility function with a constant elasticity of intertemporal substitution (see (3.13) below). The policy experiment calculates what would happen if a tax on capital was replaced by a lump-sum tax. The increase in consumption and the welfare cost are measured by comparing the steady state with the tax to the steady state without. When a tax rate of 30 percent on capital income is replaced by a lump-sum tax, consumption increases by 3.3percent and the welfare cost of the distortionary tax is measured at 11 percent of tax revenue. The increase in consumption and the welfare cost are both higher for an initial 50 percent tax rate.

Initial Tax Rate (%)	Increase in Consumption	Welfare Cost (% of Tax Revenue)
30	3.30	11
50	8.38	26

Table 2.1: Welfare Cost of Taxation

Source: Chamley (1981)

In summary, the optimal tax policy is to set the long-run tax on capital to zero. This outcome is explained by the wish to avoid intertemporal distortions. As a consequence, all revenue must be raised by taxation of labour income. This will cause a distortion of choice within periods but does not affect the intertemporal allocation. The conclusion is very general and does not depend upon any restrictive assumptions. Simulations of the welfare cost of non-optimal policies show that these can be a significant percentage of the revenue raised.

2.6 Observations

The Solow model introduces the concept of a steady state and demonstrates that capital accumulation is not sufficient to ensure continuing growth if not matched by technological progress or equal increases in other inputs. The appeal to technological progress as the source of growth illustrates the need for understanding of the source of technical progress - the assumption of it deriving from some exogenous process is just not good enough. The model also predicts convergence if countries have the same technology. This is a helpful observation for understanding the results of growth regressions. Finally, the Solow model provides the basis for undertaking the growth accounting exercises that provide the key insights into the sources of growth.

Appendix on Optimal Taxation

The analysis of the fixed saving model has touched upon some of the potential consequences of policy intervention. As a tool for policy analysis, the model is very limited given the lack of choice variables that can be affected by policy. This shortcoming is now overcome by studying a variant of the Ramsey growth model in which a representative consumer chooses an intertemporal consumption plan to maximize lifetime utility. Using this model the optimal taxes upon labour and capital income can be derived.

The Ramsey model has a single representative consumer who chooses the paths of consumption, labour and capital over time. The single consumer assumption is adopted to eliminate issues concerning distribution between consumers of differing abilities and tastes, and to place the focus entirely upon efficiency. For simplicity, it is also assumed that the growth rate of labour, n, is zero. There is a representative firm that chooses its use of capital and labour to maximize profits. Given that the market must be in equilibrium, the choices of the consumer drive the rest of the economy through the level of saving, and hence capital, that they imply. The supply of labour and capital from the consumer combine with the factor demands of the firm to determine the equilibrium factor rewards. The aim is to characterize the optimal tax structure in this economy. We assume there is a government that requires revenue of amount g_t at time t. It raises this revenue through taxes on capital and labour, which are denoted by τ_t^K and τ_t^L respectively. The government chooses these tax rates in the most efficient manner.

The choices of the consumer are made to maximize the discounted sum of the flow of utility. Letting $0< \beta <1$ be the discount factor on future utility, the consumer's preferences are described by

$$U = \sum_{t=0}^{\infty} \beta^t U(C_t, L_t). \tag{2.17}$$

The specification of the utility function implies that the consumer has an infinite life. This can be justified by treating the consumer as a dynasty with concern for descendents.

As there is a single consumer, the capital stock is equal to the saving of this consumer. This observation allows the budget constraint for the consumer to be written as

$$C_t + K_{t+1} = \left(1-\tau_t^L\right)w_t L_t + \left(1-\delta+\left(1-\tau_t^K\right)r_t\right)K_t . \tag{2.18}$$

The utility maximization decision for the consumer involves choosing the time paths of consumption, labour supply and capital for the entire lifespan of the economy. The formal decision problem is

$$\max_{\{C_t, L_t, K_t\}} \sum_{t=0}^{\infty} [\beta^t U(C_t, L_t) + \beta^t \lambda_t \left(\left(1-\tau_t^L\right)w_t L_t \right.$$

$$\left. + \left(1-\delta+\left(1-\tau_t^K\right)r_t\right)K_t - C_t - K_{t+1}\right), \tag{2.19}$$

where λ_t is the multiplier on the budget constraint at time *t*.

In solving this optimization, it is assumed that the representative consumer takes the factor rewards w_t and r_t as given. This captures the representative consumer as a competitive price-taker. (It is helpful to note that when the government optimization is considered below the dependence of the factor rewards on the choice of capital and labour is taken into account by the government. This is what distinguishes the consumer who *reacts* to the factor rewards, and the government which manipulates the factor rewards.)

With fixed factor rewards, the necessary conditions for the choice of C_t, L_t and K_{t+1} are

$$U_{C_t} - \lambda_t = 0, \tag{2.20}$$

$$U_{L_t} + \lambda_t \left(1 - \tau_t^L\right) w_t = 0, \tag{2.21}$$

and

$$\beta \lambda_{t+1} \left(1 - \delta + \left(1 - \tau_{t+1}^K\right) r_{t+1}\right) - \lambda_t = 0. \tag{2.22}$$

Using the first condition to substitute for λ_t in the second condition gives

$$U_{L_t} + U_{C_t} \left(1 - \tau_t^L\right) w_t = 0. \tag{2.23}$$

Stepping the first condition one period ahead and then substituting for λ_{t+1} in the third gives

$$\beta U_{C_{t+1}} \left(1 - \delta + \left(1 - \tau_{t+1}^K\right) r_{t+1}\right) - U_{C_t} = 0. \tag{2.24}$$

Conditions (2.23) and (2.24) describe utility maximization by the consumer. To interpret these it should be observed that there are two aspects to the consumer's decision. Firstly, within each period the consumer needs to optimize over the levels of consumption and labour supply. The efficient solution to this within-period decision is described by (2.23) which ensures that the marginal utilities are proportional to the relative prices. Secondly, the consumer has to allocate their resources efficiently across time. Condition (2.24) describes efficiency in this process by linking the marginal utility of consumption in two adjacent periods to the rate at which consumption can be transferred through time via investments in capital. Taken together for every time period *t*, these necessary conditions describe the optimal paths of consumption, labour supply and capital investment for the consumer.

The representative firm is assumed to maximize profit by choosing its use of capital and labour. Since the firm rents capital from the consumer, it makes no irreversible decisions so it need do no more than maximize profit in each period. The standard efficiency conditions for factor use then apply which equate marginal products to factor rewards. Hence the interest rate and the wage rate satisfy

$$F_{K_t} = r_t , \tag{2.25}$$

and

$$F_{L_t} = w_t . \tag{2.26}$$

Following these preliminaries, it is possible to state the government optimization problem. The sequence of government expenditures $\{g_t\}$ is taken as given. It is assumed that these expenditures are used for a purpose which does not directly affect utility. Formally, the government chooses the tax rates and the levels of consumption, labour supply and capital to maximize the level of utility. The values of these variables must be chosen for each point in time, so the government decision is a sequence $\{\tau_t^K, \tau_t^L, C_t, L_t, K_t\}$. The choices of C_t, L_t and K_t must be identical to what would be chosen by the consumer given the tax rates τ_t^K and τ_t^L. This can be achieved by imposing conditions (2.23) and (2.24) as constraints upon the optimization. When these constraints are satisfied it is as if the consumer were making the choice. As already noted, the government explicitly takes into account the endogenous determination of the factor rewards.

The optimization also has to be constrained by the budget constraints of the consumer and government, and by aggregate production feasibility. However, if any two of these constraints hold the third must also hold. Therefore one of them need not be included as a separate constraint for the optimization. In this case it is the consumer's budget constraint which is dropped. The government budget constraint that taxes must equal expenditure is given by

$$\tau_t^K r_t K_t + \tau_t^L w_t L_t = g_t . \tag{2.27}$$

In addition, the aggregate production condition for the economy is that

$$C_t + g_t + I_t = F(K_t, L_t). \tag{2.28}$$

Using the definition of investment this becomes

$$C_t + g_t + K_{t+1} = F(K_t, L_t) + (1-\delta)K_t . \tag{2.29}$$

Employing the determination of the factor prices (2.25) and (2.26), the government optimization problem that determines the efficient taxes is

$$\begin{aligned} \max_{\{\tau_t^K, \tau_t^L, C_t, L_t, K_t\}} \sum_{t=0}^{\infty} \beta^t \Big[& U + \psi_t \left(\tau_t^K F_{K_t} K_t + \tau_t^L F_{L_t} L_t - g_t \right) \\ & + \theta_t \left(F + (1-\delta)K_t - C_t - g_t - K_{t+1} \right) + \mu_{1t} \left(U_{L_t} + U_{C_t} \left(1 - \tau_t^L\right) F_{L_t} \right) \\ & + \mu_{2t} \left(\beta U_{C_{t+1}} \left(1 - \delta + \left(1 - \tau_{t+1}^K\right) F_{K_{t+1}} \right) - U_{C_t} \right) \Big]. \end{aligned} \tag{2.30}$$

The complete set of first-order necessary conditions for this optimization involve the derivatives of the Lagrangian with respect to all of the choice variables at every point in time plus the derivatives with respect to the multipliers at every point in time. However, to demonstrate the key result concerning the value of the optimal capital tax only the necessary conditions for the tax rates and for capital are required. The other first-order conditions will add further information on the solution but do not bear on the determination of the capital tax.

The necessary condition for the choice of τ_{t+1}^K is

$$\psi_t F_{K_t} K_t - \mu_{2t-1} U_{C_t} F_{K_t} = 0, \tag{2.31}$$

for τ_t^L the necessary condition is

$$\psi_t F_{L_t} L_t - \mu_{1t} U_{C_t} F_{L_t} = 0, \tag{2.32}$$

and for K_t it is

$$\psi_t\left(\tau_t^K\left(F_{K_t} + K_t F_{K_t K_t}\right) + \tau_t^L F_{L_t K_t} L_t\right) + \theta_t\left(F_{K_t} + 1 - \delta\right) - \frac{1}{\beta}\theta_{t-1}$$

$$+ \mu_{1t} U_{C_t}\left(1 - \tau_t^L\right) F_{L_t K_t} + \mu_{2t-1} U_{C_t}\left(1 - \tau_t^K\right) F_{K_t K_t} = 0. \tag{2.33}$$

The two conditions for τ_t^K and τ_t^L can be used to substitute for μ_{1t} and μ_{2t-1} in the condition for K_t. Cancelling terms and using the fact that constant returns to scale implies $K_t F_{K_t K_t} + L_t F_{L_t K_t} = 0$, condition (2.33) reduces to

$$\psi_t \tau_t^K F_{K_t} + \theta_t\left(F_{K_t} + 1 - \delta\right) - \frac{1}{\beta}\theta_{t-1} = 0. \tag{2.34}$$

Along the growth path of the economy this equation is only one part of the complete description of the outcome induced by the optimal policy. However, by focussing on the steady state in which all the variables are constant it becomes possible to use the information contained in this condition to determine the optimal tax on capital.

Consequently, the analysis now moves to consider the steady state that is reached under the optimal policy. In order to be in a steady state it must be the case that the tax rates and the level of government expenditure remain constant over time. In addition, the levels of capital, consumption and labour supply will be constant. Moreover, being in a steady state also implies that $\theta_t = \theta_{t-1}$. Using these facts, in the steady state the necessary condition for the choice of the capital stock becomes

$$\psi \tau^K F_K + \theta\left(F_K + 1 - \delta\right) - \frac{1}{\beta}\theta = 0. \tag{2.35}$$

This equation can be simplified further by observing that in the steady state the condition for the consumer (2.24) reduces to

$$\beta\left(1-\delta+\left(1-\tau^{K}\right)F_{K}\right)-1=0. \tag{2.36}$$

Using (2.36) to substitute for β, the final condition for the choice of the capital stock is

$$(\psi+\theta)\tau^{K}F_{K}=0. \tag{2.37}$$

Given that the resource constraints are binding, implying ψ and θ are positive, and that the marginal product of capital, F_K, is positive, the solution to (2.37) has to be $\tau^{K}=0$. This is the well-known result (due originally to Chamley (1986) and Judd (1985)) that the long-run value of the optimal capital tax has to be zero.

Chapter 3: Endogenous Growth

- Growth can be sustained if there are constant returns to scale in reproducible inputs
- Endogenous growth models determine the variables that affect growth through individual optimization
- A range of explanations for growth are offered including human capital and provision of a public good
- Technical progress is explained through the search for profitable innovations
- Tax policy can affect choices and therefore the rate of growth

3.1 Introduction

Decreasing returns to capital have already been identified as the source of the limit upon growth in the exogenous growth model. The removal of this limit requires the decreasing marginal product of capital to be circumvented in a way that is, ideally, determined by choices made by the agents in the economy. Models that allow both sustained growth and explain its source are said to generate *endogenous growth*.

There have emerged in the literature four basic methods through which endogenous growth can be achieved. All of these approaches achieve the same end - that of sustained growth - but by different routes. These four approaches are described and then attention is focused on the role of tax policy in growth from the perspective of these models.

3.2 The AK Model

The first, and simplest, approach to modelling endogenous growth, the *AK model*, assumes that capital is the only input into production and that there are constant returns to scale. This may seem at first sight to simply remove the problem of decreasing returns by assumption, but Section 3.3 will show that the *AK* model can be given a broader interpretation. Under these assumptions the production function is given by

$$Y_t = AK_t, \tag{3.1}$$

hence the model's name. Constant returns to scale ensures that output grows at the same rate as the capital stock.

To show that this model can generate continuous growth, it is simplest to return to the assumption of a constant saving rate. With a saving rate *s* the level of investment in time period *t* is $I_t = sAK_t$. Since there is no labour, the capital accumulation condition is just

$$K_{t+1} = sAK_t + (1-\delta)K_t = (1 + sA - \delta)K_t. \tag{3.2}$$

Provided that $sA > \delta$, the level of capital will grow linearly over time at rate $sA - \delta$. Output will grow at the same rate, as will consumption. The model is therefore able to generate continuous growth.

The only variable that is the outcome of an economic choice in the *AK* model is the saving rate, *s*. This limits potential policy effects but does draw attention to the effect that taxation can have upon saving. The empirical evidence on this issue is discussed in Section 8.3.

3.3 Human Capital

The second approach to ensure sustained growth is to match increases in capital with equal growth in other inputs. One way to do this is to consider human capital as an input rather than just raw labour time. The model requires two investment processes: one for investment in physical capital and another for investment in human capital. There can either be one sector, with human capital produced by the same technology as physical capital, or two sectors with a separate production process for human capital.

The human capital variable can be treated in the production function in two different ways. The first treatment is to view the level of the human capital input as the product of the quality of labour and labour time. Doing so allows labour time to be made more productive by investment in education and training which raise human capital. Technical progress is then embodied in the quality of labour. The standard form of production function for such a model would be

$$Y_t = F(K_t, H_t), \tag{3.3}$$

where H_t is the level of human capital. If the production function has constant returns to scale in human capital and physical capital jointly, then investment in both can raise output without limit even if the quantity of labour time is fixed.

The second treatment is to consider human capital as a distinct variable to labour time. This gives a production function of the form

$$Y_t = F(K_t, H_t, L_t). \tag{3.4}$$

This treatment is less common but is encountered in the important work of Mankiw *et al.* (1992) that is discussed in Chapter 6. The one-sector model with human capital actually reduces to the *AK* model - this is the broader interpretation of the *AK* model referred to above. To see this, note that under the one-sector assumption output can be used for consumption or invested in physical capital or invested in human capital. This means that the two capital goods are perfect substitutes for the consumer in the sense that a unit of output can become one unit of either. The perfect substitutability implies that in equilibrium the two factors must have the same rate of return. Combining this with the constant returns to scale in the production function results in the two factors always being employed in the same proportions. Therefore the ratio H_t / K_t is constant for all *t*. Denoting this constant value by *HK*, the production function becomes

$$Y_t = K_t F\left(\frac{H}{K}\right) = AK, \tag{3.5}$$

where $A \equiv F(H/K)$. This returns the production function to the *AK* form.

A two-sector model can have different production functions for the creation of the two types of capital good. This eliminates the restriction that they are perfect substitutes and moves away from the *AK* setting. In a two-sector model different human and physical capital intensities can be incorporated in the production of the two types of capital. This can make it consistent with the observation that human capital production tends to be more intensive in human capital - through the requirement for skilled teaching staff *etc*.

When human capital is incorporated into the model the role for policy is extended. The accumulation of human capital can be viewed as the outcome of an educational process. This focuses attention on how the tax system affects the decision to undertake investments in education. These issues are discussed in Section 8.2. The interaction with labour supply also raises the issue of taxation and labour supply. The empirical evidence on this is considered in Section 8.4. However, labour supply is naturally bounded. This makes it impossible to sustain growth through increases in labour alone.

3.4 Government Expenditure

Endogenous growth can arise when capital and labour are augmented by additional inputs in the production function. One case of particular interest for understanding the link between government policy and growth is when the additional input is a public good financed by taxation. The existence of a public input provides a positive role for public expenditure and a direct mechanism through which policy can affect growth. This opens a path to an analysis of whether there is a sense in which an optimal level of public expenditure can be derived in a growth model. The analytical details of this model are described below because it is an important tool for thinking about the channels through which public expenditure can impact upon growth.

A public input can be introduced by assuming that the production function for the representative firm at time *t* takes the form

$$Y_t = AL_t^{1-\alpha} K_t^{\alpha} G_t^{1-\alpha}, \tag{3.6}$$

where A is a positive constant and G_t is the quantity of the public input. The structure of this production function ensures that there are constant returns to scale in L_t and K_t for the firm given a fixed level of the public input. Although returns are decreasing to private capital as the level of capital is increased for fixed levels of labour and public input, there are constant returns to scale in public input and private capital together. For a fixed level of L_t, this property of constant returns to scale in the other two inputs permits endogenous growth to occur.

It is assumed that the public input is financed by a tax upon output. Assuming that capital does not depreciate in order to simplify the derivation, the profit level of the firm is

$$\pi_t = (1-\tau)AL_t^{1-\alpha}K_t^{\alpha}G_t^{1-\alpha} - r_tK_t - w_tL_t, \tag{3.7}$$

where r_t is the interest rate, wt the wage rate and τ the tax rate. From this specification of profit, the choice of capital and labour by the firm satisfy

$$(1-\tau)\alpha AL_t^{1-\alpha}K_t^{\alpha-1}G_t^{1-\alpha} = r_t, \tag{3.8}$$

and

$$(1-\tau)(1-\alpha)AL_t^{-\alpha}K_t^{\alpha-1}G_t^{1-\alpha} = w_t. \tag{3.9}$$

The government budget constraint requires that tax revenue equals the cost of the public good provided, so

$$G_t = \tau Y_t. \tag{3.10}$$

Now assume that labour supply is constant at $L_t = L$ for all t. Without the public input, it would not be possible given this assumption to sustain growth because the marginal product of capital would decrease as the capital stock increased. With the public input, growth can now be driven by a joint increase in private and public capital even though labour supply is fixed. Using (3.6) and (3.10), the level of public input can be written as

$$G_t = (\tau A)^{1/\alpha}L^{(1-\alpha)/\alpha}K_t. \tag{3.11}$$

This result can be substituted into (3.8) to obtain an expression for the interest rate as a function of the tax rate

$$r_t = (1-\tau)\alpha A^{1/\alpha}(L\tau)^{(1-\alpha)/\alpha}. \tag{3.12}$$

The economy's representative consumer is assumed to have preferences described by the utility function

$$U = \sum_{t=1}^{\infty} \beta^t \frac{C_t^{1-\sigma} - 1}{1-\sigma}. \tag{3.13}$$

This specific form of utility is adopted to permit an explicit solution for the steady state. The consumer chooses the path $\{C_t\}$ over time to maximize utility. The standard condition for intertemporal choice must hold for the optimization, so the ratio of the marginal utilities of consuming at t and at $t+1$ must equal the gross interest rate. Hence

$$\frac{\partial U / \partial C_t}{\partial U / \partial C_{t+1}} \equiv \frac{C_t^{-\sigma}}{\beta C_{t+1}^{-\sigma}} = 1 + r_{t+1}. \tag{3.14}$$

By solving for C_{t+1} / C_t and then subtracting C_t / C_t from both sides of the resulting equation, this optimality condition can be written in terms of the growth rate of consumption

$$\frac{C_{t+1} - C_t}{C_t} = \left(\beta\left(1 + r_{t+1}\right)\right)^{1/\sigma} - 1. \tag{3.15}$$

Finally, using the solution (3.12) to substitute for the interest rate, the growth rate of consumption is related to the tax rate by

$$\frac{C_{t+1} - C_t}{C_t} = \beta^{1/\sigma}\left(1 + (1-\tau)\alpha A^{1/\alpha}\left(L\tau\right)^{(1-\alpha)/\alpha}\right)^{1/\sigma} - 1. \tag{3.16}$$

The result in (3.16) demonstrates the two channels through which the tax rate affects consumption growth. Firstly, taxation reduces the growth rate of consumption through the term $(1-\tau)$ which represents the effect on the marginal return of capital reducing the amount of capital used. Secondly, the tax rate increases growth through the term $\tau^{(1-\alpha)/\alpha}$ which represents the gains through the provision of the public input.

Further insight into these effects can be obtained by plotting the relationship between the tax rate and consumption growth. This is shown in Figure 3.1 under the assumption that $A = 1$, $L = 1$, $\alpha = 0.5$, $\beta = 0.95$ and $\sigma = 0.5$. The figure displays several notable features. First, for low levels of the public input growth is negative, so a positive tax rate is required for there to be consumption growth. Secondly, the relationship between growth and the tax rate is non-monotonic: growth initially increases with the tax rate, reaches a maximum, and then decreases. Finally, there is a tax rate which maximizes the growth rate of consumption. Differentiating (3.16) with respect to τ, the tax rate that maximizes consumption growth is

$$\tau = 1 - \alpha. \tag{3.17}$$

For the values in the figure, this optimal tax rate is $\tau = 0.5$. To see what this tax rate implies, observe that

$$\frac{\partial Y_t}{\partial G_t} = (1-\alpha)\frac{Y_t}{G_t} = 1, \tag{3.18}$$

using $G_t = \tau Y_t$ and $\tau = 1 - \alpha$. Hence the tax rate that maximizes consumption growth ensures that the marginal product of the public input is equal to 1 which is also its marginal cost.

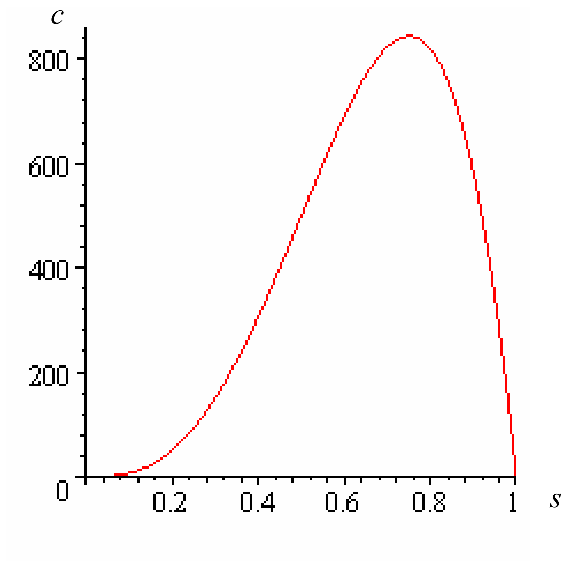

Figure 3.1: Tax Rate and Consumption Growth

This model reveals a positive role for government in enhancing growth through the provision of a public input. It illustrates a sense in which there can be an optimal level of government. Also, if the size of government becomes excessive it reduces the rate of growth because of the distortions imposed by the tax used to finance expenditure. Although simple, this model does make it a legitimate question to consider what the effect of increased government spending may be on economic growth.

The outcome of this analysis should be borne in mind when the empirical analysis is reviewed. In particular, even this basic model is able to demonstrate that taxation used to finance productive government expenditure can have a beneficial effect on the growth rate. Furthermore, if countries optimize in the choice of tax rate (or, equivalently, in the level of government expenditure) then variations in the tax rate will have little effect upon the growth rate around the optimum. This point is discussed further in Section 6.4.

3.5 Innovation

The innovation approach to endogenous growth develops the ideas of Schumpeter (1934) about creative destruction - the description of new products and processes appearing that are superior to existing ones and eventually replace them. The first attempt to formally model this description is attributed to Segerstrom *et al.* (1990) but the most focus has been placed on the work of Aghion and Howitt (1988, 1992). This line of research is surveyed in Aghion and Howitt (1998).

The first aspect of the creative process that has been modelled is the introduction of new intermediate good. Assume that output depends upon labour use and a range of other inputs. Technological progress can then take the form of the introduction of new inputs into the production function without any of the old inputs being dropped. This allows production to increase since the expansion of the input range prevents the level of use of any one of the inputs becoming too large relative to the labour input.

The second aspect is the replacement of existing products by better products Assume that technological progress takes the form of an increase in the quality of inputs. Expenditure on research and development results in better quality inputs which are more productive. Over time, old inputs are replaced by new inputs and total productivity increases. Firms are driven to innovate in order to exploit the position of monopoly that goes with ownership of the latest innovation. This is the process of "creative destruction" which was seen by Schumpeter as a fundamental component of technological progress.

The mechanics of a basic model can be described as follows. Assume that there is a continuum of types of final good available. Final good *i* is produced using a unique intermediate good according to the production function at time *t*

$$Y_{it} = A_{it} x_{it}^{\alpha} . \tag{3.19}$$

In this expression x_{it} is the quantity of intermediate good used and A_{it} is the level of technology. Each intermediate good is supplied by the firm that made the most recent innovation for that intermediate good. Being the sole innovator gives the intermediate supplier a monopoly position.

The research sector for intermediate good *i* employs n_{it} units of labour and innovations arrive at the Poisson arrival rate λn_{it}. When an innovation arrives for good i it raises the technology parameter from A_{it} to $A_t^{\max}$, where $A_t^{\max}$ is the highest attainable technology at time *t*. The firm making the new innovation then has a monopoly position until the next innovation. The maximum attainable technology rises over time at a rate proportional to the total flow of innovations (and hence proportional to the labour employed in research). In a symmetric equilibrium each sector employs n_t units of labour in research and

$$\frac{\dot{A}_t^{\max}}{A_t^{\max}} = b\lambda n_t , \tag{3.20}$$

where *b* is a factor of proportionality.

The level of research in equilibrium equates the cost of labour in research to the expected benefit of making the next innovation. The level of expected benefit is dependent on the return that is earned during the time as a monopolist until the next innovation is made. A change in the value of λ encourages research by making innovations arrive quicker but discourages by reducing the expected tenure as a monopolist. Analysis shows that the overall effect is positive. The size of innovation parameter, *b*, also has both of these effects but overall an increase in *b* will raise growth.

The focus for policy analysis suggested by these models is the effect of taxation on the incentive to innovate. The tax treatment of profit operates on the net return to innovation. A subsidy to R&D reduces the cost of innovation. These observations are the basis of the discussion in Section 9.3.

3.6 Learning-By-Doing

The fourth major approach to endogenous growth is to assume that there are *externalities* between firms which operate through learning-by-doing. This idea has been established in the economics literature at least since Arrow (1962). Investment by a firm leads to parallel improvements in the productivity of labour as new knowledge and techniques are acquired. Moreover, this increased knowledge is a public good so the learning spills over into other firms. This makes the level of knowledge, and hence labour productivity, dependent upon the aggregate capital stock of the economy. Decreasing returns to capital for a single firm (for a given use of labour) then translate into constant returns for the economy.

The policy focus suggested by learning-by-doing is the tax treatment of investment and how policy can encourage investment by firms. This is the subject matter of Section 9.2.

3.7 Other Mechanisms

In addition to these models of endogenous growth it is worth mentioning the role of foreign direct investment (FDI) in the growth process.

FDI that takes the form of physical investment (rather than the form of acquisitions) provides a source of technological improvement for the host country. This will be the case if the investing firm utilizes a level of technology above that currently in use in the host country. Much FDI in practice has taken precisely this form with firms from developed countries locating their most recent technologies in developing host countries. This raises the productivity of labour in the host country and contributes to growth.

For many developing countries FDI is an important source of economic growth and it receives much policy attention. From a world perspective there may be zero-sum elements about these policies but there are private gains. The empirical assessment of the sensitivity of FDI to policy incentives is reviewed in Section 9.5.

3.8 Taxation and Growth

Now that the range of effects has been discussed it is helpful to investigate them further within the context of a model. A simple but informative model for illustrating how a range of tax instruments can affect economic growth is provided in Zagler and Durnecker (2003). This model captures several of the important elements of endogenous growth theory.

Output at time t is determined by the aggregate production function

$$Y_t = X_t^{\alpha} G_t^{\beta} L_t^{1-\alpha}, \tag{3.21}$$

where X_t denotes the quantity of a composite intermediate input. This aggregate is composed of a set of *n* specialized intermediate inputs via the defining relation

$$X_t^{\alpha} = \sum_{i=1}^{n} x_{i,t}^{\alpha}, \tag{3.22}$$

where $x_{i,t}$ is the quantity of intermediate input *i*. The input levels are chosen to minimize the cost of production

$$C_t = (1+\tau_L)w_t L_t + \sum_{i=1}^{n}(1+\tau_{xi})p_{i,t}x_{i,t}$$

$$= (1+\tau_L)w_t L_t + (1+\tau_X)P_t X_t, \tag{3.23}$$

where τ_L is the tax on labour, τ_{xi} the tax on intermediate good *i*, and P_t the aggregate price index with τ_X a corresponding aggregate tax. The necessary conditions for cost minimization can be solved to find that

$$(1+\tau_X)P_t = \left(\sum_{i1}^{n}\left[(1+\tau_{xi})p_{i,t}\right]^{\alpha/(\alpha-1)}\right)^{(\alpha-1)/\alpha}, \tag{3.24}$$

hence

$$x_{i,t} = \left(\frac{(1+\tau_{xi})p_{i,t}}{(1+\tau_X)P}\right)^{1/(\alpha-1)} X_t. \tag{3.25}$$

Each intermediate goods is produced by a different monopolistic firm that maximize profit subject to the demand function (3.25). This leads to the optimal price

$$p_{i,t} = \frac{1}{\alpha}. \tag{3.26}$$

This implies the aggregate price when all intermediate taxes are equal is

$$P_t = \frac{1}{\alpha}\frac{1+\tau_x}{1+\tau_X}n^{(\alpha-1)/\alpha}. \tag{3.27}$$

A concept of physical capital can then be defined by

$$K_t \equiv \sum_{i=1}^{n} x_{i,t} = n^{(\alpha-1)/\alpha}X_t. \tag{3.28}$$

This allows output to be expressed as

$$Y_t = K_t^{\alpha}G_t^{\beta}(nL_t)^{1-\alpha}. \tag{3.29}$$

The equilibrium capital stock can be shown to be

$$K_t = \alpha^2 \left(\frac{1-\tau_Y}{1+\tau_x} \right) Y_t \,. \tag{3.30}$$

This implies that the growth rate is given by

$$\hat{Y}_t = \frac{\beta}{1-\alpha} \hat{G}_t + \hat{n}_t + \hat{L}_t \,. \tag{3.31}$$

A constant fraction, s, of disposable income is saved and used to finance the activities of R&D firms. Denoting the tax on saving by τ_s and that on R&D by τ_{RD} the expenditure on labour for R&D satisfies

$$(1-\tau_s) s Y_t^D = (1+\tau_{RD}) w_t E_t \,. \tag{3.32}$$

Innovations arrive at the rate

$$\hat{n}_t = \phi h_t E_t \,, \tag{3.33}$$

where h_t is publicly provided human capital.

Using there results the per capita growth rate can be found to be

$$\hat{Y}_t - \hat{N}_t = \frac{\beta}{1-\alpha} \hat{G}_t + \phi \frac{s + \alpha s (1+\tau_L)(1-\tau_\pi - \tau_x)}{1+\tau_{RD} + \tau_s + \alpha s (1+\tau_L)(1-\tau_\pi - \tau_x)} \frac{h_t N_t}{n_t} \,, \tag{3.34}$$

where τ_π is the profit tax on the producers of intermediate goods. The first term captures the positive effect that taxation has on growth through the financing of the public input. The second term captures tax effects that operate through changes in the level of innovation. Both the tax on R&D and the tax on saving reduce the growth rate. The tax on R&D reduces innovation and the tax on saving reduces capital accumulation. The other taxes have an ambiguous effect on growth, with the outcome depending on the value of the savings rate, s, relative to the value of $1+\tau_{RD}+\tau_s$.

This model could be further developed by closing the system to relate government expenditure on the productive input and human capital accumulation to tax revenue. As given above it does not have optimization by the household. This could be changed. But it still illustrates the effect of taxation.

3.9 Concluding Comments

The common property of these models of endogenous growth is that there are choices made by economic agents that collectively determine the rate of growth. Furthermore, these choices can be influenced by economic policy. For example, a government can encourage (or discourage) investment in human capital through subsidies to training or the tax treatment of the returns, or subsidies to research and development can encourage innovation, as can the details of patent law. Even in this brief discussion it has become apparent that a range of tax instruments can interact with growth-relevant choices.

The models describe these effects but do not provide any evaluation of their size and importance. In order to provide an evaluation it is necessary to consider the findings of empirical research. Without empirical data it is not possible to engage in a convincing policy analysis.

Chapter 4: Theoretical Predictions

- A policy change can affect the level of output or the growth rate of output
- A widely varying range of estimates have been given for the effect of tax reform in an endogenous growth model with human capital
- There is evidence that a move from an income tax to a consumption tax will raise growth and no evidence against the claim
- Human capital accumulation may be sensitive to changes in the tax system
- The causality between growth and human capital may run in both directions
- Scholarship programs may raise human capital accumulation but reduce saving
- The social return to R&D may be above the private return and innovation greater under a consumption tax than an income tax

4.1 Introduction

Chapters 3 and 4 have described several of the available models of economic growth. The endogenous growth models have some of the channels through which growth can be sustained. What the models do not achieve is any quantification of the effect of changes in the economic environment. This chapter reviews policy experiments that have used the theoretical models to evaluate the consequences of tax changes. The evaluation is achieved through the use of calibration and simulation.

The standard methodology is to solve a model for its steady-state growth path and then simulate the effect of policy changes upon this path. The quantification is achieved by using (in most cases) data from the US to calibrate key parameters, such as the share of capital in GDP. Other elasticities are drawn from the econometric literature or left as free parameters that can be varied to conduct sensitivity analysis. The standard policy experiment is to calculate the effect on the long-run growth rate of a variation in the structure of the tax system. The results describe the potential size of the effects caused be the policy experiment.

This chapter first clarifies the distinction between the level and growth effects of a policy reform. This is necessary to separate the short- and long-run effects of a policy. The basic simulations using a model of endogenous growth through human capital accumulation are then reviewed. This is followed by consideration of a wide range of other models that study different routes to endogenous growth.

4.2 Understanding Effects

Before discussing the results of policy experiments, it is helpful to clarify the distinction between the effect of a change in taxation on the *level* of output and its effect on the rate of *growth* of output. This distinction is illustrated in Figure 4.1 which shows three different growth paths for the economy. Paths 1 and 2 have the same rate of growth - the rate of growth is equal to the gradient of the growth path. Path 3, which has a steeper gradient, displays a faster rate of growth.

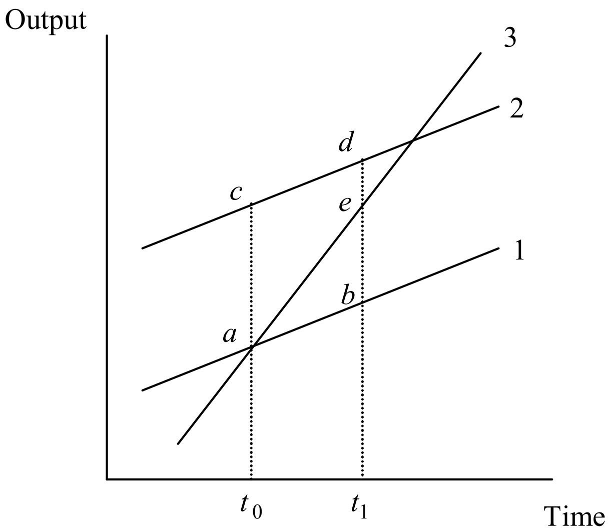

Figure 4.1: Level and Growth Effects

Assume that at time t_0 the economy is located at point *a* and, in the absence of any policy change, will grow along path 1. Following this path it will arrive at point *b* at time t_1. The distinction between level and growth effects can now be described. Consider a policy change at time t_0 that moves the economy to point *c* with consequent growth along path 2 up to point *d* at time t_1. This policy has a *level* effect: it changes the level of output but not its rate of growth. An example of such a policy is the introduction of free child care for working mothers. This policy would increase participation in the labour force and hence raise output. Once the new level of participation was reached the rate of growth would be unchanged.

Alternatively, consider a different policy that causes the economy to switch from path 1 to path 3 at t_0, so at time t_1 it arrives at point e. This change in policy has affected the rate of growth but not (at least initially) its level. Of course, output eventually achieves a higher level because of the higher growth rate. This second policy has a *growth* effect but no level effect. An example might be a change to the accounting rules on depreciation that raises the rate of investment and therefore leads to faster accumulation and a higher rate of growth.

In practice many policy changes will have some combination of level and growth effects. The exact combination is important since only the growth effects have long-term implications.

4.3 Tax Reforms

The appendix to Chapter 2on optimal taxation demonstrated the surprising and strong result that the long-run tax rate on capital should be zero. Although the derivation was undertaken for an exogenous growth model, the result also applies when growth is endogenous. The basic intuition that the intertemporal allocation should not be distorted applies equally in both cases. This is an important conclusion since it contrasts markedly with observed tax structures. For example, in 2002 the top corporate tax rate was 40% in the US, 30% in the UK and 38.4% in Germany. Although Ireland was much lower at 16%, the OECD average was 31.4% (Hindriks and Myles, 2006).

In addition to the level of corporation tax most countries employ an income tax that taxes the return to saving. This lowers the net return earned on assets and results in a disincentive to save. This leads to a lower rate of capital accumulation. Moving from an income tax to a consumption tax removes this disincentive and should raise saving.

The divergence of the observed tax rate from the theoretically optimal rate and the taxation of saving raises the possibility that a reform of the actual system can raise the rate of economic growth and the level of welfare. This question has been tested by simulating the response of model economies to policy reforms involving changes in the tax rates upon capital and labour. Such studies have provided an interesting range of conclusions that are worth close scrutiny.

The basic model for simulation analysis is an endogenous growth model with both physical and human capital entering the production function. The consumption side is modelled by a single, infinitely lived representative consumer who has preferences represented by the utility function

$$U = \frac{1}{1-\sigma} \sum_{t=0}^{\infty} \beta^t \left[C_t L_t^{\alpha} \right]^{1-\sigma} , \tag{4.1}$$

where C_t is consumption and L_t is leisure. Alternative studies adopt different values for the parameters α and σ. The second area of differentiation between studies is the range of inputs into the production process for human capital, in particular whether it requires only human capital and time or whether it also needs physical capital. The analytical process is to specify the initial tax rates, which usually take values close to the actual position in the US, and calculate the initial growth path. The tax rates are changed and the new steady state growth path calculated. The two steady states are then contrasted with a focus placed upon the change in growth rate and in levels of the variables.

Table 4.2 summarizes some illustrative policy experiments and their consequences. The experiment of Lucas (1990) involves elimination of the capital tax with an increase in the labour tax to balance the government budget. This policy change has virtually no growth effect (it is negative but very small) but a significant level effect. In contrast, King and Rebelo (1990) and Jones *et al.* (1993) find very strong growth and level effects. King and Rebelo consider the effect of an increase in the capital tax by 10% whereas Jones *et al.* mirror Lucas by eliminating the capital tax. What distinguishes the King and Rebelo analysis is that they have physical capital entering into the production of human capital. Jones *et al.* employ a higher value for the elasticity of labour supply than other studies. The model of Pecorino (1993) has the feature that capital is a separate commodity to the consumption good. This permits different factor intensities in the production of human capital, physical capital and the consumption good. Complete elimination of the capital tax raises the growth rate, in contrast to the finding of Lucas.

The importance of each of the elements in explaining the divergence between the results is studied in Stokey and Rebelo (1995). Using a model that encompasses the previous three, they show that the elasticity of substitution in production matters little for the growth effect but does have implications for the level effect - with a high elasticity of substitution, a tax system that treats inputs asymmetrically will be more distortionary. The elimination of the distortion then leads to a significant welfare increase. The important features are the factor shares in production of human capital and physical capital, the intertemporal elasticity of substitution in utility and the elasticity of labour supply. Stokey and Rebelo conclude that the empirical evidence provides support for values of these parameters which justify Lucas' claim that the growth effect is small.

Author	Features	Utility Parameters	Initial Tax Rates and Growth Rate	Final Position	Additional Observations
Lucas (1990)	Production of human capital did not require physical capital	$\sigma = 2$ $\alpha = 0.5$	Capital 36% Labor 40% Growth 1.50%	Capital 0% Labor 46% Growth 1.47%	33% increase in capital stock 6% increase in consumption
King and Rebelo (1990)	Production of human capital requires physical capital (proportion = 1/3)	$\sigma = 2$ $\alpha = 0$	Capital 20% Labor 20% Growth 1.02%	Capital 30% Labor 20% Growth 0.50%	Labor supply is inelastic
Jones, Manuelli and Rossi (1993)	Time and physical capital produce human capital	$\sigma = 2$ $\alpha = 4.99$ α calibrated given σ	Capital 21% Labor 31% Growth 2.00%	Capital 0% Labor 0% Growth 4.00%	10% increase in capital stock 29% increase in consumption
Pecorino (1993)	Production of human capital requires physical capital	$\sigma = 2$ $\alpha = 0.5$	Capital 42% Labor 20% Growth 1.51%	Capital 0% Labor 0% Growth 2.74%	Capital and consumption different goods, consumption tax replaces income taxes

Figure 4.2: Growth Effects of Tax Reform

These simulations models produce a variety of results but do not clarify the precise factors that are responsible or provide much insight into the general outcome. A number of analytical results are provided in Milesi-Ferretti and Roubini (1998). The model they consider encompasses most of those described above. It has separate production technologies for physical and human capital. Interestingly, it considers three different interpretations of leisure. In the first interpretation leisure is the usual residual time that is not spent working or studying to raise human capital. This is termed the "raw time" model. The second interpretation, "home production", has leisure produced through a production function using human and physical capital. The third interpretation just uses time and human capital in the production of leisure. This is termed "quality time".

The policy experiments consider the marginal increase of a particular tax with the government budget balanced by a change in the lump-sum transfer to the representative consumer. With this in mind it is not surprising that the results reported in Table 4.3 show that an increase in the tax rates generally reduce the steady-state rate of growth. These calculations would have more force if they determined the growth rate effect of trading one distortionary policy instrument for another.

Model	Capital income	Labor income	Consumption
Raw time	Decrease	Decrease	Decrease
Home production	Decrease	Decrease	No effect
Quality time			Decrease

Table 4.3: Effect on steady-state growth rate

An alternative perspective is provided by Song (2002) who employs a version of the Blanchard overlapping generations model with perpetual youth. The perpetual youth label arises from the fact that each consumer has an equal probability of survival into the next period. The analysis also makes the assumption that all government revenues are spent unproductively so there is no expenditure effect on growth. The argument of the paper is based on the observation that in this model the growth rate of consumption is increasing in the after-tax interest rate and in the share of human wealth in total wealth. A higher rate of tax that lowers the after-tax interest rate can cause growth to rise if it raises the share of human wealth. The paper finds that a higher rate of tax on income (meaning both capital income and labour income) raises the steady state growth rate if and only if the elasticity of factor substitution is greater than 1. This is a strong restriction for the elasticity to satisfy. The result is also shown to extend in a weaker form to an economy where physical capital is used as an input into the learning process.

Although it does not directly address issues in endogenous growth the analysis of Hendricks (2003) still merits reporting. An initial inspection of the Ramsey growth model and the overlapping generations model make them seem entirely distinct. The observation of Hendricks is that the only significant distinction is the degree of inter-cohort persistence. A pure overlapping generations model has no persistence: each consumer lives for two periods and there is no transmission of wealth between generations. The Ramsey model with a consumer whose life is infinite has complete persistence: decisions take into account the entire lifetime trajectory of welfare.

Hendricks explores the claim that persistence affects the tax elasticity in a model encompassing the Ramsey model and the overlapping generations model. The model has two key parameters. One parameter determines whether the bequest motive is operative. The other parameter determines whether there is any link between the human capital of parent and offspring. Varying the values of these parameters allows the transition between Ramsey model and overlapping generations model. Simulations are conducted for five variants of the model. Stronger persistence increases the steady-state tax elasticity of human capital for both wage and capital income taxes. Infinite lives models have higher elasticities than overlapping generations models. The message of the paper is that the specification of the model matters for the tax elasticity that is derived.

Keuschnigg and Deitz (2005) propose a change to the standard income tax system that they claim will promote growth. The proposed tax structure consists of four parts: (i) a progressive tax of labour income; (ii) a flat tax on company profits (both corporate and non-corporate); (iii) deduction of interest payments and normal return to equity from taxable profit of firms; and (iv) a proportional tax at the personal level on all forms of capital income. The rates are chosen to prevent arbitrage through shifting between labour income and profit income for owners of firms. The proposed structure has elements of a dual income tax system because of the different treatments of labour and capital income. The paper proves that this system is neutral with respect to the allocation of capital across sectors.

The effect of the proposal is simulated by placing it within an overlapping generations model. The simulations show that long-run GDP will rise by between 2 or 3 percent if the system is implemented. Note that this is the level of GDP and not the growth, so that it seems to be a large change in tax system for a small change in welfare. Since the model is one with overlapping generations there can be no long-run growth, so the analysis may not really be capturing the full growth effect of proposed tax system revisions.

This section has reported on the range of estimates that have been obtained for the effects of taxation upon growth. Some of the models predict that the growth effect is insignificant, others predict it could be very significant. What distinguishes the models are a number of key parameters, particularly the share of physical capital in human capital production, the elasticities in the utility function and the depreciation rates. In principal, these could be isolated empirically and a firm statement of the size of the growth effect given. To do so and thus claim an "answer" would be to overlook several important issues about the restrictiveness of the model. Variations on these growth models are now considered.

4.4 Components of Growth

The endogenous growth model with human capital accumulation is only one model from the many available. A review is now undertaken of a range of models that either model human capital accumulation in more detail or consider other sources of growth.

4.4.1 Education

An early model of the effect of education is described in Weale (1992). The paper discusses the channels through which education (and fertility) can affect growth and health, and the measurement of the social rate of return to education. It is observed that the high returns that have been calculated for developing economies may represent the consequence of short-term shortages of educated labour and the effect of omitted variables in regression equations. A simple model is provided in which a dynasty chooses the investment in education for each generation and the number of offspring.

The dynastic choice is then embedded in a growth model and a simulation analysis is conducted. The interesting finding of the paper is that the rate of growth is positively related to the chosen amount of education but negatively related to fertility. The major insight is viewed as the link between reduced fertility and increased education.

Trostel (1993) provides a model of investment in human capital that can be interpreted as representing educational choice. Human capital formation requires the investment of time and the investment of commodities. The commodities can either be bought indirectly through the firm of employment or directly on the market. The difference is that when purchased through the firm the goods are subsidized by the tax system (in the sense that they are tax deductible) but led to a lower income since the firm deducts the cost from payment. Goods bought directly for human capital investment are subsidized by the government. The consumer optimizes over all decision variables.

The model is simulated using a parameterization justified by appeal to the econometric literature. Unlike many papers there is a long discussion of the choice of each parameter value. What the basic simulation shows is that the effect of an increase in the proportional income tax is focused on the human capital level not on the labour hours variable. This implies that eighty percent of the adjustment in the product of labour and human capital (*LH* - the effective labour input) is through human capital, *H*. The results are summarized in Table 4.2. All symbols have standard meaning except for *x* which is the proportion of total time spent in human capital formation. The column labelled long-run equilibrium reports the percentage change in the variable for a percentage change in the income tax rate. Hence, an increase in income tax from 40 percent to 40.4 percent reduces human capital by 0.388 percent. The second column is the present value of the time path of percentage changes per present value of percentage change in the tax rate. Hence the discounted average decrease in human capital is twelve percent.

Variable	Long run equilibrium	Present value
H	-0.388	-0.123
y	-1.146	-0.802
xH	-0.480	-0.280
LH	-0.480	-0.291
K	-1.368	-0.597
w	-0.222	-0.077

r	0.667	0.230

Table 4.2: Income tax elasticities

Particular parameterizations of the general model capture alternative models that have been used previously and these have different implications for the response to taxation. From the perspective that the general model is correct Trostel thus concludes that other models can be wrong. In summary, this model provides theoretical evidence that effect of taxation on human capital accumulation can be large. The paper indicates that the change in investment in human capital can be more important than the change in working hours due to taxation. Hence, it is concluded that taxation significantly discourages human capital investment.

The ideas of Trostel are further developed in Heckman *et al.* (1998). This paper studies a version of the Auerbach-Kotlikoff model in which there is individual heterogeneity. There are several human capital (or skill) levels from which individuals make a selection. The heterogeneity is reflected in different individuals making different choices. The central focus of the analysis is the comparison of a progressive labour income tax with flat income and consumption taxes. The basic economics suggests that a move to a flat tax will encourage skill accumulation since it raises the incentive to seek higher income, and the consumption tax will encourage physical capital accumulation since it removes the tax on interest income. A selection of the results is presented in Table 4.3. The change in the stock of human capital for the two tax reforms confirms the intuition that a progressive labour income tax discourages education. In both cases the aggregate level of output increases.

	Percentage change from equilibrium with progressive tax	
	Flat tax	Consumption tax
Stock of physical capital	-0.79	4.65
Stock of college human capital	2.82	1.85
Stock of high-school human capital	0.90	0.08
Aggregate output	1.15	4.98

Table 4.3: Effect of tax reform on capital and output

It will be observed later that the standard cross-country regression reveals a positive relationship between the quantity of schooling in a country and the growth rate. Bils and Klenow (2000) explore the factors that can explain this observation. They build an endogenous growth model with a schooling choice. But the causality between education and growth runs in both directions. Schooling develops human capital, and so raises the rate of growth. In the reverse direction the effect of higher growth is an increase in the return to education, so the investment in education rises. A version of the model is calibrated using UNESCO data on educational attainment. The calibrated model is used to justify the claim that the impact of schooling on growth explains less than one third of observed cross-country correlation between education and growth. Instead, the growth to schooling effect is assessed as being potentially large.

Increased schooling can raise the level of human capital. If this schooling is publicly provided then revenue must be raised to finance the provision. The tax instrument chosen to raise the revenue can introduce distortions into the economy and has implications for the rate of growth. It is therefore not correct to infer that increased public education will necessarily raise growth without specifying the financing mechanism. These issues have been explored in a range of models.

Blankenau and Simpson (2004) observed that theoretical analysis predicts government expenditure on education increases the stock of human capital and should therefore raise the growth rate. However, this effect does not appear to be especially apparent in the data. The reconciliation between these two observations that is offered in the paper is that the taxes imposed to finance educational spending have distortionary effects. The distortions caused by the taxes then result in an offsetting reduction in the growth rate.

This idea is tested by constructing a model with overlapping generations and a range of tax variables (labour, capital, consumption, and output). When a nondistortionary output tax is used to finance expenditure there is a non-monotonic relation between spending and growth, so that growth first rises with spending and then falls. With a consumption tax used instead of the output tax the level of growth always rises with expenditure. The effects of labour and capital taxes are less clear, but cases are found where the relationship between spending and growth is non-monotonic.

The finding of non-monotonicity can be used to help understand the empirical results. The countries observed in a data set may be either side of the divide between growth increasing with spending and growth decreasing with spending. If this is the case it follows that when a regression analysis is undertaken there will be no clear relationship between education expenditure and growth. A similar argument will be discussed again later in connection with the work of Slemrod (1995). The results also confirm that the tax policy used to finance expenditure is also important for the growth consequences.

It is not necessary that education is provided publicly. Since there is a private benefit to human capital accumulation some investment in education (not necessarily the efficient level if there are externalities) will be made and financed privately even if there is no public provision. A government therefore has the choice of either relying on private choices, providing education publicly, or subsidizing private investment.

Ciriani (2007) addresses these different methods of educational financing. The setting is an extension of the model of Zhang (2005) that incorporates random ability shocks on human capital. The random shocks result in workers having different inherited abilities to learn. The human capital of each worker is determined as the product of inherited ability, spending by parent, and average spending in society. Parents are altruistic and care about the human capital of their offspring. This provides an intertemporal linkage.

The paper contrasts three financing systems: (i) private provision; (ii) free uniform public provision financed by an income tax; and (iii) subsidization of private provision financed by an income tax. The results show that subsidization can lead to higher growth than either of the other two in the short run. Subsidization can also lead to higher growth in the long run if the dispersion of inherited ability to learn is sufficiently low. In terms of the points made by Blankenau and Simpson (2004) it is important to observe that Ciriani (2007) determines the spending and tax policies simultaneously, so these result describe the net effects on growth of the government policy.

In the model of Ciriani (2007) all uncertainty is resolved before the human capital choice is made. Krebs (2003) makes the alternative assumption that there is still risk at the time at which the investment decision is taken. This causes there to be a link between the tax system, its interaction with risk, and the choices made.

Krebs (2003) analyzes a model in which households face a choice between investment in physical capital and investment in human capital. The return from physical capital is risk free. In contrast, the return from human capital investment is risky in that there is an idiosyncratic shock each period which can add to, or reduce, the stock of human capital. As a consequence of risk aversion investment is biased toward physical capital because of the risk to the return on human capital. This implies that if a reduction can be secured in the risk on human capital then the level of physical capital investment will be reduced and the level of human capital investment will be raised. A policy aimed at reducing risk can therefore benefit growth since it leads to a more balanced allocation of investment. The analysis shows that this reallocation of investment effect can be so significant that even when a distortionary income tax is used to provide insurance against human capital risks both growth and welfare can increase. The importance of this paper is that it provides a new perspective from which to think about the role of an income tax in affecting growth.

The decision to invest in human capital is affected by the discounted lifetime flow of income. In most analysis only the income from employment is considered in the lifetime flow but, although it is highly discounted at the time most human capital investments are made, the income from social security in retirement is also a factor. Lau and Poutvaara (2006) observe that the social security system affects the private return to an investment decision if the expected flow of social security is dependent upon the flow of income when working. There will also be a link between social security and the equilibrium return through the consequences of individual decisions for the aggregate capital stock. The major finding of the paper is that linkage between social security benefits and contributions made while working raises the level of human capital investment.

The role of public subsidization of education is further developed in Benabou (2002). A model is constructed in which consumers produce using their own labour and accumulated human capital. The equilibrium effect of a progressive income tax and a progressive redistribution to educational expenses are determined. It is shown that the intertemporal distortion caused by the income tax can be offset by other policies which are unanimously supported by the population of consumers. The numerical works trades off efficiency and equity to characterize an optimal interior policy. The unusual feature of the model is that there is no interaction between consumers in the market place. Each agent produces and consumes their own output less what the government subtracts or adds in redistribution. Hence, this is a model of economic activity that has no trade.

In the context of growth theory the use of college scholarship programs can be seen as a method of increasing the accumulation of human capital. The success of the programs in raising human capital is primarily dependent on the responsiveness of the demand for education. Evaluation of the responsiveness is an empirical issue which is discussed in Chapter 8. The issue that is now analyzed is how the means-tested nature of scholarship programs interacts with other economic choices and policies. The point is that the scholarship programs cannot be treated in isolation but must be viewed as part of the overall household decision process.

The analysis of Feldstein (1995a) demonstrates that the structure of college scholarship program can have a negative effect on saving. In this case a program that is designed to provide means-tested assistance to encourage human capital accumulation can damage growth by acting adversely on one of the other sources of growth.

The argument is that college scholarships are assessed on the basis of parents' ability to pay. This takes into account income and assets. The scholarship is reduced as asset holdings increase, so this provides a disincentive to save. Feldstein assumes that the system can be given the simple representation

$$S = \alpha(E - \theta A) + \beta \quad \text{for } 0 \leq S \leq E, \tag{4.2}$$

where S is the scholarship received, E is the cost of college, A is the asset holdings of the parents, α is the rate of adjustment of the scholarship, β is any lump-sum grant received, and θ is the marginal rate of tax on accumulated assets used to calculate the parental contribution. The saving effect comes from the fact that as A rises the value of S falls. This is equivalent to a higher rate of taxation applied to asset holding. An analysis of the lifecycle decision of the parents shows that an increase in θ reduces the optimal A and E. The effect upon E can be interpreted as the choice of a cheaper college. The effect of an increase in α on choices is ambiguous, but it may also reduce A.

The empirical analysis uses data from the 1986 Federal Reserve Board Survey of Consumer Finances and restricts attention to a homogenous group of households (married couple, head between 40 and 50, children under 18 but none in college, annual income positive but not more than \$100,000). Let the annual capital levy on assets under the scholarship program be t. This value is increasing in the level of income. A family with children who will, in total, spend n years in education face an education capital tax of $\theta = 1 - (1 - t)^n$. Because of the behavior of t the education capital tax also increases with income until a maximum is reached, then remains constant until the maximum qualifying income level is reached. Instrumental variable estimation generates the regression equation (with standard errors in parentheses)

$$A = -9{,}934 + \left[\underset{(1.14)}{-2.04} - \underset{(0.60)}{1.41}\,\theta + \underset{(0.026)}{0.076}\,AGE \right] Y, \tag{4.3}$$

where AGE is the age of the household head and Y is household income.

The estimated equation shows that the educational tax has a negative and significant effect upon asset accumulation. A family with income of $40,000 and a head aged 45 with two children differing in age by 2 years would face the maximum annual capital levy of $t = 0.0846$. The assumptions imply $n = 6$ and $\theta = 0.41$. The regression predicts that this family would have reduced asset accumulation by $23,124.

The paper concludes that educational scholarship programs can have major impacts upon the level of saving. The structure of the program provides a disincentive to save. When aggregated over households in the economy the result imply a significant reduction in saving for the economy. There is therefore a conflict between saving and encouraging human capital formation through scholarship programs.

A separate form of interaction is analyzed by Dynarski (2004). An incentive to save for education is provided by 529 Savings Plans and Coverdell Savings Accounts. The basis of these schemes is that the returns to saving are tax free if the withdrawals are used to finance education. The point of the paper is to analyze the interaction of these incentives with the aid packages granted by colleges. The important conclusion is that the interaction means that the marginal tax rate is in excess of 100 percent for some middle income families. This results from aid being withdrawn because of the higher return on the savings plans. The implicit message is that this is should be avoided but the paper does not explicitly address the effect on educational investment.

The accumulation of human capital does not have a single homogenous form. There are different levels of education (primary, secondary, *etc.*) and different forms of training (specific and general). Analyzing the aggregate level of human capital in an economy can overlook some of the finer detail that can influence the rate of economic growth. Most empirical analysis considers only the division into different levels. Some recent work theoretical work has tried to move beyond this to explore the implications of different forms of human capital accumulation.

Krueger and Kumar (2004) note that there has been a widening of the growth differential between the US and Europe. During the 1970s there was little difference in growth rates between the two regions. But through the 1980s, and especially in the 1990s, the US grew consistently faster than Europe. The paper observes that this has occurred during the new "information age" and that the US has been noticeably faster in the adoption of new technology. An explanation is provided as to why this might be so.

The answer proposed is that human capital can take either a general form or a specific form. Two claims then support the analysis. First, the specific form of human capital is the outcome of vocational training. Second, the general form of human capital allows much quicker adaptation to new technology. Evidence is presented to show that Europe has concentrated more on vocational training and the US has concentrated more on general training. The basic component of this evidence is presented in Table 4.4. This shows the division of the secondary education population between general and vocational training. In the US there is no separate vocational stream. The table also reports the entry rate into university. The paper asserts that university provides general training so arrives at the conclusion that the US has much less vocational training than Europe.

	% upper sec. in general	% upper sec. in vocational	University net entry rate
Austria	23	77	26
Finland	48	52	
France	47	53	33
Germany	23	77	27
Italy	28	72	
Netherlands	30	70	34
Sweden	44	53	
EU	42.4	57.6	
United States			52

Table 4.4: Education indicators

A model is constructed which captures these two features. Households choose between specific and general training. General training is costly to obtain. Firms select the rate of adoption of new technologies. It is shown that the model can replicate some of the claims: an economy with relatively more vocational training will not grow as fast as one with general training when there is technological advance. This conclusion is interesting but not absolutely compelling. The US has seen redundancies and has experienced significant costs of adjustment in the move from traditional manufacturing industries to new information technology industries. There is also the fact that the US has probably relied on a considerable quantity of imported labour in the high technology sectors. This is not reflected in the education data presented by the paper. The division of human capital into the two forms also seems unconvincing when one tries to categorize various educational programs into vocational or general.

The analysis of Blankenau (2005) considers how the division of expenditure between lower-level education and higher-level education may affect growth. The model employed has an overlapping generations structure. It is assumed that low-level education is compulsory but high-level education is optional. Part of the cost of high-level education may be funded by the government, but the remainder has to be financed privately. The return to high-level education is an increase in income. The paper is focuses on the best allocation of government expenditure to the two levels of education. The tax instrument used to finance government expenditure is a lump-sum tax on income and so is non-distortionary. It is demonstrated that high-level education should only be subsidized once a critical level of expenditure is reached. Prior to this level being reached all expenditure should be on low-level education. This is not surprising when there are decreasing returns to low-level education, the return to high-level education can be privately captured in higher wages, and there is a perfect capital market so nothing restricts efficient individual investment in high-level education.

4.4.2 Research and Development

The model of endogenous growth through innovation makes clear the importance of research and development (R&D). Aghion and Howitt (1992) emphasize the fact that a competitive market may not generate an efficient outcome because of the externalities associated with R&D. It is these externalities that have motivated research that estimates the private and social returns to innovation. If these are not aligned then there is potential for economic policy to enhance efficiency by countering the effect of the externality.

Jones and Williams (1998) build on the modelling of innovation in endogenous growth models to calculate the social rate of return to R&D and hence to contrast the optimal amount of R&D with the equilibrium amount. The idea used is to take the production function for output, the production function for "ideas" and to use these to consider a variation: reduce consumption today, raise R&D today, reduce R&D tomorrow (to keep future path of ideas the same) and ask how much output goes up. No private individual will wish to undertake this variation (since it is assumed that each is optimizing). But if there are any externalities or distortions society may wish to make the deviation. The social return to R&D is the gain in consumption from this variation. The central feature of the analysis is that the construction of the social return does not depend on market conditions but only upon production possibilities. What the market determines is where on the trade-off between R&D and consumption the economy is located.

The paper proceeds to set out a growth accounting methodology for evaluating the component of total factor productivity generated by R&D. This leads to the change in *TFP* being regressed on the share of R&D expenditure in GDP. The estimated coefficient gives the return. Table 4.5 summarizes results that studies using this methodology have obtained. The variable $\bar{r}$ (own) is the return on privately financed R&D. The variable $\bar{r}$ (used) is the return on R&D in one industry financed by R&D expenditure of another industry. The value of Sum is the social return to R&D. The studies report high estimates of both the private and social return: own R&D has a return on 27 percent and the spillover has a return of about 70 percent, so the social return is 100 percent.

Study	$\bar{r}$ (own)	$\bar{r}$ (used)	Sum	Years
Sveikauskas (1981)	0.17 (0.06)			59-69
Grilliches (1994)	0.30 (0.07)			78-89

Grilliches and Lichtenberg (1984a)	0.34 (0.08)			69-73
Terleckyi (1980)	0.25 (0.08)	0.82 (0.21)	1.07	48-66
Scherer (1982)	0.29 (0.14)	0.74 (0.39)	1.03	73-78
Grilliches and Lichtenberg (1984a)	0.30 (0.09)	0.41 (0.20)	0.71	69-78

Table 4.5: Estimated rate of return to R&D

The major point of the analysis is the observation that the methodology underlying the estimates in Table 4.5 ignores congestion in R&D, intertemporal knowledge spillovers and diminishing technological opportunities. These overlooked components include both positive and negative effects but the paper argues that their net effect must be positive. This implies that the estimates in the table are in fact a lower bound on the social return. The estimated social return is then used to predict the under-investment in R&D. The conclusion is that optimal R&D is two to four times observed R&D.

The measurement of the social return to R&D is also addressed by Comin (2004). It is assumed that innovation is a free-entry industry and therefore must satisfy a zero-profit condition. This can be used to obtain the value of innovations. The argument that there is a limited externality in embodied innovations makes it possible to derive an expression for the social value of innovation. This social value is then used to determine the contribution of innovation to output growth. What is concluded is that this contribution has a very low upper bound. This means that little of the Solow residual (see Chapter 7 for an extended discussion of the meaning of the Solow residual) can be attributed to expenditure on R&D. This is in contrast to the empirical evidence described above. It is concluded that US innovation may be taking place at a socially-optimal rate.

The basis of the Comin approach is to assume that R&D innovations are embodied. Free-entry to R&D implies R&D firms break even, so the cost of resources devoted to R&D must equal the value of newly-developed technologies. It follows that the relationship between the share of resources devoted to R&D and the growth rate of technology is a linear function of the inverse of the market value of an innovation. This presumes that innovators are small. The derivations of the paper yield the expression

$$\text{Contribution of R\&D to productivity growth} = \frac{\alpha}{1-\alpha}\frac{r-\gamma_Y}{\left(\frac{\alpha}{s}\eta^{-1}-(\eta-1)^{-1}\right)}, \quad (4.4)$$

where $1-\alpha$ = labour share in output, $s = R/Y$, R = spending on R&D, γ_Y is the growth rate of output, η is the inverse of the elasticity of substitution between different intermediate goods in production. This is evaluated using the parameters r =

0.07, $\gamma_Y = 0.034$, $\alpha = 0.33$, $r = 0.07$ and plotted in Figure 4.3. The upper line in the figure is for $\eta = 1.2$, and the lower line for $\eta = 1.5$. Note that for both values the graph has a discontinuity for slightly larger values of s. At the R&D intensity observed in the US ($s = 0.2$) the R&D contribution represents only one tenth of the annual growth rate of 2.2 percent. To account for all the productivity growth in the US the R&D intensity must be $s = 4.8$ when $\eta = 1.5$, and $\eta = 8$ when $\eta = 1.2$. These observations led the paper to conclude that much of the growth in *TFP* is unexplained.

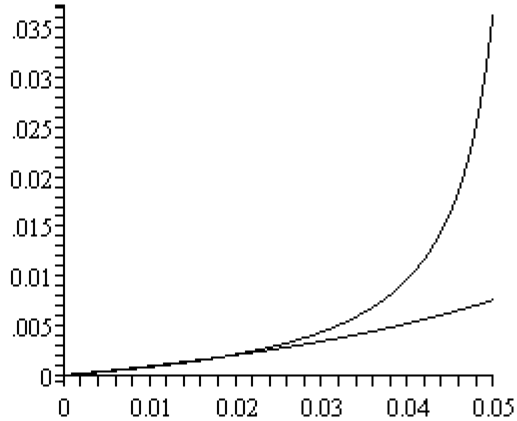

Figure 4.3: Contribution of R&D to productivity growth

An important feature of R&D is that the spillover effects are not contained within national borders. For example, innovation in computing hardware in the US rapidly diffuses across the world. This raises the level of technology in every country that adopts the new hardware. The adoption of technology created elsewhere is likely to be the major source of growth for many countries. Such observations have motivated extension of the innovation model to an international setting.

Howitt (2000) develops the model of Schumperterian innovation by creative destruction to fit within an international setting. The basic structure of the model is that firms invest in R&D and innovations arrive randomly but at a rate influenced by the R&D expenditure. The innovations transfer across countries but the process modelled for this is questionable. The transmission mechanism is that if a country makes the next innovation the level of innovation will be above the maximum achieved anywhere in the world. Hence, an innovation leapfrogs a country to the top of the technology ladder. Implicitly, this is assuming that all countries have access to the best available technology (or at least knowledge of that technology) and can improve upon it by innovation. In practice, a better description would be of countries with a range of technology levels with innovation being with respect to the best level to which they have access. Other than this self-produced innovation there is no other transmission mechanism for technology to diffuse. It might be expected that technology would filter down through trade or through foreign direct investment but these processes are not incorporated within the model.

As a consequence of the assumptions a country that does not spend on R&D simply stagnates. It is claimed that this model generates relationships between growth and economic variables that are essentially the same as for the Solow model but with the inclusion of some additional terms. Hence, the regressions that fit reasonably well with the Solow model do not show that endogenous growth models are inappropriate but in fact may be miss-specified. It is argued that the miss-specification results in an over estimate of the capital share in generating growth. These comments relate to the controversy begun by Mankiw *et al.* (1992) and discussed further in Section reftesendog. The representation of growth is interesting for the debate on endogeneity, but the international transmission mechanism for innovation does not accord with expectations.

Diao *et al.* (1999) present an alternative endogenous growth model that accounts for international spillovers of technology. The model is based on each country possessing an aggregate production function for R&D. Incorporated within this production function are two spillover effects. First, the output of R&D is proportional to the total level of accumulated knowledge with each country. Second, these is an international spillover. The international spillover arises from the trade in investment goods. The purchase of investment goods from abroad is viewed as adding to the total stock of knowledge through the technology embodied in those goods. The model is calibrated to data for Japan and employed to study the effects of trade policy and policies designed to stimulate R&D. It is shown that strategic trade policy does not increase R&D at home significantly, but can increase the spillover effect which in turn raises growth. Conversely, trade liberalization can reduce growth. Policies that directly subsidize R&D are found to have significant growth-enhancing effects at a low net cost to taxpayers.

The potential inefficiency of the competitive equilibrium when there is innovation provides scope for efficiency-enhancing policy intervention. This has led to studies of the effect of tax policies on R&D.

Lin and Russo (2002) compare the consequences of cuts in capital taxation in a model with exogenous innovation to the effect in a model with endogenous innovation. When innovation is exogenous a cut in the capital tax raises the level of saving. When innovation is endogenous a cut in the tax raises innovation as well. The model is then calibrated to fit US data. This exercise suggests that the exogenous innovation model underestimates the effect of tax cuts on innovation.

It is often observed that the private R&D choices of a firm does not into take account the losses imposed on previous innovators nor on possible duplication, so there is potential that R&D may undertaken at too high a level. However, private choices also do not take into account the social return, so providing a reason for R&D expenditure to be too low. Russo (2004) notes briefly some limitations of the empirical work on R&D as a justification for conducting a CGE study to rank the effectiveness of different tax schemes. The model used is based on those of Romer (1990a) and Jones (1995). Labour effort is an input into the advancement of knowledge. There are potential spillover effects, potential duplication effects, and crowding effects. The simulation results that are given emphasis are that: (i) incremental and comprehensive R&D tax credits produce relatively large increases in research effort and welfare; (ii) lower income tax rates and tax credits for downstream users rank next; (iii) investment tax credits for upstream producers are ineffective; and (v) incremental credits dominate comprehensive credits.

4.4.3 Government spending

Government expenditure can be used for consumption or for the provision of a public capital good. The model of Barro shows how growth can be sustained by accumulation of the public capital good. The includsion of this effect in a simulated policy experiment changes the manner in which taxation affects growth.

Baier and Glomm (2001) extend the simulations of Section 4.3. The basic assumption is that the set of productive inputs is expanded to include physical capital, human capital and a publicly-provided input. This provides a positive role for taxation to finance the public expenditure. Government expenditure is divided between investment in the productive input, provision of a utility-enhancing service, and transfer payments. These expenditures are financed by distortionary taxes on capital and labour.

The paper provides some analytical results for the special case of a Cobb-Douglas production function and some simulations. The main results are that the growth rate increases the higher is the proportion of government revenue spent on the productive input relative to the proportion that is redistributed, and that the optimal tax on capital is positive. The positive tax on physical capital is interpreted as recovering some of the return to public capital (or, alternatively, putting a price on public capital for the private firm). Simulations of a CES technology support the result that the growth rate is increasing in the proportion of government expenditure on investment. Holding spending patterns fixed and increasing the tax rate ultimately decreases the growth rate (although it may increase for low tax rates). The paper captures some aspects of the simultaneity between taxation and public expenditure that is apparent throughout the empirical literature.

Many of the policy experiments consider only tax systems with a constant marginal rate. This is typically for reasons of analytical and computational simplicity. An exception to this is the work of Li and Sarte (2003) who analyze the consequences of progressive taxation. The basic assumption is to capture progressivity by a single parameter. To achieve this a progressive tax function is defined by

$$\tau\left(\frac{y}{Y}\right)=\zeta\left(\frac{y}{Y}\right)^{\phi}, \tag{4.5}$$

where ϕ measures the degree of progressivity. This tax function is embedded in two alternative endogenous growth models: Rebelo's model where government spending is not productive and Barro's model where government spending is an input.

The analysis focuses on how changes in taxes affect growth and income distribution and hence revenues via the progressive tax. The central observation is that the marginal rate of tax is endogenous and that more progressive statutory rates do not always imply more progressive effective rate - this can be caused by changes in the income distribution. The simulation analysis reports that the growth effect of a decrease in the marginal rate of tax relative to average rate of tax was positive but small. The size of the effects is summarized in the observation that the changes in US tax laws between 1981 and 1986 contributed at most 0.29 percent to per capita GDP growth.

The effect of switching from a progressive tax system to a flat rate tax system is simulated in Cassou and Lansing (2004). The focus of their analysis is the Hall-Rabushka flat tax proposal to place a single tax rate on all labour income above a threshold and on all capital income after fully expensing investment expenditures. The model has a single representative consumer who chooses physical capital and human capital use to maximize utility. Both forms of capital require investment of resource to be produced.

The simulations consider the consequences of reform from the current US tax system. The first step is to approximate the US system by the average tax rate (ATR) function

$$ATR = 0.2528(\text{Income ratio})^n, \tag{4.6}$$

where n = 0.2144 and the income ratio is defined as income divided by mean income. Other parameters introduced are η which is the degree to which business income is double taxed, and ϕ_k the fraction of investment in physical capital that can be expensed. The outcomes of the policy experiments are shown in Table 4.6 where g_y is the growth rate of output, $\bar{\tau}$ is the mean personal tax rate, and $\bar{\tau}_b$ is the mean business tax rate. All of the reforms raise the rate of growth with the single exception of maintaining progressivity in the tax structure. The greatest increase in growth occurs when the flat tax is introduced but η remains at the value of 1 (complete double taxation of business income). These results are further evidence that progressivity is harmful to growth in these simulation models.

Tax system	Tax rate	g_y
Progressive tax system (US)	$\bar{\tau}_p = 0.253, \bar{\tau}_b = 0.35$	1.800
Baseline flat tax reform	$\bar{\tau} = 0.3437$	1.857
Reform with no change in ϕ_k	$\bar{\tau} = 0.3174$	1.854
Reform with no change in η	$\bar{\tau} = 0.3169$	1.953
Reform with no change in n	$\bar{\tau} = 0.3431$	1.638
Pure consumption tax reform	$\bar{\tau} = 0.3520$	1.878

Table 4.6: Flat-tax reforms

Some further implications of the division of government expenditure between consumption and investment are investigated by Chen (2006). The paper considers an endogenous growth model with a representative consumer. The government can divide its revenue between spending on consumption and spending on a productive input. The paper conducts an optimization exercise and considers the effects of changes in parameters upon the optimal outcome. This exercise is intended to be related to the distinctions between countries and growth rates. The essence of the results is that changes in parameters have a direct effect upon growth and an indirect effect via the re-optimization of the division between consumption and production. This leads to policy changes having stronger growth effects than predicted by models in which the government does not optimize.

4.4.4 Additional issues

There are two further papers worth noting that investigate further features of the growth process.

Palomba (2004) constructs a two-country model. This has overlapping generations of consumers but an *AK* production structure to ensure endogenous growth. The key feature of the model is that capital is internationally mobile between the two countries and locates in whichever country offers the highest net return. Each country levies a source tax on capital invested in that country plus a tax on residents capital incomes regardless of source. These taxes determine the international allocation of capital via the equalization of net rates of return. A variation in tax policy affects both the allocation of capital between countries and the total world stock of capital through the saving decisions of the consumers. The paper claims that a reduction in tax rates can increase the immediate amount of capital by obtaining a greater share of the existing stock, but ultimately led to a fall in the growth rate. Therefore, what appears to be an attractive policy in the short run does not prove to be so in the long-run.

Benabou (1996) provides a detailed survey of the literature relating inequality to growth. Three mechanisms are identified that can generate a causal link between these two variables. First, distributional effects have an effect through the balance of power in the political system. The lower is the income of the median voter the more political support there is for redistribution. Redistributive expenditures can lessen incentives for risk-taking and innovation and reduce growth. Second, imperfections in credit markets prevent the poor from being able to undertake an efficient amount of investment. Because of this, their marginal product is higher than the equilibrium level, which can be exploited by redistribution to aid growth. An increase in redistribution reduces the capital market constraints faced by the poor and allows their investments to move closer to the efficient level. Third, sociopolitical conflict can reduce the security of property rights, which discourages accumulation. A widening income gap gives the poor an incentive to engage in rent seeking. Redistribution addresses both of these issues. For these reasons it is to be expected that there will be a negative correlation between growth and inequality in cross-country data.

The links between fertility and development are studied in Lord and Rangazas (2006). The paper claims that data support the argument that an increase in the schooling of younger children raises fertility as they become more valuable and can add to family income. In contrast, an increase in schooling of older children reduces fertility because it raises the productivity of parents and the extra child income is not needed. The model is applied to long-run data from the US and England. It is also claimed that the move away from household production is also relevant for the changes in fertility. The model used is an overlapping generations one, so the growth component is limited.

4.5 Summary

This chapter has reviewed the contributions of a wide range of theoretical models. Simulation of the basic endogenous growth model with human capital accumulation produced a widely varying set of predictions. Amongst these predictions there is one element of constancy: none of the models contradicted the claim that a consumption tax will increase growth. It was also supported when more detailed modelling of the human capital decision was introduced. This is a result that will recur frequently in the review of empirical research.

The results also demonstrated that there can be two-way causality between the choice and growth. In particular, an increase in human capital accumulation raises growth and increased growth provides a greater incentive for human capital accumulation. This two-way causality is important when the results of growth regressions are discussed.

Educational scholarship programs are an example of a policy that at first sight appear only to be advantageous for growth. Closer inspection reveals that the means-tested structure of the programs gives a disincentive to save because of the rate of withdrawal with respect to asset accumulation. Human capital rises, but the net effect on growth is uncertain if saving falls.

Finally, there are good arguments that the social benefits of R&D exceed the private benefits. This provides an argument for subsidizing R&D with the intention of raising growth. The theoretical results also indicate that R&D may be sensitive to taxation. This later claim needs to be confronted with empirical evidence.

Part 3
Aggregate Analysis

Chapter 5: Growth Regressions

- Growth regressions analyze the effect of a wide range of economic and non-economic variables on the growth rate of output
- The early literature claimed several variables were significant for growth
- Evidence supported the convergence hypothesis and showed government consumption expenditure was harmful for growth
- Extreme bounds analysis reveals most variables to be fragile

5.1 Introduction

There is a substantial body of literature that seeks to identify from data the factors that determine the rate of growth. This line of research was pioneered by Barro (1991) and the general methodology now goes under the name of *Barro growth regressions*. The methodology has developed as the research has been undertaken but the conclusions (and even the methodology) remain contentious. This chapter describes the major findings of the growth regression literature and the conceptual issues that arise.

The general form of these regressions is that the growth rate of GDP is taken as the left-hand side variable in a regression. The variables on the right-hand side are selected from a very wide range of potential regressors. These range from economic variables, such as ratio of investment to GDP, to non-economic variables such as political rights and violent wars. The non-economic variables are included to capture the stability of the political environment of each country. The data are typically taken from the Summers and Heston (1988) data set and its later developments. This data set covers a large cross-section of countries and attempts to ensure consistency of definition and measurement across countries and across time.

Plosser (1992) provides a very useful table that illustrates the basic issues involved. The table summarizes the basic data on countries and the correlation between a number of variables and the growth rate of GDP. This is reproduced as Table 5.1 below. The statistics are presented for all 97 countries in the sample, and for a partition of the total set into fast-growth and slow-growth countries. The table shows that fast-growth countries have a higher investment to GDP ratio, lower inflation, engage in more trade, and have greater school enrolment rates. Slow-growth countries have faster population growth and more political instability. Initial per capita GDP in 1960 is positively correlated with growth which runs counter to the convergence argument described in Section 2.4. The essence of the growth regressions is to test whether these correlations can be supported by formal statistical significance tests of explanatory power.

	Overall average $n = 97$	Slow growth $< 0.5\%$ $n = 23$	Fast growth $> 3.5\%$ $n = 14$	Correlation with GDP growth rate
Real per capita GDP growth 1960-89	2.03%	-0.26%	4.88%	1.00
Investment share of GDP	.21	.17	.26	.61
Share of government consumption in GDP	.15	.15	.14	.10
Inflation rate	23.00%	42.11%	7.90%	-.17
Standard deviation of inflation rate	52.38	137.19	5.68	-.16
Exports as a share of GDP	.28	.24	.35	.30
Imports as a share of GDP	.33	.30	.40	.31
Secondary school enrolment rate 1960	.21	.06	.34	.41
Primary school enrolment rate 1960	.74	.44	.98	.54
Population growth	2.06%	2.55%	1.26%	-.36
Revolutions and coups per year	.20	.35	.12	-.37
Real per capita GDP in 1960	$1840	$889	$1968	.20

Table 5.1: Growth characteristics 1960 - 1989

5.2 Barro Regressions

Barro (1991) analyzed a cross-section of 98 countries using the data from the period 1960 - 1985. This analysis is worth describing in detail since it marked the start of a considerable body of literature. Several different specifications of the basic regression were run. Overall, the results showed that the growth of per capita GDP is positively related to the initial level of human capital and negatively related to the initial level of per capita GDP. This second observation is usually taken as evidence of convergence: countries with lower initial GDP grow faster than those with higher initial GDP, so there must be convergence. This demonstrates how the inclusion of further variables is able to reverse the sign of the simple correlation reported by Plosser (1992). Growth was also shown to be inversely related to the share of government consumption in GDP and positively related to the variables measuring political stability.

A flavour of these results can be obtained by reporting Barro's regression No. 1. The fitted regression equation is

$$\begin{aligned}\gamma_{y6085} = &\underset{(0.0066)}{0.0302} - \underset{(0.0012)}{0.0075}\, GDP60 + \underset{(0.0079)}{0.0305}\, SEC60 \\ &+ \underset{(0.0056)}{0.0250}\, PRIM60 - \underset{(0.028)}{0.119}\, g^c / y - \underset{(0.0063)}{0.0195}\, REV \\ &- \underset{(0.0155)}{0.0333}\, ASSASS - \underset{(0.0053)}{0.0143}\, PPI60DEV\ , \qquad (5.1)\end{aligned}$$

where the standard errors are in parentheses. The variable γ_{y6085} is the annual average growth rate from 1960 to 1985. *GDP*60 is the level of per capita GDP in 1960, *SEC*60 the 1960 secondary school enrolment rate, *PRIM*60 the 1960 primary school enrolment rate, g^c / y is government consumption spending, *REV* is the number of revolutions and coups per year, *ASSASS* is the number of assassination per million population per year and *PPI*60*DEV* is the deviation of the 1960 purchasing power parity value for the investment deflator from the sample mean.

The interpretation of these variables is that *GDP*60 is included in the regression to capture the convergence hypothesis that low income countries will grow more rapidly than higher income countries. The basis of this claim is the Solow model of exogenous growth. If all countries have the same production technology those with a lower capital labour ratio will observe a higher marginal product of capital and hence higher gains from additional investment. The variables *SEC*60 and *PRIM*60 are included to capture the role of human capital. As suggested by endogenous growth theory the accumulation of human capital can overcome the decreasing returns to capital in the Solow model and ensure continuous growth. The estimated coefficients show that increased human capital implies faster growth and that higher GDP in 1960 implies lower growth given equal levels of human capital. The coefficients can be interpreted as supporting the concept of β-convergence as defined in Barro and Sala-i-Martin (1995).

The negative coefficient on the government expenditure variable has several interpretations. It is important to observe that this is consumption expenditure by government, so that this does not conflict with the modelling of productive government expenditure raising growth. The negative value may demonstrate that government spending is somehow purely wasteful, but note that in many of the countries in the sample a significant fraction of the government consumption expenditure will be upon education which is already controlled for in the regression. It is also possible that government spending is just a proxy for the entire set of government non-price interventions. These include, for example, employment legislation, health and safety rules and product standards. It may be these non-price interventions, not the level of expenditure, that are responsible for reducing growth. The government budget constraint also means that for every expenditure made by government there is a corresponding item of taxation or borrowing to provide finance. The negative sign could be capturing the distortionary consequences of the financing. More will be said about how government size and taxation is related to economic growth in the next chapter.

The policy implications of this regression are that increased education will raise growth, subject to the caveat that this may raise government spending which has the opposite effect, and the economic stability is important for growth. The effects of educational expenditure are discussed from an alternative perspective in later chapters. At this point it is worth noting that there are significant questions to be raised about the interpretation of the human capital variable that enters these regression equations. In terms of the theory of endogenous growth human capital measures the level of skill in production activities. It is not immediately clear that the proportion of population in education is a good measure of this skill. The literature on human capital has distinguished between specific and general training. Measures of primary and secondary education are more likely to contribute to general training rather than specific training. If it is specific training that raises the productivity in employment then the education measures will not capture what is really relevant for human capital.

More recent research by Loayza and Soto (2002) in a Central Bank of Chile report provides a table of growth rates for various regions and the result of a Barro growth regression. This regression confirms with the standard results reported above. Keller and Poutvaara (2005) add both human capital and R&D into the standard growth regression framework. They show that for the non-oil producing and non-OECD countries the coefficients on physical capital, human capital and R&D are significant and positive both for income and growth.

5.3 Robustness of Coefficients

The literature on growth regression has identified a wide range of variables that one or more regression has found to be correlated with the growth rate. Loayza and Soto (2002) provide a discussion of the theory behind the inclusion of some of the most common variables. However, the theory provides limited guidance on what should be included, and even less on which variables can be excluded. In addition, the greater the number of variables that are included as explanatory variables the greater is the likelihood that some subset of variables will be highly correlated with each other thus making it difficult to disentangle the individual effects. This raises the issue of how to refine the regressions and identify the variables that need to be considered.

In a paper of fundamental importance Levine and Renelt (1992) demonstrated the basic deficiency of growth regressions. Their work took two existing papers (Barro (1991) and Kormendi and Meguire (1985)) and placed all the variables found to be significant in these papers into a single regression. When included together all of the variables became insignificant. This finding was used to motivate the use of extreme bounds analysis, a technique introduced by Leamer (1983). Extreme bounds analysis conducts a regression with a set of basic regressors, then the regressor of interest, then includes a further set of possible regressors. The latter variables are chosen from the set of potential regressors to obtain the maximum and minimum values of the estimated parameter on the variable of interest. The regression is termed *fragile* if the coefficient on the variable of interest switches from significant to insignificant as the set of regressors is changed or if the estimated parameter changes sign. Further details are given in the appendix to this chapter.

Levine and Renelt use four basic variables in all regressions. These are all supported as relevant by the theoretical analysis of the Solow growth model. These variables are the investment share of GDP, the initial level of GDP per capita in 1960, the initial secondary-school enrolment rate, and the average annual rate of population growth. In implementing the extreme bounds analysis Levine and Renelt restrict attention to the inclusion of only three additional regressors but still find almost all variables are fragile. The only variable that is not fragile is the ratio of investment to GDP for the growth regression. The analysis is repeated for an investment regression and the only variable that is not fragile is the ratio of trade to GDP. There is also some weak evidence of conditional convergence. That is, the parameter on initial GDP is negative in the regression for growth. This paper was the starting point for all of the later literature since it introduced the extreme bounds analysis and the concept of a fragile coefficient.

The problems inherent in growth regressions are explored further in Levine and Zervos (1993). Their discussion begins with a summary of the statistical problems. First, the data may be inaccurate and inconsistent. These problems are particularly relevant for growth regressions that use data from a large number of countries with differing techniques for collecting data and defining variables. Second, the data may not be drawn as a random sample if there are fundamental differences between countries. Third, there is the problem of averaging the data across a number of countries and over a time interval in which many factors are likely to have changed. There are also limitations in the use that can be made of the regressions. The regressions do not demonstrated causality but only correlation. Furthermore, the results cannot be interpreted in policy terms because many of the variables do not link directly with policy instruments.

The paper provides a simple discussion of extreme bounds analysis and the methodology for testing whether a variable has a robust relationship with growth. It is concluded that only the state of financial development and the black-market premium have a significant effect, and that other variables have a relationship that is fragile. However, it is not clear what the black-market premium is capturing. In summary this paper paints a very negative picture of the literature on growth regressions.

There are two conclusions that can be drawn from this discussion. The first is the obvious one that in fact only a very small number of variables are correlated with economic growth. The extreme bounds test reveals that most of the reported correlations are fragile and possibly an artefact of the choice of conditioning variables. The second argument that can be made is that the extreme bounds test is too strong. Under this second interpretation it is the test that is rejected and not the correlations or the methodology.

Two reasons for rejecting the extreme bounds test are provided in Sala-i-Martin (1994). The paper observes that over 50 variables have been found to be correlated with growth in the literature but before these can be taken as a guide to policy the Levine and Renelt (1992) criticism has to be addressed. The view of Sala-i-Martin is that the point estimates of the coefficient must follow a distribution as the conditioning set is changed. He then observes it is unlikely that the domain of the distribution is only positive or only negative. This suggests that the extreme bounds test may be too strong and what really matters is the distribution of the estimator and whether it is concentrated on a narrow subset of the domain. Also, it is observed that Levine and Renelt always find some set of policy variables that matter. It is proposed that the issue is the correlation of the policy variables which are all different imperfect measures of some underlying economic picture - such as high inflation distorted trade and repressed financial sectors all being present simultaneously. Hence, it is not that policy does not matter but that the data cannot precisely identify which policy.

Sala-i-Martin (1997a, b) implements an alternative method of determining which coefficients have a significance that survives regardless of the choice of other regressors. This alternative method is to run many regressions to obtain a distribution for the estimated coefficients and then look at how much weight in this distribution lies on either side of the origin. This can only be implemented by making an assumption about the distribution of the coefficients. Both the normal distribution across models and a non-normal distribution are considered. In the normal case the mean of the sample is constructed by calculating a weighted average using the likelihood of the regression as the weight. Then the variance is computed using the same weights. In the non-normal case for each regression the area under the density function to the right of 0 is calculated then the weighted average of all these densities is found. This is repeated for unweighted average to avoid the problem that spurious regression caused by endogenous regressors may assign too much weight to bad regressions. Then the procedure of Levine and Renelt is repeated using some of the regressor in all equations, one variable of interest and three drawn from the set. Sala-i-Martin found 63 variables in the literature that he chose to use (he claims more are available) plus average growth rate of GDP between 1960 and 1992. For the three fixed variables he chooses level of income in 1960, life expectancy in 1960 and primary school enrolment rate in 1960. The average investment rate was given a special role, as it appears in one set and not in another.

The results show that of the 59 variables (62 less three fixed) 58 fail the extreme bounds test in the sense that coefficient range spans zero. The one exception is the fraction of population following the Confucian religion. However, this is most likely just a dummy for East Asian countries. A larger number of variables were significant 90 or 99 percent of the time. In fact, 22 of the 59 variables have over 95 percent of their distribution located either to the right or to the left of 0. The full list along with their average estimated coefficient is given in Table 5.2 in order of significance (Equipment investment being the most significant). The most important observation is that government spending (including investment) does not appear as one of these, nor do any measures of financial sophistication. The weighting process does not seem to have much impact. The fixed variables that appear in every regression were tested and found to be significant in most regressions.

Variable	Coefficient
Equipment investment	0.2175
Number of years an open economy	0.0195
Fraction Confucian	0.0676
Rule of law	0.0190
Fraction Muslim	0.0142
Political rights	-0.0026
Latin American dummy	-0.0115
Sub-Saharan Africa dummy	-0.0121
Civil liberties	-0.0029
Revolutions and coups	-0.0118
Fraction of GDP in mining	0.0353
SD black market premium	-0.0290
Primary exports in 1970	-0.0140
Degree of capitalism	0.0018
War dummy	-0.0056
Non-equipment investment	0.0562
Absolute latitude	0.0002
Exchange-rate distortions	-0.0590
Fraction Protestant	-0.0129
Fraction Buddhist	0.0148
Fraction Catholic	-0.0089
Spanish colony	-0.0065

Table 5.2: Mean coefficients

5.4 Further Work

The have been several developments of the method of growth regression to take account of some of the difficulties noted above. These developments have used alternative estimation methods or restricted attention to a limited range of countries.

Folster and Henrekson (2001) argue that analysis of the relationship between growth and the size of government should be restricted to countries in similar wealth ranges. This argument is based on an application of Wagner's law that the demand for public sector goods depends on income and the stage of development. This argument is given support by the observation that the composition of expenditure is different between rich and poor countries. Hence, the paper focuses upon a sample of OECD countries.

The initial step is to regress the growth rate on the investment share in GDP, the growth rate of the labour force, the growth rate of the number of years of schooling, initial income and then two measures of government size (total taxes as a share of GDP and total expenditure as a share of GDP). This regression is undertaken for a pure cross-section of OECD countries using average growth rates and average values of variables over the period 1970 - 1995. In this regression the government size variables are insignificant.

The question is raised of why growth regressions average over the long run. One possible advantage of averaging is that it eliminates short- and medium-term effects such as business cycles. However, averaging has numerous disadvantages. First, simultaneity problems arise in that government size may be correlated with GDP for demographic reasons. Second, tax policy may be endogenous with high taxes maintained if growth is good. Third, averaging discards all information on within-country variation.

The paper therefore suggests the use of panel methods but with 5 year averages in order to avoid lag problems. Fixed country effects are accounted for by using dummies. Period dummies are also included to remove the spurious correlation because most countries have seen falling growth. The panel estimation reveals a highly significant negative effect for government expenditure. If the expenditure ratio increases by 10 percent of GDP then growth is lower by 0.7 - 0.8 percentage points. The estimate is subjected to an extreme bounds robustness test and expenditure is found to have a robustly negative coefficient.

The analysis of Folster and Henrekson (2001) is severely criticized in Agell *et al.* (2006). Three issues are raised. First, the work of Folster and Henrekson switches from actual growth to potential growth in their regressions and do not make this clear. Second, the authors of the reply cannot replicate the results, nor can Folster and Henrekson recover the data they use. Third, there are problems with the econometric specification. Folster and Henrekson use two-stage least squares but Agell *et al.* claim that they do not instrument properly.

Agell *et al.* also offer some comments on a number of problems with the general methodology of growth regressions - omitted variables, measurement errors, reverse causation, nonrandom sample selection – and looks at reverse causation and nonrandom sample selection in the context of Folster and Henrekson. Reverse causation refers to public sector causing growth, and growth causing the public sector. This reverse causality should be controlled by instruments. Using this technique Agell *et al.* generally find that the effects of the tax share and the expenditure share are insignificant and unstable across specifications in the correct regressions. The nonrandom sample selection problem is the addition of rich countries to the sample. These are non-random so invalidating results.

Folster and Henrekson (2006) dispute the findings of Agell *et al.*, arguing that it is based on only one sample and uses weak instruments. It is also contended that the instruments chosen by Agell *et al.* are weak and do not solve the simultaneity issue. Folster and Henrekson continue to claim that the strongest result of their paper does show a robust negative correlation between government size and the rate of growth.

Sala-i-Martin *et al.* (2004) develop a further method for aggregating regression coefficients across different regressions. This uses a Bayesian approach. The Bayesian approach begins with a specification of the prior distributions of the relevant parameters conditional on each possible model. The number of variables in the growth regressions makes this impractical since this number is so large. This has the consequence that implementation of this approach begins from an arbitrary set of priors. The method in this paper (BACE) combines averaging across models with OLS estimation. The paper provides a construction for updating the prior beliefs into posterior beliefs which is developed on the basis that the data become very informative. This leaves the problem of providing priors which is solved by choosing a mean model size with the probability attached to a model declining if it becomes larger or smaller than the mean. The alternative models were then sampled using the priors initially and then the posteriors. The data employed 67 variables from the usual range.

For a model of size 7 this generates 18 variables with a posterior probability higher than the prior probability. These are the ones that the data are suggesting should be included. The paper also reports the fraction of regression for which the absolute value of the *t* statistic for these variables is greater than 2. Table 5.3 summarizes the main results. The first column describes the explanatory variables. The second column gives the posterior mean coefficient on the variable from the regressions in which it was included. The final column gives the fraction of regressions for which its *t* statistic was greater than 2. The final column makes clear the fact that regression models can be found in which each variable would be judged as fragile by extreme bounds analysis.

Variable	Posterior mean conditional on inclusion	Fraction of regressions with |*t* stat.| > 2
East Asian Dummy	0.021805	0.99
Primary schooling 1960	0.026852	0.96
Investment price	-0.000084	0.99
GDP 1960 (log)	-0.008538	0.30
Fraction of tropical area	-0.014757	0.59
Population density coastal 1960s	0.000009	0.85

Malaria prevalence 9n 1960s	-0.015702	0.84
Life expectancy in 1960s	0.00088	0.79
Fraction Confucian	0.054429	0.97
African dummy	-0.014706	0.90
Latin American dummy	-0.012758	0.30
Fraction GDP in mining	0.038823	0.07
Spanish colony	-0.010720	0.24
Years open	0.012209	0.98
Fraction Muslim	0.012629	0.11
Fraction Buddhist0.021667	0.021667	0.90
Ethno linguistic fractionalization	-0.011281	0.52
Government consumption share 1960s	-0.044171	0.77

Table 5.2: Significance of variables

The paper then proceeds to test models of different sizes. The basic conclusion from this analysis is that not much changes. The basic 18 in the table remain at the top for all sizes with the exception of 5: malaria, Spanish, years open, ethno linguistic, government consumption share. These could be a catch-all for other effects. The conclusion is that this supports previous Sala-i-Martin work and is less negative than Levine and Renelt.

Bhargava *et al.* (2001) look at the effect of health on growth rates. This is done by using the adult survival rate (*ASR*) as a regressor in a growth regression. The data for the analysis is taken from the Penn World Tables and the World Development Indices of the World Bank. These provide two sets of slightly different regression results. The education series are taken from Barro and Lee (1996). The estimation used panel data at 5-year intervals (1965, 1970, 1975, 1980, 1985, 1990) for 92 countries.

What the econometric analysis reveals is that increased *ASR* is likely to raise economic growth for poor countries. Moreover, there does not seem to be a reverse causality from growth rate to *ASR*. For high-income countries an increase in *ASR* reduces the growth rate. It would seem that *ASR* is proxying the distribution of population in countries with different income. For the low-income countries an increase in *ASR* keeps the ratio of workforce to young high. In rich countries an increase in *ASR* raises the number of retired to the number working. This simple mechanism explains the growth effect of *ASR*. A sample of the results is reported in Table 5.3. This regression treats lagged GDP as a fully endogenous variable and appears to be their preferred specification.

Constant	0.407 (0.069)
Tropics	−0.012 (0.0049)
Openness	0.028 (0.005)
Log of fertility rate lagged five years	−0.028 (0.008)
Log of investment/GDP ratio lagged five years	0.014 (0.0029)
Log of adult survival rate lagged five years	0.358 (0.114)
Interaction between lagged adult survival rate and GDP	−0.048 (0.016)
Log of GDP lagged five years	−0.041 (0.008)
GDP at which partial derivative of GDP growth rate with respect to lagged adult survival rate is zero	1714

Table 5.3: Results from regression of GDP growth rate

Standard errors in parentheses

Human capital can be measured either by its stock or by its rate of accumulation. Middendorf (2006) has tested the performance of these measures in a growth regression for a subset of the OECD countries. The methodology is to use panel data methods with country-fixed effects and time-fixed effects. The results obtained using OLS regression show that average schooling (the stock variable) is significant and has a positive coefficient. The change in schooling (the accumulation variable) has a negative but insignificant coefficient. Instrumental variable estimation is then tried to account for endogeneity of regressors. Average schooling then becomes insignificant and the sign on the investment ratio is unstable. Middendorf suggests that these effects are indicative of poor instrument choice.

5.5 Observations

Brock and Durlauf (2001) take the criticisms even further. First they criticize the open-endedness of the theory. Observe that Durlauf and Quah (1999) count over 90 variables used, but the data sets have at most 120 countries so the chance of getting firm inferences is difficult. This also emphasizes how collinearity of variables can render coefficients insignificant. When many variables are included collinearity is very likely to arise which undermines the method of Sala-i-Martin (1997) since there will be some regression for which the effect of the variable is not robust. The regressions also rely on parameter homogeneity. However, with the number of countries being very large and the countries being very diverse it is unlikely that parameter homogeneity will hold. Regressors may be endogenous rather than exogenous and the instruments used may not be good choices. This point is illustrated by showing that the Easterly and Levine (1997) result on ethnic diversity reducing growth in sub-Saharan Africa is supported even when model uncertainty is taken into account and is strengthened when parameter homogeneity is permitted. Overall the paper provides a strong criticism of existing research but gives some evidence that it is possible to move forward.

5.6 Conclusions

In terms of economics what have we learnt? From the Sala-i-Martin *et al.* (2004) we learn that the East Asian dummy performs well - but that is predictable. The same comment can be made on the ethnic diversity variable from Easterly and Levine (1997). Schooling does well too, as does the convergence hypothesis. Beyond that we have not learned much that is economically useful for conducting any policy decisions. Ultimately this line of research is a dead end if the aim is to understand what causes growth so that we can improve the situation.

To close this chapter it is worth drawing attention to the argument of Brock and Durlauf (2001) that historical studies may inform us of more than the econometric analysis of anonymous data. The discussion of growth accounting in Chapter 7 will show that the path to growth has differed between countries. Some have grown through capital accumulation, others through innovation. There are clearly many other distinctions between individual countries. These differences are unlikely to be apparent in aggregate data. Instead, detailed historical country study is more suitable for bringing the details to light.

Appendix on Extreme Bounds Analysis

The method of extreme bounds analysis is used to test the sensitivity of egression estimates to the choice of conditioning variables. As described by Leamer (1983, 1985) there are many regression equations that have equal theoretical legitimacy. The difficulty for the investigator is to choose between the candidates. One important consideration in this choice is that he estimated coefficients are robust to different selections of conditioning variables.

Assume that we wish to estimate which variables are robustly correlated with economic growth. The data set is divided into two sets of variables. The first are those which have proved to be basic in explaining economic growth such as the share of investment in GDP. This set of variables is labelled I. The second set of variables comprises those that are potentially important for explaining growth. These could, for example, have been indicated as important in previous econometric studies.

Next we identify our variable of interest, denoted M. This variable is included in a base regression along with the set of variable I. Hence the regression

$$y = \alpha + \beta_i I + \beta_m M + u\,, \tag{5.2}$$

is estimated. Here *I* is a vector of the basic variables and β_i is a corresponding vector of parameters. This establishes an initial estimate of β_m.

This leaves the remaining pool of potential regressors. Then the regression

$$y = \alpha + \beta_i I + \beta_m M + \beta_z Z + v\,, \tag{5.3}$$

is run for every subset of variables *Z* from this pool. What we are hoping to find is that the estimated value of β_m will remain significant and of the same sign for all choices of *Z*.

More formally, the maximum and minimum values of the estimated coefficient $\hat{\beta}_m$ over all choices of *Z* are then found that are significantly different from zero at the 5% level. This is checked by adding two standard deviations to the maximum and minimum values estimated.

If β_m is significant for all choices of variables *Z* and $\hat{\beta}_m$ plus or minus two standard deviations retains the same sign then the estimated partial correlation of this variable with economic growth is said to be *robust*. The estimated parameter is *fragile* if the value changes sign or becomes insignificant.

The point of this method is that if there is really a relationship then the parameter estimator should be robust. A fragile parameter estimate is more likely to be an artefact of the data. Further discussion can be found in Levine and Renelt (1992).

Chapter 6 Tax Regressions

- The growth rate and the level of taxation appear uncorrelated in country-specific data
- Progressive tax systems create difficulties for defining an empirical marginal rate of tax
- In cross-country data there is a negative correlation between the tax rate and the growth rate
- There is weak evidence from regression analysis that the marginal rate of tax is negatively related to growth
- There is mixed evidence from regression analysis on whether it is personal income taxes or corporate income taxes that are responsible for the negative relation

6.1 Introduction

The early literature on growth regressions presented an optimistic picture of how an explanation of growth could be obtained. This optimism was lost when the robustness of coefficient estimates was challenged. The set of robustly significant variables was eventually reduced to a very small number whose nature give little insight into how policy might affect growth. It is notable that the regressions described in Chapter 5 contained very limited detail on the government sector. An aggregate measure of expenditure was considered but no measures of the tax burden. The focus of this chapter is placed on growth regressions that include one or more variables representing taxation. The regressions investigate the effect of the level of taxation and the structure of the tax system.

Taxation can have both a negative and a positive effect on growth. The negative effect arises from the distortions to choice and the disincentive effects. The positive effect arises indirectly through the expenditures financed by taxation. The endogenous growth model with a public good as an input provided a positive channel through which taxation could raise growth. The relationship was not monotonic because increases in the tax rate above the optimum would reduce the growth rate. In practice, economies could be located on either side of the optimum. Similarly, the evidence from the simulations provides a wide range of estimates for the effect of taxation upon economic growth from negligible to significant. Since the theory is so inconclusive, it is natural to turn to the empirical evidence.

6.2 Basic Evidence

At first glance, a very clear picture emerges from long-run historical evidence for individual countries: tax revenue as a proportion of gross domestic product rose significantly in all developed countries over the course of the last century, but the level of growth remained relatively stable. This suggests the immediate conclusion that, in practice, taxation does not affect the rate of growth. Data to support this claim is displayed in Figures 6.1 and 6.2. Figure 6.1 plots the growth rate of US gross domestic product and federal government tax revenue as a percentage of gross domestic product since 1930. Trend lines have been fitted to the data series using ordinary least squares regression. The two trend lines show a steady rise in taxation (the upper line) and a very slight decline in the growth rate (the lower line). Although the variance of the growth process reduces after 1940, statistical tests on US data have found no statistical difference between the average rate of growth prior to 1942, and after 1942. The data for the UK in Figure 6.2 tell a very similar story. The trend lines show an increase in taxation but, in contrast to the US, an increase in the rate of growth.

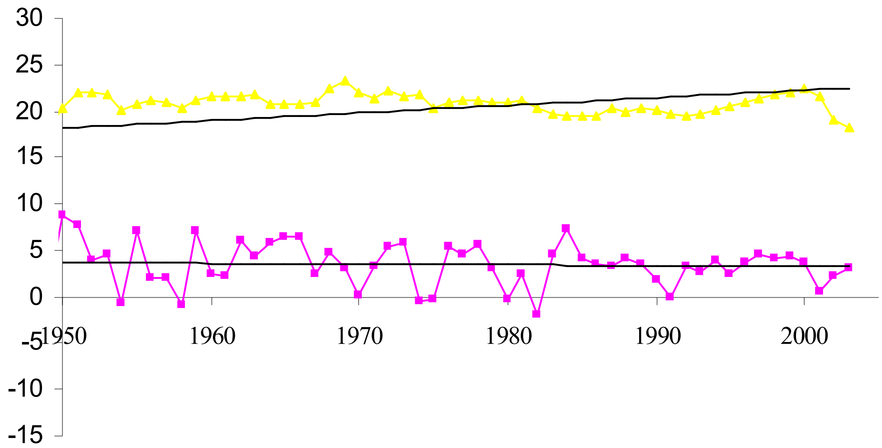

Figure 6.1: US Tax and Growth Rates

Source: US Department of Commerce: www.bea.doc.gov/

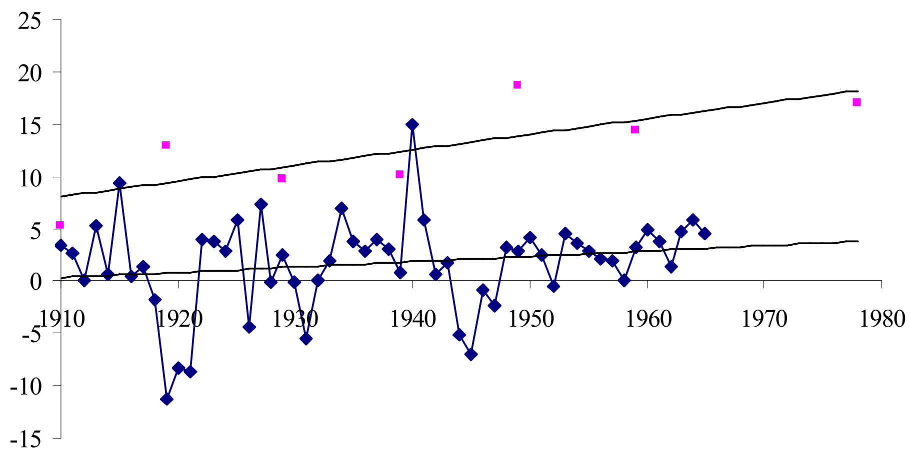

Figure 6.2: UK Tax and Growth Rates

Source: Feinstein (1972), UK Revenue Statistics, Economic Trends

The message from these figures appears compelling but must be considered carefully. There are two reasons for caution. Firstly, a contrast between tax rates and growth across time cannot answer the question "if taxes had been lower, would growth have been higher?" To do so requires a study involving countries with different regimes. Secondly, there are substantive issues that have to be resolved about the definition of the tax rate that should be used in any such comparison.

To understand the problem of definition, consider Figure 6.3 which illustrates a typical progressive income tax. There is an initial tax exemption up to income level Y_1, then an income band at taxed at rate t_1 and a final income band taxed at rate t_2, $t_2 > t_1$. What is important about the figure is that it shows how the marginal rate of tax differs from the average rate of tax. For instance, at income level $\hat{Y}$, the marginal rate is one minus the gradient of the graph whilst the average rate is one minus the gradient of the ray to the graph (shown by the dashed line). With a progressive tax system, the marginal rate is always greater than the average rate.

The data displayed in Figures 6.1 and 6.2 uses tax revenue as a fraction of gross domestic product to measure the tax rate. This measure captures the average rate of tax. However, what economic theory predicts to be important for behavior is the marginal tax rate - the decision on whether or not to earn additional income depends on how much of that income can be retained. This suggests that the link between growth and taxation should focus more on how the marginal rate of tax affects growth.

The difficulty with undertaking the analysis comes in determining what the marginal tax rate actually is. Figure 6.3 illustrates this problem: the marginal tax rate is either 0, t_1 or t_2 depending upon the income level of the consumer. In practice, income tax systems typically have several different levels of exemption (e.g. married and single persons allowances), several marginal tax rates, and they interact with social security taxes and with the benefit system. All of this makes it difficult to assign any unique value to the marginal rate of tax. The same comments apply equally to corporation tax, which has exemptions, credits and depreciation allowances, and Value Added Taxation which has exemptions, zero-rated goods and lower-rated goods. In brief, the rate of growth should be related to the marginal rate of tax but there are significant difficulties in finding an empirical counterpart.

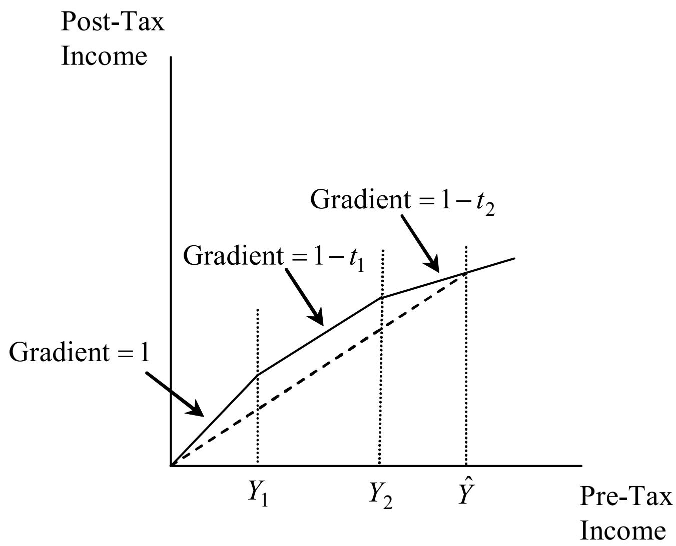

Figure 6.3: Average and Marginal Tax Rates

6.3 Empirical Results

Given these preliminaries, it is now possible to review the empirical evidence. The strongest empirical link between taxation and growth was reported in Plosser (1992). Plosser calculated the correlation between the rate of growth of per capita gross domestic product and a range of variables for the OECD countries. The share of income and profit taxes in GDP was found to have a correlation of -0.52 with the growth rate of GDP. A chart plotting average tax rates in OECD countries against GDP growth over 1960 - 1989 is given to confirm this result. Even so, Plosser warns against taking the correlation as evidence of causality and presents several potential explanations for the lack of robustness in regression equations (most policies operate through investment, policies are complex and not easily represented by variables in regressions, policies are highly correlated).

Figure 6.4 displays an updated version of Chart 6 in Plosser (1992). This figure extends the sample period through to 2004. The data points are found by averaging the growth rate and the tax rate over this period for each country. A straight line fit by least squares shows the negative relationship between the growth rate and the average tax rate identified by Plosser. The obvious limitation of this finding is that the effect of taxation cannot be accepted without considering the effect of other explanatory variables. For instance, the OECD countries differ in their income levels and, as the discussion of Chapter 5 has shown, income is one of the most robust determinants of economic growth. Other variables may also be important. The negative relationship cannot be accepted until it has been shown to survive the inclusion of additional covariates in a regression analysis.

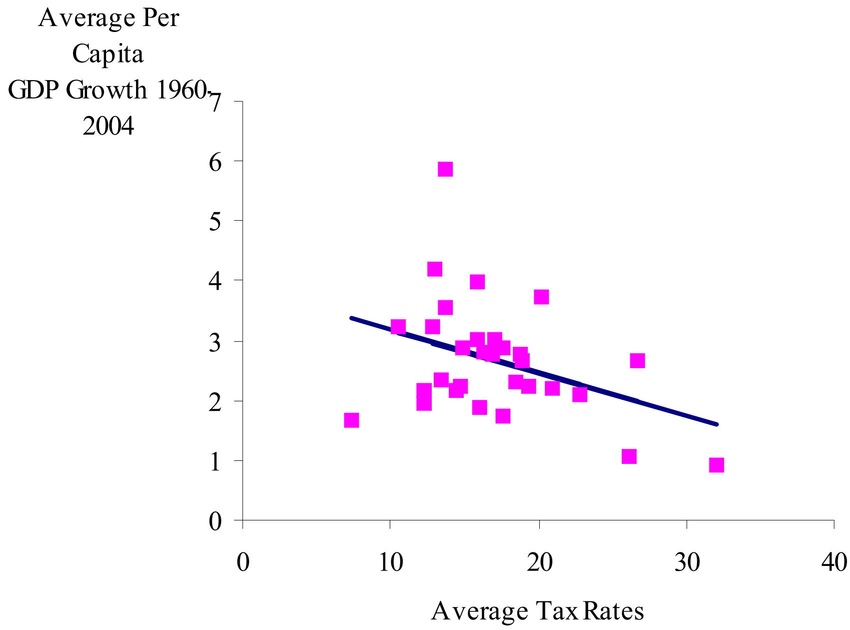

Figure 6.4: Real income growth and tax rates in OECD countries 1960 - 2004

Source: Penn World Table Version 6.2

The measure used to represent tax rates is an important issue in tax regressions. Some of the research employs the average rate of tax, while other papers attempt to construct a measure of the marginal rate of tax. This issue matters because the standard application of economic theory shows it is the marginal tax rate that matters for the degree of distortion introduced into choices. Optimal decisions are determined by trading the marginal benefit of one choice against the marginal benefit of another. The marginal rate of tax directly affects this trade-off and causes the distortion in choice. Using an average rate of tax to explain growth does not capture this important feature of taxation.

In an analysis of 63 countries Koester and Kormendi (1989) use IMF data to construct measures of the average tax rate and the marginal tax rate. The average tax rate variable is constructed by using revenue/GDP and the marginal tax rate variable is obtained from a regression of revenue on GDP and a constant. A series of regressions of the growth rate on tax variables and income are conducted. The regression results show little evidence of an effect of either average or marginal rate upon the growth rate, but the marginal rate is claimed to have an effect on the level of activity. The relevant growth rate regressions are presented in Table 6.1. The tax rates are significant when used as the sole regressor but become insignificant when the level of initial GDP is included. The inclusion of initial GDP raises the explanatory power of the regression, though it still remains small.

Variable	A	B	C	D

Constant	0.060 (8.26)	0.053 (10.48)	0.058 (8.34)	0.060 (11.4)
Average tax	−0.074 −2.18		−0.005 (−0.11)	
Marginal tax		−0.25 (−1.87)		−0.011 (−0.87)
Initial GDP			−0.052 (−2.656)	−0.048 (−3.03)
R^2	0.072	0.05	0.17	0.18

Table 6.1: Regression on marginal and average rates

The standard criticisms of this paper are as follows. First, it assumes a constant marginal rate of taxation despite significant changes in the tax systems in several of the countries over the period of the data set. Second, the inclusion of too wide a range of countries causes aggregation bias since the industrialized and non-industrialized countries may have very different responses of growth to taxation. These are criticisms that can be levelled at many of the papers in this area of the literature.

A comprehensive data series on personal tax rates was given in Sicat and Virmani (1988). An alternative series for the marginal tax rate was constructed and reported in Easterly and Rebelo (1993a). The method of construction involves computing the income-weighted average marginal tax rate

$$\Omega_y = \frac{\int_0^\infty y\tau'(y)f(y)dy}{\int_0^\infty yf(y)dy}, \tag{6.1}$$

where $\tau'(y)$ is the marginal tax rate at income y and $f(y)$ is the density function for income. The construction is completed by assuming that the marginal tax rate $\tau'(y)$ is given by the logistic equation

$$\tau'(y) = \frac{a_0}{1 + a_1 \exp(a_2 y)}. \tag{6.2}$$

This function ensures that the marginal tax rate lies between $a_0/(1+a_1)$ and a_0. Implementation of this formula is undertaken by setting the three parameters (a_0, a_1, a_2) to match chosen aspects of the data.

Easterly and Rebelo (1993b) test the tax rates of Sicat and Virmani (1988), their own method of constructing marginal tax rates, plus several other methods of defining the marginal tax rate, in tax regressions. In total 13 different measures of the tax rate are employed. The methodology adopted is to include these measures of the marginal tax rate one at a time within a basic regression equation. The basic equation contained the standard determinants of growth found to be significant in Barro regressions; notably initial income (*PRIM*60), school enrolments (*SE*C60), assassinations (*ASSASS*), revolutions (*RE*V) and war casualties (*WARCAS*). Estimation of this basic equation without the inclusion of tax rates generated the result

$$\gamma_{y7088} = \underset{(0.51)}{0.003} - \underset{(-2.81)}{0.004}\,GDP60 + \underset{(1.88)}{0.025}\,SEC60$$

$$+ \underset{(3.15)}{0.023}\,PRIM60 - \underset{(-1.29)}{0.01}\,REV$$

$$- \underset{(-1.47)}{0.003}\,ASSASS - \underset{(-1.67)}{1.157}\,WARCAS\,, \qquad (6.3)$$

with an R^2 of 0.29.

Table 6.2 reports the statistical significance level of the alternative measures of the marginal tax rate when included as an additional variable in this regression. The tax rates generally perform badly in the regressions. Only the marginal income tax rate from a regression on GDP is significant at the 5 percent level. In particular, the Koester-Kormendi (1989) marginal tax rate becomes insignificant when included alongside other variables in the regression equation.

Tax rate	Significance level
Tax rates computed using regression	
Koester-Kormendi (1989) marginal tax rate	0.194
Marginal income tax rate from regression on GDP	0.047
Marginal tax rate from regression of total revenue on GDP	0.121
Tax rates computed as ratios of tax revenue to tax base	
Taxes on income, profits, and capital gains/GDP	0.353
International trade taxes/Imports plus exports	0.243
Individual income taxes/Personal incomes	0.098
Sicat-Virmani statutory tax rates	
On first bracket	0.432
On 0.75 × average family income	0.386
On 2 × average family income	0.958

On 3 × average family income	0.587
On highest bracket	0.687
Easterly-Rebelo (1993a) marginal tax rate	0.880

Table 6.2: Significance of marginal tax rates

When the significant tax rate was included the estimated regression equation became

$$\gamma_{y7088} = \underset{(1.109)}{0.010} - \underset{(-2.25)}{6.46\times 10^{-3}} GDP60 + \underset{(2.09)}{0.0439} SEC60$$

$$+ \underset{(2.24)}{0.0247} PRIM60 - \underset{(-0.39)}{0.0439} REV$$

$$- \underset{(-1.69)}{65.7}\ ASSASS - \underset{(-2.225)}{1.436}\ WARCAS$$

$$- \underset{(-2.204)}{0.064}\ MARTAX\ . \qquad (6.4)$$

The inclusion of the marginal tax rate variable has a major effect on the value of the coefficient on assassinations. The coefficients on the other variables do not change dramatically in significance but the coefficient on initial GDP in 1960 is reduced. The effect of the marginal tax rate has the expected negative sign.

From a number of regressions involving different combinations of these variables, Easterly and Rebelo (1993b) conclude: "The evidence that tax rates matter for economic growth is disturbingly fragile".

A further analysis of the significance of a tax rate variable is undertaken in Mendoza, Milesi-Ferretti and Asea (1997). The clear finding is that when initial GDP is included in the regressions, the tax variable is insignificant. Evidence contrary to this is presented in Leibfritz, Thornton and Bibbee (1997). Their regression of average growth rates for OECD countries over the period 1980 - 1995 against three measures of the tax rate (average tax rate, marginal tax rate and average direct tax rate) showed that a 10 percent increase in tax rates would be accompanied by a 0.5 percentage point reduction in the rate of growth, with direct taxation reducing growth marginally more than indirect taxation.

Additional work on similar lines has been undertaken by Dowrick (1993) and de la Fuente (1997). These papers considered the more general issue of how the structure of fiscal policy affects growth. In particular, they investigated how the rate of growth is related to the composition and level of public sector spending. Dowrick studied a number of OECD countries and showed that personal income taxation had a negative effect on growth but corporate taxes had no effect. The results of de la Fuente showed that if public spending (measured as the share of total government expenditure in GDP) increases, growth is reduced (a reduction in government spending of 5 percent of GDP reduces growth by 0.66 percentage points) whereas an increase in public investment will raise growth. These results confirm the negative coefficient on government consumption expenditure.

Padovano and Galli (2001) also construct marginal tax rates by regressing tax revenue on GDP but improve on Koester and Kormendi by including level and slope dummies to allow for changes in the tax rate over the sample period. The regression equation for construction of the marginal tax rate variable is

$$REV = \alpha_0 + \alpha_1 GDP + \alpha_2 TAXREF + \alpha_3 (TAXREF \times GDP), \qquad (6.5)$$

where *REV* is government revenue, and *TAXREF* is a dummy for tax reform. The estimated regression equations have an average R^2 of 0.96 (the value of which suggests there may be spurious regression issues) and almost always have a value of α_1 that is significant at the one percent level. However, the estimates for α_1 show significant intertemporal variability for individual countries which seems larger than known changes in tax systems would suppose. For instance, the values for the UK are 0.285 (1950s), 0.449 (1960s), 0.324 (1970s), and 0.367 (1980s).

The estimated marginal tax is then used in a growth regression for OECD countries. The decade-average growth rate is regressed on per capita income, population growth, average rate of physical and human capital accumulation, the constructed marginal tax variable, plus other conditioning variables. The sample of results reported in Table 6.3 show that the marginal tax variable is negatively and significantly correlated with growth.

Constant	0.027 (6.67)
Marginal tax	-0.012 (-2.79)
Base year GDP	-1.42×10^{-6} (-6.32)
Population growth	1.062 (3.6)
Ratio of physical investment to GDP	0.0002 (1.84)
Investment in human capital	0.0004 (0.1)
Government consumption	-3.13×10^{-6} (-0.02)
Inflation	-0.08 (-3.02)
R^2	0.53

Table 6.3: Regression results

t statistics in parentheses

It has been noted that some tax regressions employ the average rate of tax, while others attempt to construct a measure of the marginal rate of tax. The consequence of this modelling choice is investigated by Padovano and Galli (2002) for data on 25 industrialized countries over the period 1970 - 1998. The basic argument is that individual choices are at the heart of endogenous growth theories. The relevant variable for choices is the marginal rate of tax and not the average rate. For this reason the average rate of tax should not be significant in a growth regression. In addition, the average rate of tax is also related to government expenditure and so may even enter a growth regression with positive sign. The marginal rate of tax, and measures of tax progression, should enter the growth regression with a negative sign.

The first step in the analysis is to regress tax revenue on a constant, GDP, a dummy for tax reforms, and the interaction of the dummy and GDP. The coefficient from this regression is interpreted as an approximation of the marginal tax rate. There is no attempt to disaggregate the data to find the marginal effect of different taxes. The average value for the constructed marginal tax rate across the sample of countries is 33 percent and the average tax 29 percent.

The effect of a range of variables other than the tax rates is tested by "progressive inclusion" to ensure robustness. When the average tax rate and the marginal tax rate are included separately in regressions the average tax rate is insignificant but the marginal tax is significant. A sample of the results is shown in Table 6.4 (t statistics in parentheses). Models II and III enter the tax variables separately. The lack of significance of the average tax rate is clear. Including both the average tax and the marginal tax is claimed to represent the effect of progressivity: holding the average tax rate constant while the marginal tax rate is increased represents an increase in progressivity. The results for Model VI show that when both tax variables are included the coefficient on marginal tax remains negative and significant but average tax is not significant. The results of Model III show that a 10 percentage point increase in the marginal tax rate reduces growth by 0.23 percentage points.

Variable	Model II	Model III	Model VI
Average tax	0.005 (0.2)		0.0039 (0.89)
Marginal tax		−0.023 (−3.45)	−0.0342 (−3.82)
Population growth rate	1.302 (2.897)	1.556 (3.42)	1.096 (4.578)

Investment in physical capital	− 0.0003 (−0.324)	− 0.0005 (−0.237)	0.0028 (1.379)
Investment in human capital	0.006 (3.73)	0.005 (7.1)	0.004 (4.08)
Initial GDP	− 0.0001 (−1.839)	− 0.0004 (−8.86)	− 0.0001 (−5.571)
Inflation			− 0.232 (−4.883)
R^2	0.567	0.66	0.65

Table 6.4: Regressions on average and marginal taxes

An approach designed to circumvent the difficulties involved in defining marginal tax rates can be found in Easterly (1993). Rather than look at tax rates directly, Easterly places the focus on the distortions generated by those tax rates. These distortions are found by using the data of Summers and Heston (1988) on 1980 price data for 151 commodities in 57 countries relative to the US. The variance of the prices within countries is then taken as a measure of the relative degree of distortion that exists in those economies due to taxation, quotas, price restrictions and other forms of intervention. After controlling for other determinants of growth (such as initial country income and school enrolment) the reported estimates show that the variance of input prices is a statistically significant variable in the determination of growth. In fact, increasing the variance of prices from the mean by one standard deviation lowers growth by 1.2 percentage points. This is clearly an interesting approach but it does have two deficiencies. First, the variance of prices is not proven to be a good proxy for the degree of distortion in the economy, it is merely assumed to be so. Secondly, there is no immediately obvious way to translate the effect of price variation into the effect of changes in tax rates. To do so would require knowledge of how taxes feed, through market equilibrium, into prices.

Engen and Skinner (1996) focus their discussion around the effect of a 5 percentage point cut in marginal tax rate using three methods: (1.) by studying the US historical record; (2.) by reviewing empirical evidence on cross-section studies for large samples of countries; and (3.) compiling evidence from microlevel studies. The review of US history does not suggest any concrete conclusion. Instead, the interest in the exercise lies in the demonstration that a minor change in the period under review can reverse the conclusion. This is a clear warning against making simple inferences from data.

After reviewing the results of some of the papers described above, Engen and Skinner deduce four problems with the cross-country studies. First, even if taxation has a negative effect on growth the revenues it finances may have an offsetting positive effect. Second, when a large range of heterogeneous countries are analyzed the data may be of very variable quality. Third, there may be reverse causality causing bias in the estimated coefficients. Finally, countries may differ in their taste for expenditure and in the ease of raising revenue (and both of these may be correlated with growth).

One possible route out of the difficulties of defining the appropriate tax rate is to adopt a different method of determining the effect of fiscal policy. Engen and Skinner (1996) label the regressions described above as "top-down" since they work with aggregate measures of taxation. Instead of doing this, they propose a "bottom-up" method which involves calculating the effect of taxation on *labour* supply, investment and productivity, and then summing these to obtain a total measure. Doing this suggests that a cut of 5 percentage points in all marginal rates of tax and 2.5 percentage points in average rates would raise the growth rate by 0.22 percentage points. The later chapters consider aspects of this bottom-up approach.

An alternative set of issues are addressed in Kneller *et al.* (1999). They note that there are specification problems in the regressions because of government budget balance. If the implications of budget balance are not handled correctly the regression equation is actually determining the difference of the effect of tax variables. This can be seen by writing the basic regression equation as

$$\gamma_y = \alpha + \sum_{i=1}^{k} \beta_i Y_i + \sum_{j=1}^{m} \theta_j X_j + \varepsilon , \tag{6.6}$$

where Y_i are the non-fiscal conditioning variables and X_j the fiscal variables. If the fiscal variables are comprehensive then the government budget constraint requires

$$\sum_{j=1}^{m} X_j = 0 . \tag{6.7}$$

If the regression is estimated with all fiscal variables included then it will suffer from multicollinearity. Alternatively, if one fiscal variable, say the *m*th, is excluded the equation for estimation becomes

$$\gamma_y = \alpha + \sum_{i=1}^{k} \beta_i Y_i + \sum_{j=1}^{m-1} \left(\theta_j - \theta_m\right) X_j + \varepsilon , \tag{6.8}$$

so the test of significance for $\theta_j - \theta_m \neq 0$ is actually a test of $\theta_j \neq \theta_m$. This suggests omitting a variable where the theory suggests that $\theta_m \cong 0$, so that the estimated coefficient is approximately the effect of the included variable.

These observations are implemented by breaking taxes into distortionary and non-distortionary, and expenditures into productive and non-productive. Regressions are then conducted with one of the categories omitted. The data used is for 22 OECD countries over the time period 1970 - 1995. The estimation procedure employs a two-way fixed effects model on a panel of five-year averages. A sample of the results is presented in Table 6.5. These results are interpreted as providing strong support for the Barro model: distortionary taxation reduces growth, productive expenditure enhances growth, and non-productive expenditures have an insignificant effect. The key assumption is that taxes are measured by the revenue raised as a percentage of GDP. Hence, the estimation is implicitly using the average tax rate rather than the marginal tax rate. This choice is subject to the criticisms already raised above.

Omitted fiscal variable	Non-distortionary taxation	Non-productive expenditures
Initial GDP	−0.490 (2.79)	−0.490 (2.79)
Investment	−0.020 (0.33)	−0.020 (0.33)
Labor force growth	−0.327 (1.09)	−0.327 (1.09)
Lending minus repayments	0.417 (1.829)	0.380 (2.13)
Other revenues	−0.154 (0.81)	−0.117 (1.12)
Other expenditures	0.315 (2.00)	0.279 (2.42)
Budget surplus	0.446 (2.79)	0.410 (4.60)
Distortionary taxation	−0.446 (2.79)	−0.410 (4.21)
Non-distortionary taxation		0.0370 (0.23)
Productive expenditures	0.290 (1.98)	0.253 (1.95)
Non-productive expenditures	0.037 (0.239)	
Adjusted R^2	0.602	0.602

Table 6.5: Regression results

t statistics in parentheses

This analysis is extended by Bleaney *et al.* (2001) to consider whether the five-year averaging technique commonly used for these regressions is valid. The test of validity is undertaken by running the regression for five-year averages and then running again but allowing for lagged effects of the fiscal variables. The lagged effects are found to be collectively significant. The appropriate lag length is then found by using annual data instead of averaging and extending the number of lags until the Wald χ^2 test demonstrates insignificance. This reveals that eight lags are required so long-run effects are important. The estimation results for eight lags (with each coefficient being the sum of current and lagged effects) are summarized in Table 6.6. The omitted variable is non-distortionary taxation. This is presumed to have a coefficient of zero in the regression so the stated coefficients can be interpreted as the effect and not the difference in effects. The key finding here is the large negative and significant coefficient on distortionary taxation. The definition of this variable includes all taxes other than consumption taxes. Consumption taxes are treated as non-distortionary on the grounds that they do not distort intertemporal decisions.

Investment ratio	0.120 (4.21)
Labor force growth	−0.350 (−2.67)
Other revenues	−0.041 (−0.32)
Other expenditures	0.013 (0.10)
Budget surplus	0.109 (1.012)
Distortionary taxation	−0.393 (−2.92)
Productive expenditures	0.337 (3.67)
Non-productive expenditures	0.045 (0.499)
Net lending	−3.865 (−4.03)
Lagged growth	−2.062 (−9.11)
Adjusted R^2	0.758

Table 6.6: Yearly estimation with eight lags

t statistics in parentheses

Taxes can be levied on personal income and on corporate income. A personal income tax bears upon the allocation of time between labour supply and leisure, and on the allocation of income between consumption and saving. There are grounds (which are covered in Chapter 8) for suspecting that the labour supply effect will be the larger of these two. An increase in hours of work can raise output but cannot lead to a sustained higher level of growth. In contrast, the corporate income tax affects both investment and the incentive to supply entrepreneurial skills. The margins on which these taxes operate suggest that it will be informative to trace the potentially distinct growth effects of personal and corporate income taxes.

Widmalm (2001) investigates the effect of the tax structure on growth using cross-section data on 23 OECD countries from 1965 - 1990. The methodology follows that of Levine and Renelt (1992) but used four basic variables (initial income, investment to GDP ratio, population growth, and average tax rate). The share of different tax instruments in revenue is considered first (corporate income tax, personal income tax, property tax, taxes on goods and services, and taxes on wages). A progressivity measure is constructed from the regression

$$\ln T = \alpha_0 + \alpha_1 \ln GDP + \varepsilon . \qquad (6.9)$$

The elasticity α_1 is taken as the measure of progressivity.

The results of the extreme bounds analysis of robustness are summarized in Table 6.7. The proportion of tax revenue from taxing personal income has a negative and robust correlation with growth. There is also some evidence that progressivity affects growth.

Variable	Bound	β	*t* ratio
Taxes on corporate income	High	0.027	1.03
	Base	0.009	0.38
	Low	0.001	0.05
Taxes on personal income	High	-0.023	-2.30
	Base	-0.027	-2.81
	Low	-0.033	-3.19
Taxes on property	High	0.018	0.44
	Base	0.018	0.43
	Low	-0.031	-0.62
Taxes on goods and services	High	0.052	3.44
	Base	0.022	1.98
	Low	0.021	1.54
Taxes on	High	0.014	1.34

wages	Base	0.004	0.42
	Low	0.001	0.16
Progressivity	High	-0.737	-1.83
	Base	-0.822	-2.04
	Low	-1.063	-2.52

Table 6.7: Results of extreme bounds analysis

The theoretical models identify the different routes through which household choices and corporate choices can affect the growth rate. These results suggest that taxation of the household and taxation of the corporation may differ in how they influence the growth rate. This hypothesis is addressed in Lee and Gordon (2005) who conduct a tax regression using the top corporate marginal tax rate and top personal marginal tax rate to capture the effects of taxation. They justify this choice by an appeal to entrepreneurial activity being the driver of growth, and the top marginal rate being the one that is likely to be applicable to successful entrepreneurs. This choice can be referred back to the issues in the previous literature that debated the representation of the marginal tax rate.

The results reported in Table *6*.8 are for a panel regression based on averages for three five-year periods (1980 - 1984, 1984 - 1989, 1990 - 1994) and one three-year period (1995 - 1998). The annualized growth rate is regressed on the corporate tax rate in the initial year for each observation. The variable ICRG index is a measure of the quality and corruption of bureaucrats. The final column of the table shows the effect of including both corporate and personal taxes. The standard errors (in parentheses) show that the corporate tax is significant in all three of the regressions. It remains significant when the personal tax rate is included, but the personal tax is not significant. This supports the conclusion that it is corporate taxes that are most damaging for growth since they reduce entrepreneurial activities and lessen the incentive for innovation. Cutting corporate tax rate by 10 percentage points can increase annual growth rate by 1.1 percentage points.

Estimation method	OLS	Country dummies +IV	Country dummies +IV
Corporate tax rates	-0.058 (0.019)	-0.171 (0.034)	-0.182 (0.046)
Personal tax rates			0.001 (0.026)
GDP per capita	-1.078 (0.223)	-4.321 (1.067)	-5.247 (1.282)

Primary school enrolment	0.026 (0.011)	0.017 (0.020)	0.031 (0.023)
Average openness	2.672 (0.480)	1.358 (0.713)	1.352 (0.772)
Average ICRG index	0.527 (0.201)	0.211 (0.523)	−0.115 (0.586)
Population growth rates	−0.730 (0.227)	−1.086 (0.460)	−0.952 (0.5237)
Average inflation rates	−0.0026 (0.000)	−0.001 (0.000)	−0.001 (0.000)
Constant	70719 (2.030)		
Adjusted R^2	0.323	0.651	0.665

Table 6.8: Corporate and personal taxes

Standard errors in parentheses

6.4 Limitations

Slemrod (1995) is a key paper for understanding the limitations of the methodology of tax regressions. The paper first presents simple scatter plots of the relationship between tax revenue as a proportion of GDP and the rate of growth. Across the OECD countries there is no obvious relationship and the scatter appears almost random. When a larger range of countries is considered some evidence for a positive relationship emerges but this is mainly a consequence of the relatively high growth levels in the high-revenue OECD countries. An updated version of this data is presented in Figure 6.5. This plots growth in GDP per capita against government expenditure as a proportion of GDP for 78 countries in 2004 using data from the latest version of the Penn World Tables. As observed by Slemrod there is no discernible pattern in this data. If there were a strong link between government and growth it is surprising it does not appear in the figure.

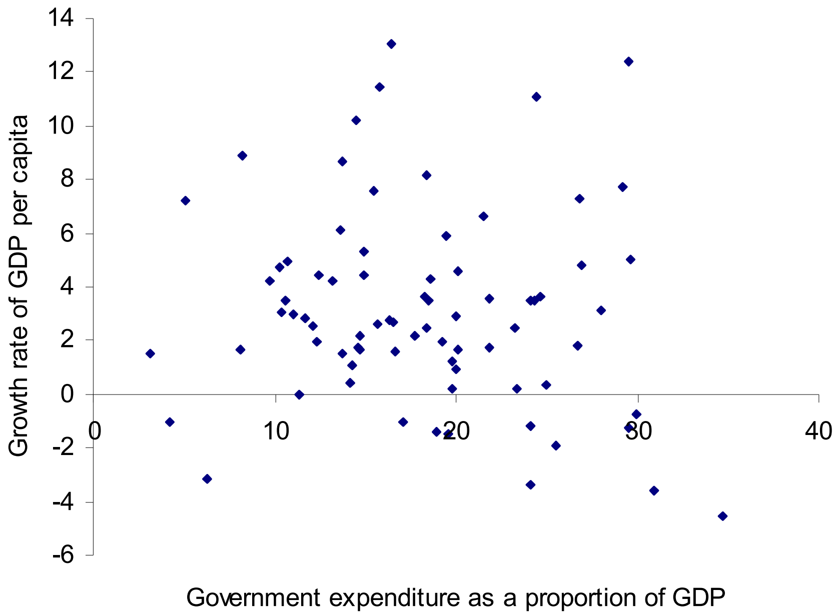

Figure 6.5: Growth and government expenditure 2004

Data: Penn World Tables Version 6.2

As noted by Slemrod (1995) the basic method of the regressions is to use national income, *Y*, as the left-hand-side variable and government expenditure, *G*, as the right-hand-side variable (or the average tax rate which is closely linked to *G* through the government budget constraint). In contrast, economic theory provides convincing arguments that there is causality running in the opposite direction: government expenditure is determined by the preferences of the population for public goods as expressed through the political system. A simple version of this view is captured in Wagner's law which relates government expenditure to national income via the income elasticity of demand for government-provided goods and services.

This argument is taken one step further by Slemrod who models the simple fact that *Y* influences *G*, and *G* influences *Y*. In essence, it is the interaction of the two structural relationships that generates the observed data. The estimation methodology has not adequately resolved the simultaneity between these two relationships and therefore the estimated coefficients do not represent the underlying structural equations. Moreover, if the level of *G* is chosen optimally given *Y* then the first-order effect of changes in *G* upon *Y* should be zero. Hence, there will be little variation for the data to capture. If there are any differences in the relationship between *Y* and *G* across countries then, combined with optimization, this will make for an even less meaningful relationship in the data.

The basic point here is concern about the lack of structural modelling in these tax regressions and the consequent lack of any clear idea of what the estimated regression equation is representing. The lack of structural modelling is also criticized by Brock and Durlauf (2004). Although these authors make the point in connection to Barro regressions it is equally true with the tax regressions. This is an area of research in which no progress appears to have been made.

Slemrod (1995) then provides a brief review of the literature up to the mid 90s and argues that the results of Barro and Plosser are not robust. The paper proceeds to discuss the tax elasticity of individual choices and provides a range of arguments why they may not be large. Also, the problem of defining marginal tax rates is discussed. Analysts use revenue to infer rates, but the link between rates and revenue depends on the ability to move into the hidden economic sector. Therefore, there is a lack of comparability of this data across countries. The comments by Easterly reinforce this generally negative perspective. These comments are especially valid given the role of Easterly in this research area.

Some of the observations of Slemrod and Easterly are captured in Table 6.9. Notice how the tax ratio is much higher in Sweden but the VAT rate is not that much larger. The difference is caused by the compliance rate. In Sweden compliance is very high but in Peru it is low. Even though the tax ratio is high in Sweden it has grown faster. The point of Easterly is that it is difficult to see how this information can be adequately captured in a regression analysis. The data also illustrate the argument of Slemrod that tax increases can cause switches into hidden economic activity. This is evidenced by the size of the informal sector in Peru.

Indicator	Peru	Sweden
Real per capita growth, 1970 – 90	-1.1	1.8
Tax ratio to GDP, average 1970 – 90	7	47
VAT rate, 1990 – 93	18	23
VAT compliance ratio, 1990 – 93	32	95
Informal sector share in labor force, 1990 - 93	56	

Table 6.9: Key indicators for Peru and Sweden

There is a further difficulty with trying to determine the effect of taxation via these regressions methods. What should matter for the economic outcome is the distortion caused by the tax (how much it changes decisions). An aggregate measure of the tax rate can never capture the varying degrees of distortion that individuals or firms with different incomes will face. This is more than just the distinction between average and marginal rate. Account must also be taken of the tax base, the existence of exemptions, and the ability to move into alternatives (such as tax-free choices or the hidden economy). Having said this, it still remains the case that all of the regressions are limited by the fact that they are unable to work with the rate of tax that affects individual decisions. For decisions at the margin we would think of the marginal rate of tax as being important. But there are discrete choices (such as choice of location) for which the average rate matters. What the regressions end up using is an aggregate average rate, or constructed marginal rate, that probably does not affect the rate that any particular economic decision maker is facing.

6.5 Observations

This review of the empirical evidence produced by tax regressions leads to the following observations. A visual inspection of tax rates and growth rates suggests that there is little relationship between the two. This is weak evidence but it does find support in some more detailed investigations in which regression equations that include previously identified determinants of growth, especially initial income, reveal tax rates to be insignificant as an explanatory variable. Other regressions find a small, but significant, tax effect.

Despite this weak evidence there remains a belief that taxes must be damaging for growth and that the evidence will eventually confirm this fact. As an example, Karabegovic *et al.* (2004) survey some of the literature and observe that "Two recent papers ... confirm the negative effects of high marginal tax rates on economic growth." The basis for this belief is the simple economic theory that the marginal rate of tax is the relevant value for creating distortions in choice, and that the distortions caused by taxation mean lower growth. Despite the compelling nature of this argument no reading of the empirical work can justify such a confident conclusion. As observed by Slemrod, (1995) "If the cost of government is so large, why is this cost so difficult to discern in time-series or cross-country studies?"

All of these results are hampered by the difficulties in actually defining marginal rates of tax and in their lack of an equilibrium relationship. More success is likely to be found in analyzing the individual choices and testing each to find the responsiveness to policy. Engen and Skinner (1996) label the regressions described in this and the preceding chapter as "top-down" since they work with aggregate measures of taxation. Instead of doing this, they propose a "bottom-up" method which involves calculating the effect of taxation on labour supply, investment and productivity, and then summing these to obtain total measure. Their application of the bottom-up method suggests that a cut of 5 percentage points in all marginal rates of tax and 2.5 percentage points in average rates would raise the growth rate by between 0.2 and 0.3 percentage points. The next three chapters will discuss the analysis that is behind the deduction of these values.

Chapter 7. Growth Accounting

- Growth accounting quantifies the separate contributions of capital accumulation, labour supply growth, and productivity increases, to output growth
- Comparing countries reveals a range of different growth experiences
- Growth has occurred in some countries primarily through capital accumulation and in others through productivity increases
- There is strong evidence of different rates of productivity growth among countries
- There is evidence that productivity growth is related to economic variables which supports the endogenous growth hypothesis
- There is evidence that the rate of growth is dependent on the level of education

7.1 Introduction

The discussion of growth theory has identified the channels through which growth can occur. In essence, these can be reduced to the accumulation of capital, the accumulation of labour, technical progress, and the improvement of market functioning. The question of the relative importance of these channels for different countries then arises. Knowing which channel matters provides guidance on how policy can best be designed. For instance, a fixed government budget may be better spent on subsidizing investment rather than education if it is capital accumulation that is driving growth.

There is a substantial literature that attempts to allocate growth to the alternative components. This literature has become known as growth accounting and a brief description of the methodology is provided in the appendix to this chapter. The result that the analysis provides is the identity

$$g_Y = \alpha_K g_K + \alpha_L g_L + SR . \quad (7.1)$$

This equation states that the growth rate of output, g_Y, is equal the sum of the growth rate of capital stock, g_K, and the growth rate of labour, g_L, weighted by their shares in national output, plus the Solow residual, *SR*. The Solow residual is that part of output growth not attributable to growth in inputs, so it captures a range of effects including technical progress and improvements in market functioning. The residual has also become known as total factor productivity (*TFP*).

Table 7.1 from Maddison (1987) summarizes the degree of productivity growth for a range of developed countries. It can be seen from this table that productivity growth accounts for a substantial fraction of growth. The table shows that the increase in growth during 1950 - 1973, and the subsequent slow-down, is due to productivity growth and not variations in factors of production. These figures also emphasize how much the endogenous growth models have to explain (and, conversely, how much the Solow model does not explain).

	1913 - 1950		1950 - 1973	
	GDP growth	Productivity	GDP growth	Productivity
France	1.20	1.42	5.10	4.02
Germany	1.30	0.86	5.90	4.32
Japan	2.20	1.10	9.40	5.79
Netherlands	2.40	1.25	4.70	3.35
UK	1.30	1.15	3.00	2.14
US	2.80	1.99	3.70	1.85
Average	1.87	1.30	5.30	3.58

	1973 - 1984	
	GDP growth	Productivity
France	2.20	1.84
Germany	1.70	1.55
Japan	3.80	1.21
Netherlands	1.60	0.81
UK	1.10	1.22
US	2.30	0.52
Average	2.12	1.19

Table *7*.**1:** Real GDP growth and productivity

A detailed application of growth accounting to a range of countries is of interest for several reasons. First, it can reveal if there have been differences in the growth process between countries. Simple economic growth models imply that all countries will develop in the same way (although possibly at different times). Data that show this is not the case will emphasize the need to treat existing models with caution and to seek better models. Second, if countries have developed differently then policy responses need to take this into account. If there is more than one way to achieve growth the best method has to be selected for each country.

7.2 East Asian Growth

The rapid growth of the East Asian economies in the 1980s provided the motivation for a number of growth accounting studies. These studies aimed to determine the source of growth in the East Asian countries and to compare this with the experience of Industrialized Western countries. The alternative hypotheses were that the East Asian growth could be due to capital accumulation, the assimilation of technical progress made abroad, or an increase in human capital. The example of these countries provided the data for testing the alternative hypotheses.

The work of Kim and Lau (1996) is typical of the research in this area. The analysis is based upon the meta-production function approach that permits countries to have different levels of technology. The quality adjusted stock of capital, K_{it}^*, is given by

$$K_{it}^* = A_{ik}(1+c_{ik})^t K_{it}, \tag{7.2}$$

where A_{ik} is the level of augmentation and c_{ik} is the rate of growth of augmentation. The method is implemented by normalizing A_{ik} (and A_{iL}) to unity for one of the countries in the sample and then estimating the remaining *A*s and *c*s. The generality of this approach is that it permits countries to have different growth experiences unlike a more basic model which would impose the same growth pattern on all countries.

Kim and Lau apply this methodology to ten Asian Pacific countries and to four industrialized Western countries. Table 7.2 summarizes the standard finding in the work of Lau and his co-researchers. The Asian Pacific Countries, with the exception of Japan, obtained most of their growth from the accumulation of capital. For example, accumulation of capital accounted for 99.5 percent of growth in output in the Philippines. Among the Asian Pacific Countries only Japan, Hong Kong, and Singapore experienced substantial benefits from technical progress. In contrast, the figures for the four Industrialized Western Countries at the foot of the table show that these countries obtained most of their growth from technical progress. A further important result arises which will be discussed further in a later chapter, namely, that the analysis also shows technical progress is purely capital augmenting. That is, technical progress is not enhancing the efficiency-equivalent quantity of labour.

Country	Capital	Labor	Technical Progress
China	92.2	9.2	-1.4
Hong Kong	55.8	16.0	28.2
Indonesia	115.7	11.5	-27.2
Japan	62.9	4.7	32.4
Malaysia	70.9	18.7	10.5
Philippines	99.5	22.6	-17.5
Singapore	60.0	20.9	20.1
South Korea	86.3	12.7	1.0
Taiwan	88.9	8.6	2.5
Thailand	71.9	12.7	15.3
France	37.8	-1.3	63.5
West Germany	43.7	-6.3	62.6
United Kingdom	46.0	3.7	50.3
United States	32.9	26.2	41.0

Table 7.2: Sources of Growth

The finding that much of the economic growth in East Asian countries is explained by capital accumulation and not through technical progress has received much attention. The conclusion is supported by the work of Tsao (1985) on Singapore manufacturing in the 1970s, and by the analysis of Young (1992) of Hong Kong and Singapore. The same conclusion is also reached in Young (1994) which regressed the output growth rate per worker on a constant and the growth of capital per worker for the period 1970 - 1985 using cross-country data from Penn World Tables. This demonstrated that total factor productivity growth in Hong Kong was relatively high, not so high in South Korea and Taiwan, and very low in Singapore. Fischer (1993) used the growth accounting framework to obtain a negative total factor productivity growth rate for Singapore and low rates of growth for Taiwan. The conclusions were generalized to a range of East Asian countries by Young (1995) and also supported by Krugman (1994).

Counter-evidence was provided by the World Bank (1993). However, the World Bank study imposed constant returns to scale and neutrality of technical progress. Both these assumptions were shown to be rejected by Kim and Lau (1996). The World Bank also assumed competition which was also rejected by Kim and Lau.

Hayami. and Ogasawara (1999) took a much longer time perspective on growth. Their data went back to 1880 and permitted the development process for Japan to be traced over an extended period. The paper advanced the hypothesis that for much of this period Japan continued to depend more heavily on physical capital accumulation due to its characteristic of borrowed-technology based economic growth. The longer time horizon provides a perspective on Japan relative to the more recently developed East Asian economies.

Crafts (1999) provides a broad survey on growth accounting applied primarily to East Asian countries. The paper notes the various estimates of the growth of total factor productivity. It also discusses the role of a range of factors in catching-up such as institutional structures. It reports some efforts at incorporating the role of schooling as a measure of the increase in human capital. From this follows the claim that after taking account of schooling the Western countries have performed better in total factor productivity growth than predicted while most Asian countries have performed worse (with some exceptions). This strengthens the previous conclusions.

The application of growth accounting confirms that there has been a variety of growth experiences across the range of countries considered. There may be some remaining issues concerning the precise size of the effects but there is little doubt that some countries have grown through capital accumulation while others have grown through increases in *TFP*.

7.3 Extensions

The applications of growth accounting described to this point have followed the standard methodology of assuming an identical production function for all countries. This is an assumption that can, and should, be tested. More recent work has taken this possibility into account.

The innovation of Senhadji (2000) is to take the value of α in the production function as potentially different between countries. The estimation results provide support for this relaxation and show that α is generally higher in industrialized countries, but not always so. The level of human capital is based on the Barro and Lee (1994) methodology of a weighted average of shares of population attaining each of seven levels of educational attainment. The weights are computed using data on observed relative earnings of the different educational groups.

The estimated values of α are summarized in Table 7.3. The first value in each column is the estimate of the production function in levels. The value in parentheses is the estimate using first differences. The two estimates are fairly similar with the exception of East Asia which could be important in understanding the source of the rapid growth in East Asia. The values of α reveal that there are significant differences between countries and that an average value of α would hide these large variations. These results are evidence that imposing a single value of α is a poor approximation. The paper also notes that $\alpha = (\partial Y / \partial K)(K / Y)$, so the value is a combination of marginal product $(\partial Y / \partial K)$ and capital output ratio (K / Y). This means there is no simple reason for expecting any correlation with type of country since a low-capital country will have a high $\partial Y / \partial K$ but low K / Y.

Region	α
Sub-Saharan Africa	0.43 (0.50)
Middle East and North Africa	0.63 (0.54)
Latin America	0.25 (0.62)
East Asia	0.48 (0.30)
South Asia	0.56 (0.42)
Industrial	0.64 (0.58)

Table 7.3: Estimate of Cobb-Douglas Production Function

These estimates are used to decompose output growth into the various factors for countries grouped into six regions. The values in Table 7.4 are obtained using the level estimates. For East Asia the first difference estimates are given in parentheses since the two estimates of α are widely different. In all cases the level estimates show that growth in the capital stock is the most important factor. The growth in human capital (measured as an average schooling variable) is the least important contributor. But note for East Asia how the first difference estimate (using α = 0.30 rather than α = 0.48) provides a different insight into the growth of *TFP*. This is low for the level estimate (0.28) but much larger (1.34) for the first difference estimate. There is a clear methodological point here that the explanation of growth in East Asia through capital accumulation requires further confirmation.

Region	*dTFP*	*dk*	*dl*	*dh*	*dy*
Sub-Saharan Africa	-0.56)	1.79	1.39	0.22	2.83
Middle East and North Africa	-0.03	3.99	0.84	0.25	5.05
Latin America	-0.39	2.31	1.22	0.28	3.42

East Asia	0.28 (1.34)	4.50 (2.86)	1.27 (1.71)	0.44 (0.59)	6.49 (6.49)
South Asia	0.55	2.87	0.99	0.25	4.66
Industrial	0.06	2.87	0.99	0.25	4.66

Table *7*.**4:** Decomposition of Growth 1960-1994

The final exercise in the paper is to regress the total factor productivity of each country relative to that in the US on a range of variables. These variables capture initial conditions (*TFP*: TFP2R_0, human capital: HKR_0, physical capital: KR_0, life expectancy: LIFE), external shocks (terms of trade: TOT), macroeconomic situation (inflation: INFL, public consumption: Cg, real exchange rate: RER, reserve-import ratio: RESM, external debt-GDP ratio: DEBT), trade regime (current account convertibility (dummy): CACON, capital account convertibility (dummy): KCON), and political stability (war casualties: DEATH) plus dummies of sub-Saharan Africa, East Asia, South Asia, Middle East and North Africa, and Latin America. The results reported in Table *7*.5 show that initial conditions are important in explaining relative *TFP*. The variables TFP2R_0 and HKR_0 have positive and significant coefficient. In particular, human capital has an important role to play here in explaining relative total factor productivity (its coefficient is ten times that on physical capital and both variables are relative to the US value and in logs).

TFP2R_0	0.93041 (0.00574)
HKR_0	0.2756 (0.06065)
KR_0	0.03223 (0.0274)
LIFE	0.00167 (0.00070)
TOT	0.03765 (0.01386)
INFL	-2.63×10^{-5} (7.42×10^{-6})
Cg	−0.03510 (0.01218)
RER	−0.07403 (0.01090)

RESM	0.93041 (0.00574)
DEBT	0.00247 (0.00134)
CACON	−0.00651 (0.01150)
KCON	−0.04722 (0.01252)
DEATH	−0.12187 (0.01568)
DUMAFR	0.23209 (0.04793)
DUMEA	0.09298 (0.04454)
DUMSA	0.05698 (0.04186)
DUMME	0.25446 (0.04428)
DUMLA	0.12846 (0.04449)
R^2	0.998

Table *7*.**5:** Explanation of relative *TFP*

Standard errors in parentheses

Vandenbussche *et al.* (2006) aim to provide a model to explain the Krueger and Lindahl (2001) result (further description is in Section 7.5 below) that the effect of the initial level of education on the rate of growth was highly heterogeneous between rich countries (including OECD members), low-income and middle-income countries, and that it was not positive for the richest countries in the sample. The theory divides labour into two groups: skilled and unskilled. The dynamics of a country's production frontier depend on the distance from the world frontier, and the division of skilled and unskilled labour between innovation and imitation. The equilibrium growth rate then becomes dependent on how these are allocated. The marginal effect of having more high-skill workers increases the closer is the economy to the frontier but the marginal effect of more low-skill workers is reduced by proximity. This can explain the difference in findings for low-income and high-income countries. Note that this analytical model has no trade and no investment in education, but just an exogenous allocation of low- and high-skill to workers.

The econometric analysis then explores this model by essentially using an interaction term between proximity to the US frontier and the proportion of the workforce that are skilled. This is applied to 19 OECD countries. Two different education measures are used because of the ongoing debate on how to represent education. Lagged public expenditure on education is the main instrument for education (this is needed because of the endogeneity issue identified by Bils and Klenow (2000)). The initial regression is not very successful, so the countries are grouped and dummies are used for the groups. Education is categorized into tertiary and below, and divided into pre- and post-1985 to reflect the information technology revolution. The estimates show that holding the quantity of low-labour constant, the growth-enhancing effect of more high-skilled labour is larger the closer to the frontier is the country. Table 7.6 provides a sample of the findings. Years PS and Years T are the number of years of primary/secondary education (PS) and tertiary education (T) of the average adult. The proximity threshold shows that for a country with *TFP* more than 35 percent below that of the US an increase in higher education will reduce growth. The results show that there was a strong proximity effect on the value of tertiary education prior to 1985 but that this declined post-1985.

Proximity	−0.09 (0.2)
Years PS	−0.029 (0.02)
Years PS post 1985	0.015 (0.012)
Years T	0.418 (0.18)
Years T post 1985	−0.113 (0.124)
Proximity*Years PS	−0.053 (0.045)
Prox*Years PS post 1985	−0.039 (0.038)
Proximity*Years T	1.2 (0.58)
Prox*Years T post 1985	−0.167 (0.5)
Country dummies	Groups
Proximity threshold	−0.348 (0.046)

Threshold post 1985	-0.295 (0.06)

Table 7.6: Proximity to frontier and value of education

Standard errors in parentheses

An alternative approach to estimation of *TFP* is to employ non-parametric analysis. The advantage of this approach is that it avoids any need to impose a functional form on the production function. It also avoids the assumption that the elasticities are equal to factor shares.

Iwata *et al.* (2003) base their estimation procedure on the conditional expectation of $\ln(Y_t)$ which is given by

$$m(\ln K, \ln L, t) \equiv E[\ln Y \mid \ln K, \ln L, t] = a(t) + F^*(\ln K, \ln L). \quad (7.3)$$

The shares of capital and labour are the derivatives of this mean function

$$s_K \equiv \frac{\partial \ln F}{\partial \ln K} = \frac{\partial F^*}{\partial \ln K}, \quad (7.4)$$

$$s_L \equiv \frac{\partial \ln F}{\partial \ln L} = \frac{\partial F^*}{\partial \ln L}. \quad (7.5)$$

The basis of the nonparametric approach is local averaging. The smoothness of the estimated curve depends on the extent of averaging. Averaging over the entire sample gives a straight line. The Iwata *et al.* paper employs three different methods of averaging to ensure that the results are not unduly dependent on the method chosen.

The paper estimates *TFP* growth for nine East Asian countries. The estimates provided do differ a little from earlier estimates. Generally, they show higher *TFP* growth for the East Asian countries than previously calculated. Table 7.7 reports the results of nonparametric estimation for a sample of countries obtained by using the traditional method based on the income share of labour used by Young (1995), and the income share set equal to 0.65 as in Collins and Bosworth (1996). Hong Kong is an exception to the general finding of higher *TFP* using the nonparametric approach. *TFP* growth in Singapore is much higher with the nonparametric estimation.

	Conventional		Nonparametric
Country	Young	Collins	
Hong Kong	4.1	4.1	3.4
Korea	2.8	2.3	3.7
Singapore	0.5	1.8	3.7

Taiwan	3.8	2.1	3.8

Table 7.7: Nonparametric and conventional estimates of *TFP* growth

Table 7.8 reports the nonparametric estimates of elasticities and income shares. For both capital and labour the elasticities differ quite significantly from the factor shares. However, the sum of the elasticities is close to 1 so the aggregate production function is not far from having constant returns to scale.

	Capital		Labor	
Country	Elasticity	Income share	Elasticity	Income share
Hong Kong	0.41	0.37	0.71	0.63
Korea	0.18	0.29	0.81	0.71
Singapore	0.17	0.49	0.63	0.51
Taiwan	0.19	0.26	0.76	0.74

Table 7.8: Nonparametric estimates of elasticities and shares

Iwata *et al.* focus on the debate between assimilation (of technology) and accumulation (this is the Lau perspective). The empirical estimates support the conclusion that the growth has come from a combination of these sources. But note that this does not test whether the changes are neutral, or capital augmenting, or labour augmenting. Hence, the paper does not really address the true sources behind the growth in total factor productivity.

Jones (2002) looks again at his model of endogenous growth through ideas. The starting point is the observation that US growth has been steady at an average of 1.8 percent over the past 125 years and that there is no time trend in US real interest rate of capital-output ratio. These facts have been used as evidence that US is on its steady-state balanced growth path. There are other observations that tell a different story. The time spent in education in the US has increased and the fraction of workers in R&D has increased from 0.25 percent of the workforce in 1950 to 0.75 percent of the workforce in 1993. These changes should have caused an increase in the growth rate. Jones suggests that the competing observations can be rationalized by distinguishing between a constant growth path and a balanced growth path. He argues that it is possible to have a constant growth rate above the balanced growth rate for a sustained period of time but with eventually levelling off.

The formal model of this idea is set in a multi-country world with physical capital accumulation and human capital accumulation. Ideas spread internationally. The number of researchers relative to employment is used as a measure of R&D intensity. The paper conducts a growth accounting exercise to find the contributing effects to growth. The key part of the paper is to try to reconcile long-run dynamics and transition dynamics. It is claimed that what is currently being observed are transition dynamics.

The basis of the model is a production function

$$y = \left(\frac{K}{Y}\right)^{\frac{\alpha}{1-\alpha}} \ell_Y h A^{\frac{\sigma}{1-\alpha}}, \tag{7.6}$$

where ℓ_Y is the proportion of the workforce engaged in productive employment (the remainder are employed in the production of ideas), h the level of human capital, and A is the total stock of ideas. The stock of ideas grows according to the worldwide employment in the production of ideas. The rate of growth on the balanced growth path is γ, so in the long run

$$g_y = \frac{\sigma}{1-\alpha} g_A = \gamma n. \tag{7.7}$$

The growth accounting is based on the growth version of the production function

$$\hat{y} = \frac{\alpha}{1-\alpha}\left(\hat{K} - \hat{Y}\right) + \hat{h} + \hat{\ell}_Y + \left(\frac{\sigma}{1-\alpha}\hat{A} - \gamma n\right) + \gamma n, \tag{7.8}$$

where $\hat{y} = \frac{1}{t}\left(\ln(y_t) - \ln(y_0)\right)$ for some base year 0. If the economy is on a balanced growth path all terms except the last should be zero. The results of the application are summarized in Table 7.9. (These numbers are computed assuming $\sigma = 1 - \alpha$.)

γ	$\hat{y}$	$\frac{\alpha}{1-\alpha}\left(\hat{K} - \hat{Y}\right)$	$\hat{h}$	$\hat{\ell}_Y$	$\hat{A} - \gamma n$	γn
0.050	0.020	-0.0007	-0.0001	0.0063	0.0140	0.0006

Table 7.9: Growth accounting US 1950 - 1993

On the basis that output growth was 2 percent annually over the sample period and that the capital-output ratio is almost constant the value attached to $\frac{\alpha}{1-\alpha}\left(\hat{K} - \hat{Y}\right)$ in Table 7.9 shows a unit increase in the capital-output ratio leads to a -0.07 percentage point fall in growth. Employment has a similarly small effect. The growth in educational attainment contributed 0.63 percentage points to growth. The largest contributor to growth (explaining 70 percent of growth) is the rise in the stock of ideas. Note that in the long run growth will come only from γn. In the short run this factor explains only 20 percent of growth. In any case, the growth accounting shows that transition dynamics associated with educational attainment and research intensity account for 80 percent of growth. Rising employment counts for 15 percent.

Hsieh (2002) computes dual estimates of the growth in total factor productivity. Dual refers to the fact that price data is used, not data from national accounts. It is argued that the claimed growth in capital in the East Asian countries would have reduced the return to capital if there was no growth in total factor productivity. If this had occurred then the capital stock growth would not have happened. Alternatively, the data in national accounts on the capital stock is not giving the correct picture, so price data should be used instead.

The method is based on the observation that an improvement in technology will shift out the factor price frontier. Alternatively, if real wage growth is due only to capital accumulation then the return to capital must fall at the same rate as wages grow. If this does not happen then there must be an increase in total factor productivity. The results presented in the paper for Korea are consistent with earlier studies, but for Singapore the growth in total factor productivity is higher.

The change in technology can also be understood by looking at the production frontier. Han et al (2002) use a varying coefficients production frontier model to look at four Asian countries. Total factor productivity growth is separated into technical efficiency change and technological progress. The results show there is evidence for growth being generated partly through an increase in inputs causing partly through growth in technical efficiency. There is weak, or negative, evidence of technological progress. The data cover the interval from 1987 to 1993, so this is a fairly short time period for judging technical progress.

The production frontier model is applied by Han *et al.* (2004) to a wider range of countries. The larger set of countries implies the frontier must be further out (or at least no further in), so there is more scope for inefficiency. The empirical results again support the hypothesis that the four best performers during 1970 - 1990 (Japan, Singapore, South Korea, Taiwan) do not stand out from other countries around the world in terms of their growth in *TFP*. It is input growth that appears to be the main contributor to their growth performance. The paper also concludes that these countries are behind the US in terms of technical efficiency. Some arguments concerning market institutions are provided to explain this finding.

7.4 Testing for Endogeneity

Information on total factor productivity can, in principle, be used to test whether the data has been generated by an economy with endogenous or exogenous growth. If growth is truly exogenous then changes in *TFP* should be independent of any economic variables. Regressing *TFP* on variables such as saving, investment, and human capital accumulation should generate estimated coefficients that are statistically insignificant. Conversely, if growth is endogenous then some economic variables will have significant explanatory power when used in a regression for *TFP*.

Mankiw *et al.* (1992) claim evidence for the Solow model with exogenous growth in productivity, especially if the production function is augmented with a human capital variable. What is meant by evidence is that the estimated model fits the data well: the coefficients are significant, with the correct sign, and generally satisfy the restrictions imposed by the model. The model also explains almost 80 percent of the variation in output within the sample of 98 countries (but performs much worse on the sub-sample of 28 OECD countries). Furthermore, the regression results imply a share of capital in output that is close to the observed value.

The empirical analysis regresses the log of GDP per capita on the log of investment/GDP (as a measure of saving), the log of the sum of population growth rate, technology growth rate and depreciation and the log of participation in secondary schooling. It is important to note the dependent variable is the level of per capita output and not the growth of output. The regression results for the augmented model are given in Table 7.10 (with standard errors in parentheses).

Constant	6.89 (1.17)
$\ln(I/GDP)$	0.69 (0.13)
$\ln(n+g+\delta)$	-1.739 (0.41)
$\ln(SCHOOL)$	0.66 (0.07)
$\overline{R}^2$	0.78

Table 7.10: Testing the Solow model

As pointed out by Bernanke and Gurkaynak (2001) the results of Mankiw *et al.* do not constitute a formal test of the Solow model against alternative growth models. The basis of this claim is that the estimation framework of Mankiw *et al.* is broadly consistent with any growth model that permits a balanced growth path. So, Mankiw *et al.* do not actually test the Solow model as a distinct alternative to other models but only test the existence of a balanced growth path.

Given this, Bernanke and Gurkaynak argue that it is necessary to test the Solow prediction that long-run growth is due only to exogenous technical change and should therefore be independent of other variables (such as the aggregate saving rate, schooling rates, and the growth rate of the labour force).

The next step is to see if growth if endogenous. If it is, then it will be correlated with some other economic variables. A test of this is undertaken by evaluating *TFP*, then regressing *TFP* on saving for physical capital, saving for human capital, and the growth rate of population. The results for a sample of 50 countries are in Table 7.11. Here s_K is the share of output devoted to gross investment in physical capital, s_H is the share of output devoted to gross investment in human capital, and n is the growth rate of population. The return on education is assumed to be equal to 7 percent. The results show that these variables, particularly the saving rate for physical capital, are significant for explaining the growth in *TFP*. Strong statistical evidence is found against the predictions of the Solow model. The rate of investment is strongly correlated with growth. Human capital accumulation and the rate of population growth are less strongly correlated with growth. The Solow model that growth determines savings does not seem to fit the data. This is evidence that technical progress is not exogenous but can be explained by variables in the model.

Constant	-0.01 (0.00)	-0.01 (0.01)	0.02 (0.00)	-0.01 (0.01)	0.00 (0.00)	0.01 (0.01)	0.00 (0.01)
s_K	0.07 (0.02)			0.07 (0.02)	0.05 (0.02)		0.05 (0.02)
s_H		0.14 (0.06)		0.06 (0.06)		0.08 (0.06)	0.03 (0.05)
n			-0.45 (0.11)		-0.32 (0.10)	-0.41 (0.117)	-0.31 (0.11)
R^2	0.28	0.08	0.26	0.28	0.39	0.27	0.38

Table *7.***11:** Regression for *TFP*

Standard errors in parentheses

Islam (1995) examines how the results of Mankiw *et al.* are modified when the data are treated as a panel. The analytical innovation is to take the constant in the standard Cobb-Douglas production function as a country-specific effect and use panel data methods to estimate the growth regression. The key point of the estimation is that the individual effect that is ignored in standard regressions is correlated with the included explanatory variables and causes omitted variable bias. The adoption of the panel approach generates a much higher rate of convergence and a lower elasticity of output with respect to capital. The estimated elasticity is closer to the empirically-observed value. This is shown in the results reported in Table *7*.12. This estimated equation is restricted to have the same coefficient (but with opposite signs) on $\ln(s)$ and $\ln(n+g+\delta)$. In addition, the value of λ measures the rate of convergence through the relationship

$$\frac{d\ln\hat{y}(t)}{dt} = \lambda\left[\ln\hat{y}^* - \ln\hat{y}(t)\right], \qquad (7.9)$$

where $\hat{y}(t)$ is income per effective worker at time *t* and $\hat{y}^*$ is the steady state level of income per effective worker.

	NONOIL	INTER	OECD
$y_{i,t-1}$	0.7919 (0.0349)	0.7954 (0.0387)	0.6294 (0.0495)
$\ln(s)-\ln(n+g+\delta)$	0.1634 (0.0238)	0.1726 (0.0524)	0.0954 (0.0581)
R^2	0.7368	0.8251	0.9642

Implied λ	0.0467 (0.0088)	0.0458 (0.0097)	0.0926 (0.0157)
Implied α	0.4398 (0.0545)	0.4575 (0.0575)	0.2047 (0.1042)

Table 7.12: Fixed effects estimate

Standard errors in parentheses

Including human capital in the form of average schooling years in the population aged over 25 does not change the results significantly. In all the estimation results the value of the fixed effect is significant. This is interpreted as capturing all the technological factors that make countries different. Countries tend to be placed where expected, such as all the African countries having a very low value for the fixed effect, and Hong Kong having the highest value. The implication of the significant fixed effect is that countries should seek to influence its value by choice of policy.

The issue of whether growth is endogenous or exogenous is an important one for policy. It would seem natural to presume that it is endogenous. The apparent surprise in the work of Mankiw *et al.* is the evidence that seems to suggest that the Solow model provides a compelling explanation of differences in per capita output across a broad set of countries. However, their analysis does not function as a test of the Solow model but only as an explanation of differences in balanced growth paths. The evidence of Bernanke and Gurkaynak strongly points to the growth in *TFP* being explicable by economic variables.

7.5 Education and *TFP*

There has been a small literature assessing the effect of education on *TFP*. One perspective is that education, in the form of human capital, enters as a stock in the production function. In a simple specification the product of human capital and hours of labour supply constitute the effective labour input. A more general specification would see human capital entering as a variable distinct from hours of labour. An alternative model is to enter education directly as a determinant of total factor productivity. Hence, an increase in education would raise total factor productivity.

Krueger and Lindahl (2001) provide a survey of the modelling of the returns to education. The focus of the paper is on the Mincer (1974) formulation of the returns to education: the earnings-education relation is log-linear. It is claimed that there is no evidence to show that this is not the case. The Mincer model implies that the change in a country's average level of schooling should be the determinant of growth. However, the regressions reviewed above have all used the initial level of education as the explanatory variable. The explanation for this choice in the growth literature is that Benhabib and Spiegel (1994) showed that the change in education is not a determinant of the growth rate. Krueger and Lindahl conclude that this result emerges because there is no signal in the education data of Benhabib and Spiegel when conditioned on the growth in the stock of capital. It is claimed the Krueger and

Lindahl analysis suggests the change and initial level are positively correlated with growth.

This line of reasoning is developed further in Ferreira *et al.* (2004). The issue they consider is the correct specification of the production function. They represent the Mankiw *et al.* formulation that underlies most of the growth analysis as having human capital enter the production function in the general form

$$Y = AK^{\alpha} H^{\phi} \left(Le^{gt}\right)^{\beta}. \tag{7.10}$$

In this formulation human capital is an input and there is exogenous labour-augmenting technical progress. The alternative form of production function is based on Mincer (1974) and has human capital (measured in terms of years of schooling, *h*) entering directly into the determination of the rate of growth

$$Y = AK^{\alpha} \left(e^{\phi h} Le^{gt}\right)^{\beta}. \tag{7.11}$$

When these alternative productions functions are logged the human capital variable enters in log from for the first and in level from for the second. Ferreira *et al.* then estimate an equation with a flexible functional form which nests these two hypotheses. The empirical testing shows that the Mankiw *et al.* form is rejected but the Mincer form cannot be rejected. Therefore, this analysis provides evidence that supports endogenous growth theory with human capital directly determining the increase in *TFP*.

7.6 Observations

The purpose of growth accounting is to determine the separate contributions of labour growth, capital growth, and innovation. This is a coarse division but it is still able to provide interesting insights.

The comparative studies demonstrate a variety of growth experiences. This is important since the basis of growth regressions is that the cross-country data represent different draws from the same underlying process. The fact that countries differ in the routes they have followed to growth undermines this assumption and provides a further reason for questioning the results of growth regressions, particularly when applied to heterogeneous sample of countries.

The growth regressions also confirm that it is possible to achieve very high short-term growth rates by capital investment alone when early in the development process. This is the clear message from the analysis of the East Asian economies during the 1980s. This point also demonstrates that technical innovation - the route emphasized by the endogenous growth literature - is not the only way to achieve growth. The evidence does demonstrate that there has been technology-driven growth in the industrialized Western countries. The confirmation that the growth experience has differed across countries is an important observation when framing policy responses. It is unlikely that the same policy will be equally successful for all. For instance, the encouragement of innovation is of limited value if an economy has no research base and has relied upon the importation of technology. What the growth accounting has not achieved is any demonstration of the role of increases in human capital relative to increases in the quality of physical capital. Both of these are captured in the Solow residual. Obtaining this information would be of considerable value for policy purposes.

The results of growth accounting exercises leave important questions unanswered. It is clear that *TFP* differs between countries but the reason why is not. Prescott (1998) argues that the difference in *TFP* cannot be explained by differences in saving rates, stocks of physical capital, or stocks of human capital. If it is assumed that all countries have access to approximately the same level of technical knowledge the only remaining explanation is that some countries simply exploit the known technology better. The explanation of why this might be the case remains to be provided.

Overall growth accounting is a well established methodology that delivers broad characterizations of the contributions to growth. These are of some value but much more detail is needed of the processes that are occurring behind these broad brush observations.

Appendix on Growth Accounting

Growth accounting is a method used to determine the contribution of each factor to the growth of output. Any growth unexplained by factor growth is viewed as attributable to technical progress.

Consider the production function

$$Y = F(K, L, A), \tag{7.12}$$

where Y is output, K is capital use, L is labour, and A is the level of technical progress. If we view each of the variables as a function of time, t, we can write

$$Y(t) = F(K(t), L(t), A(t)). \tag{7.13}$$

Differentiating with respect to time

$$\frac{dY}{dt} = F_K \frac{\partial K}{\partial t} + F_L \frac{\partial L}{\partial t} + F_A \frac{\partial A}{\partial t}. \tag{7.14}$$

If the markets for factors are competitive then the marginal products are equal to factor rewards, so $F_K = r$ and $F_L = w$. Hence

$$\frac{dY}{dt} = r\frac{\partial K}{\partial t} + w\frac{\partial L}{\partial t} + F_A \frac{\partial A}{\partial t}$$

$$= rK\frac{1}{K}\frac{\partial K}{\partial t} + wL\frac{1}{L}\frac{\partial L}{\partial t} + F_A \frac{\partial A}{\partial t}. \tag{7.15}$$

Now define the growth rates of output, capital, and labour by

$$g_Y = \frac{1}{Y}\frac{\partial Y}{\partial t}, \tag{7.16}$$

$$g_K = \frac{1}{K}\frac{\partial K}{\partial t}, \tag{7.17}$$

and

$$g_L = \frac{1}{L}\frac{\partial L}{\partial t}. \tag{7.18}$$

Dividing (7.15) by Y and using the definitions of the growth rates

$$\frac{1}{Y}\frac{\partial Y}{\partial t} = \frac{rK}{Y}\frac{1}{K}\frac{\partial K}{\partial t} + \frac{wL}{Y}\frac{1}{L}\frac{\partial L}{\partial t} + \frac{F_A}{Y}\frac{\partial A}{\partial t}, \tag{7.19}$$

becomes

$$g_Y = \alpha_K g_K + \alpha_L g_L + SR, \tag{7.20}$$

where $\alpha_K = rK/Y$ is the share of capital in national income, $\alpha_L = wL/Y$ is the share of labour in national income, and SR is the "Solow residual". The Solow residual is the part of growth that cannot be attributed to growth in the stock of capital or labour. This can be interpreted as the underlying growth in productivity due to technical progress.

This expression can be further refined. If the production function has constant returns to scale in capital and labour then the shares α_K and α_L sum to 1. The key relation can then be written

$$\begin{aligned} SR &= g_Y - \alpha_K g_K - (1-\alpha_K)g_L \\ &= g_Y - g_L - \alpha_K(g_K - g_L). \end{aligned} \tag{7.21}$$

The growth of the output labour ratio, Y/L, satisfies

$$g_{Y/L} = g_Y - g_L, \tag{7.22}$$

and the growth of the capital-labour ratio, K/L, satisfies

$$g_{K/L} = g_K - g_L. \tag{7.23}$$

These allow the Solow residual to be expressed as

$$SR = g_{Y/L} - \alpha_K g_{K/L}. \tag{7.24}$$

A second refinement is to consider the measure of labour that enters the production function as being the product of quality (h) and quantity (L). Here quality is meant to be human capital, often proxied by the number of years of schooling. The production function becomes

$$Y(t) = F(K(t), h(t)L(t), A(t)). \tag{7.25}$$

Repeating the steps above gives

$$g_Y = \alpha_K g_K + \alpha_L g_L + \alpha_L g_h + SR, \tag{7.26}$$

where the labour share is now defined in payments to quality labour hours

$$\alpha_L = \frac{whL}{Y}. \tag{7.27}$$

Under the assumption of constant returns this gives the Solow residual

$$SR = g_Y - \alpha_K g_K - (1 - \alpha_K) g_L - (1 - \alpha_K) g_h. \tag{7.28}$$

Much of the econometric analysis described in the main body of the report is concerned with determining the contribution of each factor to growth and the value the technical progress as identified by the Solow residual.

Part 4
Disaggregated Policy Effects

Chapter 8. Personal

- Educational choices are sensitive to changes in cost but less sensitive to changes in return
- Measures of natural ability perform better in growth regressions than measures of education
- The degree of sensitivity of saving to tax incentives is contentious. The effect is likely to be small
- Female labour supply is sensitive to taxation
- Entry into entrepreneurship is affected by taxation but it is not clear whether it is the level of taxation of the progressivity of taxation that matters most
- The choices of entrepreneurs are sensitive to taxation
- There is weak evidence the inequality reduces growth in low-income countries

8.1 Introduction

Endogenous growth models describe a number of separate channels through which growth can occur. The essential nature of endogenous growth is that these channels are the consequence of decisions taken by economic agents. As examples, the level of human capital results from the educational choices of individuals and the number of technical innovations is a consequence of expenditure by firms on research and development. Taxation will impact upon the rate of growth if it affects any of the economic choices involved with these growth channels.

The content of the report so far has focussed on empirical work conducted with aggregate data. The intention of from this point is to review the evidence on the individual decisions that endogenous growth theory has identified as relevant. It should be noted that this is a diverse and varied literature that was not necessarily written to answer the questions being asked of it here. In particular, the effects estimated do not always relate directly to taxation. Therefore the results have to be extracted through careful consideration.

8.2 Human Capital

The economic theory of growth has assumed that it is a measure of quality-adjusted labour that enters the production function, rather than just the quantity of labour. The quality-adjusted labour supply is typically expressed as the product of some measure of education and labour supply. This specification is implicit in the empirical applications of growth regressions and growth accounting.

This observation suggests that two points must be considered. First, how the choice is affected by the policy variables of the government. Second, what the correct measure of labour supply quality is in empirical growth theory. The latter question can itself carry implications for policy. These questions remain equally valid if human capital enters the production function in an alternative way.

8.2.1 Taxation and Educational Choice

To obtain an insight into how educational choices are determined, and how policy can affect choice, a simple model of the education decision is now analyzed.

Consider a single consumer with a two-period lifespan. In the first period they can choose to work or to be educated. Working provides a wage of w_n and education has a cost *e*. A subsidy σ is received to pay for the costs of education. The consumer's initial wealth is *W*. Income is divided between consumption, x_1, and saving, *s*. Borrowing is represented as negative saving. The capital market is initially assumed to be perfect so both saving and borrowing can be undertaken at gross interest rate *r*.

In the second period of life the consumer earns wage w_n if they did not choose education. If they chose education the wage received is $w_e > w_n$. An income tax at rate *t* is levied on income from employment and interest income from saving.

If education is not chosen then the budget constraint in the first period of life is

$$W + (1-t)w_n = x_1 + s, \tag{8.1}$$

and in the second period of life

$$(1-t)w_n + (1 + r(1-t))s = x_2. \tag{8.2}$$

These combine to give the lifecycle budget constraint

$$W + (1-t)w_n + \frac{(1-t)w_n}{1+r(1-t)} = x_1 + \frac{x_2}{1+r(1-t)}). \tag{8.3}$$

If education is chosen the period budget constraints become

$$W = x_1 + s + e - \sigma, \tag{8.4}$$

and

$$(1-t)w_e + (1 + r(1-t))s = x_2. \tag{8.5}$$

These give the lifecycle budget constraint

$$W+\frac{(1-t)w_e}{1+r(1-t)}-e+\sigma=x_1+\frac{x_2}{1+r(1-t)}. \tag{8.6}$$

The assumption of a perfect capital market implies there are no limitations upon borrowing or saving. The lifecycle budget constraint is therefore linear so the consumer's decision can be based entirely upon the discounted value of lifetime wealth. If education makes the discounted value greater, then education will be chosen. Applying this reasoning the consumer described above will choose education if

$$\frac{(1-t)w_e}{1+r(1-t)}-e+\sigma>(1-t)w_n+\frac{(1-t)w_n}{1+r(1-t)}, \tag{8.7}$$

or

$$\frac{w_e-w_n}{1+r(1-t)}>w_n+\frac{e-\sigma}{(1-t)}. \tag{8.8}$$

This reflects the requirement that the increase in wage due to education is sufficiently large to offset the cost. It can be seen from this expression that an increase in the subsidy always has the effect of making it more likely that this inequality is satisfied. The effect of an increase in the tax rate has an ambiguous effect. It raises the left-hand side and raises the second term on the right-hand side. It will make education less likely if the cost of education is greater than the interest earned in the net of tax wage.

The result above implicitly assumes that interest received and interest paid are treated symmetrically by the tax system. Now assume that interest received is taxed but there is no relief on interest payments. Assume also that the consumer has to borrow to fund education but saves if education is not chosen. This modifies the lifetime budget constraint to

$$W+\frac{(1-t)w_e}{1+r}-e+\sigma=x_1+\frac{x_2}{1+r}. \tag{8.9}$$

This has the effect of changing the discount factor between the education and no education situations. The solution to the choice problem is now dependent upon the consumer's preferences.

It is well known that there are difficulties in borrowing to finance education. This implies that it is more appropriate to model the capital market as imperfect with a higher rate for borrowing than lending. The effect of this is to create a kink in the budget constraint at the point of no borrowing or saving. It is then not enough to just consider the present value of income (since it is not clear what interest rate has to be used to do so) and the choice becomes dependent upon preferences. Moreover, the choice becomes dependent on initial wealth W.

In fact, higher-income consumers will choose education when the lower-income ones will not because the former can self-finance rather than borrow at the higher rate. The increase in subsidy will be effective in this setting for assisting those who are close to the margin. Note that if preferences are very similar then all of those who benefit and move into education because of an increase in σ will be at a similar income level. The existence of imperfections in the capital market adds further ambiguity into the tax effect.

8.2.2 Empirical Results

The first question to address is the sensitivity of educational choices to policy parameters. The available literature has paid little attention to the effect of taxation, possibly because of the basic ambiguity in its effect. Taxation also affects costs and benefits in the long-run, and evidence from behavioral economics suggests consumers may be more concerned with the short-run. The literature has focused upon determining the response of the educational decision to changes in the design of tuition subsidy programs. These programs affect the cost of education in the short term and can have significant and immediate effects. The results of this branch of the literature are now reviewed.

In terms of the model described above the literature has estimated the consequence of an increase (or decrease) in the subsidy payment, σ. With an imperfect capital market the simple model shows that a change in the subsidy will affect only a narrow group of individuals - those on the margin between choosing education and no education. If preferences are similar this group will display homogeneity in income. Moreover, the effect will also tend to be focused on the group most affected by the imperfections in the capital market. Hence, it can be expected that the affected group will display homogeneity in credit market characteristics.

The early literature from the 1970s and 1980s is surveyed by Leslie and Brinkman (1989). From the reported results they conclude that a $1000 change in the cost of education (evaluated in year 2001 dollars) was associated with a four percentage point difference in college enrolment rates.

An early contribution to the recent literature was Kane (1994) who analyzed the effect of the 1980s cut back in the Pell grant scheme for means-tested higher education support in the US. The paper employed data on enrolments in higher education to assess the role of grants and returns, with particular emphasis on black youths. What the paper found was that the direct costs of education were very important in explaining enrollment. The reduction of the subsidy raised the direct cost which caused a fall in the proportion of black youths entering higher education in the US. Evaluated at the mean characteristics of the sample, an increase of $1000 in the net direct cost of education generated a five percentage point reduction in black enrolment.

The decline in white enrolment was smaller than this figure. Conversely, the returns to education did not seem as important. This latter result was tested by including the income differential between high school and college. For blacks this did not seem to have much effect but it did matter for whites. The paper observes that costs seem more important than returns, and justifies this by appealing to an argument based on the discounting of returns. An alternative interpretation could be the role of credit market imperfections.

The analysis of educational choice is developed further in Kane (1995) which again looks at the effect of subsidies on enrollment. The paper concludes that the effect is large, particularly for students from low-income families and for those students attending two-year college. It also observes that college enrolment falls when the minimum wage is increased. The paper also concludes that the response to the targeted aid in the Pell Grant program seems to be low with no disproportionate increase in enrolment of students from low-income families. This implies that means-testing did not have the effect predicted by the model of educational choice: targeting support to marginal students should cause the most significant increase in enrolment. Two arguments that might explain this are limitations on places in colleges and lack of information of marginal students on the Pell Grant scheme perhaps through general lack of prior involvement in college education.

Seftor and Turner (2002) also analyze the Pell Grant scheme. The key feature of their work is that the sample population is older students who are in their twenties and thirties. The reason for interest in this group of students is that they typically have experience of work and are in a better position to evaluate the income they will earn in the no-education alternative. In addition, older students are likely to have developed a credit history and be able to borrow more easily on the credit market. These facts suggest that their behavior should conform closely to the predictions of the economic model. The methodology applied to the data is that of a natural experiment with difference-in-differences estimation. The paper finds that the cost elasticity of participation is high for the older students, and certainly higher than that of the younger students studied in previous papers.

Dynarski (2000) studies the HOPE program introduced by the state of Georgia. This program allows tax rebates on spending for educational purposes, thus reducing the net cost. This obviously helped the middle- and upper-income classes more since they could take full advantage of the scheme. The data is analyzed as a natural experiment using difference-in-difference estimators with nearby states without the program being used as controls. The results show that program seemed to have raised enrolment in Georgia by about 7.5 percentage points, with the enrolment probability increasing by 25 percent. This means that each $1000 in aid increased the college enrolment probability by around four percentage points.

The paper also reports evidence that the program had a differential effect on whites compared to blacks for reasons of income distribution. The overall conclusion is that the elasticity of attendance is higher than previously suspected, so that schemes can have a significant effect. However, the paper also identifies the fact that for every student who chooses education because of the scheme there are four who would have gone to college anyway but now just benefit from the subsidy. So, from this perspective, the scheme is inefficient in its allocation of funding. It should also be noted that the paper develops a very simple human capital model with benefits and costs of education that shows how the scheme may affect choice. But the prediction of the theoretical analysis reduces to an unsigned second cross-derivative, so the outcome is ambiguous.

Dynarski (2003) is interested in calculating the elasticity of higher education choice with respects to the level of student aid. To investigate this issue the paper studies the effect of the withdrawal of a program in which the children of deceased, disabled, and retired Social Security beneficiaries received a monthly lump-sum to finance study. Between 1965 and 1982 these benefits were extended to beneficiaries' children up to the age of 22, provided the child remained in full-time education. The payments were made without reference to the actual costs of education. The average value of the grant was $6700 which would almost pay for average private college in 1980. The program was abruptly terminated and from May 1982 those not already enrolled were ineligible for future subsidies.

The paper used difference-in-differences estimation of the equation

$$y = \alpha + \beta(\text{Father deceased} * \text{Before}) + \delta\text{Father deceased} + \theta\text{Before} + \upsilon, \quad (8.10)$$

where y is a measure of college attendance. Before measures whether the individual graduated from high school before the benefits were eliminated. Father deceased measures eligibility for the benefits. The variable β captures the effect on the education decision of the eligibility for aid. The data used was the National Longitudinal Survey of Youth. The cohorts in their senior high school years in 1982 and 1983 are the After group who are ineligible. The cohorts in their senior year in 1979, 1980, and 1981 are the Before group who are potentially eligible for treatment.

The empirical analysis produces an estimated value of $\beta = 0.219$ with a standard error of 0.102. The R^2 for the regression is 0.339 after the inclusion of a number of covariates. The introduction of the scheme is estimated to have increased take-up of college by 22 percent, so it has a large and significant effect.

Dynarski notes that the student aid policy may have attracted into college students who had low ex ante expected returns to college. This represents inefficient use of expenditure. Also, the significance of the policy effect could come from either relaxing the liquidity constraint due to an imperfect capital market or from the direct subsidy effect reducing the net cost of education.

The focus of Dynarski (2005) is primarily upon whether subsidy programs affect the completion rate of education. The relevance of completion is that the US has a very high entry rate into college education but the completion rate is much lower. The paper argues that any further major increases in entry are hard to achieve so completion is possibly the easier route to a significant increase in the stock of human capital. The effect of the scholarship programs in Arkansas and Georgia are studied for their effects upon entry and completion. The method is again to treat these programs as natural experiments and to use difference-in-differences estimation.

The results show that the programs increase the share of population completing college by 3 percentage points. The effect is strongest among women, with the share of non-white women completing college increasing by 7 percentage points. The size of these increases can be judged against the fact that the 27 percent of the cohort prior to the introduction of the programs completed a college degree. It is concluded that subsidy programs have a large and significant effect upon completion of college degrees but the proportion dropping out of college remains high even when education is free, so the cost of education is not the only factor preventing completion.

The studies of educational choice described up to this point have concentrated upon the effect of grants or subsidies that are paid at the time the educational costs are incurred. In contrast, Long (2003) analyzes the effect of a tax credit which accrues the year after the educational costs are met. There is potential for these tax credits to have a very different effect to the subsidies because of the difference in timing.

The US Tax Relief Act of 1997 introduced federal tax credits for higher education expenses. These credits were designed as targeted tax relief to the middle classes. The middle class target was justified using the argument that this group constituted a large proportion of those attending college but were excluded from other federal grant programs. Tax expenditures are also favored by federal budget rules since they do not appear as expenditures. The tax credit accrues on a family basis. The credit for tuition expenses in one year do not accrue until the following year.

Tax credits have several properties worth noting. First, if it is liquidity constraints that are holding down attendance at college then a tax credit will have little effect. This is because the timing does not assist with the relaxation of the credit constraint. Second, the use of credits limits the number of students who will choose college when it is not beneficial. This observation is based on the expectation that there will be an increased income against which to offset the tax credit. Third, there is no limit on how expensive the tax expenditure may be. For instance, the existence of tax credits may cause the choice of more expensive colleges which raises the tax expenditure.

The paper notes that the use of the tax credits has been well below predicted levels. This is important for interpreting the analysis of the effects. In fact, only 36 percent of those who were eligible actually claimed the tax credit. Survey evidence is reported which shows that the majority of parents were not aware of the credits. The credits can affect the number going to college or can lead to the choice of a more costly college. The data indicates no significant enrolment response to the credits. This result is obtained by treating the credit as a natural experiment with results estimated using the difference-in-differences method.

The lack of an enrolment response may be explained by the basic fact that students are not sensitive to inducements that are not received until some time in the future. The economics of hyperbolic discounting can explain this form of short-sightedness. Alternatively, the explanation could be the fact that tax credits do not relax a liquidity constraint. Or it may be that the lack of awareness means those who might change their behavior – potential students on the margin of attendance - just do not know about the tax credits. (It is interesting to observe that this paper may be also informative about the effect of publication bias in surveying the published literature. The paper concludes that the policy has no interesting effects and has not yet been published despite being in circulation for some time and receiving several citations. In contrast, all the published work tends to report significant effects.)

The role of costs in the choice of college is studied in Long (2004).The analysis exploits data on match-specific information between individuals and colleges. Using the conditional logistic choice model and a range of control variables, Long estimates that an individual is 41 percent less likely to attend a college that costs $1000 more (valued in 2001 dollars). The sample used is from the US National Education Longitudinal Survey. For the average individual the responsiveness is enough to move the first choice college to fifth place if it charges $1000 more. The paper also conducted a simulation that cut the price difference between public and private colleges in half. This resulted in up to 29 percent fewer students entering public four-year colleges. These results again reveal college choice to be cost sensitive.

The analysis of scholarships programs and educational participation provides results that confirm theoretical predictions. When the immediate cost of education is reduced participation increases. Furthermore, the reported percentage point increases from the natural experiments are relatively large and indicate that attendance is sensitive to cost. If college attendance adds to the stock of human capital and raises growth then the experience of the scholarship programs reveals an effective policy tool. The analysis of tax credits provides a different picture. The take-up of tax credits has been low and the attendance effect negligible. The difference in outcome between tax credit and scholarship program is most likely due to the timing. Two very different arguments can provide an explanation. If imperfect capital markets limit borrowing for college attendance then the tax credit will be less effective. Alternatively, if consumers exhibit the impatience described in behavioral economics (and represented by hyperbolic discounting) then they will prefer the immediate benefit of a scholarship to the deferred benefit of a tax credit. Whatever the explanation, it is clear that the timing of the receipt of support is crucial.

8.2.3 What Should Go in a Regression?

The level of human capital is one of the most important variables in endogenous growth theory. In most models it interacts with the level of physical capital to achieve the constant returns to scale that ensure the continuance of growth. The issue for the estimation of growth regressions is the measured variable that can be used to represent the theoretical construct. Furthermore, even if this issue is resolved there remains the direction of causality between growth and education. As already noted, Bils and Klenow (2000) demonstrate how growth can imply schooling just as much as schooling can imply growth.

The research of Romer (1990b), Barro (1991) and Mankiw *et al.* (1992) used data on enrolment in education programs. The drawback with this measure is that it is a flow variable whereas the theoretical variable is a stock. Barro and Lee (1993) constructed an educational measure that has been used in many later studies. This measures the stock of human capital through country survey and census data on the proportions of population with various levels of schooling. This variable goes part of the way to providing a measure of human capital but still has a number of shortcomings. One problem is the issue of comparability of the different levels of quality of schooling in international comparisons. Completion of a given level of education may imply different intellectual achievement across a heterogeneous set of countries. A second problem is that measures of primary and secondary education are silent on higher education and on the training provided by firms. The accumulation of general and firm-specific human capital while in employment can reasonably be argued to be closer to the theoretical concept of human capital than schooling. There is also the additional problem that the number of years of schooling cannot indefinitely increase to raise human capital and ensure growth.

These difficulties are recognized by Hanushek and Kimko (2000) who construct an alternative measure of labour-force quality by employing performance on international tests of ability. The tests they employ have a focus upon mathematical and science skill. These are argued to be the most relevant abilities in a practical interpretation of the human capital variable that appears in theoretical models. Results at the individual level also show the importance of mathematics in determining individual incomes (Bishop, 1992). The results of the individual tests are averaged to provide a single indicator for each country. One process of aggregation assumes the mean score is constant over time (QL1) whereas the other measures scores relative to the US mean (QL2). The two averages are highly correlated and perform similarly in regression analysis.

The first claim of Hanushek and Kimko (2000) is that the constructed measures perform better than years of schooling in growth regressions. This is illustrated by the estimated coefficients reported in Table 8.1 (with standard errors in parentheses). The constructed quality measures (QL1 and QL2) are significant in the regressions when included alongside the standard quantity of schooling variable. In contrast, the quantity of schooling variable loses significance. The inclusion of the quality variables also causes a significant increase in the explanatory power of the regression equation. These results are claimed to give strong support to the labour quality measure.

Constant	4.092 0.974	−1.756 (1.346)	−0.151 (1.142)
GDP 1960	−0.609 (0.186)	−0.481 (0.093)	−0.517 (0.112)
Annual population growth	−0.745 (0.181)	−0.038 (0.215)	−0.250 (0.211)
Quantity of schooling	0.519 (0.195)	0.106 (0.119)	0.116 (0.139)
Labor force quality (QL1)		0.133 (0.024)	
Labor force quality (QL2)			0.098 (0.015)
R^2	0.41	0.73	0.69

Table 8.1: Growth and labour-force quality

Hanushek and Kimko then extend the analysis to include countries for which international test scores are not available. This is achieved by predicting the quality measured using observed information. The regression used to undertake this includes school enrolment rates, pupil-teacher ratios, education expenditures, and regional dummies. The growth regression is then repeated using the constructed quality variables. Very similar results are obtained to those reported in Table 8.1. The paper also reports that the measures are robust in the sense of Levine and Renelt (1992) and are most informative for the countries at the top and the bottom of the growth range.

The work of Jones and Schneider (2006) further develops the argument that the concept of human capital in growth models should relate to something more basic than schooling. They claim that human capital should refer to the underlying ability to adapt to change and to problem-solve. From this perspective they argue that the level of IQ is closer to what the growth models envisage. Clearly, there is much scope for this assumption to be disputed.

Jones and Schneider (2006) use the database of Lynn and Vanhanen (2002) which has data on IQ tests for 81 countries. These tests span the 20th century. The national average IQ from this data set is included in growth regressions along with all the standard variables. It is found that the effect of IQ is positive and significant even when all the standard regressors are present. In brief, they use all three-variable combinations of the 21 growth variables that passed Sala-i-Martin's (1997) robustness test. This gives 1330 regressions. IQ was statistically significant at the 5 percent level in 99.8 percent of these regressions. The IQ measure was also included in regressions with the standard measures of human capital. The IQ variable remained significant. The variable still works when OECD countries are removed from the sample (this checks that there is not cultural bias in attainment on IQ tests in favor of OECD countries).

The key results from the paper are in Table 8.2. The coefficient value gives the average across a set of regressions and measures the effect of a one-point increase in a nation's average IQ on average annual economic growth in percent. The controls represent the pool from which the other variables in the regression were drawn Top 21 is the set of most significant variables from Sala-i-Martin (1997). Education controls are a wide range of different measures of total education in a county.

	Coefficient	% significant	% positive	No. of regressions
All countries Controls = Top 21	0.123 (0.025)	99.8	100	1330
All countries Controls = Education	0.150 (0.023)	100	100	56
Non-OECD Controls = Top 21	0.103 (0.048)	99.9	99.9	1330
Non-OECD Controls	0.131 (0.043)	100	100	56

= Education				

Table 8.2: Coefficient and significance of IQ, 1960 - 1992

Standard errors in parentheses

These results raise questions about what the human capital variable is representing in the endogenous growth framework. Previous studies have used school enrolments and years of schooling as the measure of human capital on the basis that human capital is modelled as something that can be invested in. The finding that underlying abilities are significant suggests that it is not schooling that delivers growth but just basic IQ. Therefore, the investment in education is not justified by the model. If this is correct, the role of education has to be explained by its function as a signalling device. However, there is a possibility that IQ could be endogenous in that high growth and expenditure on education can raise IQ. Closer scrutiny is required to reveal whether this is the case.

8.3 Saving

The level of saving plays a key role in the determination of the steady state in the Solow growth model. Saving is less prominent in endogenous growth models but it is still important. If there is no saving then there are no funds for investment and hence no growth. Saving is also an issue of considerable practical importance. It is frequently claimed that private saving in the UK and US (amongst others) is inadequate to fund retirement. Increases in the dependency ratio are also putting pressure on state pensions systems. The combination of these factors has led to the "pensions crisis" that threatens many developed countries. The role of tax incentives in boosting saving is important both for reasons of economic growth and for tackling the pensions crisis.

8.3.1 Taxation and Saving

The standard representation of saving behavior is generated from the lifecycle model of consumer choice. The essence of the lifecycle model is that a rational consumer chooses a lifetime plan for consumption and labour supply taking into account the lifetime budget constraint. The model also captures optimal saving behavior since the level of saving is the difference between income and the value of consumption in each period. The predictions of the model depend upon the detailed assumptions imposed but most specifications imply some degree of consumption smoothing across the lifecycle. The classic survey of the economics of saving is King (1985) which discusses in detail non-stochastic and stochastic versions of the lifecycle model.

Consider an individual with a lifetime of T periods. A choice for the consumer consists of levels of consumption, c_t, and labour supply, ℓ_t, in every period $t = 1,\dots,T$, and the value of bequest, B. These choices are made to maximize the utility function

$$U = U(c_1,\dots,c_T,\ell_1,\dots,\ell_T,B), \tag{8.11}$$

subject to the lifetime budget constraint

$$\sum_{t=1}^{T} \frac{p_t c_t}{d_t} + \sum_{t=1}^{T} \frac{w_t (1 - \ell_t)}{d_t} + B = \sum_{t=1}^{T} \frac{w_t}{d_t} + I, \tag{8.12}$$

where I is the present value of non-labour income and d_t is the discount factor in period t. The necessary conditions for optimal consumption and labour supply are

$$U_{c_t} - \lambda \frac{p_t}{d_t} = 0,\ t = 1, \ldots, T, \tag{8.13}$$

and

$$U_{\ell_t} - \lambda \frac{w_t}{d_t} = 0,\ t = 1, \ldots, T. \tag{8.14}$$

The necessary conditions can be combined with the budget constraint and solved to give the consumption demand and labour supply functions

$$c_t = c_t(p_1, \ldots, p_T, w_1, \ldots, w_T, d_1, \ldots, d_T), \tag{8.15}$$

and

$$\ell_t = \ell_t(p_1, \ldots, p_T, w_1, \ldots, w_T, d_1, \ldots, d_T). \tag{8.16}$$

Econometric analysis of such demand functions requires complete knowledge of the lifetime prices, wages, and discount factors. The effect of taxation on saving can be found by noting that

$$d_t = \prod_{i=1}^{t} (1 + r_i(1 - \tau_i)), \tag{8.17}$$

where τ_i is the tax rate on interest income at time i. The solution shows that the effect of a change in the tax rate in any period is reflected in a change in consumption and labour supply in every period. In interpreting this, it should be stressed that this is a non-stochastic model where it is assumed all variables are known at $t = 1$ when the lifetime plan is chosen. If an unexpected change occurs at $\hat{t}$ then the plan can, of course, only be revised from $\hat{t}$ onwards.

If the utility function is time separable an alternative solution method may be employed. Assume a time separable utility function of the form

$$U = \sum_{t=1}^{T} \beta^t U(c_t, \ell_t). \tag{8.18}$$

The necessary conditions are

$$\beta^t U_{c_t}(c_t, \ell_t) - \lambda \frac{p_t}{d_t} = 0,\ t = 1, \ldots, T, \tag{8.19}$$

and

$$\beta^t U_{\ell_t}(c_t,\ell_t)-\lambda\frac{w_t}{d_t}=0,\ t=1,\ldots,T\,. \tag{8.20}$$

The important observation is that the only variable that links periods is the Lagrange multiplier, λ, and this has a constant value independent of time. The implied demand and supply functions are

$$c_t = c\left(\lambda\frac{p_t}{d_t},\lambda\frac{w_t}{d_t},\beta^t\right), \tag{8.21}$$

and

$$\ell_t = \ell\left(\lambda\frac{p_t}{d_t},\lambda\frac{w_t}{d_t},\beta^t\right). \tag{8.22}$$

The implication of these demand functions is that consumption and labour supply can be seen to be directly related to within-period prices and wage rates. The time paths of labour supply and consumption (and, by implication, of saving) reflect the time paths of prices and wages. Hence, in time periods where the wage rate is high it should be expected that labour supply is high. Such claims can be made precise if additional structure is placed on the model.

More specific results can be found by specializing the model. Consider a consumer who lives for two periods. They work in the first period of life and are retired in the second period. Part of first period income is saved to finance consumption in retirement. Assume that there is an income tax at rate τ_w. The lifecycle budget constraint in the first period of life is

$$x^1+s=w\ell(1-\tau_w), \tag{8.23}$$

where τ_w is the tax on labour income, and the budget constraint in the second period of life is

$$x^2=s(1+r(1-\tau_r)), \tag{8.24}$$

where τ_r is the tax on interest income. In most tax codes these are identical. The choice of saving $\{s\}$ is made to maximize the additive utility function

$$U=U\left(x^1\right)+\delta U\left(x^2\right), \tag{8.25}$$

where δ is the discount rate.

The necessary condition can be written

$$-U'\left(x^1\right)+\delta U'\left(x^2\right)(1+r(1-\tau_r))=0\,. \tag{8.26}$$

This necessary condition shows that the income tax does not distort the allocation of consumption across the two periods. It does affect the level of consumption through an income effect. The tax on interest income does distort the choice. From the necessary condition the effect of the interest tax on saving is

$$\frac{ds}{d\tau_r} = \frac{\delta r\left[U'\left(x^2\right) + U''\left(x^2\right)\left(1 + r\left(1 - \tau_r\right)\right)s\right]}{S}$$

$$= \frac{\delta r U'\left(x^2\right)\left[1 - R_R\right]}{S}, \tag{8.27}$$

where $S < 0$ is the second-order condition for choice of s and R_R is the coefficient of relative risk aversion. It can be seen directly from this result that the effect of the interest tax is ambiguous since it has both an income and a substitution effect.

This analysis reveals that the theory is unable to predict how taxation will affect saving. It provides a model that can be estimated but the value of the elasticity of savings with respect to the tax rate is ultimately an empirical question.

8.3.2 Empirical Results

The level of saving determines the capital that is available for investment. It follows from this that the rate of growth can be increased by a policy that raises the level of saving. Such a policy will only be successful if the level of saving is responsive to changes in the net interest rate. This reasoning provided the motivation for numerous studies of the interest elasticity of saving.

The first major contribution to this literature was Boskin (1978) who estimated an aggregate consumption function on US data for the period 1929 - 1969. The estimated range of the elasticity was between 0.3 and 0.6, with the preferred estimate being 0.4. This value was much larger than the consensus of opinion from earlier estimates. The key feature of Boskin's work was the construction of an expected interest rate using an autoregressive process. Furthermore, the aggregate consumption function estimated was not founded on micro principles. The approach of Boskin was modified by Howry and Hyman (1978) by replacing the expected interest rate with the actual real interest rate and adding lagged unemployment as an explanatory variable. This generated the conclusion that the interest rate had virtually no effect on consumption. The estimated value of the elasticity was then increased by the work of Summers (1982) who found the size of the elasticity to a value possibly in excess of 1. The data were then reconsidered again by Hall (1988) and the elasticity estimated to be close to 0 but not above 0.2. More discussion of this debate can be found in Batina and Ihori (2000).

A recent analysis of the effect of taxation upon aggregate is provided by Tanzi and Zee (1998). The paper uses data from 21 OECD countries over the time period 1970 - 1994. This data includes the saving rate, plus the revenue for a number of taxes as a proportion of GDP. The econometric results are obtained by regressing the saving rate on various combinations of the tax variables. Results are presented for levels, logs, and first differences. In every case the coefficients on the tax variables are negative and, in almost all cases, are significant. This is claimed to be evidence that taxes impact upon saving. Taxes may impact on saving, but the methods of this paper cannot prove the fact. At best, the regressions establish a strong correlation. However, the cause of this correlation is not identified. For example, some countries could have high taxes in order to finance generous state pensions. The provision of generous pensions would reduce the need to save for retirement, hence causing a negative correlation between tax rates and saving. The econometric analysis is also weak. The results are generated using OLS without exploiting any of the benefits of having a panel. Nor are any of the time series properties of the data tested. Finally, no additional covariates are included in the regressions.

The nature of the analysis of taxation and saving has now changed. This reflected a move from the estimation of aggregate consumption functions on long time series to the study of the consequences of policy changes. In other literatures policy changes have been addressed using the natural experiments format, but for savings this has not been done directly. Instead, there has been more traditional structural modelling applied to the observed data.

The US has witnessed two major schemes designed to increase the level of saving. Individual Retirement Accounts (IRAs) were introduced in 1974 to allow saving in a tax-privileged form for employees without pension plans. Eligibility for IRAs was expanded by the Economic Recovery Tax Act of 1981 to permit almost all working taxpayers to contribute, and the IRA limits were increased. This led to a major increase in saving in IRAs. The Tax Reform Act of 1986 changed the position by excluding higher-income taxpayers with employer-provided pensions. Contributions to IRAs then fell considerably. 401(k) plans were made available in 1978 but did not become significant until clarification of their rules in 1981. The difference from an IRA is that a 401(k) is only available to employees of companies that choose to sponsor the plans. Contributions to a 401(k) are made through payroll deductions whereas IRA contributions are at the discretion of the employee. Further description of the programs and the revisions are given in Poterba *et al.* (1996). The analytical importance of these schemes is that they have provided data for testing the responsiveness of savings.

Venti and Wise (1990) model the consumer as having a choice between consumption, an IRA, and taxable, but liquid, savings. If the IRA and other savings are imperfect substitutes it follows that part of any increase in saving in the IRA must come from a reduction in current consumption. The data they employ comes from the Consumer Expenditure Survey. The first piece of evidence presented is the percent of families that have an IRA. This data is summarized in Table 8.3 and very clearly shows the increase in number over time. The observation is made that very few US families have any assets other than housing and that investment in other assets showed no comparable increase over the same period. These figures are interpreted as providing the first evidence that IRAs have increased saving.

1980	3.2
1981	3.1
1982	9.6

1983	15.7
1984	17.4
1985	20.0

Table 8.3: Percent of families with an IRA

The model of saving used by Venti and Wise is a very simple one that is justified by a Cobb-Douglas utility function. The optimization incorporates the rationing aspect of the limit on IRA contributions. The values predicted by the estimated model are quite close to the actual values, an observation that is presented as an informal demonstration of goodness-of-fit. They estimate that about 45 to 66 percent of the increase in IRA deposits following from the 1986 Tax Reform Act comes from current consumption, 30 percent from tax subsidies, and 3 to 20 percent is redirected from standard savings. The conclusion is that the vast majority of IRA saving is new and not diverted.

At the opposite extreme of observations are Gale and Scholz (1994). They study the effect of IRAs by comparing the choices of savers at the IRA limit with those who are not at the limit. It is concluded that IRAs have a negative or a zero effect upon savings. The contributions to IRAs come entirely from saving that would have been undertaken in any case. But Poterba *et al.* (1996) observed that this conclusion was based on excluding households who reported having savings of over $100,000. When the exclusion was reduced to $90,000 or raised to $110,000 a new estimation revealed that the conclusion was entirely reversed and implied that funds placed in IRAs were entirely new saving.

Can the effect on saving be large? It has been observed that 3/4 of contributors are the saving limit in each year. For these contributors the incentive does not affect marginal saving. So, the new effect must be small. This is the argument used by Burman *et al.* (1990) and Gravelle (1991). But it is the lifetime limit on saving that matters. Gale and Scholz (1994) demonstrate that only 30 percent contribute to the limit for three consecutive years. Hence 70 percent face a marginal incentive in at least one of the three years. Also, Feldstein and Feenberg (1983) argue that if saving moves from other sources to IRAs it would not take long for most households to exhaust their existing savings.

The arguments of Feldstein (1995b) are important for assessing whether the tax cost of IRAs (and other saving incentives) are greater or smaller than the benefits. The paper does not address the size of the benefits directly but instead focuses on the observation that previous research has miscalculated the cost. It observes that previous papers looked at the direct effect of IRAs on saving (with the typical conclusion that some deposits are diversion and some an increase) and the direct revenue loss. It has then been concluded that aggregate saving falls since the increase in saving is smaller than the revenue loss, implying the incentive is unsuccessful. The new point that Feldstein makes is that the increase in private saving raises the corporate capital stock (through the investment = saving equilibrium condition) and therefore leads to an increase in tax revenue from the corporate sector. This offsets the loss of tax revenue from offering the IRA. Compounding this effect over time then shows that the IRA can lead to increased revenue. This argument becomes important when a cost-benefit calculation is undertaken of the provision of saving incentives. If increased saving raises above the level prior to the incentive then the cost is negative. The subsidy is immediately justified without the need for any further analysis.

Hubbard and Skinner (1996) evaluate this evidence and a range of other studies. They offer the conclusion that none of the work provides a compelling answer. Instead, they suggest that the true effect lies somewhere between the two limits. The effects of 401 (k) plans are considered in the same light. Criticisms of existing work are given, and it is concluded that some 401(k) contributions represent new saving.

In addition to this, Hubbard and Skinner (1996) also simulate the effect IRAs have on capital accumulation. This is done for a range of values for the proportion of IRA deposits that represent new saving. This simulation is reported in Table 8.4. The first line provides the baseline case and the second line incorporates the effect noted by Feldstein (1985): more saving means more investment by corporations and hence more corporate tax revenues. This effect offsets the revenue cost of the saving incentive. The conclusion to be drawn from the table is that the IRA schemes are worthwhile even when only a fraction of investment is new saving. The table also shows that the effect noted by Feldstein can be quite large.

	New private saving per dollar of revenue loss			
	0 Cents	10 Cents	19 Cents	26 Cents
Baseline	$0.22	$0.81	$1.51	$2.21
Including coporate tax revenue	$0.22	$0.97	$2.33	$4.84

Table 8.4: Change in net capital accumulation per dollar increase in government revenue lost on IRAs

These arguments should be set against those made by Engen *et al.* (1996). They review the same literature and reach the conclusion that the increase in saving has been negligible. Faults are described in each of the empirical studies, such as biases in selection of the population, that are claimed to invalidate the results. In summary, it is concluded that decisions on the timing of economic transactions are responsive to taxation. Financial and accounting decisions - here interpreted as the choice of saving vehicle - are the next most responsive. Real decisions - the level of saving – are the least responsive choices. The tax incentives offered by IRAs and 401(k) plans therefore cause a reallocation of saving between types of asset but have little effect on the level of saving.

Poterba *et al.* (1996) review their research into the effect of IRAs and 401(k)s on other savings. In Poterba *et al.* (1994, 1995) households are divided into groups according to their participation in savings programs. The data demonstrate that within each group there was no reduction in other asset holdings as saving in IRAs and 401(k)s increased. In contrast, the asset holding of households that did not participate in the programs generally decreased over the same period. Poterba *et al.* also consider the difference in asset holdings of those eligible for 401(k)s and those not eligible. Before the introduction of the programs the asset holding of the two groups are equal. After the introduction the asset holdings of the eligible group rise significantly relative to those of non-eligibles, with almost no change in non-401(k) assets. This again suggests a significant effect of the incentives. The results are summarized in Table 8.5. On the basis of the evidence Poterba *et al.* (1996) conclude that, although the methods may be imperfect, the incentives provided by IRAs and 401(k)s have clearly led to an increase in saving rather than simply the diversion of saving from other assets.

Income interval	Eligible	Non-eligible
< 10	2,033	1,378
10 – 20	4,045	1,997
20 – 30	5,499	2,558
30 – 40	8,693	3,256
40 – 50	14,470	6,206
50 – 75	26,093	10,080
> 75	51,080	29,842

Table: 8.5: Mean total financial asset balances

Auerbach (2002) studies the effect upon national saving of the tax cuts in the Economic Growth and Tax Relief Reconciliation Act of 2001. This act has a number of unusual features including the back-loading of the tax cuts and the "sunset" after 2010. These features particularly affect saving because of the long time horizon. The paper considers the effect on saving of the provisions for reducing marginal income tax rates, the reform of the Earned Income Tax Credit, and the increase in child tax credit. It does not analyze the phased repeal of the estate tax. This omission seems important since the treatment of estates is relevant for saving if there is a bequest motive.

The paper conducts the analysis by using the Auerbach-Kotlikoff overlapping generations economy. This is simulated over the period 2001 - 2020, and 2150 is employed as representative of the steady state. The simulations vary in the length of time the tax cuts remain in place and in the tax instrument that is adjusted after repeal to reclaim revenue. The pattern of results is that savings initially fall, then rise, but fall again. In every simulation savings are lower in the long-run that at the initial point. They are also lower in the steady state. The point is made in the paper that the steady-state effect is larger than at first apparent. This is because capital accumulation is lower on the path to the steady state. Output is therefore also lower and, since savings are reduced as a proportion of output, the value of saving is much reduced over what it would have been without the Act.

The work of Cunningham and Engelhardt (2002) uses data from the Health and Retirement Study to study the responsiveness of 401(k) saving to taxation and employer matching. The advantage of the data set is that it contains detailed information on each individual. In particular the data permit the calculation of individual contribution to 401(k) saving.

Taxation is introduced into the analysis by assuming that the marginal dollar of saving is placed either in a 401(k) or in an IRA. The two forms of saving are viewed as imperfect substitutes so there is not complete switching from one to the other. Viewed from the present (time 0) a dollar invested in a 401(k) if there are T years to retirement is

$$V^{401} = (1-\tau_T)(1+m\xi_T)(1+r)^T, \tag{8.28}$$

where r is the interest rate, m is the employer matching rate, ξ_T is the fraction of the employer match that is vested in T periods, and τ_T is the tax rate at the time of withdrawal. For an IRA the value of a marginal dollar is

$$V^{IRA} = (1-\tau_T)(1-\gamma)(1+r)^T + (1-\tau_T)\gamma(1-\tau_0)(1+r)^T$$
$$+\tau_T\gamma(1-\tau_0), \tag{8.29}$$

where γ is the fraction of a pre-tax dollar contributed to an IRA that is not tax deductible. The relative tax benefit of a 401(k) compared to an IRA is then defined by

$$\frac{V^{401}}{V^{IRA}}. \tag{8.30}$$

This variable is calculated for all the individuals in the data set and employed as one of the regressors. This construction shows that no simple tax effect can be calculated from the regression results. The tax rates entering the calculation of (8.30) are different between individuals according to their location in the income distribution. All that the econometrics predicts is the average effect of a change in the relative tax benefit.

The econometric analysis finds that (8.30) has a positive coefficient but is not statistically significant in most of the regressions. For the preferred regression the parameter estimate implies that the limit on tax deductibility for IRA introduced in the Tax Reform Act of 1986 raised 401(k) saving by 6 percent.

It should be noted how the techniques used to analyze these savings programs differ from the econometric analysis of consumption. The standard tool used to understand consumption is the lifecycle model and its representation through the Euler equation (see Attanasio, 1999). This structural approach has not been applied in the savings debate reported. Instead, the papers have attempted to use tests that are independent of an underlying theory. This could be one of the explanations for the lack of a consensus on the size of the tax effect. Further discussion of this point can be found in Attanasio and Banks (2001).

There is one further important point to be raised. The recent interest in behavioral economics has focused attention on the assumptions that are embedded in standard models of the savings decision. Experimental and empirical evidence has generated a range of "anomalies" where choices do not fit with the models predictions (see Thaler (1990)). Two of the most prominent areas for anomalies are choice under uncertainty and intertemporal choice. Both of these issues are central in the savings decisions.

The standard model employs expected utility maximization. There are numerous alternative theories of choice under uncertainty including those of Epstein and Zin (1989) and Kahneman and Tversky (1979, 1986). These theories suggest modified probabilities for weighting states, or alternative preference representations. The other key aspect of the standard model is exponential discounting. Numerous experiments provide evidence that individuals are more impatient in the short-run than suggested by exponential discounting, but are more patient in the long-run. This has led to the construction of alternative discounting schemes with hyperbolic discounting being the most prominent. The implications of hyperbolic discounting for choice have recently been explored (Laibson and Harris, 2000) but no compelling empirical implementation has been published yet. The impatience implied by hyperbolic discounting can be interpreted as a lack of self-control which pushes an individual into choosing immediate consumption and a postponement of saving. Such lack of self-control has been advanced as an explanation for the use of savings plans that involve a degree of commitment. A 401(k) plan ensures that savings are tied until retirement and therefore involves commitment. The behavioral conclusion is that the commitment aspect, and not the tax effect, explains the popularity of the plans.

Behavioral economics has opened many issues and it will be some time before a balanced assessment can be made. Research into anomalies may either prove to be a dead-end or it could lead to a new understanding of the reality of choices.

8.4 Labour Supply

Labour supply is an important component in the production process. In models of economic growth it combines with human capital to determine the quantity of effective labour, and hence the level of output. Despite this, the analysis of labour supply in terms of the number of hours worked is of secondary importance for a discussion of growth. This is a consequence of the number of working hours and participation being bounded variables. Both have natural limits so cannot continue to rise to support sustained growth. For effective labour to continue to increase it is the human capital component that is critical.

An impression of the value of the labour supply elasticity can be obtained by reviewing the results on Blundell *et al.* (2000). This paper uses data from the UK Family Expenditure Survey to estimate labour supply responses to the tax changes in the 1980s. The changes involved a steady reduction in the basic rate of tax (from 33 percent in 1978 to 25 percent in 1992), a reduction in the top rate of tax (from 83 percent in 1978 to 40 percent in 1992), an increase in the rate of contribution to National Insurance (from 6.5 percent in 1978 to 9.0 percent in 1992). The focus in on the labour supply of women since there is much more variation in female labour supply than in male labour supply. For reasons of social norms adult males are invariably in full-time employment with a labour supply elasticity approximately 0. In contrast, female labour supply can be more elastic with part-time employment possibilities and participation effects.

The estimated elasticities are reported in Table 8.6. The wage elasticities (both non-compensated and compensated) are all positive. The elasticity is highest for women with young children. This group have the lowest average hours and it is here that participation effects and part-time working are most significant. These results confirm that labour supply of some groups of the population is sensitive to taxation.

	Wage elasticity	Compensated wage elasticity	Other income elasticity	Mean hours
No children	0.140	0.140	0.000	32
Youngest child 0 – 2	0.205	0.301	-0.185	20
Youngest child 3 – 4	0.371	0.439	-0.173	18
Youngest child 5 – 10	0.132	0.173	-0.102	21
Youngest child 11+	0.130	0.160	-0.063	25

Table 8.6: Female labour supply elasticities

8.5 Entrepreneurial Activity

Ever since the work of Schumpeter (1934) the role of entrepreneurial activity has been emphasized as one of the determinants of growth. New entrants to a market may use innovative techniques of production, introduce original products, or adopt different forms of organization. If any of these changes are successful there will be spillovers to existing firms. These observations reveal the importance of the rate of entry of new entrepreneurs for growth through innovation.

The role of tax policy can be understood by considering the choice of a potential entrepreneur. Assume two alternative choices are available: remaining in employment or founding a new business as an entrepreneur. The characteristic of employment is that the level of income can be treated as certain. Income as an entrepreneur is more likely to be risky, with an income level above that for employment if successful but an income less than that for employment if unsuccessful. Entrepreneurship is chosen if the expected utility of the risky income stream exceeds the utility of the sure income.

Taxation of income affects this choice process in two ways. Firstly, a progressive income tax reduces the post-tax income for successful entrepreneurship relative to post-tax income for unsuccessful. This provides less incentive for a risk-averse individual to choose the entrepreneurship option. Secondly, if losses from entrepreneurship can be set against other income then the government takes a share in the risky project and the variance of income is reduced. This raises the incentive for a risk-averse individual to choose entrepreneurship. In addition, there is also the possibility that ownership of a small business may provide opportunities for under-reporting of income. This effect raises its attractiveness.

These ideas can be easily formalized. Let employment provide income Y. Self-employment results in income $Y_s > Y$ if successful, and income $Y_f < Y$ if unsuccessful. Assume success occurs with probability p. The income tax system provides a lump-sum grant, g, and has a constant marginal rate, t. Self-employment is chosen if

$$pU\left(g+(1-t)Y_s\right)+(1-p)U\left(g+(1-t)Y_f\right)>U(Y). \qquad (8.31)$$

The two effects of taxation on this decision can be observed by noting that the expected level of post-tax income in self-employment is

$$E(Y)=g+(1-t)\left(pY_s+(1-p)Y_f\right), \qquad (8.32)$$

and the variance of post-tax income is

$$\text{var}(Y)=p(1-p)(1-t)^2\left(Y_s-Y_f\right)^2. \qquad (8.33)$$

An increase in the tax rate reduces expected income but also reduces the variance of income. The effect on the choice between employment and self-employment then depends on the trade-off between risk and return in preferences. These ideas are developed further in Kanbur (1981) and Peck (1989).

The empirical research of Gentry and Hubbard (2000) focuses on the role of progressive taxes in discouraging the risk-taking inherent in choosing entrepreneurship. Data from the Panel Study on Income Dynamics is used covering the period 1979 - 93. The investment of entrepreneurial capital is not recorded in the data set so self-employment is used as the indicator of status. A probit regression is used to model the probability of entry into self-employment. The key variable is a measure of tax progressivity. This variable is defined as the difference between the marginal rate of tax faced when successful as an entrepreneur with the tax rate faced when unsuccessful. Two cases are considered. The "less convex" case has successful increasing income by 50 percent from the level in employment and unsuccessful reducing it by 25 percent. For the "more convex" case the changes are replaced by 100 percent and 50 percent, respectively. Given these income levels the marginal tax rates are predicted by the TAXSIM model (Feenberg and Coutts, 1993).

The estimated probit model is reported in Table 8.7. Many of the variables have the expected sign. The important exception to this rule is the tax rate on employment. Theoretically, a higher tax rate in employment should make self-employment a more attractive option. However, the negative coefficient is not significant. The focus of the paper is the convexity variable. This has the expected negative sign and is very significant. This result shows that an increase in progressivity reduces the probability of choosing self-employment.

Variable	Less convex	More convex
Tax rate on employment	-0.000166 (0.000109)	-0.0000313 (0.000106)

Convexity in tax rate	−0.00121 (0.000129)	−0.00133 (0.0000931)
Head's labor earning	−3.01 (1.07)	−2.98 (0.998)
Head's labor earning squared	0.832 (0.363)	0.788 (0.333)
Dividend and interest income	0.914 (0.223)	0.668 (0.214)
Age	0.000962 (0.000618)	0.000712 (0.000606)
Age squared	−11.9 (7.88)	−8.98 (7.73)
Minority	−0.0137 (0.00172)	−0.0134 (0.00168)
Female head	−0.0188 (0.00172)	−0.0164 (0.00168)
Single (single = 1)	0.00779 (0.00244)	0.00906 (0.00242)
Number of kids	0.00199 (0.00073)	0.00309 (0.000720)
Homeowner	−0.00503 (0.00190)	−0.00596 (0.00187)
Rural	0.00106 (0.00167)	0.00101 (0.00163)
Less than high school	0.00507 (0.00254)	0.00546 (0.00252)
Some college	0.00975 (0.00255)	0.00913 (0.00248)
College	0.0124 (0.00315)	0.011 (0.003037)
Some post-college education	0.0166 (0.00497)	0.0142 (0.00467)
Pseudo-R^2	0.031	0.041

Table 8.7: Self-employment and progressivity of taxation

Standard errors in parentheses

The interpretation of the empirical results is that the choice of self-employment is sensitive to the progressivity of the tax system. The estimated coefficient shows that a 5 percentage point increase in the convexity measure reduces the probability of entry by 0.61 percentage points - which is a decline of approximately 20 percent in the number of self-employed given the average entry probability of 3.1 percent.

An alternative approach to the same questions is pursued by Cullen and Gordon (2002). The data employed is a series of cross-section samples of income tax returns for 21 of the years between 1964 and 1993. The tax returns do not provide any method of distinguishing entrepreneurial income so an indirect method has to be used to identify the set of entrepreneurs. The method chosen is to focus on reported non-corporate losses and identify entrepreneurs by those with losses greater than 10 percent of wage and salary income. The regression analysis then estimates a model that explains the proportion of the sample that is identified as entrepreneurs.

The results of the regression again show that the entrepreneurship choice is sensitive to taxation. A decrease in the personal income tax reduces the proportion choosing to become entrepreneurs because it lessens the effect of sharing losses with the government. The size of this effect is that a 5 percentage point reduction in the personal income tax reduces the proportion choosing entrepreneurship by 30 percent. The choice of entrepreneurship is also sensitive to the corporate tax rate. A 5 percentage point reduction in this, from 15 percent to 10 percent, is estimated to double entry into entrepreneurship.

In a series of paper Carroll *et al.* (1998, 2000a, 2000b) have also investigated the tax returns of entrepreneurs to investigate the effect of the tax changes introduced by the 1986 Tax Reform Act. The tax returns considered are for individuals between the ages of 25 and 55 who reported being sole proprietors in 1985 (before the tax reform) and in 1988 (after the tax reform). The first paper (1998) analyses the investment decision. This is modelled using the basic equation

$$\text{Prob}(I_{88} > 0) = \alpha_0 + \alpha_1(\%\Delta c) + \alpha_2(\%\Delta c \times I_{85}) + \alpha_3 I_{85} + X\beta \,, \tag{8.34}$$

so that the probability of making a positive investment in 1988 is a function of the change in user cost of capital ($\%\Delta c = \ln(c_{88}) - \ln(c_{85})$), a dummy for positive investment in 1985, the interaction of the change in user cost and the dummy, plus a vector, X, of other personal and economic characteristics. The error is assumed to be normal to that the model becomes a probit. The results from conducting this estimation are reported in Table 8.8. The user cost variable, which incorporates the tax rate, has a negative and statistically significant coefficient both without and with the additional regressors. The size of the effect implied by these estimated values is that a 5 percentage point increase in the marginal tax rate of all the proprietors in the sample reduces the mean probability of investment falls from 0.335 to 0.300.

Intercept	-0.795 (0.0304)	-1.38 (0.607)

$\%\Delta c$	-1.26 (0.400)	-1.33 (0.419)
$\%\Delta c \times I_{85}$	-1.47 (0.584)	-1.41 (0.586)
I_{85}	0.822 (0.0472)	0.814 (0.0474)
Age		3.13 (3.07)
Age^2		-4.58 (3.76)
Capinc		0.0605 (0.163)
Married		0.0739 (0.0887)
Dependents		-0.354 (0.2032)
MFG		0.0754 (0.155)
Wholesale		0.159 (0.171)
Retail		-0.0641 (0.0979)
Finance		0.0245 (0.0956)
Service		0.137 (0.0650)

Table 8.8: Probability of investing

The second paper (2000a) applies very similar methods to estimate the relationship between the personal income tax rate of the sole proprietors and the probability that they employ labour. A brief model is presented that assumes that monitoring must be undertaken when employees are taken on, and that proprietors differ in the cost monitoring places upon them. Assuming that the monitoring cost is normally distributed ensures the probability of employing at least one worker can be modelled as a probit. The estimation results show that the probability of offering employment in sensitive to taxation. A 10 percent increase in the entrepreneur's tax price (defined as one minus their marginal tax price) raises the mean probability of hiring by 10 percent.

The subject of the third paper (2000b) is the growth rate of gross business receipts for the same set of sole proprietors. Once more the tax returns in 1985 and 1988 are used and the change in receipts measured between these two years. The (log) of the change in receipts is regressed up the (log) of tax price and the set of explanatory variables. The tax price variable has a positive and significant coefficient, showing that a lower marginal tax rate is correlated with increased business growth.

The conclusion of this literature is that entry into self-employment - interpreted as engaging in entrepreneurial activity - is sensitive to taxation. The papers reviewed agree on the sensitivity but provide mixed evidence on how choices will change. This is not surprising since the tax system interacts with the self-employment choice in several different ways. In particular, progressivity reduces the relative benefit of successful outcomes whereas higher tax rates provide increased risk-sharing with the government.

8.6 Inequality

There are several reasons why the rate of growth may be linked to the degree on inequality. Inequality can increase growth because the rich have a higher propensity to save. Redistributing to the rich therefore raises capital accumulation. Inequality may reduce growth because fiscal policy responds by introducing distortionary taxes to redistribute which retards growth. Capital market imperfections can prevent the poor from borrowing to invest in human capital or to engage in entrepreneurial activity. Inequality can lead to social insecurity and instability, providing an uncertain environment for investment. Inequality can also increase fertility which can reduce growth.

A very extensive survey on the theory and empirical evidence relating economic growth to inequality is provided by Benabou (1996). His argument develops initially from the examples of South Korea and the Philippines. These countries were similar in many dimensions in the 1960s except that there was less inequality in South Korea. Since 1960 South Korea has grown much more rapidly than the Philippines and per capita output is now significantly higher. This example is taken as evidence of the general hypothesis that inequality reduces growth.

The empirical evidence seems more concerned with whether there is convergence in income distributions between countries and whether spending on education is reducing inequality. It is concluded that the evidence on this point is mixed. The survey on the effect of inequality on growth is summarized in Table 8.9. This reports the sign and significance of the inequality variable in growth regressions.

Author	Sign and Significance
Alesina and Rodrik, 1994	- ***
Benhabib and Spiegel, 1996	- *
Bourguignon, 1994	- ***
Brandolini and Rossie, 1995	0

Clarke, 1992	- ***
Deininger and Squire, 1995	- **
Keefer and Knack, 1995	- ***
Perottie, 1992	-***
Perottii, 1994	-***
Perotti, 1996	-***
Persson and Tabellini, 1992	-***
Persson and Tabellini, 1994	-***
Venieris and Gupta, 1986	-***

Table 8.9: Summary of growth regressions using inequality as an explanatory variable

*** Consistent sign and generally significant[0pt]

** Consistent sign and sometimes significant[0pt]

* Consistent sign but generally not significant

Further evidence on the link between inequality and growth is provided by Barro (2000). The technique in this paper is to take a standard growth regression and then include a Gini coefficient to capture the effect of inequality on growth rates. There is found to be little overall relation between growth and the Gini coefficient. In the basic regression equation coefficient on the Gini measure of inequality is estimated to be 0. But when the sample is split into poor countries and rich countries there is weak evidence the inequality reduces growth in the poor countries but raises it in the rich. The coefficient on the Gini for low-GDP countries is negative (-0.033) but insignificant. The coefficient on the Gini for high-GDP countries is positive (0.054) and significant. It is proposed that this is evidence on a nonlinear relation between inequality and growth.

Ododokun and Round (2004) investigate the effect of inequality on growth for 35 African countries. Unfortunately, there is a lack of significance and very poor fit in the regression equations. But what is concluded is that there is some evidence that inequality hindered economic growth. Given the regression equations reported in the Table 8.10 this evidence can only be classed as weak. The explanatory power of the regressions is very low.

Constant	0.091 (1.4)	0.056 (0.9)

Log Per Capita Income	-0.003 (-0.5)	-0.003 (-0.4)
Population Growth	-10.711 (-2.0)	-10.708 (-2.0)
Govt. Consumption/GDP Ratio	-0.0001 (-0.1)	-0.0001 (-0.1)
Gini Coefficient	-0.042 (-0.9)	
Income Share of the Poorest 40%		0.108 (1.2)
Adjusted R^2	0.049	0.062

Table 8.10: Estimated effect of Income Inequality on Economic Growth

t statistics in parentheses

The paper then proceeds to investigate the effect on inequality on various explanatory variables in growth regressions. It claims that there is strong evidence for credit market imperfections as a channel through which inequality can reduce growth because of the way that this limits human capital accumulation. This is achieved by regressing school enrolment rates on a range of variables including an inequality measure. Increased inequality is shown to reduce enrolment. The effect is significant at secondary and tertiary schooling levels and the regression equations have more explanatory power. There is also strong evidence for inequality increasing social instability. Finally some evidence for inequality increasing fertility. There is no evidence supporting the endogenous fiscal policy channel.

8.7 Summary

The chapter has summarized the empirical literature on the sensitivity of individual choices to taxation. The educational choice is sensitive to cost but does not appear to be significantly affected by changes in return. The evidence on the relation between savings and tax incentives is contentious. The net effect may well be small. It is noteworthy that both the educational and the saving decisions involve intertemporal choices with uncertainty. The standard models are therefore open to all the criticisms that have been raised by behavioral economics. If the anomalies discovered in that literature properly characterize behavior the explanation for the results are clear. This is an issue that is under considerable current investigation. The choice to become an entrepreneur is sensitive to taxation, as are the choices made when an entrepreneur. Whether it is the level of taxation or the progressiveness of taxation that matters most is still to be resolved.

Appendix on Natural Experiments

The problem with much econometrics is that the problem of correlation between the right hand variables in a regression. This makes it difficult to disentangle their separate effects. What is needed is some independent variation of the variables so that the individual effect can be obtained.

A natural experiment occurs when an exogenous change allows the derivation of the effect of a change in a single variable. An example of how this can occur is if one state changes a policy (such as introducing a subsidy to college tuition) while other neighboring states do not. In the absence of other changes that do not affect the states asymmetrically this allows the identification of the effect of the variable that has changed. This is called a natural experiment because it is not under the control of the investigator but has the same form of changing one variable of interest as one would in a controlled experiment.

The value to the investigator is that it is typically conducted on large populations with all reactions natural and no selection bias. The standard terminology is to call the subjects exposed to the policy change the *treatment group* and those not exposed the *control group*. Natural experiments also have the benefit that if the change in policy is truly exogenous then there should be no selection bias in the allocation of subjects to the treatment or control groups.

In most applications of natural experiments the situation involves before and after design with an untreated comparison group. This is the case if one state or country alters a single policy but are otherwise exposed to the same influences. The method of estimation this case is that of *difference in differences*.

Assume observations on a population of $i = 1, \ldots, N$ subjects in two time periods $t = 0,1$. The value of the observed action is y_{it}^{j}, where $j = 0$ for the control group and $j = 1$ for the treatment group. The model is then specified by

$$y_{it}^{j} = \alpha + a_1 d_t + \alpha^1 d^j + \beta d_t^j + \varepsilon_{it}^{j}, \tag{8.35}$$

where $d_t = 1$ if $t = 1$ and 0 otherwise, $d^j = 1$ if $j = 1$ and 0 otherwise, and $d_t^j = 1$ if $t = 1$ and $j = 1$ and 0 otherwise. The value of a_1 captures how the groups are affected by time, and α^1 captures the time invariant differences between the groups. The variable d_t^j is a dummy for membership of the control group after it receives the treatment and β is the true effect of the treatment for the outcome of this group.

The identifying assumption is that β would be zero in the absence of treatment. If this is the case then the unbiased estimate of β can be obtained by differences in differences

$$\hat{\beta}_{dd} = \left(\bar{y}_1^1 - \bar{y}_0^1\right) - \left(\bar{y}_1^0 - \bar{y}_0^0\right), \tag{8.36}$$

where the bar denotes the mean value over *i*, the subscript denotes the time period and the superscript denotes the group. The value of $\hat{\beta}_{dd}$ provides a measure of the effect of the treatment.

Further discussion of estimation for natural experiments can be found in Meyer (1995).

Chapter 9: Corporate

- Firms are responsible for investing in physical capital and undertaking innovation
- Natural experiments confirm that investment responds to tax incentives
- Research and development expenditure has an elasticity of approximately 1 with respect to subsidies
- There are significant international spillovers of research and development and these have increased with globalization
- Foreign direct investment is sensitive to tax rates on corporate income
- Financial development indicators are positively related to growth

9.1 Introduction

The corporate sector (or the production sector more generally) controls many of the economic variables that determine the rate of growth. One key variable in both exogenous and endogenous growth models is the level of investment in physical capital and there has been a substantial literature analyzing the theory and empirics of investment. Innovation through the entry of new entrepreneurs has already been addressed in Chapter 8. Another source of innovation is purposeful expenditure on research and development. There has been much recent empirical addressing the response of R&D to tax incentives. From a global perspective R&D expenditure is concentrated in a small number of large industrialized economies. This does not mean that smaller and developed economies do not benefit from R&D since there can be spillovers either through knowledge or through trade in products that embody R&D. The benefits of R&D can also be transferred across economies by foreign direct investment. The chapter reviews the empirical evidence on all of these activities.

The structure of the corporate sector and the general business environment can also affect decisions that are relevant for growth. The role of entrepreneurship has already been identified. An extension of the same argument identifies the importance of small and medium enterprises in the economy. These firms are often viewed as being relatively more engaged in innovation. All firms need financial backing to support the development of ideas into products. The state of development of the financial sector determines whether funds are available at terms reflecting the true degree of risk. Finally, capital must be combined with labour for production to occur. The organization of labour markets - meaning flexibility and competitiveness - are relevant in this respect.

9.2 Physical Capital

The basis of investment theory is the simple observation that a firm will purchase new capital when the marginal benefit exceeds the marginal cost. Turning this observation into a convincing theory of investment has proved a difficult task. There are several reasons for the difficulties. First, investment involves durable goods so the benefits accrue over time. Both the benefits of the investment and the cost are uncertain at the point of investment. Second, investment involves an adjustment cost and a degree of irreversibility. These may not be observed by the analyst or known fully to the firm. Third, there is also uncertainty about future tax policy and the tax treatment of depreciation. Fourth, investment is dependent on the interaction of the corporation with financial markets. Finally, there are very general issues surrounding the objectives of the firm. An economic model may be built on the basis of profit maximization or maximization of market value. The managers of a firm may be pursuing different objectives. Nonetheless, models of investment do have some predictive power though they are by no means perfect.

9.2.1 Investment Theory

This section will provide a very brief introduction to investment theory to illustrate how the investment decision can be affected by taxation. A full model of the investment decision requires much more detail since it must combine the interaction of the firm, its managers, and the firm's shareholders. A comprehensive theory also has to address the interaction of the corporate and personal tax systems.

The most commonly used theory of investment is based on the concept of Tobin's *q*. Tobin (1969) argued that the investment decision should be based on the market value of investment relative to the replacement cost. If the market value exceeds the replacement cost then it would be rational for the firm to purchase additional capital. Conversely, if the market value were less than the replacement cost then the firm should reduce capital.

Denoting market value by V and replacement cost by K the q theory of investment states that investment, I, satisfies

$$I = I(q)K, \tag{9.1}$$

where $q = V / pK$, $I'(1) = 0$, $I'(q) > 0$ if $q > 1$ and $I'(q) < 0$ if $q < 1$. Here pK is the nominal value of the capital stock. The fact that the capital stock adjusts gradually can be explained by the existence of adjustment costs that are convex in the amount of investment. If there were no adjustment costs then instantaneous investment (or disinvestment) would ensure that q was continually equal to 1.

The inclusion of taxation affects the decision of the firm. This can be motivated following the approach of Hayashi (1992) and Summers (1981). Let a fraction b of new investment be financed by debt. In the absence of tax the firm would invest if

$$\frac{V}{pK} + b - 1 > 0. \tag{9.2}$$

Now add a tax credit for new investment (*ITC*) and tax savings for future tax-deductible depreciation allowances that have present value *Z*. Let *B* be the present value of tax savings on the existing capital stock. The firm will now invest if

$$\frac{V-B}{pK}+b-1+ITC+Z>0. \tag{9.3}$$

Let τ_d be the marginal tax rate on dividends and τ_c be the effective tax on capital gains. The firm has a choice between retaining earnings and investing or paying a dividend. Earning will be retained up to the point at which the last investment raises market value by $(1-\tau_d)/(1-\tau_c)$. Investment then occurs if

$$\frac{(V-B)(1-\tau_c)}{pK(1-\tau_d)}+b-1+ITC+Z>0. \tag{9.4}$$

Finally, the costs of investment are deducted from taxable earnings. Let the corporate tax rate be τ. The *q* theory including taxation is then described by the investment function

$$\frac{I}{K}=h(Q), \tag{9.5}$$

$$h(0)=0, \tag{9.6}$$

$$h'>0, \tag{9.7}$$

where

$$Q=\frac{\frac{(V-B)(1-\tau_c)}{pK(1-\tau_d)}+b-1+ITC+Z}{1-\tau}. \tag{9.8}$$

This model predicts that investment will not be caused by changes in τ. An increase in τ raises the rate of investment (or disinvestment) but does not affect the sign. All the other taxes and credits can affect the sign of investment. For example if $V>B$ then an increase in the tax on capital gains may turn investment into disinvestment. An increase in the tax on dividends has the opposite effect. Investment tax credits have the expected effecting of encouraging investment.

9.2.2 Empirical Results

One of the earliest serious pieces of empirical research on investment was undertaken by Hall and Jorgenson (1967). The paper estimated the effect of three revisions in the tax treatment of investment in the US. The paper concluded that the effects are "dramatic" with investment being highly sensitive to taxation. The major limitation of the model was that it assumes an arbitrary distributed lag formulation for investment. This assumption was motivated by a partial adjustment story for investment but otherwise has no explicit justification in the model. Later papers have questioned the conclusion of this paper on the basis of much more sophisticated (and internally consistent) modeling strategies.

Summers (1981) estimates the investment equation implied by the *q* theory described above. The data used are for non-financial corporate investment in the US over the period 1931 - 1978. Regressions are run for the simplest *q* model and for a model with a tax-adjusted *q*. The paper finds that the tax-adjusted *q* formulation has more explanatory power. This suggests that the tax effects are important.

The results show that an increase of 5 percentage points in the investment tax credit would raise total investment by about 3 percent. Simulations of the model are then conducted for a parameterized version. A reduction in the corporate tax rate from 46 percent to 40 percent raised the steady-state level of investment by 9 percent. Eliminating the capital gains tax raised steady-state investment by 18 percent. Two significant comments have been made about this analysis. First, the value of *q* is potentially endogenous in the regressions. Second, the firm is irrational in its financial structure given the treatment of personal and corporate taxes. This irrationality was a standard criticism of investment models and is difficult to reconcile with the optimization of investment. Since the publication of this research the behavior of firms in financial decisions has changed (notably the importance of share buy-backs - see Brealey *et al.*, 2005).

Chirinko (1993) observes that the performance of q theory has generally been unsatisfactory in empirical research. By unsatisfactory is meant a very low R^2 and serially-correlated residuals. The structure of the residuals has been explained by ad hoc dynamic adjustment arguments but such adjustment does not fit with the optimizing framework from which the *q* theory is derived. In addition, a variable representing cashflow is significant in many regressions. The importance of cashflow suggests liquidity constraints in financing investment but these are not incorporated with the model. A further important criticism is that the adjustment costs implied by the estimated coefficients are unreasonably large.

It is noted that the use *q* theory requires two steps to be undertaken to determine the effect of a tax change. The first step is to find the effect of the tax change on *q*. Next, the effect of *q* on investment is found by using the estimated investment equation. It is claimed that the first step is difficult to perform satisfactorily since it requires determination of how tax parameters feed back into asset prices and the value of *q*. This argument is used to claim that the significant reaction of investment to taxation in the Summers' analysis is due to the specification of the tax code and the generation of large tax increases. In fact, a dollar of tax loss will in the model of Summers (1981) led to a cumulative change of the capital stock over five years of $0.18 to $0.37 for a relatively low value of the adjustment cost - which is a relatively small response. Other models of investment (besides the *q* theory) are also noted to provide limited tax responses.

The Tax Reform Act of 1986 has provided the basis of many studies of tax responses. Auerbach and Hassett (1991) looked at the effect of the removal of a 10 percent investment tax credit to investment in machinery. This change should have reduced machinery investment relative to investment in structures, but in fact machinery investment increased after reform. This observation is contrasted to that of their earlier work (Auerbach and Hassett, 1990) which concluded there was no tax effect. The 1991 paper instead reports that the growth in machinery investment was a long-term trend starting before the tax reform. In fact, the tax reform seems to have resulted in less growth than there would otherwise have been. This conclusion is obtained from using a cross-section study which has some additional variation in how the tax changes were implemented across industries (36 categories of equipment and structures for 7 industry groupings).

The estimation procedure is based on a two-stage process. First, the data for 1953 - 85 are used to estimate a reduced form model for investment demand that does not include any variables measuring the impact of taxes. At the second-stage the out-of-sample post-tax-reform residuals are related to residuals in the tax rate variables in the post-tax-reform period 1987 - 89. The structural model over-predicted investment in both equipment and structures for the post-reform period. The second stage involves the calculation of a tax wedge variable which is then used as a regressor to explain the out-of-sample forecast error. Results for this second-stage regression for investment in equipment are reported in Table 9.1. The coefficient on the user cost (which captures the surprise tax change caused by the reform) is negative and significant. When average tax paid is also included (on the basis that the average tax payment affects cash flow and potentially investment) the coefficient is insignificant and does not have the theoretically predicted sign. The paper concludes that investment is sensitive to taxation.

Period	1987	1987
Constant	-0.00 (-0.02)	-0.01 (-0.46)
User cost	-0.99 (-5.62)	-0.85 (-4.27)
Taxes paid		5.17 (1.27)
$\bar{R}^2$	0.59	0.61

Table 9.1: Investment after reform

The consequences of the Tax Reform Act of 1986 are also studied by Cummins and Hassett (1992). The paper first notes that earlier literature had not found a large effect of taxation. A number of reasons are provided for why this conclusion has been reached. These reasons focus on the consequences of using aggregate data to estimate investment equations. Aggregate data hides any change in the composition of investment and the use of instruments for tax changes leads to weak estimation. These observations are used to motivate use of the natural experiment approach.

Auerbach and Hassett (1991) use industry and asset level data. In contrast, Cummins and Hassett use more disaggregated firm-level data. The estimation model is based on the usual q theory of investment. The results generate an elasticity of investment with respect to Q of about -1.1 for equipment and about -1.2 for structures. Also, a lower estimate than many previous papers is obtained for the size of adjustment costs which are about 25 percent of the cost of new equipment. The paper also finds that the cash-flow variable is significant but has a lower coefficient than in previous work.

Cummins *et al.* (1994) apply the natural experiment methods to tax reforms in the US from 1962 to 1988. The paper used firm-level panel data to exploit cross-sectional variation and to ensure that tax reforms are exogenous (taxation of investment may not be exogenous at the aggregate level). There were 13 reforms during 1962 - 88. There were changes (both up and down) in the average rate of taxation and changes in taxation on different types of asset. A tax component that is one minus the present value of tax savings from depreciation allowances and other investment incentives is constructed for 22 classes of equipment and 14 types of structure as classified by the Bureau of Economic Analysis. The plot of these for types/years revealed the variation to be large.

The initial model is given by

$$\frac{I_{i,t}}{K_{i,t-1}} = E_{i,t-1}\left(S_{i,t}\gamma\right) + \varepsilon_{i,t}, \tag{9.9}$$

where $S_{i,t}$ is an underlying structural variable and γ is a coefficient related to convex adjustment costs. It is assumed major changes in *S* are infrequent and hard to predict. This motivated the use of the experimental approach to find the effect of changes in *S*. The estimation technique is based on the assumption that *S* is known immediately following a tax reform. This allows that expectation to be dropped so

$$\frac{I_{i,t}}{K_{i,t-1}} = S_{i,t}\gamma + \varepsilon_{i,t}. \tag{9.10}$$

Given this the deviation of the observed $I_{i,t} / K_{i,t-1}$ from the value that is predictable at $t-1$, $P_{i,t-1}\left(I_{i,t} / K_{i,t-1}\right)$, depends on the surprise change in *S*

$$\frac{I_{i,t-1}}{K_{i,t-1}} - P_{i,t-1}\left(\frac{I_{i,t}}{K_{i,t-1}}\right) = \left(S_{i,t} - P_{i,t-1}\left(S_{i,t}\right)\right)\gamma + \varepsilon_{i,t}. \tag{9.11}$$

The estimation procedure is to construct estimates of $I_{i,t-1} / K_{i,t-1} - P_{i,t-1}\left(I_{i,t-1} / K_{i,t-1}\right)$ and $S_{i,t} - P_{i,t-1}\left(S_{i,t}\right)$ then to pool a cross-section of these to estimate γ.

The estimated effect of neoclassical fundamentals on investment were more statistically significant and economically significant than found in earlier work. The estimates implied reasonable adjustment costs. For each major tax reform in US since 1962 the cross-section pattern of investment changed significantly. A selection of the results is given in Table 9.2. Years marked with an *f* follow a major tax reform. Years marked with an *o* are other tax reform years. The nature of the estimation method implies that the coefficient on *Q* should be most precisely estimated when there was a reform. This is confirmed to be the case by the t statistics reported in the table. Further results showed that a cashflow variable was also significant but its inclusion did not have a major impact on the coefficient of tax-adjusted *q*. The coefficient on *Q* is larger than in previous work and translates into a much higher sensitivity of investment to tax incentive.

Year	Number of firms	$\overline{R}^2$	Intercept	Q
1963*f*	251	0.056	−0.028 (2.74)	0.874 (3.86)
1964	362	0.000	0.044 (3.13)	0.011 (0.063)
1965*o*	457	0.033	−0.020 (1.27)	0.742 (3.95)
1966	606	0.001	0.031 (3.38)	0.109 (0.73)
1967	636	0.000	0.030 (2.83)	0.002 (0.023)
1968*o*	666	0.018	0.026 (1.11)	0.554 (3.46)
1969*o*	682	0.028	0.028 (1.12)	0.607 (4.44)
1970*o*	722	0.049	−0.030 (4.14)	0.533 (6.10)
1971*o*	707	0.046	−0.085 (9.09)	0.494 (5.81)
1972*o*	735	0.037	−0.056 (8.84)	0.446 (5.29)
1973*f*	828	0.029	−0.046 (6.64)	0.470 (4.97)
1974	874	0.000	−0.025 (3.46)	0.054 (0.50)
1975	959	0.002	−0.068 (10.87)	−0.119 (1.28)
1976*o*	1007	0.037	−0.003 (0.61)	0.515 (6.23)
1977	1046	0.001	0.055 (9.96)	0.074 (0.79)

1978	1063	0.001	0.065 (10.22)	0.080 (0.812)
1979	1077	0.002	0.026 (3.37)	0.138 (1.41)
1980*o*	1081	0.024	−0.003 (0.51)	0.491 (5.15)
1981	1103	0.001	−0.022 (3.77)	0.088 (0.83)
1982*f*	1114	0.030	−0.026 (5.07)	0.599 (5.84)
1983*o*	1130	0.023	−0.004 (0.74)	0.609 (5.85)
1984	1136	0.000	0.028 (3.43)	−0.020 (0.20)
1985	1160	0.001	0.032 (4.15)	0.085 (0.83)
1986	1188	0.001	0.021 (2.50)	0.105 (1.14)
1987*f*	1250	0.034	−0.026 (3.18)	0.613 (6.66)
1988	1294	0.001	−0.030 (1.15)	0.127 (1.32)

Table 9.2: Investment equations

Cummins *et al.* (1996) build upon the work of Cummins *et al*. (1994) to analyze investment demand for countries in addition to the US. The paper finds that fundamentals are important and are relatively similar across countries. More importantly, the results show that investment does respond to tax changes. The data employed related to tax reforms in 14 countries and the investment decisions of over 3000 firms. Firm-level data was used rather than aggregate time- series data. Aggregate time-series data are seen as having three problems. First, policy is not exogenous (incentives are introduced when investment is low). Second, frequent changes in corporate taxation make it difficult to judge a firm's expected tax treatment. Third, noisy stock market value makes it hard to isolate the effects of tax changes.

The paper first presents estimates of the q theory by using standard techniques. The model estimated is based on the equation

$$\frac{I}{K} = \mu + \gamma Q + \varepsilon \,, \qquad (9.12)$$

which is a standard linearization of the q theory. This equation is estimated for Australia, Belgium, Canada, Denmark, France, Germany, Italy, Japan, the Netherlands, Norway, Spain, Sweden, the UK and the US. These estimates provide reasonable values for the coefficient on Q that are similar across countries but the adjustment costs are about 70 percent of a unit of investment expenditure.

The natural experiment method is applied by choosing one reform for each country that seems to represent the best experiment. The model is estimated only for that year. By best is meant a large change in the tax code and the avoidance of years in which it was known tax reviews were taking place. The estimated coefficients on Q are higher than standard estimate (see Table 9.3) and imply an adjustment cost of 5 - 10 percent of investment expenditure. The cashflow variable is included in the regression reported. This should not matter according to neoclassical theory but previous work has found that it does. Here it is significant for some of the countries. Note how the explanatory power of the regression equation is still fairly low.

	Intercept	Q	$\frac{CF}{K}$	$\bar{R}^2$
Australia	-0.130	0.647 (0.238)	0.083 (0.109)	0.063
Belgium	0.054	1.613 (0.593)	0.006 (0.109)	0.194
Canada	-0.044	0.803 (0.210)	0.230 (0.064)	0.123
Denmark	-0.210	0.865 (0.469)	0.003 (0.127)	0.026
France	-0.010	0.650 (0.292)	0.104 (0.068)	0.073
Germany	0.006	0.879 (0.249)	0.078 (0.077)	0.082
Italy	0.104	0.644 (0.241)	0.061 (0.116)	0.057
Japan	-0.026	0.819 (0.198)	0.354 (0.042)	0.222
Netherlands	0.049	0.296 (0.344)	0.299 (0.187)	0.043
Norway	-0.812	1.376 (0.487)	0.706 (0.289)	0.284

Spain	-0.014	0.888 (1.397)	0.461 (0.273)	0.059
Sweden	-0.226	0.644 (0.243)	−0.050 (0.163)	0.078
United Kingdom	-0.126	0.490 (0.186)	0.278 (0.035)	0.145
United States	-0.022	0.528 (0.085)	0.108 (0.014)	0.063

Table 9.3: Natural experiment estimates of q theory

Standard errors in parentheses

Hubbard (1998) addresses the reason for the significance of the cash flow variable. Many papers on investment, including those reviewed above, have found that cash flow is an important explanatory variable in the regressions. If the neoclassical theory is correct then cash flow should not appear. The main point of this paper is to explain how credit market imperfections can lead to limits on borrowing and therefore make retained earnings the first source of investment funding. This effect causes cash flow to be relevant for the investment decision. Taxation can interact with this effect through the different consequences that alternative tax schemes have for the flow of retained earnings. This means that the response to tax policy may be different between firms that are constrained by capital market imperfections and those that are not constrained.

The observed data used in empirical estimation is the value of investment undertaken. The value is the product of the quantity and the price. Goolsbee (1998) looks more closely at the composition of the increases in investment generated by tax incentives. If a tax incentive raises investment it will cause price of investment to rise unless the supply curve is horizontal. The paper runs regressions for tractors, and then for a set of industries. The tractor regression shows that a 10 percent investment tax credit raises the prices of investment goods by more than 6.5 percent. Therefore, much of the increase in investment is absorbed in an increase in price rather than an increase in quantity. The general regression shows that 13 out of 22 sectors have a positive and significant coefficient on the ITC term, showing that an increase in the credit raises the price of investment goods. The major increases are in fabricated metals, heavy machinery, and large transportation equipment. The four where the effect goes in the wrong direction are computers, communications equipment, cars, and instruments - industries with significant technological advance where computation of meaningful price indices may be difficult.

9.3 Research and Development

Innovation is one of the major components of economic growth. The modelling of innovation assumes that educated personnel are combined with capital equipment to undertake research effort. The outcome of the research is random, with successful innovations arising with a probability that is an increasing function of personnel and equipment. An innovation raises *TFP* either by adding a new product or by replacing an existing product with one of higher quality.

This brief description reveals two aspects. First, there is the level of expenditure upon R&D inputs. This is the statistic that is measured in the data. It has been extensively analyzed to determine its sensitivity to tax incentives. Second, there is the R&D output of new innovations. In the modelling of innovation there is a causal relation from expenditure to innovation output, but the two are not the same. The effect upon growth of R&D depends primarily on the output. The effect of tax policy on the output of R&D has not been investigated.

The Economic Recovery Tax Act of 1981 included a tax credit for R&D expenditures. The Act provided a stimulus to R&D through a 25 percent credit that was obtained on R&D expenditure above that in a base year. The introduction of this credit has provided good data for testing the sensitivity of R&D to incentives.

Berger (1993) analyzed two effects of the 1981 Act: how much expenditure increased, and how much of the increase was absorbed by an increased prices for R&D input (called an implicit tax). The study is based on data for 263 firms from Compustat that were clustered in manufacturing. A fixed effects estimator with a different intercept for each firm was used. Each firm's original data point was replaced with the deviation from the firm's times-series sample mean. Then OLS was applied to the data on deviations from mean for a pooled regression on a number of variables. The paper concludes that $1.74 of additional spending took place for every dollar of tax credit, indicating significant sensitivity of R&D to incentives. The implicit tax (the increase in the price of inputs) is estimated to be no more that 27.2 percent, so there is a significant increase in the quantity of R&D.

The argument that part of any increase in R&D is absorbed into increased prices of R&D inputs is developed further in Goolsbee (1998). It is observed that federal spending in the US on R&D is significant. Total expenditure on R&D is about 2 to 3 percent of GDP, and the federal share of this expenditure is between one third and two thirds. The paper observes that empirical research on R&D tends to focus on these values and discusses how federal programs may raise or lower spending without looking more closely at the breakdown of expenditures. The simple point is made that the supply of scientists is inelastic (training takes considerable time so adjustment is slow). An increase in R&D expenditure will increase the demand for scientists and therefore push up wages. As a consequence, any increase in R&D spending is partly absorbed into wages. This implies research that analyzes only the total level of spending on R&D will overstate the incentive effect. An empirical analysis is undertaken to show that this effect is significant. The 11 percent increase in R&D spending following the 1981 Act is claimed to have raised wages by 3.3 percent, so giving a net increase in R&D of just 7.6 percent. This result is given as evidence that measuring only expenditure overstates the effects of incentives.

Hall and Van Reenen (2000) summarize the results of several empirical studies. The first set of results in Table 9.4 provides estimates of the effect of the Research and Experimentation (R&E) credit introduced in the Tax Reform Act of 1981. The table reveals that early studies found a low elasticity (around 0.6) but later studies found an elasticity of around 1. The difference in the results is explained by a process of learning by firms and the development of credibility for the incentive. This could also reflect set-up costs for R&D which make it less responsive over the short-term.

Author	Eisner *et al.* (1983)	Berger (1993)	Hall (1993)	Hines (1993)
Period of credit	1981 - 1982	1981 - 1988	1981 - 1991	1985 - 1989
Control period	1980	1974 - 1980	1980	Not relevant
Data	600 firms	263 firms	800 firms	116 firms
Estimated elasticity	Insignificant	1.0 – 1.5	1.0 – 1.5	1.2 – 1.6

Table 9.4: Estimated R&D elasticity for US firms

The responsive of R&D to incentives has also been analyzed for countries other than the US. The results of some of these studies are provided in Table 9.5 for a range of countries. Hall and van Reenen claim that the Australian study employs the most convincing methodology, and that this also finds an elasticity of approximately 1.

Country	Canada	Sweden	Australia	France
Author	McFetridge and Warda (1983)	Mansfield (1986)	Australian Bureau of Industry (1993)	Asmussen and Berriot (1993)
Period of credit	1962 - 1982	1981 - 1983	1984 - 1994	1985 - 1989
Data	Aggregate	40 firms	> 1000 firms	339 firms
Estimated elasticity	0.6	Small	1.0	0.26

Table 9.5: Estimated R&D elasticity in non-US studies

The conclusions offered by Hall and van Reenen are that there is substantial evidence tax incentives have a significant effect on level of R&D performed and that the most compelling evidence is obtained from employing the natural experiment approach. It is concluded that the evidence reveals an elasticity of approximately 1, but there may be considerable worldwide variation around this value.

The work of Hall *et al.* (2002) extends the analysis of how fiscal incentives affect R&D expenditures. They study data for nine OECD countries over a 17 year period. The paper treats changes of policy within countries, and differences of policy between countries, as natural experiments. The estimation method controls for a range of influences and country characteristics. The final conclusion is that a 10 percent fall in R&D cost leads to a 1 percent rise in R&D in the short run and a 10 percent rise in the long run. This implies a long-run elasticity of approximately 1. The consequences of the US tax credit are also considered by Billings *et al.* (2001). Their regression results support the finding of Hall *et al.* that there is a reasonably significant effect of the credit, with an elasticity between 1 and 2 for spending.

Bloom, Griffith and van Reenen (2002) examine the effect of fiscal incentives on R&D using a dataset for nine OECD countries over the time period 1979 - 1997. The paper confirms the standard result that the long-run effect is large but the short-run effect is small. In particular, a 10 percent fall in the cost of R&D is estimated to cause a 1 percent rise in R&D spending in the short run but a much larger 10 percent rise in the long run. These are the same values as identified by Hall *et al.*

The study of the nine countries is motivated by claiming it is harder to disentangle the effect of the tax incentive from other macroeconomics changes if a single country (typically, the US) is studied. A cross-section of countries provides more variation that can be used to provide a stronger estimate of the incentive effect. Changes in the rules concerning R&D and taxation are used to identify the tax-price changes in a natural experiments framework. A simple model is constructed that produces a user cost for R&D capital. This user cost is calculated by using details of the tax systems for each of the countries and is then employed in the regressions. The estimated equation is

$$r_t = \lambda r_{t-1} + \beta y_t - \gamma \rho_t + \varepsilon , \tag{9.13}$$

where r = log of industry funded research, y = log of output and ρ = their estimated user cost of capital. In the preferred specification of the regression equation the estimated coefficients are as summarized in Table 9.6. The value of γ is the short-run elasticity. The value of $\gamma/(1-\lambda)$ is the long-run elasticity. It can be seen that the short-run and long-run elasticities are different, with the long-run elasticity being much larger in value. This is consistent with the findings of previous studies.

λ	β	γ	$\frac{\gamma}{1-\lambda}$
0.868 (0.043)	0.1439 (0.163)	-0.144 (0.054)	-1.088

Table 9.6: Estimation of R&D equation

The theory of endogenous growth places great emphasis on the role of research and development. It is therefore reassuring that the empirical work has produced estimates of the sensitivity of R&D to tax incentives that is consistent across studies and across countries. In the short run R&D has a fairly low elasticity but in the long run the elasticity is approximately 1. Hence, in the long run, a change in tax incentive is matched by approximately the same change in R&D. But it remains important to recall the earlier comments that these papers refer to the value of R&D spending. This is not the same as success in R&D (nor, if the cost of inputs increases, is it the same as the real increase in R&D effort). If firms are rational in their choice of R&D projects then those with the highest expected return will be undertaken first. The introduction of a tax incentive will see only marginal projects undertaken. Hence, the additional projects will have a lower expected return than average, and a change in expenditure will overstate the success effect. For these reasons, the estimated elasticity most likely over-estimates the true effect of the incentives upon *TFP*.

The theoretical models represent R& D in the very favorable context of a race with the probability of winning raised by the amount of expenditure. The winner, by definition, then has an innovation of a higher quality than anyone else's innovation. In an international context this gives all countries a chance of succeeding with R&D. In practice R&D a small number of countries are responsible for the vast majority of R&D expenditures. If there are returns to scale in R&D, or if the new increment of innovation is dependent upon the base from which a country begins, then the benefits from incentives to R&D will only be significant in those countries already domination R&D.

What these observations suggest is that further work is required to clarify the link between R&D expenditure and R&D success. Success may be measured by the number of patents granted, or even the link between patents and financial results. What would be interesting is investigate the explanatory factors in a regression of patents on R&D. Is there a scale effect, or an effect feeding in through previous position? This form of knowledge would provide a more suitable targeting of tax incentives.

9.4 Imported R&D

In an integrated world economy every country can benefit from R&D wherever it is undertaken. The benefits can arise directly through learning about new techniques and methods. They can also be obtained indirectly from the importation of imported producer goods that embody new technologies. Increases in international trade assist the diffusion of innovation around the world by the indirect method. A small literature exists that has quantified these effects.

Coe and Helpman (1995) consider the relationship between *TFP* and R&D stocks for 21 OECD countries plus Israel over the period 1971 - 90. The estimation process is built upon the basic regression equation

$$\ln TFP = \alpha_0 + \alpha_1 \ln S^d + \alpha_2 m \ln S^f , \tag{9.14}$$

where S^d is the domestic stock of R&D and S^f is the foreign stock. The variable m is the share of imports in GDP. This is included in the regression to reflect the argument that innovation can be imported in manufactured producer goods. The R&D stocks were constructed from expenditure data using the perpetual inventory model.

Three variants of this regression equation are estimated. In the first column of Table 9.7 m is set equal to one for all countries so no account is taken of import shares. In the second column S^d is interacted with a dummy for G7 membership to allow a different effect for the seven largest countries. In the third column the interaction term is retained and m is permitted to vary across countries. For all three specifications the elasticity of *TFP* with respect to foreign R&D is positive and large (the paper reports no standard errors for the individual parameters so significance cannot be assessed).

$\ln S^d$	0.097	0.089	0.078
$G7 * \ln S^d$		0.134	0.156
$\ln S^f$	0.092	0.060	
$m \ln S^f$			0.294
R^2	0.534	0.600	0.630

Table 9.7: *TFP* and foreign R&D

The values reported in the third column are then applied to the individual countries to construct country-specific elasticities. These elasticities are reported in Table 9.8. The elasticity of *TFP* with respect to R&D is restricted to be identical across the G7 countries, and identical across the other 15 countries. The general picture is that of an increase over time of the elasticity of foreign R&D. This is consistent with the view of increased international integration and the process of globalization. The variation in the elasticities can also provide an explanation for differences among countries of *TFP* growth.

	World R&D	Foreign R&D			Domestic R&D
	1990	1971	1980	1990	1971 - 90
United States	0.267	0.016	0.030	0.033	
Japam	0.261	0.028	0.037	0.027	
West Germany	0.311	0.056	0.072	0.077	
France	0.301	0.045	0.061	0.067	0.234
Italy	0.292	0.046	0.067	0.058	
United Kingdom	0.315	0.063	0.081	0.081	
Canada	0.309	0.059	0.078	0.075	

Australia	0.132	0.043	0.049	0.055	
Austria	0.192	0.091	0.106	0.114	
Belgium	0.337	0.129	0.181	0.260	
Denmark	0.169	0.091	0.094	0.092	
Finland	0.152	0.079	0.088	0.075	
Greece	0.172	0.050	0.063	0.094	
Ireland	0.243	0.124	0.180	0.165	
Israel	0.231	0.147	0.154	0.153	0.078
Netherlands	0.236	0.133	0.146	0.158	
New Zealand	0.144	0.075	0.086	0.066	
Norway	0.188	0.133	0.124	0.111	
Portugal	0.210	0.099	0.117	0.132	
Spain	0.141	0.043	0.043	0.063	
Sweden	0.171	0.067	0.087	0.093	
Switzerland	0.190	0.115	0.106	0.113	

Table 9.8: Country-specific elasticities

This analysis is extended by Coe *et al.* (1997) into a detailed analysis of the extent to which the R&D of 22 industrialized countries spills over into 77 developing countries. The paper observes that the industrialized countries accounted for 96 percent of world R&D in 1990, and 92 percent of R&D within the OECD was accounted for by the seven largest economies. Three changes are made to the earlier specification to model spillovers into developing economies: a human capital variable is included (secondary school enrolment), the import measure is restricted to machinery and equipment, and only foreign R&D is included. The preferred specification estimates an elasticity of *TFP* with respect to foreign capital stock of 0.058 and an elasticity with respect to imports of 0.279. These values are taken as evidence of significant spillovers.

These estimates of international R&D spillovers are employed in a simulation analysis by Bayoumi *et al.* (1999). The purpose of the simulation is to determine the size and implication of the spillovers. The model used is a version of MULTIMOD (see Masson *et al.*, 1990) that includes 12 countries representing the G7, smaller industrialized countries, and developing countries. Following the comments of Lichtenberg and van Pottelsberghe de la Potterie (1998) the regression equations are augmented by the inclusion of the import share of GDP as a separate variable. The coefficient on this variable is negative (so a higher import ratio lowers *TFP*) but its inclusion raises the estimated elasticity for foreign R&D stock.

With this modification the equation linking *TFP* to R&D for the G7 is

$$\ln TFP = \alpha_1 + 0.24 \ln S^d + 0.26 m \ln S^f - 3.18 m , \tag{9.15}$$

where α_1 is a country-specific constant. The smaller industrialized countries are modelled as having a lower elasticity with respect to own R&D

$$\ln TFP = \alpha_2 + 0.08 \ln S^d + 0.26 m \ln S^f - 3.18 m . \tag{9.16}$$

The developing countries are modelled as undertaking no R&D so *TFP* in these countries only advances through the foreign component%

$$\ln TFP = \alpha_3 + 0.43 m \ln S^f - 5.09 m . \tag{9.17}$$

The results of three policy experiments can be briefly described as follows. First, if the US increased its R&D investment by 0.5 percent of GDP and then maintained the new ratio of R&D to GDP its output would rise by over 9 percent after 80 years, the output of other industrialized countries would rise by almost 3 percent, and the output of the developing countries by 3.5 percent (note that these are level effects, not growth effects). Second, if all industrialized countries made an R&D increase of 0.5 percent of GDP then their output would rise by 17 percent (after 80 years) and that of the developing countries by over 10 percent. Third, if the developing countries became more open and expanded trade by 5 percent of GDP their output would rise by 6.5 percent after 80 years. These results reveal the size of the effects to be significant but, being based on simulation, are only indicative of the possibilities.

9.5 Foreign Direct Investment

Foreign direct investment (FDI) includes acquisition of foreign firms and investment in new plants overseas. It is clear how the latter can transfer technological innovation between countries: if the new plant is more productive than existing plants, *TFP* must rise. The route by which acquisitions can raise *TFP* is more indirect. *TFP* can rise if the new ownership introduces improved methods of working and innovations in management systems. The recent experience of China provides clear evidence of how foreign direct investment can raise the productivity of the host country and stimulate the growth process.

The question that has been addressed in the empirical literature on FDI is what factors determine the location decisions of firms. Particular emphasis has been given to the role of taxation. Economic theory suggests taxation should be important since the location decision should involve the comparison of post-tax profits between alternative locations. Taxation is also important from a policy perspective since tax incentives are one of the main strategic variables through which countries compete to attract FDI.

A simple introduction to international taxation from the perspective of the US, and a description of how the system of foreign tax credits works, is provided by Hines (1999). The paper also surveys the empirical evidence of the extent to which taxation affects foreign direct investment. The paper also raises the issue of international tax avoidance and how this can be successful in an international context. The conclusions essentially argue that tax competition (in the sense of setting a tax policy from a strategic point of view) is a successful way for countries to behave.

The main point of the paper is to argue that for FDI into the US, and for US FDI abroad, the evidence suggests there is a significant negative elasticity of -0.6. If correct, this value of the elasticity demonstrates that taxation reduces FDI (or reductions in taxation can raise FDI). The first evidence reviewed is the aggregate time series studies of Hartman (1984), Boskin and Gale (1987), and Young (1988) where the *q* theory of investment motivates the use of after-tax rates of return as the key variable. It is further noted that when the level of FDI is separated into that financed by retained earnings of foreign affiliates and that financed by transfers of funds from parent companies, the former is more elastic with respect to taxation. It is observed that these aggregate studies suffer from a number of potential problems of interpretation concerning the reason for the observed correlation (for instance, if affiliates re-invest all earning these count as FDI, so FDI appears correlated with the after-tax rate of return).

Slemrod (1990) uses time-series data and exploits cross-sectional differences to improve the estimates. The cross-section aspect is obtained by distinguishing FDI into the US by the country from which it originated. This gives two types of country. Japan and the UK operate a system of international taxation that gives tax credits for foreign tax paid. In contrast, companies from Australia, Canada, France, Germany, and the Netherlands are essentially free from home country taxation on profits earned in the US. Consequently, the second group have a stronger incentive to invest in low tax years than do firms from the UK and Japan. Using data over the period 1962 - 1987 Slemrod found no clear empirical evidence that there is any significant difference between the two groups. This is counter to what is expected and raises questions about the sensitivity of FDI to taxation.

The tax treatment of companies in the US treats differs across industries because of the assets in which they invest. This motivated Swenson (1994) to consider tax effects at the industry level for the period 1979 - 1991. Swenson found that industries in which the after-tax cost of capital increased most following the 1986 Tax Reform Act were those in which foreign investors concentrated their investment. This is consistent with investment from countries that receive tax credits since the US treatment does not then matter for the overall level of profitability. Auerbach and Hassett (1993) proved counter-evidence to this claim by providing evidence that there was no significant difference in behavior between investors from countries granting foreign tax credits to those from countries not granting credits.

The studies that are described next are cross-section. These studies exploit the variation in tax rates across countries to obtain estimates of the tax effect.

Grubert and Mutti (1991) analyze American owned Property, Plant, and Equipment (PPE) in manufacturing affiliates in 33 countries in 1982. The marginal effective tax rates are not available for all the countries so instead an average effective tax rate on equity is used. This is calculated from the tax returns of US affiliates operating in the countries. A sample of the results is presented in Table 9.9. The variable τ is the tariff levied and t_e is the constructed average tax rate. The investment policy dummy is designed to capture countries where an active investment policy placed limitations on the holdings of foreign companies. The result shows an elasticity of at least -1.5 with respect to the local tax rate, and a much higher value when the inverse of the tax rate is the explanatory variable.

Constant	-22.5 (-4.96)	-26.6 (-5.68)	-21.1 (-4.80)	-25.0 (-5.68)
GDP	0.92 (5.71)	0.92 (6.36)	0.98 (6.21)	1.01 (7.20)
GDP per capita	1.42 (3.72)	1.72 (4.77)	1.13 (2.87)	1.36 (3.69)
$1+\tau$	2.58 (1.66)	3.92 (2.64)	2.20 (1.46)	3.32 (1.88)
$1-t_e$	1.96 (1.74)		1.50 (1.36)	
$1/t_e$		0.11 (2.50)		0.11 (2.59)
Distance	0.82 (1.14)	0.71 (1.03)	1.28 (1.75)	1.23 (1.82)
Investment policy			-1.14 (-1.87)	-1.27 (-2.30)
R^2	0.63	0.66	0.66	0.71

Table 9.9: Majority owned foreign affiliates

Hines and Rice (1994) extend the study of the distribution of PPE to US affiliates in 73 countries. They report an estimated elasticity with respect to taxation of -1. Altshuler, Grubert, and Newton (1998) compare the sensitivity in 1984 to that in 1992. Using data on PPE in 58 countries they estimate that the elasticity of PPE with respect to taxation has risen from -1.5 in 1984 to -2.8 in 1992.

The effect of sub-national taxes in the US has also been considered. There is considerable sub-national variation in the US since state taxes on foreign corporations varied (in 1998) from 0 percent to 15 percent. Ondrich and Wasylenko (1993) studied new plant establishments over 1978 - 1987. They modelled the probability of location in each state and their analysis led to an implied elasticity of -0.6.

Hines (1996) also examined the effect of state tax rates on the distribution of foreign direct investment within the US. The paper compares the location decisions of companies from countries with tax credit systems (so they have no real need to avoid

US taxes if lower than taxes in their own country) to companies from countries without tax credit systems (who have a direct incentive to search for lower taxes).

The estimated model is based on the reduced form equation

$$I_{ij} = \alpha_i \gamma_j + \beta_j s_i \gamma_j (\tau_i - \bar{\tau}) + \gamma_j u_{ij}, \tag{9.18}$$

where I_{ij} is investment in state *i* from investors in country *j*. α_i (unobservable) and s_i (observable) reflect the size of business activity in state *i*. τ_i is the tax rate in state *i* and $\bar{\tau}$ is the average state tax rate (formed using shares s_i). The estimated tax effect is large. Those not receiving tax credits are estimated to reduce investment by 9 - 11 percent for every 1 percentage point rise in taxation. This effect is found to be strongest when tax rates were low. But caution is suggested about taking these large figures too literally.

Devereaux and Griffith (1998) propose a model in which firms make choices about whether to supply a market, and if they choose to supply whether it is done by production at home or in that market. This gives rise to an estimation of the probabilities of each choice being made. The dataset looks at US firms and their choice of location in Europe. The only countries considered in Europe are France, Germany, and UK. The average effective tax rate matters for the choice of location, conditional on the firm having chosen to locate in Europe. The central estimate is that a 1 percentage point increase in the effective average tax rate in the UK would lead to a reduction in the probability of a US firm choosing to produce there by 1.3 percentage points. The equivalent value for France is 0.5, and for Germany around 1. Tax is significant. However, the average effective tax rate does not have an effect on the choice between producing in Europe, supplying Europe from the US, or not supplying Europe at all.

The location decisions of US firms are also analyzed by Grubert and Mutti (2000) The paper uses data aggregated from the tax returns of over 500 US multinationals for the year 1992. It looks at the role of host country tax rates in determining the location decision of capital investment. The empirical work shows that the average effective tax rate has a significant effect on the choice. The tax responsiveness is lower if the host country has a restrictive trade regime. They use OLS to estimate the equation

$$\ln K_i = f + g \ln(1 - t_i) + d \ln X_i, \tag{9.19}$$

where K_i is the amount of capital located in country *i*, t_i is the tax rate in *i*, and X_i is a vector of all other variables describing location i. As in any study of this kind there is debate about the appropriate tax rate. This paper uses the average effective tax rate. This can be computed since they have the tax return data. The role of tax credits and residual tax in the US can also matter.

The estimation results are summarized in Table 9.10. Trade Regime is measured by the four point scale given in the World Bank Development Report, with 0 the most open. The tax rate is calculated using total income taxes paid in the host country divided by the sum of earnings and profit. This is done to avoid issues about the definition of taxable income which may be dependent on investment incentives and depreciation provisions. The finding here is of a large elasticity of 3.23, which falls in value as the trade regime becomes more restrictive. The conclusion of the paper is that the choice of location is sensitive to taxation.

Variable	Coefficient
$\log(1-t_i)$	3.23 (3.02)
Trade Regime $*\log(1-t_i)$	-1.51 (2.44)
$\log(GDP)$	0.805 (4.58)
$\log(GDP$ per capita$)$	0.418 (2.92)
Trade Regime	-0.607 (2.59)
North America	2.40 (3.95)
Latin America	1.55 (4.82)
EEC	0.788 (2.37)
Asia	0.640 (2.03)

Table 9.10: Sensitivity of FDI to taxation

t values in parentheses

The results of this empirical literature are placed into a common framework by De Mooij and Ederveen (2003). They compute that the median value (taken as the median from all of the results published in the surveyed papers) of the tax elasticity is - 3.3. This implies a 1 percentage point increase in the tax rate reduces FDI by 3.3 percent. The contribution of the paper is to use a common definition of elasticity. This definition is the semi-elasticity (the percentage change relative to the level change). The distribution of the values of this semi elasticity from the studies is given. This shows that most estimates are negative but the range is very large. Then the paper performed a meta analysis of the results. This involved regressing the calculated semi elasticity on the characteristics of each study. This was repeated for various subsets of the studies. The value of -3.3 is the simple mean of the sample with outliers removed. Various refinements of this result are also given.

Table 9.11 reports the semi elasticities extracted from the papers. Each of the surveyed papers ran a number of different formulations of regression equation which gives rise to the number of elasticities reported. The estimated elasticity is then turned into a semi-elasticity and the mean is calculated. The paper uses this data to make the claims noted above, but the results are displayed here since they provide easily interpretable evidence of the size of the elasticity.

Study	Number of elasticities	Mean semi-elasticity
Hartman, 1984	6	-2.6
Bartik, 1985	3	-6.9
Boskin and Gale, 1987	12	-5.8
Newlon, 1987	2	-0.4
Young, 1988	12	-1.1
Murthy, 1989	4	-0.6
Slemrod, 1990	58	-5.5
Grubert and Mutti, 1991	6	-1.7
Papke, 1991	2	-4.9
Hines and Rice, 1994	4	-10.7
Jun, 1994	10	-0.5
Swenson, 1994	10	1.3
Devereaux and Freeman, 1995	4	-1.6
Hines, 1996	46	-10.9
Pain and Young, 1996	6	-1.5
Cassou, 1997	17	-7.5
Shang-Jin, 1997	5	-5.2
Devereaux and Griffith, 1998	10	-0.8
Billington, 1999	2	-0.1
Broekman and van Vliet, 2000		-3.3

Gorter and Parikh, 2000	15	-4.5
Grubert and Mutti, 2000	15	-4.0
Altshuler, Grubert and Newton, 2001	20	-2.7
Benassy-Quere, Fontagne and Lahreche-Revil, 2001	4	-5.0
Swenson, 2001	95	-3.9

Table 9.11: Summary of elasticity estimates

An alternative perspective on the effect of taxation is provided by Kessing *et al.* (2006). Their research looks at CBA (mergers and acquisitions in overseas countries). It is shown that fiscal decentralization has a negative effect on CBA activity. When taxes are included in the regressions the statutory tax rate also has a negative effect though it does not affect the decentralization coefficients. It should be noted that there is a problem with the use of a statutory tax rate given the numerous incentive schemes.

9.6 Small and Medium Enterprises

Beck *et al.* (2005) provide a range of arguments for why the relative size of the Small and Medium Enterprise (SME) sector may matter for growth. Among these arguments are the links between the size of this sector and increased competition, entrepreneurship, and innovation. SMEs may also be more productive than larger firms but are limited by borrowing constraints caused by imperfect capital markets. A large SME sector can also raise employment if the firms are labour intensive. If there is any truth in these arguments then government support of SMEs will increase the growth rate.

The paper provides cross-country evidence on the link between SMEs and growth. The measure of the SME sector is the share of the manufacturing labour force in firms with 250 or fewer employees. This is taken from the database created by Ayyagari *et al.* (2003). The growth regression finds a statistically significant relation between the relative size of SME sector and growth. However, this relationship is reported not to be robust to using instruments to test for endogeneity. That is, it is not clear which way the causal relation runs. The test of causality is to use instruments to extract the endogenous part of the SME variable leaving the exogenous part to be regressed on growth. The exogenous part does not explain very well, so there is a lack of causality. It is claimed that "even if SMEs increase growth, government subsidization of SMEs will not necessarily have this effect".

9.7 Labour Market Institutions

The functioning of an economy is related to the structure and operation of its markets. Daveri and Tabellini (2000) make a very simple argument about how the labour market institutions in Europe have contributed to lower growth. The labour market in Europe is characterized by strong trade unions. High labour taxes are then fed into wages through union bargaining and this creates unemployment. Thus, high taxes led to a higher natural rate of unemployment and a lower growth rate.

Data to motivate this argument are presented in Table 9.12. This presents unemployment rates and growth rates for Europe and the US for four decades from 1960. These can be seen to be inversely related: as unemployment in the EU has grown relative to the US, the EU growth rate has fallen.

	1960-70	1971-80	1981-90	1991-98
Unemployment				
EU	2.5	3.7	8.2	9.9
US	4.8	6.4	7.1	5.8
Growth				
EU	4.4	2.4	2.3	1.7
US	2.6	1.8	1.7	1.8

Table 9.12: Unemployment and growth

The data for the EU are claimed to support this perspective. An increase in unemployment comes about because of the substitution of capital for labour as wage rates rise. The regression results show that unemployment has a negative and significant coefficient. These are reported in Table 9.13 for one regression in levels and one regression in first differences (standard errors in parentheses). If the conclusion on the effect of unemployment is correct then it is not taxes alone but their interaction with institutions that determines the growth rate. However, the regression in first differences has very little explanatory power and in the level regression only two variables have significant coefficients. This is very weak evidence for the argument.

	Levels	First differences
Capital taxes	−0.006 (0.013)	0.036 (0.025)
Unemployment	−0.098 (0.039)	−0.227 (0.081)
Initial GDP	−3.30 (0.643)	0.013 (0.095)

Initial schooling	0.013 (0.010)	0.019 (0.017)
Adjusted R^2	0.44	0.09

Table 9.13: Growth regressions with unemployment

9.8 Financial Development

Schumpeter (1934) argued that the role of financial intermediaries may be important for economic growth because they choose which firms to support. The allocation of efficient allocation of finance to the correct projects is essential for entrepreneurial activity to flourish. Financial intermediaries can also support the growth process through the encouragement of saving and investment.

An analysis of the Schmumpeterian viewpoint using the method of growth regressions is undertaken by King and Levine (1993). The paper used data on 80 countries over the period 1960 - 1989. Four different measures of financial development were introduced. First, LLY was financial depth which is the overall size of the formal financial intermediary sector (ratio of liquid liabilities to GDP). Second, BANK was deposit banks domestic credit divided by deposit money bank plus central bank domestic credit. Third, where the financial system distributes its assets was reflected by using (a) PRIVATE the ratio of claims on non-financial private sector to domestic credit and (b) PRIVY the ratio of claims on the non-financial private sector to GDP.

They run a standard form of growth regressions to see the effect of the inclusion of the four financial development variables. The results are summarized in Table 9.14. Each of these regressions also includes log of initial income, log of initial secondary school enrolment rate, ratio of government expenditures to GDP, inflation rate, ratio of exports, plus imports to GDP.

Financial indicator	Coefficient	Standard effor	R^2
LLY	0.024	0.009	0.50
BANK	0.032	0.010	0.50
PRIVATE	0.034	0.010	0.52
PRIVY	0.032	0.010	0.53

Table 9.14: Growth regressions for contemporaneous development

The next step was designed to test whether financial development can act as a predictor of future growth. The method was to average growth over each decade and to use the value of the financial development variable at the start of the decade as a predictor. The results of this exercise are described in Table 9.15. (Each of these regressions included log of initial income, log of initial secondary school enrolment rate, ratio of government expenditures to GDP, inflation rate, ratio of exports, plus imports to GDP.) The results offer support for the hypothesis that financial development is a good predictor of economic growth.

Financial indicator	Coefficient	Standard effor	R^2
LLY	0.034	0.009	0.42
BANK	0.028	0.011	0.40
PRIVATE	0.016	0.009	0.39
PRIVY	0.037	0.011	0.42

Table 9.15: Growth and initial financial indicator

A longer-term perspective on the growth implications of the development of financial intermediation was presented by Rousseau and Wachtel (1998). They used time-series methods to analyze data for the period 1870 - 1929. Five countries were analyzed: the US, the UK, Canada, Norway, and Sweden. The results demonstrated that there was a long-term relationship between output per capita and financial intermediation (in the sense of cointegration). Financial intermediation was shown to Granger-cause growth, but not the converse. In interpreting this final statement it should be emphasized that Granger causality is a statistical concept and not directly related to economic causality.

An alternative perspective on the link between growth and development is presented by Rousseau and Wachtel (1998). Their analysis considered the relative rates of growth of different industries across countries. The analysis was based on the hypothesis that industries needing a greater proportion of external finance will grow relatively faster in countries with more developed financial sectors. This idea was implement by determining the degree of external financing for each industrial sector in the US and assuming that the same degree of external finance was required in every country.

The estimation procedure is based on the equation

$$\text{Growth} = \text{Constant} + \sum_{i=1}^{m} \beta_i \text{Country indicators} + \sum_{i=m+1}^{n} \beta_i \text{Country indicators}$$

$$+ \beta_{n+1}\left(\text{Industry } j\text{'s share of manufacturing in country } k \text{ in } 1980\right)$$

$$+ \beta_{n+2}\begin{pmatrix} \text{External dependence of industry } j \\ \times \text{Financial development of country } k \end{pmatrix}. \tag{9.20}$$

The focus was on the coefficient β_{n+2} that captures the interaction between the need for external finance and the level of financial development. Average growth over the period 1980 - 1990 is then regressed on four different measures of financial development: total capitalization, bank debt, accounting standards, and accounting standards in 1983. The results are reported in Table 9.16. In each case the interaction of the financial development variable and external dependence is positive and significant in explaining growth. The differential in real growth rate is defined as follows. The industries at the 25th percentile and at the 75th percentile of external dependence are identified. The growth rate of these industries in the 25th percentile country and 75th percentile country in terms of financial development are calculated. The differential is then defined as how much faster the 25th percentile industry grows relative to the 75th percentile industry in the 25th percentile country as compared to the 75th percentile country. This is interpreted as a measure of the importance of financial development. The results show that the value of this differential is large, certainly when measured relative to typical growth rates of approximately 3.5 percent per year.

Variable	Total capitalization	Bank debt	Accounting standards	Accounting standards in 1983
Industry's share ot total value added in manufacturing in 1980	-0.912 (0.246)	-0.899 (0.245)	-0.643 (0.2047)	-0.587 (0.223)
Interaction	0.069 (0.023)	0.118 (0.037)	0.155 (0.034)	0.099 (0.036)
R^2	0.290	0.290	0.346	0.239
Differential	1.3	1.1	0.9	0.4

Table 9.16: Industry growth and financial development

A very specific aspect of financial development is considered in Jayaratne and Strahan (1996). The US has witnessed a process of intrastate bank reform that has seen 35 states relax laws on intrastate branching since 1970. The effect of this process on growth is estimated by making a comparison of the growth performance of the states that have reformed with the states that have not. The results show that reform has a positive and significant effect on state growth rates. The estimated equations predict a growth rate increase of between 0.51 and 1.19 percentage points in the years following banking reform.

The channel through which financial intermediation can affect growth is investigated in Beck *et al.* (2000). The level of development of financial intermediation is measured by the value of credit provided by financial intermediaries to the private sector as a proportion of GDP ("Private credit"). This variable is included in growth regressions and in regressions that explore the level of capital accumulation and private saving. Table 9.17 reports the basic growth regression results. Cross-country data refers to an Instrumental Variables estimator with the data for 63 countries averaged over 1960 - 1995. Panel data refers to a dynamic Generalised-Method-of-Moments estimator with a panel constructed by averaging over seven periods of five years. The p-value is reported under each estimated coefficient. It can be seen the financial development has a positive and significant coefficient for both regressions.

	Cross-country data	Panel data
Constant	2.643 (0.527)	0.082 (0.875)
Initial income	−1.967 (0.001)	−0.496 (0.001)
Average years of schooling	1.548 (0.0787)	0.950 (0.001)
Openness	0.931 (0.042)	1.311 (0.001)
Inflation	4.270 (0.096)	0.181 (0.475)
Government size	−1.207 (0.132)	−1.445 (0.001)
Black market premium	−0.139 (0.914)	−1.192 (0.001)
Private credit	3.215 (0.012)	1.443 (0.001)

Table 9.17: Financial intermediation and economic growth

Further empirical analysis in Beck *et al.* (2000) shows that the Private credit variable is also positive and is significant in explaining total factor productivity growth. However, it is not significant in explaining physical capital accumulation or private saving. Therefore the paper provides evidence that the development of financial intermediation raises growth through increasing total factor productivity.

9.9 Conclusions

The choices are firms are central to models of endogenous growth. Firms are responsible for investing in physical capital and for undertaking the research and development that generates innovation. A key policy question is how taxation affects these choices. Some early attempts at modelling investment were based on ad hoc formulations. Others were based on an optimizing framework but delivered poor empirical estimates. The application of the natural experiment method to tax reforms has produced much stronger estimates and confirmed that investment does respond to tax incentives.

The same comments apply to research and development. The estimation procedures have improved and consistent estimates of the response of R&D to incentives have been reported. R&D is more responsive in the long run than in the short run, and R&D expenditure has a long-run elasticity of approximately 1 with respect to subsidies. Countries that do not undertake R&D have been shown to benefit significant international spillovers. These spillovers have increased over time with the development of globalization. Foreign direct investment is route through which R&D can be transmitted between countries. This, too, is sensitive to tax rates on corporate income. Finally, firms need funds to undertake investment and R&D. This explains why financial development indicators are positively related to growth.

Chapter 10 Country Studies

- Country studies evaluate specific tax proposals and tax reforms
- The US Economic Growth and Tax Relief Reconciliation Act of 2001 was predicted to reduce saving and lead to lower output
- A broadening of the tax base and the use of a general sales tax has been proposed for India
- Incentives to encourage FDI have been costly in terms of lost tax revenue for Vietnam
- The tax reforms of New Zealand have not reduced the tax burden but have changed that tax mix
- Frontier analysis can be applied to identify efficient tax structures

10.1 Introduction

This chapter presents a review of several country-specific studies. These studies evaluate tax proposals or tax reforms from a growth perspective. The studies are interesting for the variety of methods used. These include evaluation of the changes in the individual components of the growth process and the estimation of an efficiency frontier for alternative tax structures.

10.2 US

The US Economic Growth and Tax Relief Reconciliation Act of 2001 (EGTRRA) was a significant piece of tax legislation. The Act modified several areas of the US Internal Revenue Code, including those relating to income tax rates, estate and gift tax exclusions, and qualified and retirement plan rules. The overall effect of the act was to lower tax rates and to simplify the rules for plans such as IRAs and 401 (k)s. An interesting feature of the Act was that many of the tax reductions were designed to be phased in over a period of up to 9 years and that its provisions are designed to "sunset" (revert to the provisions that were in effect before it was passed). The Act will sunset on January 1, 2011, unless new legislation is enacted that makes its changes permanent.

Gale and Potter (2002) consider the details of the Act, its budget implications and distributional implications, and then move on to address the growth consequences. They summarize the tax changes as reducing income tax rates, repealing the estate tax, providing new subsidies for education and retirement saving, and indirectly reducing public saving. The net effect on growth of the economy is concluded to be negative.

The process for reaching this conclusion is as follows. Assume that the tax changes do not affect technical progress or the coefficients on capital and labour in a Cobb-Douglas production function. This places the focus on how the reform will affect labour supply and the capital stock. The labour input is interpreted as the product of time and human capital, and the physical capital input as the sum of home and overseas invested capital. Reference was then made to data from the Congressional Budget Office that predicted that the Act would raise the after-tax return to labour by between 2.2 and 2.8 percent, and the return to capital by between 0.6 and 3.4 percent. The empirical literature is used to support a labour supply elasticity of 0.05 for males and 0.30 for females (observe that the value for female labour supply is slightly higher than that reported in Section 8.4 but it is not unreasonable). These labour supply elasticities were then used to predict the labour supply response using the predicted increase in return to find the increase in hours. This provides an estimate of a 0.48 percent increase. It was then argued that there was no empirical literature that provided a clear prediction of the human capital effect of the change in return. Appeal was therefore made to the work of Dynarski (1999, 2000) to argue that change in tuition deduction and employer exclusion will increase human capital by 0.21 percent. The total change in effective labour supply is 0.69 percent.

The next step is to pick a similar path through the components of saving to arrive at a change in capital stock. The redistribution of after-tax income towards high-income households is predicted to raise saving by 0.36 percent of GDP. Next, estate tax repeal is assumed to raise private saving by 0.13 percent of GDP. The Act is predicted to reduce public saving by 1.58 percent of GDP, so the next effect is a decrease in saving of 1.09 percent of GDP. One third of this decline is assumed to be offset by an increased inward flow of capital from outside the US, leading to the final conclusion of a -0.73 percent of GDP reduction in saving. This figure is employed to arrive at a reduction in capital stock of 2.16 percent of GDP by 2011.

The final step in the argument is to use a simple parameterization of the Cobb-Douglas production function to calculate the implied change in output. The base case conclusion using the figures above is a predicted reduction of -0.31 percent. The explanation for this finding is the distinction between the private incentives of the tax reductions and the effect on public saving. The calculations predict the Act will raise labour supply, human capital, and private saving, but it causes an even greater reduction in public saving. It is this net reduction in saving that causes the predicted output decrease.

It is worth stressing that the calculations lead to a conclusion about the level of output. There is no prediction on how the Act will affect the growth rate effect. This was a consequence of the initial assumption that technical progress was unaffected by the reform. This emphasizes the difficulty in moving from knowledge of how the components of growth change to a prediction of the resulting change in *TFP*.

10.3 Non-US

China has experienced very rapid economic growth. This has been accompanied by major revisions in the tax system. These changes are described by Gordon and Li (2002) in a brief review of the recent history of Chinese tax reform. (A more detailed description of the changes is given in Huang (2006)). The central observation of Gordon and Li is that the tax system was initially focused on collecting revenue from a few large firms. In addition, there were high tariffs on imports. The high rates were coupled with corruption and evasion so that collected revenues were low. These features combined to deter entry of new firms, distort government decision making, and ultimately stifle the rate of economic growth.

The paper then notes the changes that have since taken place in a series of reforms to the tax system. In brief, accounting procedures have been modernized, a VAT system has been introduced, and corporate tax rates have been lowered. It is claimed that these changes have all contributed to growth.

The main point of the paper is to observe that a major factor in increasing growth has been the process of decentralization. From 1980 the central government allowed local governments to collect and retain taxes from the firms that located in their regions. This gave local governments an incentive to encourage firm entry and reduces the information problems in collecting taxes. The National Tax Bureau now has responsibility for collecting VAT, excise taxes, and income taxes from state-controlled enterprises. Local Tax Bureaus collect business taxes, individual income taxes, agricultural taxes, and property taxes. This is all supported by a legal system that provides harsh punishments for tax evasion.

One element of the Chinese success has been the use of tax incentives to attract foreign direct investment. Many other countries, such as Thailand, have also benefited from the use of incentives. Fletcher (2002) reviews the theory behind the pros and cons of tax incentives and applies the analysis in a study of tax incentives in Cambodia, Lao PDR and Vietnam. The important point is made that for firms from countries operating a tax credit system, such as the US and UK, a tax incentive abroad is a transfer to the US or UK government rather than a direct benefit to the investing firm. (This applies except where there is a tax sparing agreement, but these agreements are not mentioned in the paper.) The empirical evidence on the elasticity of investment with respect to tax incentives is then reviewed. The paper reports the Hines finding that a 1 percentage point reduction in the corporate income tax rate leads to a 2 percent increase in investment.

The analysis of the data for three countries is then considered. It is concluded that simple schemes are just as good as complex schemes. The data also reveal a significant cost of offering the tax incentives. This is estimated to be $224 million for Vietnam in 2001. A simple plot of the quantity of FDI for the three countries shows that this peaked in the mid-1990s and then decreased until the end of the sample period (2000). Plots are presented to show that FDI is negatively related to an index of tax incentives and negatively related to the standard corporate tax rate for a cross-section of South East Asian countries. But both of these relationships are a consequence of Hong Kong which is a clear outlier in the data (highest FDI, lowest incentives, and lowest tax rate). Without Hong Kong there appears to be very little relationship. The paper concludes by conjecturing that tax incentives are not the primary determinant of investment and that accelerated depreciation may be the best policy.

Poirson (2006) describes the Indian tax system as currently having high marginal rates but low revenues because of the narrow base and low level of tax productivity (the effectiveness of collecting taxation). Appeal is made to elements of the empirical literature reviewed above that this tax structure is bad for growth. The argument begins from the hypothesis that a reform combining lower statutory rates with base-broadening would raise growth. A set of proposals are then described that involve lowering the rate of direct taxation, broadening the base, and introducing a VAT on goods and services. The report then proceeds to analyze the proposed reform from a growth perspective. It is claimed that this reform could partly be achieved through the removal of exemptions and improved tax administration. The proposals are broadly praised by the report, but it offers no quantification of the effect upon growth.

An interesting alternative methodology for explaining the link between taxation and growth is provided by Branson and Lovell (2001). The analysis starts with a discussion of the reform process undertaken by New Zealand in the 1980s. This reform matched what is proposed for India: a reduction in progressivity of personal income taxes, a reduction in the rate of corporate taxes, a broadening of the income tax base, and the introduction of a goods and services tax. It is observed that this reform has not reduced the overall level of taxes and the ratio of direct to indirect taxation has remained high. The remainder of the paper is focused on relating the tax burden and the tax mix to economic growth and characterizing the optimal structure.

The analysis states the standard growth accounting expression

$$g_Y = \alpha_K g_K + \alpha_L g_L + SR, \qquad (10.1)$$

and asserts that the five variables (α_K, g_K, α_L, g_L, and *SR*) are determined by the tax burden, tax mix, and a vector *Z* of other variables. Denote the revenue from direct taxes by *D* and the revenue from indirect taxes by *I*. Then the tax burden is $B = (D + I)/Y$ and the tax mix is $M = I/D$. The tax mix and tax burden are related to the rate of growth by writing

$$g_Y = f\left(\frac{Y}{D}, \frac{Y}{I}, Z\right). \qquad (10.2)$$

The next step in the analysis is to "solve out" the vector *Z*. Assume that some realizations of *Z* are good for growth and others are bad for growth. Years where growth is high must then represent relatively favorable realizations of Z. These years are identified by solving a linear programming problem which finds the extent to which Y/D and Y/I could be reduced in each year while achieving the observed rate of growth. Let $0 \le \theta^t \le 1$ be the solution of this programming problem in year *t*. In the most efficient years no reduction in revenue would be possible without reducing growth, so $\theta^t = 1$. Inefficient years would have a value of $\theta^t < 1$. The value of θ^t summarizes information on the vector *Z* in each year.

The effect of the tax burden and tax mix are then computed by running the regression

$$\ln(g_Y) = \beta_0 + \beta_1 \ln\left(\frac{B}{\theta}\right) + \beta_2 \ln(M) + \frac{1}{2}\beta_3\left[\ln\left(\frac{B}{\theta}\right)\right]^2$$

$$+ \frac{1}{2}\beta_4[\ln(M)]^2 + \beta_5 \ln\left(\frac{B}{\theta}\right)(M)). \qquad (10.3)$$

Given the estimated coefficients it is possible to choose the optimal burden for a given mix by maximizing over *B*, or to find the optimal mix for a given burden by maximizing over *M*.

The application to data for New Zealand over the period 1945 – 1995 concludes that the observed tax burden exceeded the optimal tax burden (given the mix) for every year with the exception of 1951. The observed tax mix is less than the optimal mix in most years, and especially so in the years around 1980 when the New Zealand economy was performing poorly in terms of growth. The mean growth maximizing tax mix comprises 65 percent direct taxes and 35 percent indirect taxes. In summary, it is concluded that the tax burden in New Zealand did more to reduce growth than did the tax mix.

10.4 Comments

These country studies demonstrate a variety of methods of evaluating tax reforms. However, none makes a truly comprehensive assessment of the growth consequences of a reform. Gale and Potter provide detailed calculations for the effects of the reform on each component of growth, but assume away any consideration of total factor productivity. The methodology of Branson and Lovell is an interesting alternative to the established techniques and may prove worthy of development.

Part 5
Conclusions

Chapter 11: Summary and Implications

11.1 Introduction

This chapter presents a brief summary of the individual chapters. It then offers some observations on the implications for policy of the literature that has been reviewed. The chapter concludes with a discussion of areas in which further research is required.

11.2 Individual Chapters

The following comments summarize the findings of the literature review.

Chapter 2: Exogenous Growth

- The Solow growth model predicts consumption per capita will reach a limit unless there is technical progress.
- The source of technical progress is not modelled so the effect of policy cannot be analyzed.
- The model predicts convergence: countries with a low capital stock will grow faster than countries with a high capital stock.
- In the long-run it is inefficient to have a tax on capital income.

Chapter 3: Endogenous Growth

- Endogenous growth models provide an explanation of sustained growth.

- Several mechanisms through which growth can be sustained have been identified.

- The accumulation of human capital raises the supply of effective labour and demonstrates a theoretical role for education to raise growth.

- The existence of a productive public sector input can result in taxation having a beneficial impact on growth.

- The pursuit of innovation emphasizes the value of Research and Development.

- Taxation can affect a range of personal and corporate choices that impact on growth.

Chapter 4: Theoretical Predictions

- Simulation of human capital models generates widely-varying outcomes for tax-reform experiments.

- Almost all the results support the claim that a move from income taxation to consumption taxation will raise the rate of growth even though the predicted effect may vary.

- The growth-increasing effect of moving from an income tax to a consumption tax is magnified when human capital accumulation is modelled.

- Scholarship programs that assist with the financing of education can reduce the incentive to save through their interaction with the tax system.

- Research and development may have a high social value considerably in excess of its private value and expenditure on research and development may be sensitive to taxation.

Chapter 5: Growth Regressions

- The initial promise of growth regressions to reveal the causes of growth has not been realized.

- Very few variables are robustly correlated with economic growth.

- Those variables that are robustly correlated with growth offer little guidance for the design of a growth-increasing tax policy.

- Individual country studies should be more informative about the causes of growth than cross-country aggregate analysis.

Chapter 6: Tax Regressions

- Tax systems are complex and multi-dimensional.

- Tax regressions face a difficult task in constructing an empirical equivalent of "the marginal tax rate".

- Many regressions use a measure of the average rate of tax. Economic theory predicts that the average rate is not the relevant variable for most decisions.

- A number of alternative methods have been proposed for constructing a representative marginal rate of taxation.

- Empirical evidence for the hypothesis that the level of taxation affects economic growth is very weak. This applies when measures of the average rate of tax are used in the regression and when measures of the marginal rate of tax are used.

- Tax regressions deliver better results when each tax is included separately. There is evidence that income taxes are damaging for growth relative to consumption taxes.

- The lack of structural modelling limits the interpretation of the estimated equations and leaves the causality issue unresolved.

Chapter 7: Growth Accounting

- Growth accounting identifies the contributions of capital, labour, and technical innovation to productivity growth.

- Applications of growth accounting have provided convincing evidence of different growth experiences across countries. Some countries have achieved growth almost entirely through capital accumulation. Other countries have achieved growth through a combination of capital accumulation and productivity improvement.

- The change in total factor productivity depends on economic variables. This provides evidence in favor of the endogenous growth model.

- The contribution of individual components to total factor productivity growth cannot be determined through the application of growth accounting.

Chapter 8: Personal

- The empirical evidence on the effect of taxation on saving is contentious. This is true for the aggregate elasticity of saving and for the response of saving to favorable tax treatment.

- The evidence on the effect of IRA and 401 (k) plans is disputed but there is probably a small response of saving to the tax incentive.

- Subsidies that reduce the cost of education raise enrolment rates. The effect can be significant for groups that are constrained by capital market imperfections.

- The empirical counterpart of the theoretical human capital construct has been contested. Measures of underlying ability perform better in growth regressions than measures of formal education.

- The decision to become an entrepreneur is sensitive to taxation. It is not clear if it is the level of taxation or the progressivity of taxation that matters most.

- Behavioral economics challenges many of the assumptions of traditional economic analysis. These challenges are especially relevant in the context of intertemporal decision making.

Chapter 9: Corporate

- Models of investment have traditionally performed poorly in explaining the empirical data.

- The investment model provides stronger predictions when set within the natural experiments framework. The frequent changes in tax rules for investment allowances and depreciation allow estimation of the response.

- Investment is increased by tax incentives.

- The effect of subsidies on research and development expenditure has been estimated very cleanly and consistently. Research and development expenditure is sensitive to subsidy in the long term.

- Research and development expenditure is concentrated in small number of countries but international spillovers are significant.

- Foreign direct investment has been extensively studied. It is responsive to tax incentives.

- Taxation affects the choices of entrepreneurs. An increase in taxation reduces their probability of employing labour and of investing, and reduces the rate of growth of small firms.

Chapter 10: Country Studies

- The empirical results have been used to calculate the output effect of policy reforms.

- The results have not been used to calculate the effect upon total factor productivity growth of a tax reform.

- Lower rate, base broadening, and an increase in consumption taxes relative to income taxes, are the package of reforms generally accepted to be growth enhancing.

- Frontier analysis can determine efficient tax structures and guide tax reform.

12.3 Policy Conclusions

This section offers some brief comments on the policy implications derived from the review of the theoretical and empirical analysis of taxation and economic growth.

Tax instruments

- There is no empirical evidence in the aggregate data that the rate of economic growth is related to the level of taxation.

The level of government consumption expenditure was a significant variable in some growth regressions but this correlation was not robust. Many specifications of tax rate variables have been employed in tax regressions but none has provided a convincing result when other covariates have been included. It is important to note that this is not making the claim that the structure of taxation does not affect the rate of growth.

- There is evidence that growth is higher when the corporate income taxis lower.

When the aggregate level of taxation is separated into components for the different taxes the level of corporate income tax becomes significant. The policy implications of this observation have to be carefully considered within an international setting. The corporate income tax affects investment at home, and foreign direct investment. If the increase in growth is driven by foreign direct investment (through the process of internationally-mobile capital seeking the maximum post-tax return) a multilateral reduction in corporate income taxes will not be beneficial.

- Increases in the personal income tax reduce growth only by affecting the decision to choose entrepreneurship.

The personal income tax might affect growth through it effect on labour supply, human capital accumulation, and saving behavior. Labour supply is connected with a level effect, not a growth effect so even if labour supply is sensitive to taxation this is not important for growth. The effect of the income tax on human capital and saving are theoretically ambiguous. These are discussed further below. There is clear evidence that the personal income tax does affect the choice to enter entrepreneurship and the decisions of entrepreneurs. An increase in personal income tax reduces growth by discouraging entrepreneurship.

- A change in the tax mix that increases the importance of consumption taxes relative to income taxes will raise growth.

The theoretical mechanism through which this argument works is very clear. Income taxes distort the choice between consumption and saving by reducing the return on saving. This raises the effective price of consumption tomorrow relative to consumption today. An increase in saving raises the rate of increase of the capital stock. The effect is apparent in the aggregate tax regressions and is implicit in the disaggregated empirical results.

Choice variables

- The empirical evidence on *saving* is mixed but on balance suggests some sensitivity to tax incentives.

The aggregate elasticity of saving with respect to taxation was an issue of contention in the 1970s. The debate has now moved to the sensitivity of saving to tax incentives. However, the results remain equally contentious. Behavioral economics provides an alternative model of saving behavior which could explain the empirical evidence.

- *Educational choices* at the college level are sensitive to incentives but there is no evidence on how they are affected by tax instruments.

The effect on college attendance of scholarship programs is cleanly estimated and can be large for some groups of the population. But these incentives relate to choices in the near-term. How the income tax, which operates on the long-term return to education, affects education decisions is not known. This is another dimension of choice to which behavioral economics might contribute.

- The decision to become an *entrepreneur* is affected by the level of taxation and the progressivity of taxation.

Theoretical analysis predicts that taxation alters the risk and return characteristics of the income stream faced by a potential entrepreneur. The empirical results show that the net effect is a reduction in the probability of entrepreneurship being chosen. This can reduce innovation in the economy and have an adverse effect upon the growth rate.

- *Investment* expenditure is sensitive to tax incentives.

The empirical analysis of tax reforms has established stronger estimates of the tax response. The estimates show that investment will increase when the tax-adjusted user cost falls.

- Expenditure on *Research and Development* is sensitive to tax incentives.

The sensitivity of R&D expenditure to tax incentives is one of the most clearly estimated coefficients in the entire literature reviewed. The use of natural experiments coupled with significant changes in policy has given a good measure of the value. The elasticity is smaller in the short run than in the long run, and is consistent across countries.

- The level of *Foreign Direct Investment* is sensitive to tax incentives.

Foreign direct investment arises from mobile capital seeking the highest net return. It is therefore no surprise that it is responsive to taxation. This is true between different states within the US, and between countries. There have been many studies of foreign direct investment with good consistency in recent estimates of the tax elasticity.

- The choices of *entrepreneurs* are sensitive to tax incentives.

The empirical analysis has identified sole-proprietors with entrepreneurial activity. The research has shown that the business decisions of sole-proprietors are affected by the personal tax system. An increase in taxation reduces the probability that they will employ workers, reduces the probability that the will invest, and reduces the rate of growth of their business.

12.4 Discussion

A number of comments have been made in the body of the review on unanswered questions and on limitations of the methodology. This section expands upon some of those comments.

The review has noted at many points that there are convincing estimates of economic responses to changes in policy. These estimates have invariably been obtained by the use of microeconometrics. Microeconometrics is a set of tools that has developed in the past two decades into set of very powerful techniques for examining micro-level decisions. In contrast, the review has also noted the limited success of the aggregate econometric analysis. There appear very few significant relationships in the aggregate data on economic growth. This has brought the analysis to a position where many of the relevant micro responses are known. If they are not known, a methodology exists for discovering them wherever suitable data is available. In principle, it should be possible to aggregate these micro-level reactions to find the overall effect of a policy reform upon growth. The work of Gale and Potter (2002) provides a template for how this can be partially achieved - partially is justified here because Gale and Potter consider only the level effect of the policy reform and do not attempt a calculation of the change in total factor productivity.

There is a good reason why Gale and Potter do not try to calculate the change in *TFP*. This reason is the lack of any existing empirical evidence that can guide such a calculation. This point can be understood from another perspective. The application of growth accounting determines a separation of growth into three components (or four if human capital is treated separately). Two of these components - the growth in the capital stock and in labour supply - are observed. The third, the growth of *TFP*, is calculated as the residual. This provides a measure of *TFP* growth but no understanding of what has caused that growth. This issue was discussed at length in Prescott (1998) who raised important questions about the limitations for current understanding. Those questions currently remain unanswered.

In brief, what is missing from the body of knowledge is the link from changes in the variables identified as important by endogenous growth models to changes in the value of *TFP* calculated by growth accounting. The work of Bernanke and Gurkaynak (2001) investigated the determinants of *TFP* by using a regression analysis. That work provided evidence of the endogeneity of *TFP* growth and could form the basis of interesting extensions.

The aggregate regressions analysis has met with limited success. It is natural to question whether it is possible to improve these regressions. Certainly, using variables that represent the separate components of the tax system (direct taxes, indirect taxes, *etc.*) has led to some improvement but there are limits on how far this can be taken. As Slemrod noted, if there was a significant effect of taxation on economic growth hidden in the data why has it proved so hard to find? The answer lies either in the fact that there is no major effect or that the correct specification of the models has still not been found. The comments made in this report have all tended to support the former conclusion, at least for the range of values of the tax variables currently observed.

An important point is made by Slemrod (1992) that relates to all analysis of tax responses. The empirical work focuses on the question of how a change in taxation affects behavior in a narrow range of the choice space. A change in the chosen level of an economic variable is not the only possible response to taxation ad there is an important class of more general responses. It is possible to alter the timing of an action, or engage in financial or accounting practices that alter the taxable position of the action. The extreme version of this form of response is to move from the observed to the hidden economy. These changes are not immediately apparent in the aggregate data and require a more extensive form of analysis. Generally, an increase in taxation can be met by behavioral changes that attempt to mitigate the effect by making choices that are outside the data used in the analysis. The analysis of the hidden economy (Schneider and Enste, 2000).has made it clear that there is a significant body of economic activity outside the normal process of measurement. These issues have not been fully resolved in the analysis of the aggregate data.

There is a considerable variety of theoretical work exploring models of endogenous growth. One important limitation of this literature is the lack of a compelling model of economic growth that captures the international transmission of technical innovation. Bayoumi *et al.* (1999) provide an empirical that identifies the size of the effects but does not explore the underlying processes. A model should reflect the concentration of research and development amongst a few major economies and explore the diffusion process for the resulting innovations. Models that are available (for example, Howitt, 2000) have a very simple structure and place countries in a position of symmetry.

Important questions have also been raised about what the human capital variable entering the theoretical model represents in the empirical data. The standard interpretation is that it relates to schooling (which is why schooling was included from the outset in growth regressions). This provides a convenient fit with a model of choice in the amount of investment that can be undertaken. This leads to a process of human capital accumulation, so endogenizing the rate of growth. The empirical evidence suggests that this might not be the correct interpretation. The success of mathematical ability and IQ measures in growth regressions casts doubt on years of education being the correct measure of human capital. Clearly, the resolution of this debate has implication for some very important areas of public policy. The link between economic growth and education needs to be more closely tested in order to justify this emphasis.

Finally, two brief issues that have not featured in the empirical analysis of growth. First, behavioral economics is becoming increasingly established as a mainstream approach. The key point is that changes to the method of discounting or to the formulation of preferences imply very different responses of choices to taxation. An assessment from the perspective of behavioral economics could provide a very different policy interpretation of the empirical findings. Second, no mention has been made of government non-price intervention. This might have been proxied by measures of government size in aggregate regressions. Given the increasing relevance of economic regulation it justifies a separate analysis.

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