GROWTH AND RELATIVE LIVING STANDARDS – TESTING BARRIERS TO RICHES ON POST-WAR PANEL DATA

by

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DEDICATION

To My Father and Mother

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ABSTRACT

The main purpose of this thesis has been to estimate and simulate a general equilibrium model of growing small open economies by taking a new testing approach. The effect of business tax and regulation on growth, together with potential effects of government spending on education and R&D, is embodied in this model. We argue that regressions of growth on its supposed causes are not on their own persuasive evidence of these causes. Instead we propose to test theories by a two-stage Popperian procedure in which rejection can occur at each stage. The structural model is estimated on post-war panel data for 76 countries and the bootstrap is used to produce the model's sampling variation for the analysis of panel regressions of growth. In the first stage the model as tightly specified must pass an estimation test in its structural form; in the second its bootstrapped implications must be consistent with the growth regressions it implies. We test two main classes of growth theory: one is the Incentivist theory in which growth is caused by incentives for people to engage in entrepreneurial activity, the other is the Activist theory where direct government intervention to stimulate particular activities – specifically education and R&D – causes growth. We are able to reject the latter for education at both the structural and the bootstrap levels; and for R&D at the bootstrap level, though not the structural. We accept the Incentivist theory at both levels.

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INTRODUCTION

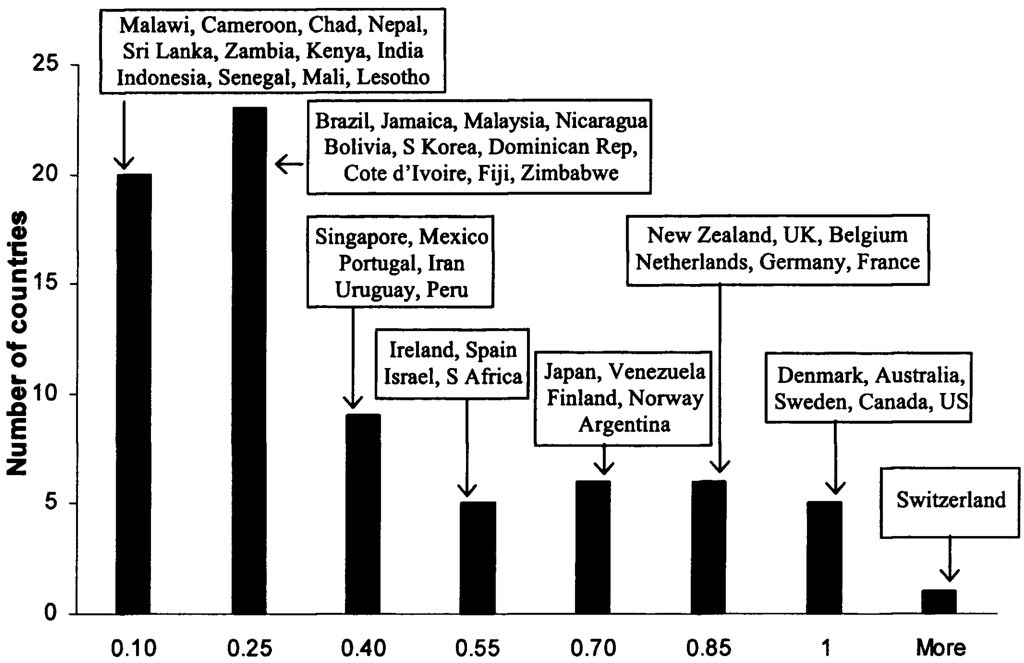
1. INTRODUCTION

The goal of this thesis is to take the simplest possible Real Business Cycle model and adapt it to endogenous growth in such a way that we can use dynamic testing techniques on its aggregate predictions, using the Penn Table post-war data. The effect of business tax and regulation on growth, together with potential effects of government spending on education and R&D, is embodied in a model of a small open economy with growth choices. This thesis takes a new approach to testing by using the bootstrap and a two-stage Popperian procedure in which rejection can occur at each stage.

Economic growth has been the core of macroeconomic research. Economists have more and more come to understand that long-run growth is as important, perhaps even more important than short-run fluctuations. Why GDP was up or down a few percent over the last few months can be an appealing question. But even more important are why growth varies enormously across countries over long periods of times, why the U.S. or Switzerland is much richer than Congo or Cameroon, and why growth rates of many western countries have decreased over the past few decades. Figure 1.1 plots the distribution of per capita GDP relative to the United States in 1970. The highest per capita GDP of $20,424 for Switzerland was more than 37 times the lowest value, $445 for Malawi. The United States was the second highest with a value of $16,487. The figure also depicts several representative countries for each range of per capita GDP relative to the US. The broad view is that the richest countries consisted of the OECD and a few countries in Latin America, e.g. Venezuela and Argentina. Most of Latin America and some Asian countries were in a middle range of per capita GDP. The poorer countries were most African together with some Asian countries.

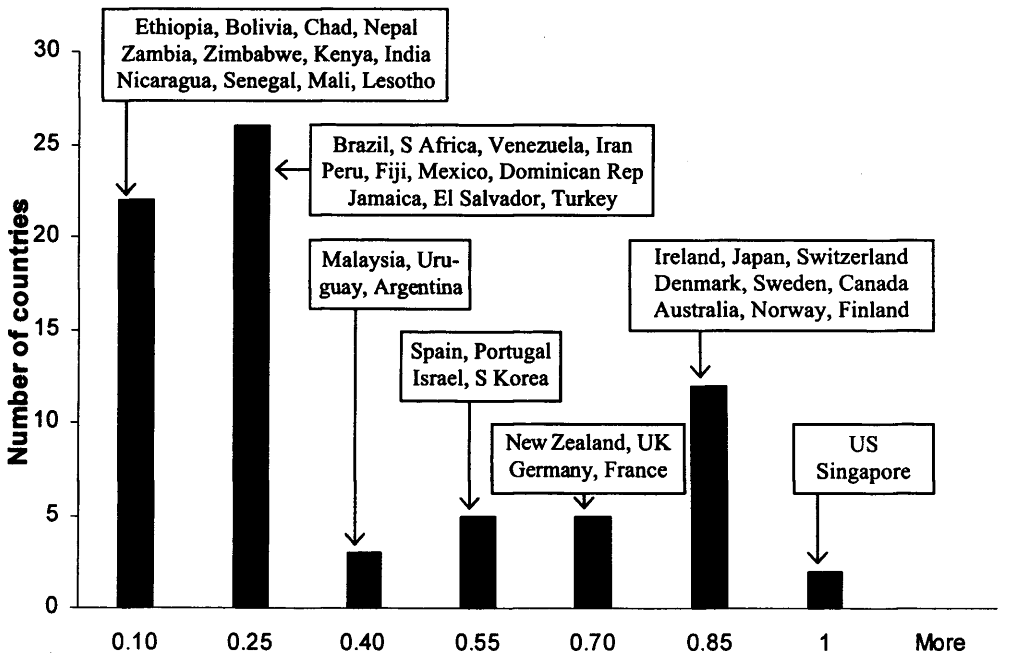
Figure 1.2 plots the distribution of per capita GDP relative to the United States in 2000. The lowest per capita GDP value of $585 for Ethiopia is only 1/55 of the highest value, $32,132 for the US. Figure 1.2 again lists representative countries within each range of per capita GDP. The OECD countries still dominated the top group, joined by several East Asian countries, such as Singapore and Taiwan. Most other Asian countries as well as most Latin American countries were in the middle range of per capita GDP in 2000. Sub-Saharan Africa, however, dominated the lowest range.

Figure 1.1: Distribution of countries' per capita GDP relative to U.S. in 1970



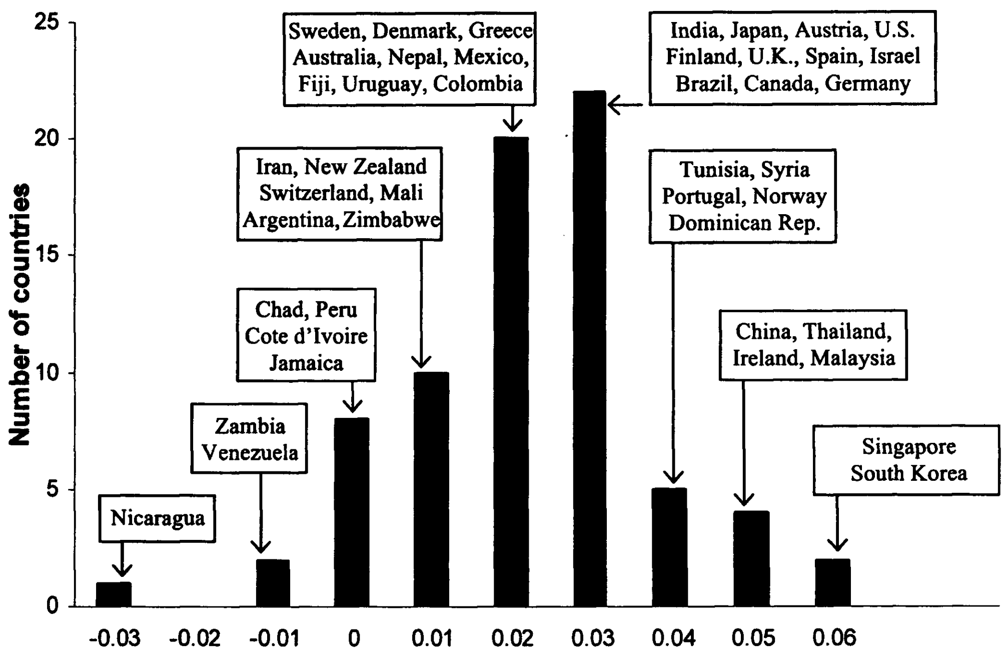
Note: The data, for 76 countries, are PPP adjusted values of per capita GDP from Penn World Tables. Representative countries are listed in each box. Countries are selected according to the availability of data on different variables in this thesis.

Figure 1.2: Distribution of countries' per capita GDP relative to U.S. in 2000



If we want to understand why countries diverge substantially in living standards (figures 1.1 and 1.2), we have to ask why countries have such big differences in long-run growth rates. When cumulated over several decades, even small differences in these growth rates have much greater impacts on standards of living than the kinds of short-run fluctuations that seem to have drawn more attention of macroeconomists. Figure 1.3 shows the average growth rates for the period of 1970-2000. Along with the last two figures, we can clearly see that sub-Saharan Africa started relatively poor in 1970 and grew at the lowest speed, and it ended up the poorest area in 2000. Most Asian countries started a little above Africa but grew faster and ended up mainly in the middle. Some Asian countries even ended up in the high range after dramatic growth. Latin America started in the middle to high level and ended up mainly in the middle after 30 years below average growth rates. Last, the OECD countries started highest in 1970, grew at middle range or a bit higher speed, so that they were still the richest in 2000.

Figure 1.3: Histogram for per capita GDP growth rate, 1970-2000



Economists have, in some sense, always known the importance of growth. The 1980s saw a new wave of vigorous developments in the area that is later called endogenous growth theory. This new growth theory has explored ideas that were largely ignored in the older research. Increasing returns, human capital, education, learning-by-doing, innovation, R&D, public infrastructure, and externalities are now central to research in economic growth. In this literature such ingredients 'enter the production function'- that is contribute to the generation of output- which are themselves enhanced in their effects by the extra output. Hence growth may enter a 'self-feeding' phase when these elements are present or increased beyond a certain threshold. Meanwhile, new data on economic growth have become available for a large sample of countries, allowing new studies to include a healthier interplay between theory and empirics.

We started thinking about this question a few years ago, no doubt, inspired by the work of Lucas (1988) and Aghion and Howitt (1998). Over the years, our thoughts have evolved. As in any such process, earlier ideas were refined or challenged once insights were gained. As we know, technology is a lever to riches and therefore all countries would be rich if they just used this lever, but why don't poor countries apply the better technologies that are available and become rich? Now we are more and more inclined to believe the answer is that growth and accumulated living standards depend on the freedom of business to innovate and sell their innovations via free entry into business, an idea in line with Parente and Prescott (1999 and 2000). They argued freedom could be withdrawn by regulations, taxes, or a variety of government restrictions designed to protect existing producers – 'barriers to riches' as they term it. Over the past decade a variety of indices have been constructed to measure this freedom. Here we use one compiled by the World Bank on the costs of entering and exiting from business. This index we combine with a measure of general taxation to create what we call for simplicity a 'business tax rate'. Our aim in this paper is to explore in a deliberately simplified model whether the Barriers to Riches theory, which we will call 'Incentivism', can explain post-war growth across the world (76 countries, 1970–2000, in data from the Penn Tables).

Plainly there has been a wide range of work, in the form of both history and case studies, devoted to explaining growth and the proximate factors causing it (see for example Easterly, 2001, and Snowdon, 2007, chapter 2, for a useful survey). Parente and Prescott themselves calibrate general equilibrium models and see whether these can replicate the facts of relative living standards and growth episodes since 1820. They reject in particular models in which capital accumulation (including and excluding intangibles) and education account for these when there are no barriers to the transmission of best world available practice; the problem is that investment and education rates are too similar across countries to generate the necessary differences in performance. The model that succeeds is one where the transmission of best practice is blocked differentially across countries by the government protection of insiders. However here we aim to carry out a more limited and complementary study in terms of econometrics on post-war panel data and attempt to set this Incentivist theory up in a way that is testable on this data.

Ranged up against this thesis are a variety of theories that growth depends on active government intervention to promote particular sorts of activity: two we focus on here are education and R&D. We will measure the extent of government intervention to promote these by respectively government spending as a percent of GDP on all levels of education and the government percentage share of total country R&D spending. These theories we will call 'Activism'. According to Incentivism growth is triggered by people choosing to be entrepreneurial in response to incentives; these activities could take the form of acquiring skills via education or by doing 'R&D', but if so these would just be some of the forms their activity could take but that activity would be defined by its focus on exploiting business opportunities. According to Activism it is these latter specific activities that generate higher productivity and therefore government can raise growth by subsidising them.

For our tests of these theories we abandon the widely-used method of regressing, usually in panel data, growth on a selection of exogenous 'growth drivers' and checking whether a particular driver is statistically significant.[1] We argue that this method is flawed by potential data-mining, by likely bias and by lack of identification. If one writes down a model of endogenous growth (as we will shortly do) one finds that it is complex and non-linear so that it does not have a linear reduced form; thus the linear 'reduced forms' written down for testing are no more than guesses at the variables, either exogenous or predetermined, that might be included among the determinants of growth. Even if their inclusion is correct, the omitted variables will in general include powers or other combinations of these included variables; hence the error terms will be correlated with the regressors and there will be bias whose size and direction cannot be estimated reliably.

Partly because authors have been conscious of these problems, they have included various menus of 'control' or 'nuisance' variables in these regressions. The trouble comes in the criteria for choosing them as many can be suggested in the absence of a tightly specified underlying structural model being applied. The statistical significance of the key variable under test will in general be much affected by this choice; hence the vulnerability of the method to data-mining.

The problem of identification arises because we do not know what model is generating these 'reduced forms'; many different models could give rise to some relationships between the chosen regressors and growth. For example if the regressors are correlated (due to transmission within the model) with the true causal mechanisms whatever they are one could obtain significant regression coefficients on the chosen regressors which in fact come from a quite different set of causes.

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[1] Leach (2003) and OECD (Leibfritz et al, 1997) provide useful surveys of this literature. Studies include Barro (1991), Koester and Kormendi (1989), Hansson and Henrekson (1994), Cashin (1995), Engen & Skinner (1996), Leibfritz et al (op. cit.), Alesina et al. (2002), Bleaney, Gemmell & Kneller (2000), Folster & Henrekson (2000), Bassanini & Scarpetta (2001), Benson and Johnson (1986), Chao and Grubel (1998), Easterly and Rebelo (1993), Grier and Tullock (1989), King and Rebelo (1990), Levine and Renelt (1992), Peden and Bradley (1989), Plosser (1992), Scully (1989, 1991, 1995), Slemrod (1995), Smith (2001), Vedder and Gallaway (1998).

For such reasons the large literature above may not be regarded as entirely persuasive evidence. Those for example who think R&D is the major factor determining growth will not be impressed by regressions showing that tax rates are correlated with growth. Vice versa with regressions highlighting R&D those favouring the tax explanation are unwilling to be persuaded.

In this paper we take a new approach to testing, one that has been used in time-series macroeconomics with some promising results. This approach we will term Popperian because it is an attempt to take as far as possible the principles of rejection put forward by Popper (1934). In these the idea is to set out the model to be tested and to use all possible implications of it for the data to reject it. For this purpose the model must be specified quite unambiguously and must be identified – that is it must not be able to be confused with another model. Secondly the model must be estimated on the data and must not be rejected at this stage. Thirdly, if there are other relationships it might imply or be consistent with – in this context these will be growth regressions – such regressions must be consistent with the model being true. This approach is new and therefore we set out carefully below the steps to be followed in this paper.

We start by insisting on a clearcut 'null hypothesis' by which we mean a hypothesis treated as true for purposes of testing (by 'null' has often strictly been meant the 'zero' hypothesis of no relationships at all because this is the one that is taken to be rejected in much statistical testing; however we adopt the definition of 'working' or 'initially believed' hypothesis here because in our approach it will be this, not the zero hypothesis that is to be rejected). This null hypothesis is the micro-founded (structural) theory of endogenous growth in this case that we are going to test. This theory will be set up to permit three variants, viz. Incentivist or Activist, and in the latter case either stressing education or stressing R&D.

This theory being specified is then estimated on the data in its structural form. It may be rejected at this stage, if the critical parameters cannot lie within the range required at some statistical confidence level. Here since the data we have is panel data there are practical limitations to how far we can apply the restrictions implied by the structural model. For example expectations of future variables cannot in practice be generated by solving each country's model forwards at each point of time as we would with time-series data for one country. Instead what we do is to estimate two key structural equations; these are the production function and the labour supply function, both necessary for our purpose in explaining output supplied. We fit these to the levels of variables in the data. Our model's specification is to variable levels, so it is appropriate to estimate it in these terms, so that it can be tested for these implications.

The theory as constructed and estimated in this way then, assuming it cannot rejected at this stage, can be reused to test its further implications for linear 'reduced forms' of interest. Here these forms are the growth regressions with which we began. We may ask whether each model can explain the growth regressions implied by it that we observe. To do this we note that each structural model as constructed above a) implies the exclusion of all variables other than those it identifies as causal (a zero restriction: these should therefore not appear in the reduced form) b) together with the panel data, implies certain errors – the 'structural error terms' in each structural equation. These latter errors can be regarded as the effects of non-systematic factors omitted from the model that may affect output (productivity) and labour supply (leisure preference). Clearly each model will partition the data differently into the part explained by the drivers it identifies as the identified causes and the part allocated to these errors. This difference of partitioning is what distinguishes one model from another.

To explore whether a model can explain the growth regressions, we bootstrap the random elements in the error processes together with the random elements in the exogenous variables to create the sampling variation of the data as implied by the model. This sampling variation permits us to derive statistical confidence limits for the parameters of the growth regressions under the null hypothesis of the model. In turn this allows us to reject the model at this last stage.

The Thesis is organised as follows. The second chapter establishes a theoretical framework by reviewing the main approaches taken to model the roles of human capital and technological change in endogenous growth. It will also present in which way the growth drivers affect output in each of these models. We then focus on the tax policy implications of the models laid out in the previous chapter, and provide a theoretical basis for examining the different mechanisms through which government policies influence long-run growth. Finally, we will turn to the empirical evidence evaluating the impact of human capital and taxation on economic growth. In chapter 3 we will point to Parente and Prescott's view that the differences in productivity across countries and some factor of the degree of non-intervention promise the best hope of explaining the stylised facts of growth. Then we extend their idea to a broader context by discussing that entrepreneurship and entry, serving as a conduit for knowledge diffusion, is the missing link in endogenous growth literature between knowledge creation and economic growth, and finally we discuss how government may facilitate such link. In chapter 4 we sketch out the two rival models (i.e. 'Incentivist' and 'Activist') and conduct a preliminary test by estimating reduced form equations on panel data in the form of decade averages from 1970-2000. Chapter 5 represents the crux of the thesis. We construct a model of a small open economy with endogenous growth and provide more deliberate empirical tests of the two rival ideas. The structural model is estimated on post-war panel data and the bootstrap is used to produce the model's sampling variation for the analysis of panel regressions of growth. We propose and use a two-stage Popperian procedure in testing, where statistical rejection can occur at either the structural or the growth regression stage. The final chapter summarises the important findings as well as contributions of this thesis, and finally suggests some directions for future research.

2

HUMAN CAPITAL, INNOVATION AND GROWTH: THEORIES

2. HUMAN CAPITAL, INNOVATION AND GROWTH: THEORIES

In this section, we do not attempt to provide an exhaustive overview of endogenous growth theories. Rather, from that huge growth literature we can perhaps single out three different models as front runners, which also have had the biggest impact on the empirical literature that is the subject of the following section. These are the augmented neoclassical growth model, the Lucas (1988) model and the Romer (1990) model, which will consecutively be studied below.

2.1 Toward Endogenous Growth

The fact that the major subject of study — the long-run growth rate was exogenous to the model was the most unfavourable property of the growth literature in the 1950s and 60s.

One early attempt to extend AK model was based on the idea that technological knowledge is the factor that growths automatically with capital, due to the proposition that technological knowledge is itself a kind of capital good. It is storable since it does not wear out completely whenever it enters a production process, it can be used in combination with other factors of production to produce final output, and it can be accumulated by knowledge-creation activities (e.g. R&D), a process involving the withdrawal of current resources for purpose of future benefits. Therefore, it is fair to say knowledge is just a kind of disembodied capital good. Since we can think of K broadly as an aggregate of different kind of capital goods, we may as well assume that technological knowledge is included in this aggregate.

Frankel (1962) formulated aggregate output as $Y = \overline{A}K^{\alpha}L^{1-\alpha}$, where $\bar{A}$ is a common scale factor of technology. Each firm in the economy has the same technology and the same factor prices, it will use the factors in the same proportion. Since it would be realistic to think that the stock of knowledge depends on the amount of capital per person in the economy, another assumption was made by Frankel that the common scale factor $\bar{A}$ is a function of the overall capital/labour ratio: $\overline{A} = A(K/L)^{\beta}$.

Frankel argued that although $\bar{A}$ was endogenous to the economy, it was taken as given by each firm, because the firm would only internalise a negligible amount of the effect that its own investment decisions have on the aggregate stock of capital. He then discussed a special case when $\alpha + \beta = 1$, in which the two equations above imply $Y = AK$. That is, output rises in proportion to the capital increases, even though there is continual full employment of labour and even though there is substitutability in the aggregate production function since knowledge automatically rises in proportion.

An influential contribution has been made by Mankiw, Romer and Weil (1992), in which they provided another simple extension to the Solow model by introducing human capital as a separate input into a standard Cobb-Douglas production function. The centrepiece of this human-capital augmented Solow model is the production technology that takes the form $Y_t = K_t^{\alpha} H_t^{\beta} (A_t L_t)^{1-\alpha-\beta}$, or in intensive form $y_t = k_t^{\alpha} h_t^{\beta}$, where Y_t, K_t and L_t are defined as usual, H_t is the stock of human capital and $h = H/(AL)$, A_t is the level of technology. Population and the level of technology grow at the exogenous rates n and g, respectively, and depreciation rate of capital is δ, as in the Solow model.

Steady state values of k and h (k^* and h^*) can be obtained:

$$k^* = \left(\frac{s_K^{1-\beta} s_H^{\beta}}{n+g+\delta} \right)^{\frac{1}{1-\alpha-\beta}} \tag{2.1}$$

$$h^* = \left(\frac{s_K^{\alpha} s_H^{1-\alpha}}{n+g+\delta} \right)^{\frac{1}{1-\alpha-\beta}} \tag{2.2}$$

Note that because of the assumed property of diminishing returns to either physical or human capital and just as in the original Solow model, measured in units of labour, all quantities are constant in the steady state, leading capital per worker (K/L and H/L) and output per worker (Y/L) to grow at the rate of technological growth g, which is exogenous. This means any change in the rate of investment in human capital s_H has nothing to do with the long-run growth rate of the economy, i.e. there is no rate effect.

However, a rise in s_H can certainly have a level effect. As the steady-state equations (2.1) and (2.2) imply, the level of steady-state income per capita is positively determined by the rates of investment in physical/human capital and negatively determined by the rate of population growth. Thus, an increase in the proportion of income invested in the accumulation of human capital stock lifts the steady-state level of income upwards, resulting in a higher long-run growth path.

Human capital is actually regarded as a separate additive input in production in MRW human-capital augmented Solow model. Indeed, it is modelled in completely the same way as physical capital – it is accumulated by withdrawing a portion of income and then putting it into the production process, produced with the same technology as both physical capital and consumption, and depreciates at the same rate as physical capital. Finally, long-run growth is still exogenous in this model as in the original Solow model, and its rate is determined by technology growth.

2.2 Endogenous Growth Models

Models that are said to have "endogenous growth" must both allow continuous growth and determine the level of its growth. To achieve unceasing growth the decreasing marginal product of capital must be circumvented and in a way that is explained by the model. Although there is always a danger in attempting to map a very broad literature into a small set of 'classes' or 'categories', we find it quite instructive to distinguish between two basic approaches to modelling the relationship between growth and education. The first approach, discussed in subsection 2.2.1, is initiated by Lucas (1988) and inspired by Becker's (1964) theory of human capital. The main idea is that growth is primarily triggered by the accumulation of human capital, so that variations in growth rates across countries are mainly due to differences in the rates at which those countries accumulate human capital over time. While the second approach, which traces back to the seminal contributions by Nelson and Phelps (1966) and also Romer (1990) and which has been recently resurrected by the Schumpeterian growth literature, bases on the idea that growth is primarily driven by the stock of human capital, which in turn determines a country's ability to innovate or catch up with more advanced countries. Therefore, differences in growth rates across countries primarily come from the differences in human capital stocks and thereby in those countries' abilities to innovate or apply new technology (discussed in subsection 2.2.2).

2.2.1 The Lucas Approach

In his pioneering contribution to the endogenous-growth literature, Lucas (1988) presented an economy in which there are infinitely lived individuals who choose at each date how to distribute their time between current production and skill acquisition (e.g. schooling), and skill acquisition increases productivity in future periods.

Lucas introduced the following production technology:

$$y = Ak^{\beta}(uh)^{1-\beta} \qquad (2.3)$$

where u is the proportion of the representative agent's time that is put into work, h is the human capital or skill level of the individual, and the level of technology, A, is assumed to be constant which means it can in principle be omitted from the equation or included within the capital term. Population grows exogenously. Equation (2.3) indicates the way human capital affects current production.

Lucas made the most important assumption of the model about the law of motion through which the human capital evolves. He wrote: "*To complete the model, the effort* $1-u_t$ *devoted to the accumulation of human capital must be linked to the rate of change in its level,* h_t*. Everything hinges on exactly how this is done.*" [2]

In particular, the second basic equation in Lucas model is:

$$\dot{h} = Bh(1-u), \quad B > 0 \qquad (2.4)$$

where the parameter B is the maximum attainable growth rate of h, such as productivity of schooling. Equation (2.4) spells out how current schooling time (1- u) affects the

[2] Lucas (1988, p18)

accumulation of human capital.[3] The assumption that human capital accumulation is linear suggests that no matter what amount of human capital has been accumulated, a given effort invariably generates the same percentage increase, i.e. the growth rate of human capital is unaffected by its level. Romer (2001) gave a possible explanation for this assumption: the acquisition of skills may effectively prepare or facilitate learning. For example, he said that children learn basic knowledge (such as literacy) in primary school which may not significantly affect their ability to contribute to the production in the future. Nevertheless, it lays the foundations of obtaining productivity-enhancing skills during their further education and their future career.

Whether there are external effects of human capital results in different characters of the steady state in the Lucas model. To be precise, Lucas (1988) generalised (2.3) by allowing for some degree of contemporaneous spillovers among workers of the form $y = Ak^{\beta}(uh)^{1-\beta}(h_a)^{\gamma}$, where $h_a = \frac{1}{n}\sum_{i=1}^{n} h_i$ is the average human capital in the economy. The externality emerges because the effect on h_a of individual decisions with respect to the acquisition of human capital is too small to be perceived by the representative individual, i.e. the benefits of higher average human capital (e.g. the leading-edge technology) are shared by the whole population and cannot be appropriated by an individual.

In the case where $\gamma = 0$ (no externality) in the steady state, output, physical and human capital per capita grow at the same rate, that is, a balanced growth path. If $\gamma > 0$ (i.e. a positive external effect), we would see a more rapid physical capital growth than human capital growth. Moreover, when external effect exists, a competitive equilibrium will generate suboptimal growth, which may justify the government intervention.

In any case, the assumption that human capital accumulation involves constant returns to the existing stock of human capital produces a positive growth rate in steady

[3] If learning by doing rather than education were the primary source of human capital accumulation, equation (10) should be replaced by something like

$\dot{h} = Bhu$.

That is, the growth of human capital increases with production.

state equal to $g = B(1-u^*)$, where u^* is the optimal allocation of individuals' time between production and education.[4] Education effort (1- u^*) can in turn be shown to depend positively on the productivity of schooling measured by B and negatively on the rate of time preference ρ and the coefficient of relative risk-aversion θ.

Lucas's influential model provides a fundamentally way to do growth theory and has been extended in several directions. For example, Rebelo (1991) added physical capital into eq. (2.4) while maintaining constant returns of $\dot{h}$ with respect to human and physical capital stocks, which made it possible to analyse the effects of taxation policies on steady-state growth. He concluded that an increase in the rate of income tax does have an impact on the steady-state growth rate in his model where physical capital is introduced as an input into human capital accumulation, while such effect does not exist in the Lucas model.

2.2.2 Innovation Models

One of the implausible properties of both the standard neoclassical approaches and the Lucas approach is the assumption that education influences individuals' productivity equally on all jobs, no matter whether these jobs are innovative or just repetitive. This means even if the technology remains stationary, human capital remains an ordinary input in the production function and the marginal productivity of education (i.e. additional units of human capital) always remains positive.

Not just doubting the capital accumulation mechanism linking education to growth, Benhabib and Spiegel (1994) gave support to the Schumpeterian approach by reviving the simple Nelson and Phelps (1966) model. They set up and tested an augmented version of the Nelson-Phelps in which human capital not only foster the application of new technologies, but also makes it easier to innovate at the frontier, according to

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[4] That is, u^* maximises the representative consumer's intertemporal utility

$$\int_0^\infty \frac{c_t^{1-\theta}}{1-\theta} e^{-\rho t} dt$$

subject to the production function, human capital accumulation equation, and $\dot{k} = y - c$.

equation: $\dot{A} = f(h)(\bar{A} - A) + g(h)\gamma A$, where the second term capture the innovation component of growth.

The evolution of the frontier technology is left exogenous in either Nelson/Phelps model or Benhabib/Spiegel model, implying that human capital can only enable the country to narrow the gap to the leading-edge technology. Observing that highly skilled labour or scientists as the single most important input in R&D activities, Romer (1990) fine-tuned the idea that technological progress, and thus growth, merely comes from adoption of existing technologies — it should also involve the creation of new technologies.

In what follows, we will show the essence of the Romer (1990) model, concentrating on the role of human capital.

The economy has three sectors in this model: research sector, intermediate goods sector, and final goods sector. First, the research sector put the current knowledge stock and human capital to generate designs for new capital goods, and then sell them to the intermediate goods sector, where the designs and savings of the economy are combined to produce intermediate capital goods. Note that each intermediate good is produced by a monopolistically competitive firm that gets the infinitely-lived patent from the research sector for its production. And finally the final-goods sector combines labour and human capital with the intermediate capital goods to produce final output. The final goods sector has the production function: $Y = H_Y^{\alpha} L^{\beta} \sum_{i=1}^{A} x_i^{1-\alpha-\beta}$, where x_i are the intermediate producer durables used in final goods production, A is the stock of knowledge, H_Y is human capital used in production, and Y and L are output and labour. A novel property of the Romer model is that it disaggregates capital into different types of intermediate inputs which have additively separable impacts on output. As the above production function shows, the number of various intermediate capital goods in the economy is determined by the stock of knowledge, A.

The most important assumption made by Romer is that knowledge is nonrival, which determines the choice of this particular market structure (i.e. monopolistic competition). Romer indicated that under monopolistic competition, increasing returns to scale exists because of the nonrival input that constitutes a fixed cost. The price of intermediate goods is higher than the marginal cost under the monopolistic competition due to monopoly rents, which enables firms in the intermediate goods sector to compensate the patents and thereby finance R&D activities. However, such increasing returns to scale would not exist if we assume perfect competition, where no research activities would be undertaken in this case. This is because in a competitive equilibrium output sells at marginal cost, the firm's gains would be exhausted by the payment of the rival inputs (i.e. capital and labour), which means it would have no money to pay for the fixed cost.

Another impact of the nonrivalry of knowledge is on the production of knowledge itself. The stock of knowledge, A, is represented by the number of designs generated in the research sector, and evolves according to the following dynamic equation:

$$\frac{\dot{A}}{A} = BH_A \qquad (2.5)$$

where B is a parameter measuring the productivity of research, and H_A is human capital allocated to the research sector, subject to $H = H_Y + H_A$.

Equation (2.5) indicates that the creation of new knowledge is a function of the current knowledge stock and of human capital employed in research activities. The self-sustained growth in this model can be achieved because: (i) higher stock of knowledge leads to an increasing variety of products; (ii) Romer makes an assumption that all researchers can make use of the current stock of knowledge, i.e. there is knowledge externality, which explains why the stock of knowledge, A, is included in the production function of new knowledge in equation (2.5).

In addition, the linearity of equation (2.5) suggests that the productivity of human capital in research rises with A, which in fact implies that knowledge can grow without bound, thus leading to endogenous growth. In the steady state, the stock of knowledge, capital, and output all grow at the same rate, driven by technological change. Meanwhile, equation (2.5) demonstrates that the growth rate of A is dependent upon the stock of human capital devoted to research, H_A, which can be shown is a linear function of the total human capital stock, H, and the rate of interest. In other words, a one-off increase in the stock of human capital will be enough to induce a permanent increase in economic growth, which is different from the Lucas model where only the rate of accumulation of human capital affects growth.

2.3. Taxation in Endogenous Growth

The endogenous growth models examined in section 2.2 form a theoretical basis for exploring the growth effects of alternative tax policies. To make it easier for us to compare the tax effects in various endogenous growth models, we start by establishing a framework which contains the basic ingredients of these models. Suppose goods are produced using labour and other inputs with diminishing rate of return, which we call the 'k-factor'. The essence of endogenous models is to obtain a non-decreasing rate of return to the 'k-factor', and different endogenous growth models have different mechanisms to offset the 'k-factor'. Let us call any of the offsetting factors the 'x-factor'. Goods are produced with the 'k-factor' and the 'x-factor' according to Cobb-Douglas production function

$$y_t = Ak_t^{\alpha} x_t^{1-\alpha} \tag{2.6}$$

We follow the common practice of assuming infinite-lived households maximising a CIES (*constant intertemporal elasticity of substitution*) utility function, as given by

$$U = \int_0^{\infty} e^{-\rho t} \cdot \left[\frac{c_t^{(1-\theta)} - 1}{(1-\theta)} \right] dt \tag{2.7}$$

where c_t is per capita consumption and ρ is the positive rate of time preference. And the solution to the maximisation problem implies $\dot{c}/c = (1/\theta) \cdot (r_t - \rho)$, where r is the real rate of interest. The relation between r and ρ determines whether households choose a pattern of per capita consumption that rises over time, stays constant, or falls over time. Under the current assumptions, growth can be sustained only if the real rate of interest is large enough to compensate for deferring consumption.

The real rate of return to the '*k*-factor' is

$$r_t = \alpha A \left(\frac{x_t}{k_t} \right)^{1-\alpha} \tag{2.8}$$

The real rate of interest in competitive equilibrium must be equal to the real rate of return to the '*k*-factor' in equation (2.8), which shows that if the '*x*-factor' is accumulated equal to or faster than the '*k*-factor', the real rate of return of interest will be non-diminishing, which in turn leads to a sustained long-run growth.

The different mechanisms of '*x*-factor' and the corresponding taxation effects on growth are examined as follows.

A). Tax Effects on Factor Accumulation

Suppose a flat income tax is levied at a rate of τ. Then after-tax per capita income becomes

$$y_t = (1-\tau) A k_t^{\alpha} x_t^{1-\alpha} \tag{2.6a}$$

and the after-tax rate of return to the k-factor will be

$$r_t = (1-\tau)\alpha A \left(\frac{x_t}{k_t} \right)^{1-\alpha} \tag{2.8a}$$

As shown in equation (2.8a), the negative steady-state tax effect on growth is obvious – a rise in income tax rate reduces the rate of return to the k-factor given the x-factor, which in turn leads to a fall in the steady-state growth rate. However, the increase in the income tax might have indirect growth effects from the change in the x-factor. The net long-run growth effects of taxation are sensitive to model specifications, as summarised in Table 2.1, which shows that the tax effects on steady-state growth rate can be negative, zero, or positive. What we need to examine further is the conditions behind these different growth models.

Table 2.1: Tax Effects in Different Endogenous Growth Models

Endogenous growth models		Steady-state growth rate	Tax effect	Growth maximising tax rate
Fiscal effects on factor accumulation	Without spillover: Lucas (1988)	$g=\frac{B-\rho}{\theta}$	0	Irrelevant
	Without spillover: Rebelo (1991)	$g=\frac{(1-\tau)^{\beta/\beta+1-\alpha}\psi-\rho}{\theta}$	–	$\tau^*=0$
	With spillover: Romer (1986)	$g=\frac{(1-\tau)\alpha A-\rho}{\theta}$	–	$\tau^*=0$
Fiscal effects on production externalities	Publicly-provided private goods: Barro/Sala-i-Martin (1992)	$g=\frac{(1-\tau)\alpha(A\tau^{1-\alpha})^{1/\alpha}-\rho}{\theta}$	+ or –	$\tau^*=1-\alpha$
	Publicly-provided public goods: Barro/Sala-i-Martin (1992)	$g=\frac{(1-\tau)\alpha[A(\tau\cdot n)^{1-\alpha}]^{1/\alpha}-\rho}{\theta}$	+ or –	$\tau^*=1-\alpha$
	With congestion: Barro/Sala-i-Martin (1992)	$g=\frac{(1-\tau)(A\tau^{1-\alpha})^{1/\alpha}-\rho}{\theta}$	+ or –	$\tau^*=1-\alpha$
	Cashin (1995)	$g=(1/\theta)[(1-\tau_1-\tau_2)\cdot (A\tau_1^{\alpha}\tau_2^{\beta}g^{-\alpha})^{1/1-\alpha-\beta}-\rho]$	+ or –	$\tau_1^*=\alpha$ $\tau_2^*=\beta$
Productivity growth	Romer(1990)	$g=\frac{\alpha BH_A-\rho}{\theta+\alpha}$	0	Irrelevant
	Aghion and Howitt (1998)	$g=\hat{g}(\beta_n,\beta_k,g_L,\lambda,\sigma,\rho,\varepsilon,\delta)$	+	N/A
Other fiscal effects	Stokey and Rebelo (1993)	$g=\frac{A+(1-\theta)\dot{v}(l)-\rho}{\theta}$	0	Irrelevant
	Rebelo (1991)	$g=\frac{\alpha[A(1-\tau_i)-\rho]}{1-\alpha(1-\theta)}$	–	$\tau^*_i=0$

When human capital is modelled as in Lucas (1998) where only human capital is used as an input in the production of new human capital ($\dot{x}=Bx_h$, where B is the productivity parameter of human capital production), the real rate of return to capital is

$$r=(1-\tau)\alpha A\left(\frac{x_y}{x}\frac{x}{k}\right)^{1-\alpha}=B\left(\frac{x_h}{x}\right) \tag{2.8b}$$

where x_h and x_y are human capital allocated respectively to human capital production and goods production, and ${x_y}/{x}$ and ${x_h}/{x}$ are constant in steady state. The households invest more in the human capital producing sector when facing a higher τ. This results in a smaller ratio of physical to human capital in the long run which exactly offsets the direct disincentive of an increase in τ and therefore, as shown in Table 2.1, we get a zero net growth effects of this increase in the income tax rate.

The growth implications of income taxation will change dramatically if human capital accumulation is modelled as in Rebelo (1991), where both physical and human capital are inputs in producing new human capital: $\dot{x} = Bk_h^{\beta} x_h^{1-\beta}$, ($k_h$ and x_h are the physical and human capital used in producing new human capital). The steady-state growth rate is then $g = (1/\theta)\cdot[(1-\tau)^{\beta/\beta+1-\alpha}\psi - \rho]$, where ψ is a function of A, B, α, and β. This Equation indicates that the factor ratio adjustment partially offset the direct disincentive of τ. Therefore, the net growth effects are negative.

The difference in the results of the Rebelo (1991) model and the Lucas (1988) model is actually caused by the difference in their human capital accumulation process and their tax treatments. As both models assume the income from the human capital producing sector is not taxed while income from the goods producing sector is taxed at the rate τ, human capital is actually taxed indirectly in the Rebelo (1991) model through physical capital used in the sector producing new human capital, whereas in Lucas (1988) model it is not taxed even indirectly since only human capital is used in producing new human capital. The tax effects on growth can also be negative even in the Lucas model by just assuming that the income from both sectors is taxed.

When knowledge spillover is taken into account, the net growth effects of income taxation become ambiguous. In Romer (1986), for example, the 'x-factor' in equation (2.6a) now becomes the spillover of knowledge from other producers, approximated by the amount of the average stock ($x = k$ in steady state). Then from equation (2.8a) we obtain $r = (1-\tau)\alpha A$ and therefore the long-run growth rate is equal to

$$g = (1/\theta)[(1-\tau)\alpha A - \rho]$$

Because the private sector does not take the positive spillover effect into account, the equilibrium growth rate will be lower than socially optimal growth rate. This means that a steady-state growth rate above the equilibrium level can be attained through a subsidy or an investment tax credit. However, either subsidy or investment tax credit need to be financed by taxation. If lump-sum taxation is unattainable and an income tax has to be levied, the above discussed negative growth effects of income taxation still remain. Therefore, the negative effects from income taxation and the positive effects from subsidy or investment tax credit lead to undetermined net growth effects.

B). Tax Effects on Production Externalities

Some literature on endogenous economic growth has provided insights into how and where tax revenue is spent, which proves to have important growth implications. Although tax revenue does not have steady-state growth effects when it is used to provide public services which enter people's utility function but not production function,[5] it can be shown that tax policy does have impact on growth if the tax revenue spending is productive in growth models that incorporate public services. The optimal tax policy also hinges on the nature of the public services on which tax revenue is spent.

We can illustrate the possibilities by considering the case that tax revenue is spent on the public inputs necessary for goods production and those inputs have the nature of private goods, which are rival and excludable. We base our discussion on Barro and Sala-i-Martin (1992) and assume that government runs a balanced budget and levies a proportional tax at rate $\tau = x / y$. Therefore, the government purchases ($x = \tau y$) is the '*x*-factor' in this setting. From (2.6) we have $y = Ak^{\alpha}(\tau y)^{1-\alpha}$, then we get $\frac{x}{k} = (A\tau)^{1/\alpha}$, and, substituting it into (2.8a) we obtain

[5] However, Alogoskoufis and Ploeg (1990) argued that this may not the case in endogenous growth models built on the overlapping generations framework, where the current generation knows that some of the tax burden will be transferred to future generation. Therefore, people respond by making their consumption path flatter. Hence, a rise in government consumption results in a lower steady-state growth rate of the economy.

$$r_t = (1-\tau)\alpha\left(A \cdot \tau^{1-\alpha}\right)^{1/\alpha} \tag{2.8c}$$

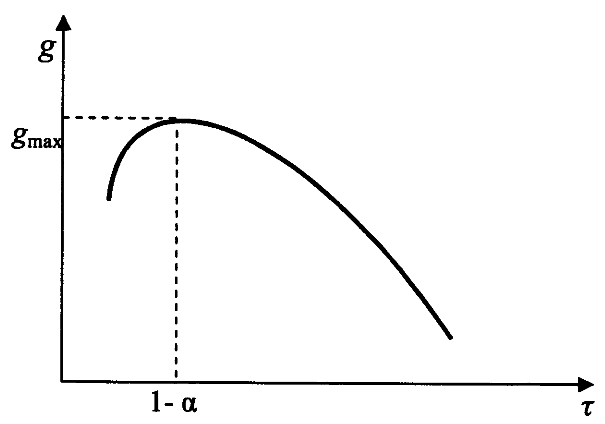
and
$$g = \frac{(1-\tau)\alpha(A\tau^{1-\alpha})^{1/\alpha} - \rho}{\theta}$$

The after-tax real rate of return to capital in (2.8c) shows there is a positive indirect effect through the increase in the spending of tax revenue x, besides the negative direct effect of a rising τ on r. In order to see the effect of an increase in the income tax rate on the steady-state growth rate, we can take the derivative of g with respect to τ:

$$\frac{\partial g}{\partial \tau} = (1-\alpha)\left(\frac{1}{\tau} - \frac{1}{1-\alpha}\right)\left(A \cdot \tau^{1-\alpha}\right)^{1/\alpha} \tag{2.9}$$

It can be seen from equation (2.9) that growth and the income tax rate have an hump-shape relation (see Figure 2.1). In particular, a rise in τ will have a positive (negative) effect on the after-tax real rate of return to capital and therefore on the steady-state growth rate if the income tax rate is smaller (larger) than the competitively determined income share of government, which is the supplier of public inputs. An increasing income tax rate will raise the long-run growth rate until the optimal size of public services is reached ($\tau = 1 - \alpha$); beyond this optimal point, however, a further increase in public infrastructure will deter the long-run growth rate and, therefore, a higher income tax rate can only lead to a lower long-run growth rate.

Figure 2.1: Hump-shape relation between *g* and *τ*



Two other cases in Barro and Sala-i-Martin (1992) are worth a mention. One is that public inputs have the nature of public goods (nonrival and nonexcludable, as Samuelson-style); the other is that public productive services (e.g. highways, water systems, police and fire services, and courts, etc.) are subject to congestion. In these cases, the basic results do not change, that is, an hump-shape relation between the income tax rate and the steady-state growth and the growth maximising income tax rate is positive and equal to 1–α.

Cashin (1995) established a model by adding public transfer payments as productive inputs in private production functions. He pointed out that public transfers could improve the enforcement of private property rights and induce workers with a below-average stock of human capital to leave the workforce, thus raising the marginal product of private capital.

The production function in his model is given by $y_t = Ak_t(G_t / K_t)^{\alpha}(T_t / K_t)^{\beta}$, where G_t / K_t is the ratio of the aggregate public capital stock to the aggregate private capital stock, and T_t / K_t is the ratio of the aggregate public transfers to the aggregate private capital stock.

He specified two tax rates, τ_1 and τ_2, on output used to fund the provision of public capital and transfers, respectively. Without going into detail it can be shown that the steady-state growth rate is equal to

$$g = \frac{(1-\tau_1-\tau_2)\cdot(A\tau_1^{\alpha}\tau_2^{\beta}g^{-\alpha})^{1/(1-\alpha-\beta)} - \rho}{\theta} \qquad (2.10)$$

Equation (2.10) shows a non-monotonic relation between steady-state growth rate and the taxes – g initially rises with increases in τ_1 and τ_2; after taxes rise beyond the optimal point (τ_1 = α and $\tau_2 = \beta$), g falls with increases in τ_1 and τ_2. This prediction indicates again the trade-off between the growth-enhancing public capital goods and transfers and the growth-decreasing effect of distortionary taxes which need to be levied to finance the provision of the public capital goods and transfers.

We have seen hump-shape relationship between the income tax rate and the steady-state growth rate in all previous four cases, where the growth effects of income taxation becomes ambiguous due to the presence of externalities.

C). Tax Effects on Productivity Growth

In the benchmark model of endogenous growth driven by innovation as in Romer (1990), τ is irrelevant to the steady-state growth, namely

$$g = \frac{\alpha B H_A - \rho}{\theta + \alpha}$$

On the face of it, it is surprising that the steady-state growth rate is unaffected by income taxation, since the innovation model emphasises deliberate efforts to innovate and income taxation should have a negative impact on innovation incentive, and thereby affecting long-run growth. It can be shown that this negative effect of income taxation on innovation does exist, but is offset completely. This result follows from the assumption that by the free entry condition, the price of a design is equal to the present value of monopoly profits from exploiting the design. The monopoly profits in turn are positively associated with the price of the capital goods.

As a result, although the return to human capital in the final goods sector does decline as income tax rises, the price of capital goods also falls due to this higher income tax rate. This leads to lower monopoly profits of purchasing a new design, and therefore a lower price of design and eventually, returns to human capital in the research sector decrease by the same proportion as that in the final goods sector. Hence, human capital allocated to the research sector (H_A) does not change in equilibrium in response to the change in income tax rate and therefore the long-run growth rate is unaffected.

However, Aghion and Howitt (1998) demonstrated government subsidy rate on R&D activities could have impact on the long-run growth in their Schumpeterian model, where a new good or method tends to make old one obsolete in a 'creative destruction' process. In particular, in order to parameterise the incentives to innovate and accumulate capital they introduced two subsidy rates in their model, β_n and β_k – the proportional rates at which research expenditures and capital are subsidised. They finally derived the steady-state growth rate, expressed as (see Aghion and Howitt (1998)-chapter 12 for technical details):

$$g = \hat{g}(\beta_n, \beta_k, g_L, \sigma, \lambda, \delta, \varepsilon, \rho)$$

This growth equation says that the steady-state growth rate depends positively on the two subsidy rates (β_n and β_k), the population growth rate (g_L), the size of innovations (σ), and the productivity of R&D (λ); and negatively on the rate of depreciation (δ), the elasticity of marginal utility (ε), and the rate of time preference (ρ).

It should be noted, however, that a success subsidy is very difficult to implement in practice because it requires the government to identify promising areas of research that have substantial spillover benefits.

2.4. Empirical Evidence

2.4.1 Evidence -- Human Capital, Innovation and Growth

There has been huge and growing number of empirical attempting to estimate the impact of human capital / education in growth regressions. As mentioned earlier these papers have largely referred education to schooling. Indeed, educational attainment (e.g., the average years of schooling) and school enrolment rates (e.g., the proportion of certain part of the population enrolled in school) are the two most frequently used proxies for human capital. In terms of econometric specifications, these studies fall into two broad categories, which will be discussed respectively in the following subsections.

A). Empirical Studies Testing Convergence Equations

In the first category, the empirical work normally consists of running an equation coming from the prediction of conditional convergence, as posited by neoclassical growth models. The basic estimated equation is the relationship between growth rate and the initial level of output with other variables that control for the determinants of the steady state. One would expect here that a county starting with low income level is likely to have a higher growth rate. The idea behind this kind of investigations can be summarised by:

$$\Delta \ln y_i = \alpha_0 + \alpha_y \ln y_{0i} + \sum_{j=1}^{n} \alpha_j X_{i,j} + \varepsilon_i \tag{2.11}$$

where $\Delta \ln y_i$ is country i's average growth rate output per capita from the initial date t_0 to date t_1, and $X_{i,j}$ denotes other certain variables except the log of per capita output ($\ln y_{0i}$) that can have impacts on growth, e.g. initial level (or the rate of change) of human capital, or some measure of government policies, such as government spending in GDP.

One of the earliest empirical investigations was carried out by Romer (1990), where he ran a cross-country regression to test his theoretical model in Romer (1989). He estimated the average growth rate (1960~85) on investment rate, the initial level of income, the share of government spending in GDP and human capital stock (measured by the literacy rate) for 112 countries. His findings indicated that the literacy rate had a positive significant impact on growth while the rate of change of the literacy rate, when added in, was insignificant. Thus he suggested that literacy might act via the investment rate and also pointed out that the overall results might not be very robust because of omitted variables.

In the influential work of Barro (1991), he conducted a cross-sectional regression for 98 countries between 1960 and 1985 and used school enrolment rate rather than literacy rate to measure human capital stock because the literacy rate seemed to be inconsistently measured world wide, even though he acknowledged that enrolment rate might more reflect the investment flow into human capital than its stock. He found that when controlling for initial income and other variables, the primary and secondary school enrolment rates in 1960 are both significant in his growth regression, which is consistent with his prediction that the level of initial schooling is positively related to growth. However, he pointed out that if enrolment rates are regarded as a measure of investment in human capital rather than of its stock, the significant relationship between enrolment rates and growth could come from an overall good economic situation that increases both economic growth and the investment in human capital.

However, it was argued that school enrolment ratio also has big flaws, even being used as a flow variable (see Barro and Lee (1993) and Gemmell (1996) for more discussions). Firstly, enrolment ratio can hugely bias the actual flow since it does not take into account dropouts which is quite high for certain countries. Secondly, a large time lag exists between the year children begin education and the year they increase the human capital stock (i.e. the year they enter the workforce). Therefore, Barro and Lee (1993) created decade-average pooled data on educational attainment (years of schooling) as proxy. Using this dataset, Barro and Lee (1994) found the initial level of male secondary schooling was significantly and positively related to subsequent growth while the initial level of female secondary schooling had a negative effect. The authors explained that this discrepancy might be a good measure of 'backwardness' – less female schooling reflects more backwardness and therefore greater growth potential through the convergence mechanism. In addition, they found a significant positive coefficient on the change in male secondary attainment when it was included in the growth regression, and significant negative for female; and finally no other attainment measures (primary or university education, etc.) were found significantly related to growth.

Using a similar method, Barro and Sala-i-Martin (1995) reported some findings contrary to those of Barro and Lee (1994): higher schooling is significant positive for male and significant negative for female, as for secondary attainment. Moreover, they could not find any additional variables (e.g. changes of male and female secondary or higher schooling) have significant effects in the regression.

Mankiw, Romer and Weil (1992) estimated a structural convergence equation – a Cobb-Douglas production function with human capital. Unlike the empirical studies reviewed above where the authors typically selected the independent variables that they thought were relevant factors determining growth (i.e. $X_{i,j}$ in Eq. 2.11), Mankiw et al.

chose variables according to an explicit theoretical model. They obtained the following transitional equation after some manipulation within their augmented Solow model:

$$\ln y_t - \ln y_0 = (1-e^{-\lambda t})\left\{\ln A_0 + gt + \frac{\alpha}{1-\alpha-\beta}\ln s_K + \frac{\beta}{1-\alpha-\beta}\ln s_H - \frac{\alpha+\beta}{1-\alpha-\beta}(n+g+\delta) - \ln y_0\right\} \quad (2.12)$$

Mankiw et al. ran equation (2.12) using data for 98 countries over the period of 1960-85. They used the average proportion of the working-age population enrolled in secondary school as the proxy of the rate of investment in human capital.[6] They found that their human capital variable substantially improved the fit of their model. The explanatory variables picked up 46% of the variance in the rate of growth. The coefficient on schooling was significantly positive as expected. Therefore, the investment in human capital positively affected the growth of output.

One flaw in the testing by Mankiw et al.(1992) is their stringent assumption that A_0 is constant across countries or uncorrelated with other explanatory variables. By allowing for country-specific effect, one can effectively release the assumption and avoid omitted variable bias. Islam (1995) conducted a panel estimation in order to tackle the heterogeneity in the production technology among countries.[7] By such technique, he exploited the time-series variation in the data to investigate country effects. (that is, $\ln A_0$ in Eq.(2.12) was treated as a time-invariant country effect term). He studied three sub-samples as in Mankiw et al by dynamic panel estimation with fixed country effects using the schooling data in Barro and Lee (1993). Surprisingly, he eventually obtained a negative effect of human capital on growth (a significant coefficient on schooling for the whole sample and insignificant one for the OECD and intermediate samples), which contradicted the theory and other empirical papers reviewed above.

[6] Barro (1991) also used school enrolment rates, but they had different interpretation – human capital investment in Mankiw et al. (1992), while human capital stock in Barro (1991).

[7] The panel estimation differs pooled estimation mainly in that it takes into account individual country effects that pooled method does not allow for.

Using a panel data of 97 countries from 1960 to 1985, Caselli, Esquivel, and Lefort (1996) also had strange findings that human capital had a negative and significant effect on economic growth. Table 2.2 summarises the major findings of the reviewed studies of convergence equations.

Table 2.2: Summary of studies estimating convergence equations

Author	Human capital variable	Data	Human capital effect
Romer (1990)	Literacy rate	1960 – 85; Cross section	+/significant on initial human capital
Barro (1991)	School enrolment rate	1960 – 85; Cross section	+/significant on initial human capital
Barro / Lee (1994)	Years of schooling	Decade-average 1965-75, 1975-85; Pooled	+/significant on both initial level and change of human capital for male secondary schooling; –/significant on initial level human capital for female secondary schooling
Barro and Sala-i-Martin (1995)	Years of schooling	Decade-average 1965-75, 1975-85; Pooled	+/significant for male secondary and higher; –/insignificant for female secondary; –/significant for female higher
Barro (1998)	Years of schooling	Decade-average 1965-75, 1975-85, 1985-95; Pooled	+/significant on initial human capital for male secondary and higher combined; –/insignificant on initial human capital for female secondary and higher combined
Below are studies estimating explicit structural convergence equation			
Mankiw, Romer and Weil (1992)	School enrolment rate	1960 – 85; Cross section	+/significant on investment in human capital
Gemmell (1996)	New measure based on enrolment rates	1960 – 85; Cross section	+/significant on both initial level of and investment in human capital
Islam (1995)	Years of schooling	Five-year averages; 1960 – 85 Panel	–/significant on end-of-the-period level of human capital
Caselli et al (1996)	School enrolment rate	Five-year averages; 1960 – 85 Panel	–/significant on investment in human capital

The surprising results from the panel studies of Islam and Caselli et al have evoked much controversy. In fact, Islam (1995) argued that human capital might work via technology rather than via the conventional way (merely an input in production). When using the panel estimation, therefore, we would not separate the effects of human capital variables on A_0 from the fixed country effects. These issues together with the measurement errors suggested by Krueger and Lindahl (2001) provide the possible explanation for the strange findings in the above panel estimations.

B). Empirical Studies Testing Aggregate Production Function

These studies basically estimate the log-linear form of aggregate production function $y_t = A_t k_t^{\alpha} h_t^{\beta}$, expressed as

$$\Delta \ln y_{it} = \Delta \ln A_{it} + \phi_1 \Delta \ln h_{it} + \phi_2 \Delta \ln k_{it} \qquad (2.13)$$

In terms of data availability, one advantage of structural convergence estimations reviewed above is that they only need the data on investment rates rather than capital stocks (in practice, it is difficult to get reliable data for the latter). However, some studies attempt to find in some way appropriate proxies for physical capital stocks and test the aggregate production function. A merit of this macroeconomic production function estimation is the subtraction of initial level of technology A_0, which is unobservable. But technology growth – $\Delta \ln A_{it}$ in Eq.(2.13) is also unobservable. Some studies tackle this problem by assuming it is constant across countries.

Benhabib and Spiegel (1994) made an early attempt to investigate the aggregate production function by using alternative proxies for physical capital stock. Their international cross-country estimations indicated that per capita GDP growth was negatively and insignificantly affected by the growth of human capital (measured by enrolment ratios or years of schooling from Barro and Lee (1993)) for the whole sample. Although they suspected low-growth-rate African countries resulted in the odd estimate, it did not make much difference when they attempted to omit African countries from the data or insert African country dummies. They also reported a limited role of other variables (e.g. political stability; initial income level).

Similar to the conclusion in Islam (1995), Benhabib and Spiegel were skeptical about the conventional channel through which human capital works, i.e. as another input in the production function. In particular, they investigated a more structural model by regressing TFP growth on human capital variables serving as technology innovation term and catch-up term. The estimation showed that catch-up term had significant positive effects for both developing-country sub-sample and the whole sample, while the impact of innovation term dominated the catch-up term for the sub-sample of the most developed countries. They also suggested that human capital induced more physical capital and thus a mutual impact existed between the two factors. All these results led Benhabib and Spiegel to believe that human capital works in some way different from the traditional channel specified by normal growth accounting exercises.

Pritchett (2001) estimated Eq. (2.13) by using his own aggregate data on the growth of human capital per labour and found a negative and insignificant effect of the growth of human capital on economic growth, the same finding as that in Benhabib and Spiegel (1994). Pritchett suggested several possible reasons for the failure of proving the positive impact of human capital on growth at macro level: there might be faster growth in the supply of educated worker than demand, leading to reduced returns to schooling; or the education system failed so that extra schooling would not give extra skills.

In summary, the evidence on the impact of human capital on economic growth has been mixed. In one strand of studies (typically led by Barro (1991) and Mankiw et al. (1992)) that are focused on convergence equations, human capital is in general capable of explaining the growth variations across economies; whereas another strand that aimed at testing the aggregate production function usually failed to find robust relationship between the change in human capital and growth, and even negative relations were reported in some studies.

The conclusions of these studies can not be taken for granted due to the discussed limitations of methodology and data. On balance, however, the evidence appears to tell us that human capital improvement has some consequences on economy. There also seem to be grounds for considering that human capital stock has prominent effects on technology catch-up, by enhancing a country's capability in using new technologies.

2.4.2 Evidence – Tax Policies and Growth

There have been many studies using cross-country regressions to search for empirical link between long-run growth and taxation. The basic regression form of these studies can be expressed as:

$$g = \beta_0 + \beta_1 y + \beta_2 \tau + \sum_{i=3}^{n} \beta_i x_i$$

where g is the growth rate of per capita income; y is initial per capita income; τ is policy variable; and x_i are variables explaining steady-state growth, $i = 3, 4, \ldots n$.

In endogenous growth framework, x_i are typically proxies for human capital stock. Initial income controls for transitory dynamics – a negative β_1 implies poor countries grow faster. The policy experiment is to test whether β_2 is significant.

Barro (1991) obtained a significant negative relation between the level of government distortions (measured by real government consumption minus spending on education and defence as a percent of real GDP from 1970 to 1985) and economic growth (averaged over 1960-85) among 98 countries.

Plosser (1992) also found a significant negative link between the level of taxes on income and profits (as a share of GDP) and real per capita GDP growth.

Levine and Renelt (1992) pointed out that Barro's result holds only for a special conditioning set and that government distortions variable would not be significant when other regressors (e.g., exports to GDP and domestic credit growth) are included in Barro-type growth regression. Similarly, Agell *et al.* (1995) found that in OECD countries the links between government spending/taxes and economic growth are not robust. Easterly and Rebelo (1993) also conclude that the level of taxes is insignificant in the cross-country regressions. In their opinion, Barro and Plosser obtained significant coefficients simply because the level of government spending or taxes is highly positively correlated with the initial level of income; tax-to-GDP ratios are usually lower in poor countries, which then begin to catch up (i.e. convergence effect). Hence, Barro's and Plosser's findings do not hold if the initial level of income is controlled for.

In a cross-country analysis for the 1970s, Koester and Kormendi (1989) only found a significant negative correlation between the marginal tax rates and the level of real GDP per capita, but not the rate of growth when the latter was controlled for the initial level of income. In particular, a 10 percentage drop in marginal tax rates would raise per capita income by more than 15 percent in an average developing country (and more than 7 percent in an average industrial country). Thus, a revenue-neutral tax reform that decreases tax progressivity would shift the whole growth path upward.

Grier and Tullock (1989) investigated economic growth among OECD countries over the period 1951 – 1980 and found that the effect of "government growth is negative and significant" in their economic growth analysis.

Scully (1991) searched the link between tax revenues, tax rates, and economic growth for his 103-country sample. He concluded, in general, that economic growth rates were maximised if governments levied no more than 19.3 percent of GDP. He finally pointed out that expending government size would have a substantial negative impact on resources allocation and therefore economic growth.

The results in Engen and Skinner (1996) suggested modest effects – a tax reform that changes all marginal tax rates by 5 percent and average tax rates by 2.5 percent results in 0.2 percent to 0.3 percent differences in the rates of economic growth. However, even such small effects on growth rate can have great cumulative consequences for standards of living.

Folster and Henrekson (2000) found a quite strong statistical link between tax and growth in their panel study of OECD countries. In particular, a 10 percentage rise in public sector size results in roughly one per cent point decrease in growth rate. They also concluded that the more econometric problems are solved, the more significant the link between taxes and growth becomes.

Dar and AmirKhalkhali (2002) investigated 19 OECD countries over the period 1971–99 and indicated that productivity of capital and total factor productivity growth are lower in countries with bigger size of governments; while the countries that have smaller government sector usually reflect higher efficiencies as a result of lower tax burden, clearer market rules which support more efficient allocation of resources, and the absence of 'crowding-out' effects that restrain the incentives for capital investment and new technology.

Alesina et al. (2002) examined the impact of changes in government fiscal policy on profits and investment. From their panel study, they concluded that rises in public spending (or size of government) led to increases in private sector labour costs, which in turn eroded business profits and investment. In particular, they found an increase of 0.15 percentage points in the investment-to-GDP ratio (and a cumulative increase of 0.74 percent after five years) in response to a 1 percent reduction in primary spending as a share of GDP. They also found that various types of taxes had negative effects on profits and investment, but such effects were smaller than the effects of government spending. Lastly, and maybe their most solid evidence of the strong link between economic growth and government size, is that fiscal policies that promoted economic growth were largely achieved by spending cuts while those experienced downturns were mainly associated with tax rises.

On balance, the researches reviewed above mainly indicate that the size of government does have some consequences on economic performance. Intuitively, this is reasonable since we all understand that there are particular goods/services that must be provided or regulated by government. A crucial issue addressed in these studies is what the right size is given an objective of the most efficient use of resources and economic growth maximisation. Among these findings most countries seem to have exceeded the optimal government size.

But it should be noted that although from the theoretical point of view, we prefer lower taxation (on output, consumption, labour or capital incomes), such proposition does not always find an echo in empirical findings, e.g. Koester and Kormendi (1989); Easterly and Rebelo (1993); Hansson and Henrekson (1994); among others. Table below reports studies on the relationship between taxation and economic growth.

Table 2.3: Major findings of taxation on economic growth

Author	Data coverage	Main explanatory variables	Comment
Barro (1991)	98 countries over the period 1960-1985	Human capital, govt. consumption, political instability indicator, price distortion	1% point of GDP increase in tax to GDP ratio lowers output per worker by 0.12%.
Koester and Kormendi (1989)	63 countries for which at least five years of continuous data exists for the 1970s.	Marginal tax rates, average tax rate, mean growth in labour force & population	10% decrease in marginal tax rates would increase per capita income by 7%-15%; but insignificant tax effects on growth.
Easterly and Rebelo (1993)	32 countries over the period 1970-1988	Income-weighted average of marginal tax rates	level of taxes is in-significant
Hansson and Henrekson (1994)	Industry-level data for 14 OECD countries	Govt. transfers, consumption, total outlays; education expenditure; govt. investment	Govt. transfers, con-sumption and total outlays have a negative impact on growth whilst government investment is not significant
Cashin (1995)	23 OECD countries over the 1971-1988 period.	Ratio of public in-vestment to GDP, ratio of current taxa-tion revenue to GDP, ratio of expenditure on transfers to GDP.	1% point of GDP increase in tax to GDP ratio lowers output per worker by 2%.
Engen & Skinner (1996)	US modelling toge-ther with a sample of OECD countries.	Marginal tax rates, human capital, investment.	2.5% point increase in tax to GDP ratio reduces GDP growth by 0.2% to 0.3%.
OECD - Leibfritz, Thornton & Bibbee (1997)	OECD countries over the 1965-95 period.	Tax-to-GDP ratio, physical and human capital formation and labour supply.	10% point increase in tax to GDP ratio reduces GDP growth by 0.5% to 1%.
Bleaney, Gemmell & Kneller (2000)	17 OECD countries over the 1970-1994 period.	distortionary tax, pro-ductive expenditure, net lending, labour force growth, invest-ment ratio.	1% point of GDP increase in distortionary tax revenue reduces GDP growth by 0.4% points.
Folster & Henrekson (2000)	Sample of OECD / non-OECD countries over the 1970-1995 period.	Tax-to-GDP, govt. expenditure-to-GDP, investment-to-GDP, labour force growth, human capital growth	10% point increase in tax to GDP ratio reduces GDP growth by 1%.
Alesina et al. (2002)	18 OECD countries over the 1960-1996 period.	primary spending, transfers, labor taxes, taxes on business, indirect taxes, govt. wage consumption (all in share of GDP).	1% increase in govt. spend-ing relative to GDP lowers the investment-to-GDP ratio of 0.16% and a cumulative fall of 0.80% after 5 years.

Note: Other studies of which these are a representative sample include: Chao and Grubel (1998), Grier and Tullock (1989), King and Rebelo (1990), Levine and Renelt (1992), Peden and Bradley (1989), Plosser (1992), Scully (1989, 1991, 1995), Slemrod (1995), Smith (2001), Bassanini & Scarpetta (2001), Vedder and Gallaway (1998).

3

PRODUCTIVITY, ENTREPRENEURSHIP AND GROWTH

3. PRODUCTIVITY, ENTREPRENEURSHIP AND GROWTH

3.1 Introduction

Endogenous growth theory has made two crucial contributions that provide an intellectual breakthrough. The first is that human capital and knowledge are key factors determining growth. The second is that they, unlike the more traditional factors of labour and physical capital, endogenously affect growth. However, empirical evidence supporting the predictions derived from these models is ambiguous: for instance, why have some countries less endowed with knowledge – and often small (e.g., Korea) – grown fast and persistently? And why have other countries with high rates of R&D spending experienced quite slow growth during the last decades?

As we will show in section 3.2, Parente and Prescott (1993, 1994, and 2000) have made two fundamental propositions. The first is that understanding the large cross-country differences in per capita income needs an understanding of differences in total factor productivity, i.e., a country's efficiency in using its resources. They argue that cross-country differences in TFP vary across industries whereas cross country differences in human capital accumulation, generally speaking, do not. Thus the true explanation must be the differences in TFP. The second is that differences in TFP are caused mainly by barriers to the adoption of best-practice production methods, due to vested interests with the witting or unwitting support of the government.

There has been a large literature advocating that removal of domestic and international barriers to flow of goods, capital and technologies can contribute to economic growth, particularly through TFP growth. Besides Parente and Prescott, Coe and Helpman (1995) also provide evidence in this regard that there might be technology spillovers across countries through trade flows, hence not only domestic R&D but also foreign R&D can improve productivity growth. Benhabib and Spiegel (1994) present evidence in favour of human capital as one of the major sources of TFP growth, rather than merely as a normal factor in the production function, as it is assumed in traditional growth theory.

Note that focus of the original endogenous growth models is on *why* knowledge affects growth, not *how*. When it comes to the diffusion of knowledge within countries, the endogenous growth theory assumes that spillovers are automatic, that is, no barrier to commercialising ideas and knowledge. Therefore, there is a missing link in the endogenous growth model between knowledge and economic performance. Some authors have recently put forth entrepreneurship as a third factor of a new 'new-growth theory', exploiting the opportunities provided by new ideas and knowledge that are not sufficiently utilised by incumbent firms. They argue that by acting as a conduit for knowledge diffusion, entrepreneurship is the missing link between investment in new knowledge and growth. In section 3.3, we extend Parente and Prescott's idea to a broader context and highlight the important transmission mechanism, namely entry and entrepreneurship that determine the link between knowledge creation and economic development, and finally we discuss how government/institutions may support such link.

3.2 Parente and Prescott's View

Parente and Prescott in their series of papers illustrate that endogenous growth theory is not a quite useful tool for explaining the evolution of the international income distribution in spite of the large amount of effort made. Rather, they suggest that exogenous growth theory is more useful in this regard. In fact, they find that neoclassical growth theory, after some deliberate modifications, can explain the pattern of economic progress quite well, while endogenous growth theory can not.

3.2.1 The Failure of Endogenous Growth Models

Parente and Prescott (1994, 2000) divide endogenous growth models into two types. The first is models of perfect competition. The frontrunners in this line are Romer (1986), Lucas (1988), and Rebelo (1991). These models attempt to concentrate on the decision of people to accumulate capital, where capital consists of tangible and intangible. The essence of these models is that at the aggregate level there are no diminishing returns to reproducible capital so as to achieve sustained growth. These models predict that cross-country differences in preferences or policy will cause permanent differences in economic growth rates.

Parente and Prescott argue that these models are not useful because they fail to account for several key development facts, the most important of which is the so-called 'growth miracles'. They stress that all of the development miracles are a recent phenomenon and are confined to countries that lagged far behind the industrial leader at the time the miracle started. Also, later entrants to modern economic growth have typically been able to double their income in far less time compared to early entrants. All of this indicates that a country's potential for rapid growth is greater the farther behind the top industrial countries. An endogenous growth model (e.g. Rebelo's Ak model (1991)) implies that a growth miracle is just as likely to take place in the US as it is in South Korea. What the US has to do to achieve this is simply to adopt South Korean institutions and policy. It is not reasonable because most people think the policy and institutions in the US at the moment is at least as good as South Korean ones. Meanwhile, the model implies that development miracles are just as likely to have happened in 1900 and in 2000. All the failures lead Parente and Prescott to conclude that this branch of endogenous growth models may not be quite suitable to explain some key stylised facts in economic development.

Nevertheless, Parente and Prescott attempt to add a human capital production sector to the neoclassical model, but such extended model still fails as a theory of international income differences. The problem, they argue, lies with the technology side. In particular, this problem is the assumption of a common TFP across countries. They also provide some direct evidence of the limited role of schooling in explaining world income variations. There is no significant difference in schooling across industries within a given country. Hence, if differences in schooling capital were the key factor to explain income variations, then one country would be the leader in all industries, and not just a few. This and other evidence shown in their paper indicate that we need something else to account for the observed income disparities across countries. In particular, they suggest we consider TFP differences.

The second type of the endogenous growth literature is the models of imperfect competition. The seminal papers in this line are Romer (1990), Grossman and Helpman (1991), and Aghion and Howitt (1992). These papers share the property of explicitly modelling the decisions of private agents to engage in costly R&D activities. These models add in imperfectly competitive components through granting monopoly power to the successful innovator. If the opportunity to obtain monopoly profits does not exist, then no self-interested individual would be willing to undertake R&D. More recent papers in this line, such as Jones (1995) and Young (1998) make various adjustments on those original papers in order to deal with an implausible feature of these models – the scale effect, i.e., a country with more populations has a higher growth rate and perhaps a higher level of per capita income.

As Parente and Prescott argue, this type of endogenous growth literature has the merit of helping us understand how knowledge has created and developed and how the industrial leaders have been able to increase their per capita output during last two centuries. But R&D models cannot explain why the whole world is not rich.

In their opinion, although poor countries do not put much effort into their R&D activities for various reasons, they do not have to. There is a much cheaper and easier means for them to improve their standard of living. They only need apply readily available and more productive ideas/technologies developed elsewhere to their production of goods and services. The problem is why poor countries don't use this existing stock of knowledge more efficiently. R&D models do not answer this question. This is indeed, as the authors stress, how Japan and Korea went from being relatively low-income countries to richer countries during the post-war period; and this is why the authors concentrate on the barriers to the technology adoption, rather than on the creation of more productive technologies.

3.2.2 Productivity and Barriers to Technology Adoption

Parente and Prescott (2000) combine their previous research and demonstrate that exogenous growth theory, in contrast to conventional endogenous growth models, can explain the evolution of the international income distribution both before 1950 and after 1950. In fact, they propose a modified version of Solow model to achieve that goal.

They first argue that the major drawback in Solow model if being used to explain the world income differences is that it does not allow for a mechanism through which countries differ in the quantity of technology they use. All the differences in cross-country incomes arise from the differences in savings rates, which may differ due to different tax codes or preferences. The failure of this model in accounting for world income disparity is the absence of any systematic differences in savings rates among countries with different level of economic development.

To tackle this problem, Parente and Prescott (1994) set up a model of technology adoption. They begin at the micro level and take into account the choices of a firm to improve the technology of its production. Technology adoption incurs cost. The quantity of resources needed to apply a certain technology is affected by the policy of the country where the firm is situated, and also by the stock of knowledge available in the world, which can be assumed to grow exogenously. The authors aggregate over firms and demonstrate that the equilibrium behaviour of the country is similar to that of the neo-classical growth model with two capital stocks and with TFP differences. Here the TFP, representing the proportion of the knowledge in the world adopted by the economy, is a function of the economy's policies and institutions. An economy that has more costly policies and institutions employs less of the current knowledge stock in the world and therefore a lower TFP. Parente and Prescott show that a small difference in policy is able to exert important impacts on steady-state income level of the magnitude we have seen during the post-war period.

Following their first attempt, Parente and Prescott (1999) go on to consider the reason why policies and institutions that restrict firm's technology decisions exist. They carefully examine past and recent economic history both at the industry level and macro level and point out that the major reason such policies exist is to protect the insiders with vested interests from outside competition. These insiders typically are specialised factor suppliers to the existing production process, have the 'state erect barriers' to the adoption of superior technology. Parente and Prescott set up a model to demonstrate how these insiders under the state's protection impede the adoption of better technology and even result in, in some circumstance, an inefficient use of current technology. They also attempt to quantitatively analyse the impact of entry barriers on an economy's productivity. In particular, they assume that in the sector of the economy with entry barriers, the goods production is constrained by a coalition of workers and the demand for goods is price-inelastic. The coalition decides a size sufficiently large to prevent entry of more productive technologies, and once entry has been deterred the coalition dictates work practices and its members' wages to control production and thus raise prices and members' wages. This model economy is quite stylised and the authors use available data to parameterise the model. They report a striking result that given estimates of the entry costs that prevail in low-income countries, a superior technology that is more than three times as productive as the technology being used by the vested interest group is not adopted.

Hansen and Prescott (1999) take the last step to remedy the drawbacks in the Solow model. They describe how the neoclassical growth theory can be incorporated in a model with Malthusian element to explain the various starting dates of modern economic development. In particular, they examine the transition of a country from a Malthusian production technology to a Solow production technology. The per capita income of a country will not change, provided the country still engages in the

Malthusian production technology. Only when the country makes transition to the Solow production technology, does modern economic development start. The transition is achieved when the knowledge stock rises above a critical level. Countries with higher barriers to technology adoption and capital accumulation have higher critical levels.[8]

With a series of modifications as shown above, the extended Solow model can successfully explain the pattern of the world income distribution and its evolution from past and recent history. Meanwhile, it can improve our understanding of why the growth miracles have happened. A growth miracle in the model means the switch by an economy from a low steady state to a high steady state led by the reduction of government protection. For an economy to undergo a growth miracle, it is necessary that the economy is not exploiting a large amount of the readily available stock of useable knowledge in the world and therefore is poorer than the industrial leader. If the protection retarding the adoption and efficient use of this stock are reduced in such an economy, a growth miracle will occur. However, this is not the case for those already rich countries. The reason is that rich countries are using almost all the useable knowledge. For the rich, as Parente and Prescott discuss, growth is mainly triggered by the growth of productive knowledge.

This modified model in also consistent with the fact that all growth miracles are a recent phenomenon and that the countries that start modern economic development later are able to increase their incomes much quicker than earlier countries. The reason for that is quite simple. The useable knowledge stock today is much more than that in the 19th century. Therefore, a hundred years ago there was no large difference in the amount of knowledge unexploited by rich countries and by poor countries. Hence, development miracles could not occur, but the difference is huge today. If poor countries can reduce their barriers to the adoption of the technologies developed elsewhere, significant improvements in their standard of living are achievable over a relatively short time.

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[8] Ngai (2000) shows that this model can account for the starting dates of modern economic development.

3.2.3 Brief Summary and Policy Implications

The objective of Parente and Precott's work is not only to identify a factor that may contribute to world income disparities, but also to quantify that contribution. Their calibrated general equilibrium model produces the sought-for big differences in TFP between high and low monopoly-arrangement economies. Although there have been other papers, such as Krusell and Rios-Rull (1996) and Acemoglu and Robinson (2000), attempting to model the same idea that vested interests discourage adoption of superior technologies. Parente and Precott's model differs in that it identifies a specific mechanism through seriously modelling the industrial organisation of technology adoption, and also in that they subject the model to quantitative scrutiny.

They present plenty of case studies and anecdotes based on past and recent economic history in order to validate the proposition that resistance of established interest groups can restrict the introduction of best practice techniques. There are a number of examples of successful and unsuccessful resistance from rich and poor countries. One lesson appears to be that technology developments almost always meet defence of groups that would lose rents. The point is whether or not that defence will be successful. For us to understand how strong resistance to technological progress is, quantitative evaluation of the effectiveness of the resistance is required in any circumstance.

From the standpoint of public policy, Parente and Prescott stress that governments 'must stop protecting monopoly rights of industry insiders with vested interests in the current production process, as well as stop granting new monopoly rights in the future'. (Parente and Prescott (2000), p.141). Other policies to encourage competition, for example the pursuit of free trade, can also play significant role. International trade matters for growth precisely because it is a vital source of competition. Parente and Prescott finally conclude with the claim that 'there is no reason why the whole world should not be as rich as the leading industry country' (p. 145).

Of course, there is no shortage of alternative possible types of 'barriers to riches' – barriers to the adoption of better technologies may not be the only reason why developing countries have low levels of income per capita. Within a vested-interest framework, for instance, some research can be devoted to groups other than organised labour. Beyond the vested-interest framework, we have even more choices: differences in education, R&D, and investment may also account for certain proportion of cross-country income differences, bearing in mind that empirical evidence does exist which shows theses factors matter. Therefore, testing this against other factors can be very interesting, which is the major task of this thesis. Parente and Prescott's proposition according to which human capital differences are not big enough to account for cross-country differences in per capita income is derived from models in which human capital is only another input in the production of goods and services. A model in which human capital is also an input in learning the leading-edge technology has yet to be quantitatively scrutinised.[9] Although we may have other potential causes of barriers to riches, this certainly does nothing to detract from the value of Parente and Prescott's work, namely to have undertaken an elaborate (though necessarily not conclusive) analysis of the monopoly power of organised labour as one of the main reasons for poor productivity performance. Of course, wherever economists will eventually settle on the sources of barriers to riches, the policy implications do not differ much from those advocated by Parente and Prescott: competition, privatisation, and trade liberalisation.

3.3. The Link Between Entrepreneurship, Entry, and Growth

In this section, we extend the proposition of Parente and Prescott to a broader context. In particular, we look at the relationship between entrepreneurship and economic growth. As discussed above, endogenous growth theory fails to account for divergent levels of income across countries, or the fast growth of countries such as South Korea. In terms of policy, the failure of endogenous growth models to give an adequate

[9] A recent attempt has been made by Sarquis and Arbache (2002), where they introduce human capital in total factor productivity instead of only including it in a standard Cobb-Douglas production function; and find that productivity depends on human capital and is accompanied by enhanced external effects.

explanation for different levels of economic development is worrisome because the growth drivers proposed by endogenous growth literature (for example, the share of GDP on R&D expenditures) might not be the real route to growth. Although endogenous growth models make innovation an endogenous factor, they barely explain why and how individuals and firms seem to create, absorb, and adopt innovations at quite different levels across countries given common amount of investment in R&D (see, for example, Martin and Sunley (1998)).

It is widely recognised that entrepreneurship has been omitted from the standard models of economics, and we think it is even more critical that it has been omitted from growth theory. What is missing within the endogenous growth framework is *why* the ability of individuals and firms to learn and innovate differs across different places. While Romer (1990 and 1994) and Krugman (1991) described the roles that knowledge externalities and spillovers play in driving endogenous growth, they shed little light on the actual mechanism through which knowledge spills over. Entrepreneurial firms or establishments are one such mechanism transmitting the knowledge spillovers. Therefore, an increase in the role of entrepreneurial activity may support the spillovers of knowledge, thereby driving subsequent growth. For example, Audretsch and Keilbach (2003) explain the re-emergence of entrepreneurship and posit that entrepreneurial activity may be missing link in accounting for variations in economic performance. An alternative and broader view of such link is that it is the institutional fabric that leads to the variations in high and low growth.

To investigate the link that is missed in the endogenous growth literature, in this section we first look at the relationship between entrepreneurship and economic growth, then we review the literature that provides an explanation from institutional perspective for the differences in income and growth rates across regions and see how government can facilitate the link. By doing so, we are able to open up the 'black box' of innovation to see why some counties have experienced fast economic development while others have not.

3.3.1. The Research Gap

Recent studies in this stream of literature are confined largely to the microeconomic or firm level – there is an apparent gap in research connecting entrepreneurship to economic development at the macroeconomic level. This is due to the scarcity of explicit theoretical structures connecting entrepreneurship to growth and to the great difficulty in defining and measuring entrepreneurship at all.

While some recent studies of the determinants of entrepreneurship are theoretical such as Kirzner (1999) and Boettke and Coyne (2006), others are empirical such as Hart and Hanvey (1995), Braunerhjelm (1996), and Acs (2002). All of them attempt to highlight the questions of why people start up business and what decides who will be an entrepreneur.

The impacts of entrepreneurship on economic performance have also gained a lot of attention. The literature in this field, however, has been largely limited to either the level of the new firm or regional level. There is a gap or ignorance when it comes to connecting entrepreneurship to growth at national level. The large literature investigating this linkage at the firm level has mainly used firm growth and survival to measure economic performance (for example, Acs and Audretsch (1989), Reynolds (1997), Arauzo-Carod and Segarra-Blaso (2005), and Michelacci and Silva (2005)). The main stylised facts obtained from these studies are that growth is triggered by entrepreneurial activities, proxied by firm size, age, or start-up rates. The growth of small and new establishments is significantly higher than that of big and established ones. Also, new firm formation is determined not only by profit expectations, but also by the overall economic conditions, e.g. barriers to entry.

Some attempts have been made to extend the link between entrepreneurship and performance beyond the firm level, trying to identify the empirical regularity within or across geographic space. Studies in this stream consist of Hart and Hanvey (1995), Callejon and Segarra (1999), and Varga and Schalk (2004), among others. All these studies have more or less obtained a positive relation between entrepreneurship and economic performance at the regional level.

Nevertheless, plainly absent is literature connecting the consequences of entrepreneurship to economic growth at country level. The objective of the following discussions is to attempt to narrow such gap in research by exploiting what can be learned from the literature providing the microeconomic evidence linking entrepreneurship and growth, and relating such literature to our endogenous growth study in the cross-country context.

3.3.2 Entrepreneurship and Economic Growth

Entrepreneurship has positive effects on competitiveness and growth in different ways. The first way is by creating knowledge spillovers.[10] Hirschman (1970) discusses that a knowledge worker for various reasons may exit the firm where the knowledge is generated in order to start a new firm. In fact, the knowledge production function is reversed in this spillover process. Knowledge is embodied in a worker and the firm is started endogenously via the worker's effort to appropriate the value of his knowledge through innovation activities. Entrepreneurship thus acts as a mechanism creating knowledge spillovers from an existing company to a new one. Cohen and Levinthal (1989) argue that a firm improves its ability to adopt new ideas and techniques created outside the firm and is thus able to appropriate part of the returns accruing to investments in new technology externally developed in other firms.

The literature analysing mechanisms generating knowledge spillovers is scarce and still underdeveloped at the moment. Nevertheless, entrepreneurship is a promising area where transmission mechanisms have been identified. Enhancing the role of entrepreneurship activity will promote knowledge diffusion and ultimately economic performance. Therefore, insight into the process of the knowledge spillovers is crucial

[10] Romer (1986), Lucas (1988) and Grossman and Helpman (1991) emphasised that knowledge spillovers are a crucial mechanism underlying endogenous growth theory. They are less precise, however, about the actual process of how knowledge is transmitted across individuals and firms.

and should be regarded as a focus for public policy promoting economic growth and development.

A second means by which entrepreneurship fosters economic growth is that it increases the number of firms and therefore more competitions. Porter (1990) discusses that competitions are more contributive to knowledge externalities than is local monopoly. Local competition in Jacobs (1969) corresponds to the competition for new knowledge embodied in knowledge workers. He argues that augmenting the number of firms increase the competition for new ideas on the one hand, on the other increased competitions among firms also stimulate new entrants specialising in a specific new product niche. The reason lies in that the necessary complementary inputs are more easily obtained from small specialist niche firms than from large firms. Glaeser et al. (1992) as well as Feldman and Audretsch (1999) also support the claim that increased competitions are beneficial for growth performance.

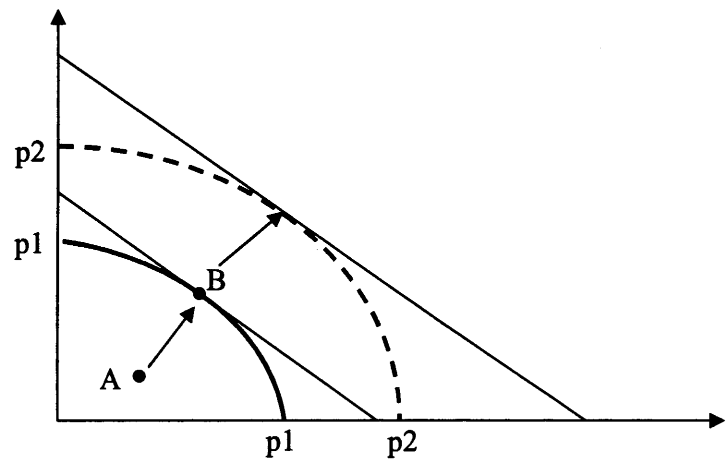
Needless to say, 'entrepreneurship' and 'entry' are related topics. New firms can take the place of obsolescent incumbents through 'creative destruction' means that may be regarded as a key micro-determinant of economic development. From this standpoint, new entrants are those individuals Schumpeterians called 'energetic types' who show their 'essential features' by putting forward the 'new' into a variety of activities and by dropping the existing routines (Santarelli (2006)). Hence, entrepreneurship is about the role of creative individuals and risk takers who set up new firms or revive an established one (see Hébert and Link, 1999). In more general terms, it has been discussed that entry of new firm can be conducive to unemployment reduction and employment creation (see Thurik (2003), Hart and Oulton (2001)), and ultimately higher economic growth (see Van Stel, et al. (2005)).

Another way in which entrepreneurship enhances economic growth is by increasing the variety among firms (Cohen and Klepper, 1992). Entrepreneurship not only results in the rising number of firms, it also increases the diversity of firms in a certain place. The theoretical basis for examining the relationship between diversity and economic performance has been made by Jacobs (1969), who points out that the most crucial sources of knowledge diffusion are from outside of the industry where the firm operates and that cities are a key source of enormous innovations since cities have the largest diversity of knowledge sources (see Jaffe et al. (1993) and Audretsch and Feldman (1996) for more discussions). In Jacobs' opinion, it is the exchange of complementary knowledge and ideas across diverse firms and individuals that generates considerable returns on new knowledge. Jacobs sets out a theory underpinning the proposition that the diversity of industries within a geographic space enhances knowledge externalities and therefore innovation activities and economic growth.

Finally, Kirzner (1985, 1999) argues the role that the entrepreneur could play in economic progress is through the alertness to opportunities – that is, the recognition of knowledge formerly unnoticed. Entrepreneurial discoveries are realisations of ex post mistakes made by entrepreneurs. The presence of mistakes offers wider range for profit opportunities that entrepreneurs can recognise if they move in a direction more accurately next time. According to Kirzner, alertness is referred to realising where to look for knowledge. In this respect, economic progress is a process through which entrepreneurs capture or respond to profit opportunities rather than creating them. Without entrepreneurship, without awareness of the new opportunities, the long term gains might still be untapped.

Despite various ways in which entrepreneurship spurs economic growth, we can depict that entrepreneurship plays a dual role in the economic progress (see Figure 3.1). Entrepreneurs, by capturing formerly unnoticed profit opportunity, lead the country from an economically (also technologically) inefficient production point (A) to the economically (also technologically) efficient point (B). Furthermore, by discovering new technology (including knowledge spillovers) and new production processes, which employ resources in a more efficient way, entrepreneurship shifts the whole production possibility curve outward from p1 to p2 (Kirzner, 1985). Such shift reflects the key source of economic growth, namely increases in output from increases in productivity.

Figure 3.1: Entrepreneurship and Growth



Empirical evidence on entrepreneurship and growth

In what follows we point to the relationship between entrepreneurship and economic growth as evidenced in a number of empirical studies (largely limited to the microeconomic level). Recent studies have identified the empirical regularity between different measures of entrepreneurship, most commonly start-up rates, and growth. Other measures, such as business ownership rates and the ratio of SMEs, sometimes are also used. The measure of growth most frequently used is the changes of employment over time. Whatever the measure they use for entrepreneurship or the sample size (city, region, or country), all of these papers have more or less ascertained a positive relation between entrepreneurship and economic growth.

Recently, Acs (2002) evaluates the link between start-up rates and economic growth in the 1990s for over three hundred regions in America. He gets robust evidence that startup rates are significantly positively correlated with the growth rates in those regions. This empirical link between entrepreneurship and growth is also proved to be much more powerful than for other regional variables, namely population growth rates, human capital, and income levels. These findings are consistent with other papers, such as Reynolds (1999).

Some studies show that the results found for earlier periods appear to have shifted in later periods. For example, Audretsch and Fritsch (2002) document that different results have been found for the 1990s, as compared to the 1980s, in Germany. They find the robust empirical evidence that the source of growth in Germany has changed from the established incumbents in the 1980s to entrepreneurial firms in the following decade, which seems that a process of convergence is occurring between Germany and the US. In spite of uncontrolled institutional differences, the link between entrepreneurship and growth is obviously converging in both countries. These findings have been confirmed in Audretsch and Keilbach (2003), in which they test a production function model using the data for different regions in Germany.

The positive link between entrepreneurship and growth has also been found at other regions besides in the United States and Germany. For instance, Fölster (2000) focuses on Sweden and evaluates not only the employment changes within new entrepreneurial firms but also on the overall relationship between self-employment shares and total employment. He shows how to connect micro behaviour with macroeconomic performance and finds that rises in self-employment ratio in Sweden have contributed positively to regional employment growth. Hart and Hanvey (1995) attempt to connect measures of new firm formation to employment creation across different regions in the UK in 1980s. They conclude that employment generation came mostly from SMEs. Callejon and Segarra (1999) attempt to identify the relationship between new-firm startup rates as well as death rates (or combined as a measure of turbulence) and TFP growth across regions as well as industries by using data of manufacturing industries in Spain for the period of 1980-92. Their results suggest that both new-firm birth rates and death rates positively affect the TFP growth at regional level.

It has long been recognised that entrepreneurship varies across geographic space. Therefore, all the positive impacts of new firm formation and new business start-ups reviewed above would be particularly strong at the regional level where it has been identified that differences in the endowment of entrepreneurship may be a key determinant of variations in regional knowledge spillovers, productivity, and output (see Varga and Schalk, 2004).

There have been only a small number of studies at the country level, but positive empirical relationship between entrepreneurship and economic growth has also been found. For instance, Thurik (1999) gives statistical evidence from a cross-sectional study of OECD countries for the period of 1984–94, that higher degree of entrepreneurship, as proxied by business ownership rates, led to higher employment growth rates at the national level. More recently, Audretsch and Fritsch (2002) document that OECD countries having greater degree of entrepreneurship also have achieved lower levels of unemployment and higher rates of growth. In an attempt to evaluate the of robustness across different measures of entrepreneurship, samples, time spans and specifications, Audretsch and Thurik (2002) conduct two sets of empirical work in a panel study for OECD countries to investigate the effects of entrepreneurship changes on growth. Each of them uses a different measure of entrepreneurship, specification and countries. In the first test, entrepreneurship is measured by the relative ratio of economic activity undertaken by small firms. It relates entrepreneurship changes to growth rates by using a panel data of 18 OECD countries for 5 years to verify the proposition that increases in entrepreneurial activities results in higher subsequent growth rates. The second one creates an index of self-employment to measure entrepreneurship and relates changes in entrepreneurship to unemployment at the national level for 1974-98. They finally obtain consistent findings from these two separate tests, namely greater entrepreneurship rates are proved to cause lower unemployment and faster subsequent growth.

3.3.3 Policy, Economic Freedom, and Entrepreneurship

As previously discussed, government regulations, interventions, and taxes would prevent the private sector from exploiting available opportunities. In general, where there are greater incentives to exploit superior techniques, the private sector will take more risks and use more resources than where taxes are high and regulations are stringent.

This highlights the crucial role of social institutions and policy frameworks, within which in principle self-interested agents can internalise certain externalities. In this section, we focus on the importance of institutions in the process of economic progress by analysing their impact on entrepreneurial activity and innovation. The literature reviewed here confirms that institutions characterised by free-market capitalism, or 'economic freedom,' are conducive to higher levels of productive entrepreneurial activities, higher per capita income levels and higher economic growth rates. In fact, institutions can influence the allocation of individuals to positive-sum entrepreneurial activities and that these activities are themselves correlated with economic progress; that is to say, policy frameworks and institutions are the link through which entrepreneurship drives economic growth.

Firstly, institutions can reduce transactions costs through making the rules of the game explicit as well as reducing uncertainty. The reduced transactions costs not only make the current exchanges more profitable, but also induce more potential exchanges since lower transactions costs turn formerly unprofitable exchanges into profitable now. Good institutions allow people to obtain the benefits from trade by making it possible for widespread economic exchange to take place with lower transactions costs (see Steckbeck and Boettke (2004)).

Furthermore, institutions help entrepreneurs to decide the production possibilities in a country by lowering transactions costs as well as facilitating people to get the payoffs from exchange. Institutions mix with other elements of production to help determine the costs (production and transaction) of mixing resources in some ways and therefore help entrepreneurs to decide which activity is profitable. (see Boettke and Coyne (2003)). From society's point of view, profits reflect gains to the society. Before bringing a product to market, people need to withdraw resources from other potential uses.

Consequently, production costs are in fact the opportunity costs of resources. Therefore profits represent the increases of wealth because they are the value created those opportunity costs. By reducing transactions costs, institutions augment the scope of profitable exchanges, thereby creating more wealth for the country.

Baumol (1990) stresses the difference between productive and unproductive entrepreneurship. In contrast to those who argue that regional differences in 'entrepreneurial spirit' can account for regional variations in entrepreneurship, Baumol state that no robust evidence has been found that entrepreneurial spirit varies largely in different regions. Rather, regional variations in measured entrepreneurship (e.g., start-up rates) come from different institutional factors across regions. We should expect greater start-up rates in regions where the returns to new business are higher. Conversely, in regions where the expected profits to new business are lower, for example due to excessive taxes and stringent regulations, we should expect lower start-up rates. Baumol shows how different institutional policies over time lead to entrepreneurial efforts being made in different directions.

Baumol also argues that entrepreneurial efforts are aimed at the exploitation of all available profit opportunities. Entrepreneur activities are the awareness of real profit opportunities that had formerly gone neglected. However the awareness of profit opportunity requires specific time and space. Innovative individuals in countries with good institutions have a better chance to engage in wealth-creating jobs (e.g. IT) and also undertake wealth-creating ('productive') entrepreneurial activities. Just like positive-sum entrepreneurship can lead to better economic performance, negative-sum ('unproductive') entrepreneurship may cause lower growth rates.

According to the argument that entrepreneurship is the discovery and capture of opportunities for personal profit, R&D expenditures are not really entrepreneurship (Holcombe, 2003). However, countries with higher expected profits for R&D are more likely to have more productive entrepreneurial innovations since entrepreneurial activities are influenced by local incentives and knowledge.

The economic development literature has only recently started to acknowledge the significance of institutions and policy frameworks. There is an expending literature on the role of institutions in accounting for variations in growth across countries (see North (1990), Barro (1996), Acemoglu, Johnson, and Robinson (2001), Gwartney, Holcombe and Lawson (2004)). They measure the quality of institutions similarly. Acemoglu et al. (2001), for instance, use protection against expropriation as the proxy. Gwartney et al. (2004) use the Economic Freedom of the World index and they conclude that better institutions lead to higher level of income per capita in that country. They also report that rises in a country's Economic Freedom ranking cause higher economic growth rate.

In terms of its role in technology diffusion, Green, Melnyk and Powers (2002) show that the higher the degree of economic freedom in one country, the larger the amount of technology spillovers. Countries with bad institutions provide few incentives for people to adapt new technology. Moreover, creative persons and firms clustered in space are exposed to much more entrepreneurial opportunities that people spread through space.

Kreft and Sobel (2005) also confirm that institutions lead to entrepreneurship which spurs economic progress. Because the role of institutions varies across countries and is very persistent over time, this may give an answer to the discontinuous character of convergence and divergence. Their findings suggest that the link between entrepreneurship and growth is via the role of institutions. Countries with better economic institutions are more likely to continuously outperform those with bad institutions since good institutions foster innovation and entrepreneurship.

Finally, the reverse side of evidence, namely poor institutions retard economic growth, has also been identified, such as excessive taxation and regulation, inconsistent or unstable monetary and fiscal policy. (see Frye and Shleifer (1997), Shleifer (1997), Johnson, McMillan and Woodruff (2000), Shleifer and Vishney (1994), Gwartney, Holcombe and Lawson (1998), Soto (1989, 2000)).

The literature reviewed above is important because, in contrast to conventional growth literature focusing on education and R&D expenditures, it implies that areas with good policy / institutions will be richer and grow faster, generating the large gap between the rich and poor. Although investments in R&D are consistent with a high-income/high-growth country, they are not the root source of growth (see Boettke and Coyne (2006)). Instead, it is the underlying institutions and policy frameworks stimulating people to undertake those activities that decide the future growth path of the country. Countriess with good institutions are likely to have more people engaged in positive-sum activities and therefore we should expect countries with better institutions to have larger amount of positive-sum entrepreneurship and ultimately higher growth rates.

4

TWO RIVAL MODELS

– A PRELIMINARY EXAMINATION

4 TWO RIVAL MODELS – A PRELIMINARY EXAMINATION

4.1 Introduction

In the previous two chapters, we have reviewed key models of endogenous growth where human capital and knowledge creation play the crucial role in economic development; we have also discussed Parente and Prescott's work which shows the importance of business entry for growth and also shows that neither education nor capital stock deepening can account for growth and living standard differences across countries. It is business entry that allows one country to acquire the world's stock of knowledge via capital inflow/globalisation.

In the following two chapters (4&5), we will test two rival strands of thoughts — Incentivist and Activist.

We start chapter 4 by outlining the two views: growth in the Activist view is caused by public spending on desirable elements (human capital, R&D, etc.); while in the Incentivist case growth is caused by personal incentives which are mainly influenced by taxation, that is, it is removal of barriers that allow technology to be translated into economic growth. We then go on to show the distinct implications of these two views on empirical test. We sketch out two rival models and estimate reduced form equations on panel data from 1970 to 2000. In our Incentivist approach, growth is seen as depending on the business tax rate, which we interpret as the marginal costs levied by the country on firms' closure/setup costs and the marginal tax rate. In the Activist approach, as exemplified by Aghion and Howitt (1998), growth is seen as depending on government subsidies to investment and to R&D. Our later empirical work investigates just what these relationships look like: there appears to be no identifiable effect of R&D

and other capital subsidies on growth but there is an effect of taxation depressing growth.

The reduced form relationships investigated in chapter 4 can only be a first approach to the empirical testing of these theories. In chapter 5, we will go on to develop and test a structural micro-founded model of general equilibrium to evaluate these effects. We assume an open economy, usually small so that each economy is drawing on the world capital stock so capital is endogenous and responds to what labour and technology do; we have the other (resource) factor entering exogenously but do not give it much of a role (it is somehow fixed for each country); what we focus on is the way in which human choices affect technology as well as labour supply. Thus we essentially take the model of Lucas (1988). However we broaden it to include not just education but also most importantly entrepreneurship and R&D. This model allows us to test the different mechanisms of the two rival theories. We also apply a new testing technique in our empirical work to avoid some drawbacks of other empirical studies of endogenous growth.

We finally obtain consistent results in these two chapters that the model with business taxation is accepted while the models featuring government spending on education and R&D are rejected.

4.2 'Incentivism' Vs. 'Activism'

The new class of growth models see certain elements (e.g. human capital, innovation, etc.) as generated by forces within the economy ('endogenously'). The view of these models is often found to be associated with the advocacy of well-chosen government policies to increase public spending in ways that add to those elements. They purport to show that certain sorts of well-targeted subsidies can raise growth by raising the rate of research and development. It seems fairly obvious after all that public spending can directly finance education, infrastructure and R&D. If so, it is natural to argue that this will add to the stock of these desirable elements and so promote growth. On this view, to pay for this spending the tax rate will need to rise somewhat but the extra growth will itself raise revenue. The higher tax rates will not affect growth. We will call this the 'activist theory of development'. However R&D per se, the evidence shows, is not a cause of growth since much of it is wasted. It is also hard to find evidence of such policies increasing growth. This is to be expected since government does not have superior information about the sources of fruitful innovations; hence how can it target such subsidies effectively?

A more promising argument of this view is that innovation per se raises the economy's productivity because some of the innovations will be superior to existing methods, though many will not; by a Darwinian selection process the good ones will survive and the existing alternatives be abandoned, so raising productivity overall – a typical Schumpeterian viewpoint. Although this process is socially beneficial and not risky because on average a proportion of innovations will always succeed and more than defray the costs of the innovators, it is individually risky; if I innovate I may be lucky and hit on something good, but more likely I will not and lose my invested funds, time and effort. Hence innovation will only occur if the rewards for success are high.

Furthermore, the Schumpeterian stress that monopoly can foster economic progress. According to Schumpeter, innovations need lots of nonfirm-specific investments, and monopoly profits are required to finance those investments. Such view is also highlighted in some key endogenous growth theories of Romer (1990), Aghion & Howitt (1992), and Grossman & Helpman (1991). The monopoly means a group in each industry is the sole player in the market and the monopoly rights are protected by regulations that make it costly for a group of potential adopters of better technologies to enter the industry. The stronger is this protection, the more resources a group of possible adopters with new technologies have to spend to conquer resistance to the adoption of the superior technologies.

We, however, are sceptical about the argument that poor countries are poor because they were unable to foster enough such 'supremacy'. Rather, we believe that for many poor countries the reason is that they have protected such power. Our view is that remove or limit the protection, a country will become rich. People will accumulate any physical and human capital required to produce better technology. Of course, this assumes a market economy with strong incentives for people to engage in entrepreneurial activity.

In sharp contrast to the 'activism', the alternative policy approach would not necessarily dispute the importance of the elements identified in the endogenous growth literature as mechanisms of growth transmission. Rather it would question whether these elements would have their effect in the absence of strong incentives for entrepreneurial activity. Firms in low-income countries can 'import' new technologies that are developed in other countries, so that these firms do not have to make any large nonfirm-specific investments. Even though the use of the better technology might need large amount of factor-specific and firm-specific investments, these investments do not require monopoly rents to attract people to undertake them. For such reason, we do not see the factor stressed by Schumpeter being important in explaining why some countries are merely one-fiftieth as rich as some others. Thus it is people who invest in their own (or their children's) education and knowledge, who make use of infrastructure to produce goods and services, and who use research and development to innovate. It follows that in this policy approach the level of taxation- which is the main ingredient effecting personal incentives- will be the key determinant of growth. When it is high, however much is spent on education etc, it will not fructify in enterprise and growth; when it is low, moderate public spending on these elements can have a strong effect on economic growth. In this approach, it is not denied that basic public sector provision of 'public goods' is necessary, rather that it should be restrained efficiently to enable the tax rate to remain low. Our later empirical work will investigate just what this relationship looks like: we expect a rather nonlinear relationship, with growth little affected by rising tax rates at low levels but far more heavily affected as the tax rate rises beyond these. We will call this policy approach 'the incentivist theory of development'.

Such relationship is suggested by various growth mechanisms. As discussed earlier, innovation will only occur if the rewards for success are high. This is where high marginal tax rates can greatly depress innovation. Another growth mechanism is that of learning by doing. When people work they acquire new knowledge about how things can be done; processes are improved by practice and so on. There is a link here with tax rates too in that high marginal tax rates discourage work and by this route also learning by doing.

There is also growth of productivity through catching-up on known technologies. For example, China has boomed largely by transferring western technology and capital to work with its low-paid unskilled workers. Similarly India has boomed by getting its workers to acquire western skills in areas such as finance and software. Thus where skills (human capital) are poor or physical capital backward there is scope for catch-up which is a form of arbitrage. It is only restrained by the risks of the acquirers losing their rewards; this again points up the dangers from high marginal tax rates, poor property rights in host countries, high costs of education or business set-ups or intrusive regulatory burdens.

These various mechanisms suggest that there is a link between marginal tax rates and per capita growth. The effect of this arrangement on a country's output can be large. Our later empirical work relates the growth rate to the marginal tax rate on business formation and profit. In the estimation restricted to be consistent with a number of observations among rich and poor countries, we find the estimated relationship is -0.4, implying that a 10 percent fall in the marginal tax rate will raise growth by 4 percent; for example for the UK a fall in the average marginal tax rate from 40 percent to 36 percent would raise growth from 2.5 percent to 2.6 percent. This may not sound much but because of compounding it has a massive effect on the public finances in terms of present values; in effect a government can legitimately argue on this basis that it can 'afford' to cut taxes because future revenue growth will 'pay for' the immediate loss of revenues.

Thus in summary, 'incentivist' means that the model has growth coming from general business innovation due to the incentive to obtain profit from it; hence the policy implication is that the marginal tax rate on income from business activity should be cut- this marginal tax rate includes the general income tax. It is 'incentivist' because what matters is individual business incentives and therefore general tax rates on businessmen (who could be any person) rather than specific government programmes or subsidies. ‘Activist’ means that the model has growth coming from investment in education or in R&D; hence government should target its spending and subsidies on these narrow areas. It is ‘activist’ because government activity focused on these areas is the key to growth. Therefore, incentivist and activist are quite distinct from each other in the policies involved.

4.3 Two Simple Models of Growth

How might one test these two policy approaches to growth? The key idea that separates them is the effect of incentives on 'dynamic activity'- that is, on entrepreneurial decisions to invest and innovate. In the activist approach this effect is absent; taxation has incentive effects on *allocation* (the standard welfare effects on productive efficiency and consumer choice) but not on dynamism and not therefore on the production function or its contributing elements (beyond these allocation effects, eg on labour supply). In the incentivist approach, the dynamic effect is all-important (beyond a certain low threshold of taxation below which government barely functions); with it growth occurs, without it is does not- regardless of how much public spending is directed at education, infrastructure and R&D.

Consider therefore the nature of causality and exogeneity in each view.

In the activist case, growth is caused by public spending on desirable elements, with no effects from taxation. Public spending on these variables being a choice resulting from the political process, we can regard it as exogenous. There may be feedback from the economy's behaviour to these variables but it is uncertain in direction and takes a long time.

In the incentivist view, growth is caused by incentives and thus by taxation. The level of public spending on desirable elements is now irrelevant. The level of taxation is generated by public choices and it is now exogenous for the same reasons as above. Taxation is usually a side-effect of choices to spend public money on publicly chosen objectives, it is no less the result of policy choice.

In effect therefore our rival theories imply rival sets of exogenous variables. We can test them against each other straightforwardly on this basis.

Notice that a whole set of *other* variables — for example human capital and R&D — are *endogenous* on *both* views. Therefore, they cannot enter our tests except as endogenous results of the two rival sets of exogenous variables. Showing that education for example enters output does not discriminate between the two views. Much of the empirical literature on endogenous growth investigates mechanisms of this sort but cannot shed light therefore on our empirical choice between these two policy approaches.

In what follows we compare these empirically on available post-war data. We develop two simple 'exemplar' models representing each approach and test their reduced forms on the data.

Notice that throughout we assume that spending and taxes must be matched to satisfy the budget constraint on government. While plainly the pattern of taxes can be deferred or hastened, the real present value of taxation must equal the real present value of spending plus present real public debt. Taxation here includes the 'inflation tax' if that is chosen by the authorities (ie they choose to print money as a financing mechanism). We assume that citizens anticipate the tax effects of policies and react to the present value of taxation. A more transparent way of representing this is as the 'permanent tax rate' it implies (i.e. the constant tax rate that has the same present value). It follows from our assumptions that this permanent tax rate is equal to public spending as a share of GDP plus an adjustment for real debt interest.

In our incentivist model, we assume that output is produced by labour of different efficiency; there is a (uniform) distribution of efficiency across people. People can choose to become more efficient (by unspecified actions such as investment in human and physical capital, via learning and borrowing) but to do so they run risks; they cannot be sure how successful their attempt will be, they could either be a lot more efficient or hardly better at all at the two extremes. Against this, they will lose their existing (certain) income/efficiency level, incur costs of changing their situation and pay a marginal tax rate on their increased income. Weighing these elements, people in lower income levels will decide to take the plunge; the marginal income level at which the plunge is taken rises the lower the tax rate and in turn determines the growth rate.

In our activist model, we follow Aghion and Howitt (1998) who set out an economy in which R&D determines growth and public subsidy to capital investment and to R&D in turn determine R&D. This model is large and complicated in detail. But the basic ideas are simple enough. Final goods are produced by an imperfectly competitive inputs industry in which innovation occurs because of R&D. R&D is created by diverting output from final production; as an innovation occurs it is universally adopted in the input industry, causing existing producers to lose profit. Thus a wedge is driven between the private gain from innovation and the social gain, in the sense that an innovator will only appropriate the gain from the innovation until the next innovation comes along whereas society will gain for ever the full improvement on each innovation. There is therefore a case for subsidy of R&D. The extent to which a country innovates and therefore grows will depend critically on this subsidy. The argument for subsidising not merely R&D itself but also investment generally is that new investment increases the adoption speed of innovation because new capital embodies the new technology.

4.4 Basic Results in Testing the Two policy Approaches

As noted in our introductory remarks, growth is seen in the incentivist approach as depending on the tax rate, which we interpret as the marginal costs levied by the state on a) firm closure *plus* b) firm set-up *plus* c) the marginal tax rate (which we take to be approximated by the average overall share of public spending in GDP). Thus to test this we run the panel regression of growth on this tax rate.

In the activist approach, as exemplified by Aghion and Howitt (1998), growth is seen as depending on government subsidies to investment and to R&D specifically. To approximate the investment subsidy we took the difference between the world real interest rate and the national real interest rate; while this difference will be cyclical, as the real interest differential and the expected real exchange rate change respond to shocks, over the decadal averages we use in the data such effects should be minimal, leaving the systematic effect of government policy in protecting industry against world real capital costs. While subsidies to R&D are not readily available we have found data on the amount of government spending on R&D and we use this as a measure of the subsidy to R&D (of course government R&D spending is not charged for and can be considered 100% subsidised).

The results we find are shown below. Because it is hard to know whether country and time effects are random or fixed, we run both regressions on both assumptions. The assumption that these effects are 'fixed' amounts to saying that each country for example has a specific set of differences that endure through time and can be attributed to detailed causes. The assumption that they are 'random' asserts instead that each country varies around the basic relationship randomly; sometimes omitted factors will drive it towards more growth, sometimes towards less, and there is no systematic effect always pushing that country up or down. In theory it is hard to support the idea that country effects are fixed, in the sense that growth does not seem to be associated with countries as of right (eg because of their racial characteristics or their geography); neither of our two theories asserts that, rather they suggest that it is underlying policies that cause growth. Hence it is attractive to think of country effects as being random.

Time effects however are a different matter. Here it seems reasonable to argue that in particular decade events were either favourable or unfavourable to growth, independently of the fundamental determinants of growth. Such reasons would be the behaviour of technological change at the world level which one would expect to have particular effects on particular decades.

Hence our preferred regressions treat country effects as random and time effects as fixed. But we report all combinations and as can be seen below the direction of the results is robust to the choice of these assumptions.

4.4.1. Results for the Incentivist Approach

We perform panel estimation on the empirical model

$$\ln G_{it} = \alpha + \alpha_t + \alpha_i + \phi \ \ln r_{it} + \varepsilon_{it} \tag{4.1}$$

where the subscript i stands for country i, G_{it} is GDP growth rate per capita, r_{it} is the tax rate defined above, α_t is dummy variable specific to each time period, α_i is dummy variable specific to each country, ε_{it} is unobservable stationary error, and α is constant.

We use the panel data that are averaged over consecutive decades from 1970 to 2000 for 100 countries. Data on growth rate in real GDP per capita and tax rate originate from the Penn World Table Version 6.1.

Table 4.1: Incentivist approach basic results

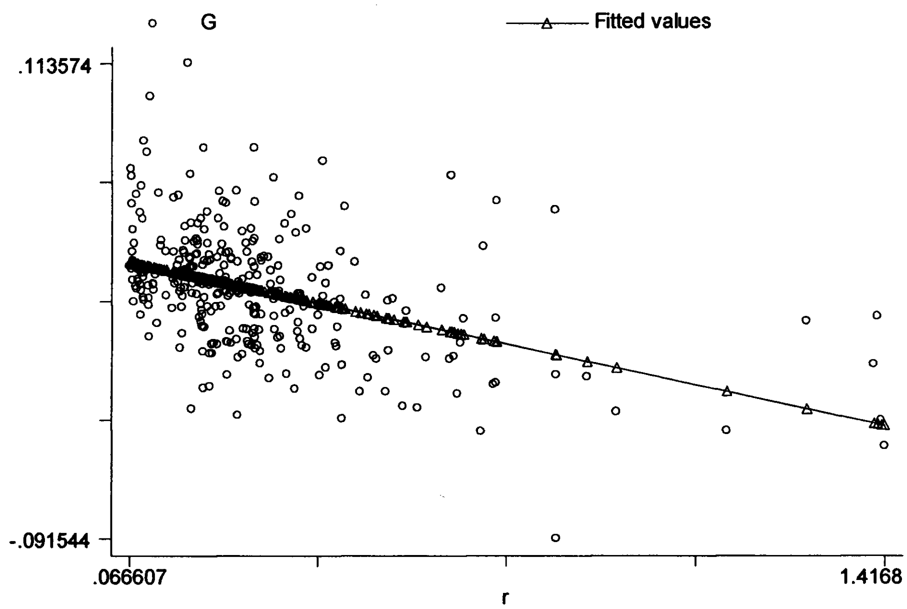
Dependent var. is ln*Gadj*	Cross-sectional regression	Random country effect (with fixed time effect)	Fixed country and time effects
ln*r*	-0.4131001*** 0.0660606	-0.4089624*** 0.0675931	-0.2777889 0.2114343
constant	-3.598126*** 0.119624	-3.665844*** 0.1186308	-3.47297*** 0.2984599
R^2	0.1383	0.1596	0.1552
observations	295	295	295

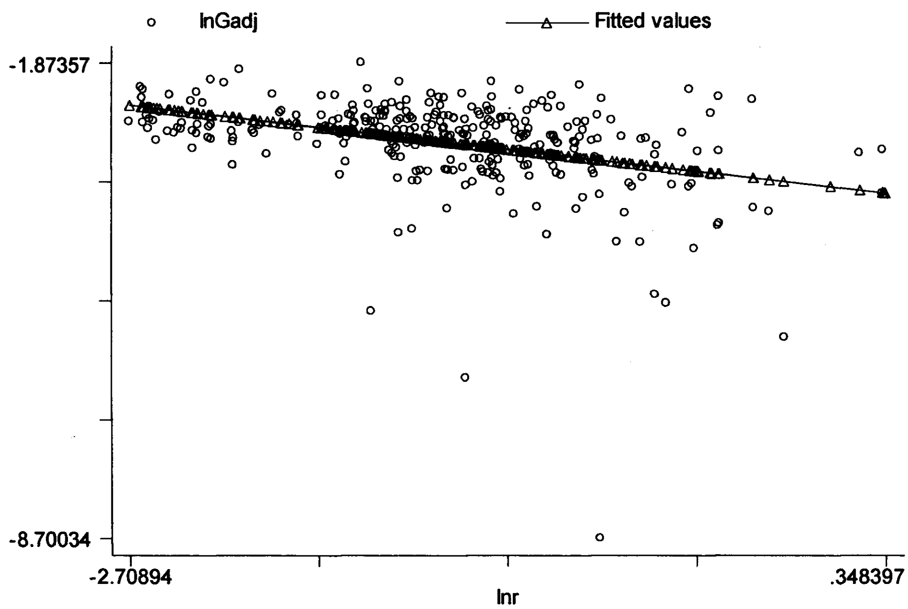
Below each parameter estimate, we report its robust standard error. Three asterisks denote statistical significance at the 1% level, two asterisks at the 5% level and one asterisk at the 10% level.

ln*Gadj* = ln(G+0.04) due to the possible negative value of G for some countries. Observations with growth less than –0.04 (-4% per annum) are omitted as outliers with special reasons (such as civil wars etc)

Because heteroskedasticity could be important across countries, we run the regressions with robust standard errors. These standard errors do not differ greatly, however, from those that assume a homoskedastic error term. Overall, we find an overwhelmingly strong negative relation between tax and growth (a much stronger relation in the random effect model)- specifically an elasticity of growth to tax of approximately –1.4 at the mean of g (0.016) under random country effects, -1.0 with fixed country effects. This elasticity drops by a third if country effects are fixed and becomes statistically insignificant, indicating that time variation within countries still gives an effect but it is not so large and is poorly determined. We would argue that the random effects results are to be used on theoretical grounds.

Figure 4.1: Correlation between growth rate in real GDP per capita and tax rate





Adding control variables:

Many of the regressions we report above in our survey add in 'control variables' that are treated as exogenous determinants of growth. Plainly it is not our view that they are exogenous in this way. However it is of interest as a pure sensitivity exercise to check whether including them would affect our basic result, that tax rates affect growth. In the tables below we record the regressions with four such variables: initial GDP per capita (which should control for a country's potential to 'catch up'; the lower GDP the greater the growth); human capital; physical capital stock; and the rate of investment/GDP.

If we confine ourselves to the model in which country effects are random, we see that the basic result is immune to including these variables, singly or in combination. With fixed country effects the tax elasticity is insignificant; this remains the case with controls added singly but when they are all added the regression becomes so collinear that it breaks down in essence. Again however we would point to the random country effects results as making the most sense.

- Initial value of GDP per capita — ln*G0*.

Table 4.2: Adding initial value of GDP per capita

Dependent var. is ln*Gadj*	Cross-sectional regression	Random country effect (with fixed time effect)	Fixed country and time effects
ln*r*	-0.4585302*** 0.077744	-0.450433*** 0.0914043	-0.3133433 0.2046511
ln*G0*	-0.0388517 0.0463611	-0.0388247 0.0544193	-0.665156*** 0.175467
constant	-3.343886*** 0.3531412	-3.200959*** 0.3710283	2.036531 1.429603
R^2	0.1403	0.1596	0.0177
observations	295	295	295

- Initial value of human capital variable — ln*hc0*.

Table 4.3: Adding initial value of human capital variable

Dependent var. is ln*Gadj*	Cross-sectional regression	Random country effect (with fixed time effect)	Fixed country and time effects
ln*r*	-0.3359003*** 0.0635351	-0.2824532*** 0.1006879	-0.1513985 0.1633693
ln*hc0*	0.0982599* 0.0585831	0.191008** 0.0859461	0.0557751 0.1579874
constant	-3.605208*** 0.1316414	-3.506455*** 0.1541899	-3.141061*** 0.3213641
R^2	0.1533	0.1874	0.1613
observations	255	255	255

Where *hc* is proxied by average schooling years in the population over age 15, from Barro and Lee (2000).

- Initial value of physical capital variable — ln*pc0*.

Table 4.4: Adding initial value of physical capital variable

Dependent var. is ln*Gadj*	Cross-sectional regression	Random country effect (with fixed time effect)	Fixed country and time effects
ln*r*	-0.2285145*** 0.0737142	-0.2201459** 0.098377	-0.2942235 0.2092666
ln*pc0*	0.0125749 0.0456652	0.0310193 0.0414442	-0.0111547 0.1666652
constant	-3.401858*** 0.3538077	-3.390082*** 0.30208	-3.147642** 1.469304
R^2	0.0676	0.1166	0.1018
observations	168	168	168

Where *pc* is proxied by capital stock per worker (1985 intl. prices) from the Penn World Table.

- Ratio of investment/GDP — ln*invest*.

Table 4.5: Adding ratio of investment/GDP

Dependent var. is ln*Gadj*	Cross-sectional regression	Random country effect (with fixed time effect)	Fixed country and time effects
ln*r*	-0.1853692*** 0.0658581	-0.2010656*** 0.0806375	-0.228244 0.2120415
ln*invest*	0.3552623*** 0.0785507	0.329507*** 0.0773946	0.2688975* 0.1501412
constant	-4.227441*** 0.2126837	-4.076769*** 0.1814519	-3.944269*** 0.4867979
R^2	0.2060	0.2183	0.2167
observations	295	295	295

Where *invest* is proxied by the ratio of investment/GDP from the Penn World Table.

- Adding ln*G0*, ln*hc0*, ln*pc0* and ln*invest*.

Table 4.6: Adding all control variables

Dependent var. is ln*Gadj*	Cross-sectional regression	Random country effect (with fixed time effect)	Fixed country and time effects
ln*r*	-0.1906314*** 0.0626646	-0.1770296* 0.0963501	-0.0310333 0.1550151
ln*G0*	-0.1534513** 0.0782778	-0.274614*** 0.0921151	-1.328827*** 0.1914185
ln*hc0*	0.1060642 0.1085019	0.139463 0.1128301	-0.0523443 0.1963471
ln*pc0*	-0.0425998 0.0595577	0.0338131 0.0710202	0.5468776*** 0.1519144
ln*invest*	0.3883018*** 0.0975898	0.371204*** 0.1254544	0.4716634*** 0.1684907
constant	-2.790863*** 0.4433326	-2.349998*** 0.4931368	2.30601* 1.386747
R^2	0.1769	0.1859	0.0070
observations	159	159	159

4.4.2 Results for the Activist Approach

We perform panel estimation on the empirical model

$$G_{it} = \beta + \beta_t + \beta_i + \lambda KSUB_{it} + \theta HSUB_{it} + v_{it} \tag{4.2}$$

where G_{it} is GDP growth rate, $KSUB_{it}$ and $HSUB_{it}$ are respectively government subsidy rates to investment and to R&D as defined above, β_t is dummy variable specific to each time period, β_i is dummy variable specific to each country, v_{it} is unobservable stationary error, and β is constant. Unfortunately we lose nearly two thirds of the observations because of data gaps. We also ran these 'activist' regressions in log form but it made no essential difference.

Table 4.7: Activist approach basic results

Dependent var. is *G*	Cross-sectional regression	Random country effect (with time effect)	Fixed country effect (with time effect)
KSUB	-0.0328874 0.0281843	-0.0428637** 0.0192169	-0.0651416** 0.026076
HSUB	-0.0172619** 0.0080792	-0.0074287 0.007605	-0.0016591 0.010384
constant	0.0291336*** 0.0047852	0.0268741*** 0.0058173	0.0229654*** 0.0069056
R^2	0.0567	0.0454	0.0164
observations	122	122	122

Below each parameter estimate, we report its robust standard error. Three asterisks denote statistical significance at the 1% level, two asterisks at the 5% level and one asterisk at the 10% level.

The parameter estimates for θ in random and fixed effect models are not quantitatively and statistically significant at conventional levels of confidence. More surprisingly, parameters λ and θ both have negative sign in all three models, which denies the proposition of Aghion and Howitt (1998) that growth rate depends positively upon the two subsidy rates. In particular, a 1 percent increase in government subsidy rates to investment is associated with a reduction of the growth rate of 0.03-0.06

percentage whilst 1 percent increase in government subsidy rates to R&D reduces GDP growth by roughly 0.007.

Figure 4.2: Correlation between GDP growth rate and subsidy rate to investment

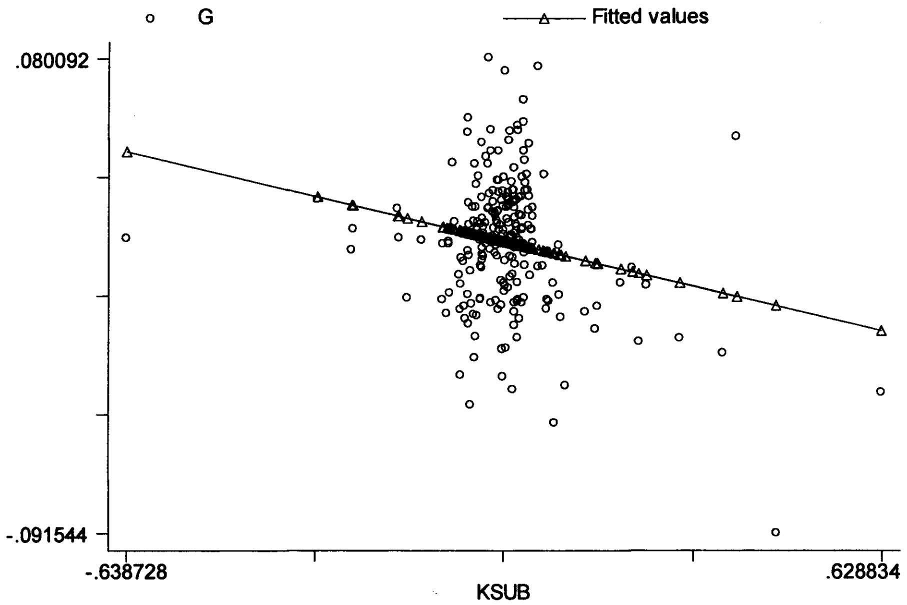
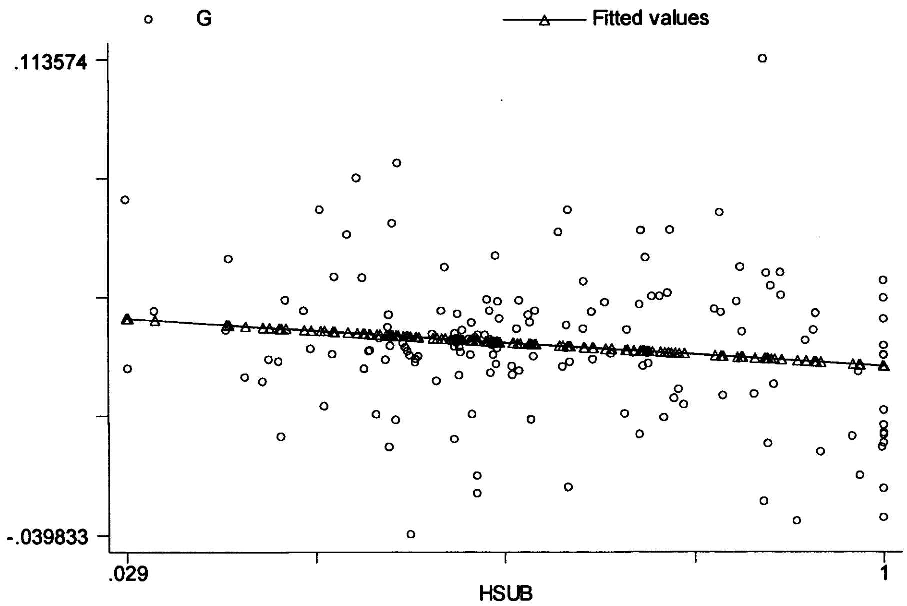


Figure 4.3: Correlation between GDP growth rate and subsidy rate to R&D



Adding control variables:

Again we add the control variables used above to this activist case, for sensitivity reasons. They do not change the insignificance of these subsidy effects.

- Initial value of GDP per capita — *G0*.

Table 4.8: Adding initial value of GDP per capita

Dependent var. is *G*	Cross-sectional regression	Random country effect (with fixed time effect)	Fixed country and time effects
KSUB	-0.0336705 0.0280481	-0.0439847** 0.0194498	-0.050478* 0.0278378
HSUB	-0.0150529 0.0100392	-0.00669 0.0078479	0.0044165 0.0104769
G0	1.58e-07 3.25e-07	1.03e-07 3.65e-07	-1.36e-06 9.57e-07
constant	0.0263072*** 0.0090049	0.0257932*** 0.0067726	0.0308422*** 0.0088099
R^2	0.0590	0.1510	0.0048
observations	122	122	122

- Initial value of human capital variable — *hc0*.

Table 4.9: Adding initial value of human capital variable

Dependent var. is *G*	Cross-sectional regression	Random country effect (with fixed time effect)	Fixed country and time effects
KSUB	-0.0321332 0.0260735	-0.0446653* 0.0189903	-0.0621612** 0.0252276
HSUB	-0.0077816 0.0093707	-0.0010778 0.0079445	-0.0001638 0.0105279
hc0	0.0017704** 0.0008503	0.0024214*** 0.0009453	-0.003529 0.0029477
constant	0.0120623 0.009843	0.0091207 0.0082923	0.0438552** 0.0186494
R^2	0.0907	0.0991	0.0252
observations	115	115	115

- Initial value of physical capital variable — *pc0*.

Table 4.10: Adding initial value of physical capital variable

Dependent var. is *G*	Cross-sectional regression	Random country effect (with fixed time effect)	Fixed country and time effects
KSUB	-0.0739059** 0.0345323	-0.0763963*** 0.0223675	-0.0492111* 0.0258339
HSUB	-0.0227255** 0.0115609	-0.0163448* 0.0090925	0.0199514 0.0158965
pc0	-3.46e-07** 1.59e-07	-3.67e-07** 1.61e-07	-1.00e-06** 4.60e-07
constant	0.0417207*** 0.0097311	0.0401149*** 0.00743	0.0275565*** 0.0104124
R^2	0.1684	0.2006	0.0282
observations	91	91	91

- Ratio of investment/GDP — *invest*.

Table 4.11: Adding ratio of investment/GDP

Dependent var. is *G*	Cross-sectional regression	Random country effect (with fixed time effect)	Fixed country and time effects
KSUB	-0.0298795 0.0222218	-0.0398512** 0.0170956	-0.064688*** 0.0249827
HSUB	-0.0001929 0.0077747	0.0016656 0.0069521	0.0048042 0.0100272
invest	0.1299014*** 0.0192989	0.1271213*** 0.0217512	0.1330205*** 0.0530812
constant	-0.007778 0.0073933	-0.0066479 0.0077625	-0.0103057 0.0148337
R^2	0.3676	0.3693	0.3524
observations	122	122	122

- Adding *G0*, *hc0*, *pc0* and *invest*.

Table 4.12: Adding all control variables

Dependent var. is *G*	Cross-sectional regression	Random country effect (with fixed time effect)	Fixed country and time effects

KSUB	-0.0596485 0.0382799	-0.0678567*** 0.0209594	-0.0400569 0.0258894
HSUB	-0.0114324 0.0103655	-0.0055815 0.0090662	0.0188148 0.0153496
G0	-2.56e-07 5.12e-07	-5.18e-07 6.29e-07	-2.98e-06* 1.58e-06
hc0	0.0006172 0.0011025	0.0003154 0.0012224	-0.0016911 0.0029981
pc0	-4.22e-07*** 1.34e-07	-3.78e-07 2.61e-07	-1.39e-08 6.35e-07
invest	0.1003211*** 0.0265871	0.1270069*** 0.0300039	0.1134434* 0.0596572
constant	0.0128621 0.0123803	0.0045307 0.01179	0.0230241 0.0280673
R^2	0.3001	0.3406	0.0699
observations	89	89	89

4.5 Summary

In this chapter we have looked at two rival models of the effects of public spending: the 'activist' according to which spending raises growth via its effects in subsidising R&D, and the 'incentivist' according to which it reduces it by penalising incentives through higher taxes. We have sketched out the rival models and estimated reduced form equations on panel data in the form of decade averages from 1970-2000. What we have found is that there appears to be no identifiable effect of R&D and other capital subsidies on growth but that there is an effect of taxation depressing growth — in this we join a growing literature that finds similar negative tax effects on growth. We experimented with different functional forms and found a log/log was the closest fitting. Though our theories suggest that no control variables should be added (for initial GDP per capita, education per head, capital/GDP or investment/GDP) to either theory, we have- as a robustness check- added these and found that they do not destroy our basic results.

Plainly such reduced form relationships can only be a first approach to the empirical testing of these theories. We need to develop and test structural micro-founded models of general equilibrium to predict these effects with greater assurance, which is what we attempt to do in the following chapter. Meanwhile the evidence such as it is points to a negative effect of tax on growth.

5

TESTING A MODEL OF ENDOGENOUS GROWTH FOR A SMALL OPEN ECONOMY

5 TESTING A MODEL OF ENDOGENOUS GROWTH FOR A SMALL OPEN ECONOMY

5.1 Introduction

In this chapter we first set up a general equilibrium model of a small open economy with growth choices. We show that this economy can be summarised in two equations: one equation contains the production function which is essentially structural, an 'engineering relationship' with capital solved out in terms of its first-order condition; productivity in it is a function of the business or other taxes. The other equation is the labour supply equation derived from first order conditions as partially solved out. The resulting two error terms include what the data and model imply are the omitted effects of the exogenous errors. Thus the two equations constitute a 'structural model' in the sense that they jointly exactly replicate the data country by country in a way entirely constrained by the model and its solution method; and that they can be solved to give the paths of output and labour supply. Note that there are different sources of endogenous productivity growth in this structural model. We focus primarily on the role of entrepreneurial activity. In this way we propose to test the Incentivist theory where productivity growth is triggered by people choosing to be entrepreneurial in respond to incentives. Meanwhile, we also generalise the model by taking into account other opportunities households may face for raising their productivity – education and R&D, which correspond to the Activist theory where government subsidies to education and R&D are the main drivers of productivity growth. (See section 4.1 for detailed discussions on Incentivism and Activism).

When it comes to empirical testing, we abandon the widely-used method of regressing, usually in panel data, growth on a selection of exogenous 'growth drivers' and checking whether a particular driver is statistically significant. As we will argue in section 5.3, this method is flawed by potential data-mining, by likely bias and by lack of identification. For these reasons the large literature reviewed in previous chapters may not be regarded as entirely persuasive evidence. We, instead, propose a new testing approach — two-stage Popperian procedure in which rejection can happen at each stage. The idea is to set out the model to be tested and to use all possible implications of it for the data to reject it. For this purpose the model must be specified quite unambiguously and must be identified – that is it must not be able to be confused with another model. In the first stage of our new approach the model as tightly specified must pass an estimation test in its structural form; in the second its bootstrapped implications must be consistent with the growth regressions it implies. Only if the model can force its way through both stages are its results to be believed.

In this new testing process, we focus primarily on the role of barriers to business (section 5.4). We begin by testing this theory on its own. We estimate the structural model and test for whether the business barriers variable enters appropriately. We then see whether the model can generate (via the bootstraps) the reduced form relationships we find between business barriers and economic growth.

Also in this section, we consider whether the same results could have been produced with a model with no business barrier effects at all. This is to check whether an alternative identification could have been at work, apparently producing effects of business barriers in reduced form relationships even though no such effects exist at the structural level. As we will show, this possibility can be rejected.

In section 5.5, we go on to see whether yet other models without business tax but with alternative mechanisms of growth — education and R&D (the Activist model) — could have generated the reduced form relationships we observe. Again the idea is to check whether alternative identifications could produce the reduced forms we observe. Again we can reject these alternatives in favour of the business barriers variable alone.

5.2. The Model

We begin (essentially as in Gillman and Kejak (2005) and following the same essential approach as Lucas (1988)) from a standard intertemporal utility function and a perfectly competitive firm sector with a Cobb-Douglas production function, from which households derive wages for their labour supply as workers and dividends for their capital; under constant returns to scale dividends and wages add up to total GDP. We assume that each household owns a corresponding firm for which it works (at competitive wage rates because it could always decide to work elsewhere) and also may undertake entrepreneurial activity to innovate its methods, so raising its productivity. This is the model's mechanism of growth; notice that it is essentially the same as the diversion of people's time to education or to R&D, each of which also would raise productivity. However each household must buy its consumption and investment goods from other firms. Government taxes both in order to make transfer payments back to households (for redistributive purposes) and there is no government spending. The economy is open but is 'small' in the strictest sense; that is, it can borrow on world markets at the world real interest rate and its goods prices are also set on world markets. Each economy in our world of 76 countries will face the same world market; following Parente and Prescott each country has a different level of total factor productivity and the choices of its citizens determine how fast they raise this, by diverting their time from normal work to productivity-enhancing activities. In doing this they can draw on the world stock of available knowledge and borrow world capital to implement their resulting higher productivity output.

We go on to show that this economy for our purposes (examining its growth behaviour) can be represented by three equations: the production function reduced to a function of productivity and labour supply, a labour supply function of labour/consumption taxation, and a productivity function of the accumulated tax rate on entrepreneurial activity.

5.2.1 Derivation of the 3-equation Model

The representative household's utility function seen from period 0 is:

$$U_t = E_0 \sum_{t=0} \beta^t (\ln c_t + \alpha_t l \ln x_t) \tag{5.1}$$

where α_t is a stationary preference error process,

subject to

$$(1+\tau_t)c_t + k_t - (1-\delta)k_{t-1} + b_t = y_t + (1+r_{t-1})b_{t-1} + \Gamma_t - \pi_t z_t \tag{5.2}$$

where:

τ is the tax rate on consumption — this is assumed to be the sole general tax (so that dividends and wages are taxed indirectly through consumption);

π is tax levied on entrepreneurial activity;

consumption (c), capital stock (k), foreign bonds (b), leisure (x), entrepreneurial activity (z) and government transfers (Γ) are all expressed per capita;

δ is depreciation and r is the real rate of interest on foreign bonds. Goods are bought by some system of organised barter and so we ignore the role of money in this economy;

$y_t = A_t k_t^{\gamma} X_t^{\zeta} (1 - x_t - z_t)^{1-\gamma-\zeta}$ is the Cobb-Douglas production function of the household (and firm combined). X represents exogenous other production factors – such as 'land'/natural resources — assumed to be owned by households.

At this stage we treat entrepreneurial activity, z, as fixed. But we will return to it once we have introduced productivity determination below.

From the household's first order conditions we get

$$\frac{1}{c_t(1+\tau_t)} = E_t \frac{\beta(1+r_t)}{c_{t+1}(1+\tau_{t+1})} \; ,$$

From which we can derive the consumption condition:

$$c_t = \frac{1}{\beta(1+\tau_t)} E_t \frac{c_{t+1}(1+\tau_{t+1})}{1+r_{t+1}} \qquad (5.3)$$

Note here we have ignored the risk premium term in r, which is assumed to be small and constant.

The condition relating the marginal product of capital (which we also denote by the shadow real dividend rate, d_t) to world real interest rates plus depreciation:

$$r_t + \delta = \frac{\gamma y_t}{k_t} = d_t \qquad (5.4)$$

and the condition relating labour supply to the marginal product of labour (which we also denote by the shadow real wage, w_t):

$$a)\ w_t = \frac{(1-\gamma-\zeta)y_t}{(1-x_t-z_t)}; \quad b)\ x_t = \frac{\alpha_t l c_t (1+\tau_t)}{w_t} \qquad (5.5)$$

Using the marginal productivity of capital condition, we can replace capital in the production function by terms in the shadow dividend (determined in 5.5).

$$y_t = A_t^{\frac{1}{1-\gamma}} \left(\frac{\gamma}{d_t} \right)^{\frac{\gamma}{1-\gamma}} X_t^{\frac{\zeta}{1-\gamma}} (1 - x_t - z_t)^{\frac{1-\gamma-\zeta}{1-\gamma}} \tag{5.6}$$

What this means is that the household can obtain whatever capital it needs to produce its desired output at a fixed price on world markets; thus it is only limited in the output it can produce by the supply of labour offered at the going shadow wage.

We now turn to the determination of productivity growth and the marginal condition determining z.

In this model representative households choose how much to invest and work within their available production technology. This technology is assumed here to improve through households' innovation by finding out about better processes. We assume that there is some innovative or entrepreneurial activity a household can undertake which involves spending the time denoted as z above. In endogenous growth models one key channel of growth is via labour being withdrawn from 'normal' work and being used for an activity that raises productivity. Here we think of it as 'innovation', as in Klette and Kortum (2004); in Lucas' models (Lucas (1988)) it would be 'education'; in models stressing R&D, as in Aghion and Howitt (1998), it would be research activity. Notice that in all three ways that productivity growth might be enhanced, the maximisation issue is exactly the same: the household must divert an appropriate amount of time away from standard work into this growth-enhancing activity. It decides how much time to devote to z by maximising its expected welfare as above.

We write the growth of productivity as:

$$\frac{A_{t+1}}{A_t} = a_0 + a_1 z_t + u_t \tag{5.7}$$

where u_t is an error process, and the parameter a_1 is the effect of the entrepreneurial activity on productivity growth.

Going back therefore to the household's optimising decision, its first order condition for z_t at time 0 is given by[11]

$$0 = E_0 \sum_{t=1}^{\infty} a_1 \frac{A_0}{A_1} \beta^t \frac{y_t}{(1+\tau_t)c_t} - \lambda_0 (w_0 + \pi_0)$$

from which we can obtain

$$z_0 = \frac{\left\{ E_0 \sum_{t=1}^{\infty} \beta^t \frac{1}{(1+\tau_t)} \frac{y_t}{c_t} \right\}}{\lambda_0 (w_0 + \pi_0)} - \frac{a_0 + u_0}{a_1}$$

We now compare $a_1 z_0$ with (5.7) and find that

$$\frac{A_1}{A_0} = \frac{a_1 \left\{ E_0 \sum_{t=1}^{\infty} \beta^t \frac{1}{(1+\tau_t)} \frac{y_t}{c_t} \right\}}{\lambda_0 (w_0 + \pi_0)} \tag{5.7a}$$

What this is telling us is that entrepreneurs make allowance for the productivity growth already coming from other sources when they decide on optimal effort; they exactly offset these in their decision, so that it is purely entrepreneurs that determine productivity growth. To evaluate this equation we note that our tax rates are a random

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[11] This is obtained by differentiating the Lagrangean above with respect to z_0 remembering that (5.7) determines A_t. Thus we obtain

$$0 = E_0 \sum_{t=1}^{\infty} a_1 \frac{A_0}{A_1} \lambda_t y_t - \lambda_0 (w_0 + \pi_0)$$

Note that $\frac{\partial y_t}{\partial z_0} = k_t^{\gamma} X_t^{\varsigma} (1 - x_t - z_t)^{1-\gamma-\varsigma} \frac{\partial A_t}{\partial z_0} = \frac{y_t}{A_t} \frac{\partial A_t}{\partial z_0}$ $(t \geq 1)$; while since $A_t = \frac{A_t}{A_1} \frac{A_1}{A_0} A_0$ and $\frac{A_t}{A_1}$ is independent of z_0 it follows that $\frac{\partial A_t}{\partial z_0} = \frac{A_t}{A_1} A_0 \left\{ \partial \frac{A_1}{A_0} \Big/ \partial z_0 \right\} = \frac{A_t}{A_1} A_0 a_1$. Hence finally $\frac{\partial y_t}{\partial z_0} = y_t \frac{A_0}{A_1} a_1 = y_t \frac{a_1}{a_0 + a_1 z_0 + u_0}$.

walk and that (see appendix) c_t/y_t is non-stationary. We approximate the latter as a random walk. Omitting second order (variance and covariance) terms then the numerator of (5.7a) is given by $\frac{\beta}{1-\beta}\frac{1}{(1+\tau_0)}\frac{y_0}{c_0}$; then using (5.5) for w_0 and substituting for λ_0, we obtain

$$\frac{A_1}{A_0}=\left\{\frac{a_1\beta}{1-\beta}\frac{1}{(1+\tau_0)}\frac{y_0}{c_0}\right\}\Big/\left\{\frac{1}{c_0(1+\tau_0)}\left(\frac{\alpha_0 lc_0(1+\tau_0)}{x_0}+\pi_0\right)\right\}=\left\{\frac{a_1\beta}{1-\beta}\cdot\frac{y_0}{c_0}\cdot\frac{x_0}{\alpha_0 l}\right\}\Big/\left\{(1+\tau_0)+\pi_0\frac{x_0}{\alpha_0 lc_0}\right\} \tag{5.7b}$$

We now linearise this as

$$\frac{A_1}{A_0}=\phi_0-\phi_1(\tau_0+\pi_0')+error_0$$

where $\pi_0'=\pi_0\frac{x_0}{\alpha_0 lc_0}$ is the tax on entrepreneurs normalised by the ratio of preference-adjusted leisure to consumption; and since $\frac{A_{t+1}}{A_t}=\Delta\ln A_{t+1}+1$, gathering constants as ϕ_0' and letting $u_t'=error_t$ we obtain

$$\Delta\ln A_{t+1}=\phi_0'-\phi_1(\tau_t+\pi_t')+u_t'$$

What we see is that the 'tax rate on entrepreneurs' consists of both the general tax rate and the particular imposts levied on business activity as such. These would include corporation tax for example if it is not rebated to the shareholder as an imputed tax already paid on dividends. Here we pay especial attention to the levies on entry and exit from business as measured by international bodies.

5.2.2 Generalising the Analysis to Different Sorts of Endogenous Productivity Growth

The analysis above treats every household as being a potential entrepreneur in its choice of z; hence the relevant tax rate on z is the business tax, $\tau + \pi'$. We now introduce the idea that different households face different opportunities for raising their productivity; for some education may be the way while for others (no doubt typically embodied in large firms) investment in R&D. In this way we propose to test the Activist theories that government subsidies to education and R&D are the essential drivers of productivity growth. We suppose that there are proportions v_π, v_e and v_ρ of these households respectively in the population; they add up to unity. Each type of household maximises exactly as above with the only change being that:

1. for each the relevant special tax rate corresponding to the tax on entrepreneurship alters to that special for its particular growth activity.

2. the total of household behaviour is obtained by adding together each of these groups and weighting it by its proportion in the population.

Thus now

$$\Delta \ln A_{t+1} = \phi_0' - v_\pi \phi_\pi (\tau_t + \pi_t') - v_e \phi_e (\tau_t + e_t') - v_\rho \phi_\rho (\tau_t + \rho_t') + u_t'$$

where the coefficients ϕ denote the response of each household type and π_t', e_t', ρ_t' represent the respective tax rates (or subsidies, negative tax rates).

We may also note that when we are dealing with macro aggregates, they are all weighted averages of these various types.

5.2.3 Completing the Model

To complete the model, we require:

(1) the government budget constraint which brings together the revenues it raises from households and the transfer it pays over; the government too can borrow from abroad via foreign bonds but for simplicity we assume it does not as it has no impact on the model's workings.

$$\tau_t c_t + \sum (\pi_t' z_{\pi t} + e_t' z_{et} + \rho_t' z_{\rho t}) = \Gamma_t$$

where the z are subscripted by their relevant household type.

(2) goods market clearing in which households buy consumption and investment goods (gross investment $= k_{t+1} - (1-\delta)k_t$) from firms who may supply them either from their own output or from net imports (m) purchasable on the world market at going (exogenous) world prices. If firms have excess output they export it onto the world market at these prices. We set world prices at unity, ignoring terms of trade changes as an exogenous variable with no impact on the model's workings.

$$y_t + m_t = c_t + k_{t+1} - (1-\delta)k_t$$

It can easily be verified that the balance of payments constraint is implied (via Walras' Law) by the household and government budget constraints, the constraint that firms have no surplus profits (all earnings are distributed via wages and dividends) and goods market clearing.[12]

[12] Thus taking the household budget constraint
$(1 + \tau_t)c_t + k_{t+1} - (1 - \delta)k_t + b_{t+1} = y_t + (1 + r_t)b_t + \Gamma_t - \sum (\pi_t' z_{\pi t} + e_t' z_{et} + \rho_t' z_{\rho t})$
we note that the tax terms cancel with the government transfer via the government's budget constraint so that $c_t + k_{t+1} - (1 - \delta)k_t + b_{t+1} = y_t + (1 + r_t)b_t$
Now we use market clearing to substitute out for y_t so that

5.2.4 Solution of the Model

The model is most conveniently analysed in loglinear form. We have from (5.3):

$$\ln c_t = -\ln(1+\tau_t) + E_t \ln c_{t+1} + E_t \ln(1+\tau_{t+1}) - E_t \ln(1+r_{t+1}) + constant \qquad (5.8)$$

Here we have made use of the fact that when x is lognormally distributed lnEx = Elnx + 0.5varlnx. We assume throughout that our errors are lognormal and have a constant variance, so that the variance and covariance terms are included in the constant term above. To loglinearise x_t we proceed by linearising (5.5b) as:

$\frac{\Delta x_t}{\bar{x}} = \overline{\left(\frac{\alpha l c}{wx}\right)} \Delta \tau_t + \left(\frac{1+\tau_t}{x_t}\right) \Delta \left(\frac{\alpha_t l c_t}{w_t}\right)$ which we can approximate, adding a constant of integration, as:

$$\ln x_t = \overline{\left(\frac{\alpha l c}{wx}\right)} \tau_t + \ln c_t - \ln w_t + \ln \alpha_t + \text{constant} \qquad (5.9)$$

Using (5.5a) above to substitute out wages (and assuming lnx_t ≈ ln(1− x_t − z_t) because leisure and working time are approximately equally divided and assuming entrepreneurial time is very small relative to the other two) yields:

$$\ln x_t = l^* \tau_t + 0.5\{\ln c_t - \ln y_t\} + 0.5 \ln \alpha_t + \text{constant} \qquad (5.10)$$

where $l^* = 0.5\left[\overline{\left(\frac{\alpha l c}{wx}\right)}\right]$.

It can be shown that {lnc_t − lny_t} is a non-stationary process (for the formal derivation see the appendix); the reason lies in the permanent income hypothesis, that

$c_t + k_{t+1} - (1-\delta)k_t + b_{t+1} = c_t + k_{t+1} - (1-\delta)k_t - m_t + (1+r_t)b_t$
Cancelling terms yields the balance of payments
$b_{t+1} - b_t = r_t b_t - m_t$
where net lending abroad (the capital account deficit) equals net interest from abroad minus net imports (the current account surplus).

consumption equals permanent income from home output plus interest on foreign assets. The stock of foreign assets then follows a random walk because consumers use foreign assets as a way of smoothing any fluctuations of home income around permanent income. It follows that we can replace this term (plus the stationary preference error) with a non-stationary error process, which will plainly be correlated with the other errors in the model and may also be autocorrelated.

In order to solve the model and eliminate expected future terms it is necessary to make assumptions about the behaviour of the exogenous variables. We assume that world real interest rates, r, are stationary and autoregressive of order 1: $r_t = (1 - \lambda)r^* + \lambda r_{t-1} + \varepsilon_t$. We assume that all the policy variables, essentially the tax rates, are random walks, which is frequently found empirically since tax changes are generally the result of policy change which is by construction unexpected.

A full explicit solution in terms of the forcing processes requires dynamic programming. However as noted earlier we treat the log of the consumption/income ratio in (5.10) as a random walk error process and include it with the error due to work preferences, also likely to be a random walk like productivity. Thus our model for estimation becomes:

$$\Delta \ln A_{t+1} = \phi_0' - v_\pi \phi_\pi (\tau_t + \pi_t') - v_e \phi_e (\tau_t + e_t') - v_\rho \phi_\rho (\tau_t + \rho_t') + u_t' \qquad (5.7c)$$

We integrate this into levels to become $\Delta \ln A_t = -\sum_{i=1970}^{t} \{v_\pi \phi_\pi (\tau_i + \pi_i') + v_e \phi_e (\tau_i + e_i') + v_\rho \phi_\rho (\tau_i + \rho_i')\} + \phi_0' t + u_t'$ where $\zeta_t = u_t'/(1-L)$. We then substitute this for $\ln A_t$ in equation 5.6, which becomes our first equation to be estimated

$$\ln(1 - x_t) = -l^* \tau_t + v_t \qquad (5.10a)$$

where as noted above we have treated $\ln(1-x) \approx -\ln x$.

(5.6) in loglinearised form is now:

$$\ln y_t = (\frac{-1}{1-\gamma}) \sum_{i=1970}^{t} \{v_\pi \phi_\pi (\tau_i + \pi_i') + v_e \phi_e (\tau_i + e_i') + v_\rho \phi_\rho (\tau_i + \rho_i')\}$$

$$+ \psi \ln(1 - x_t) + (1-\psi) \ln X_t + c + \phi_0' t + \xi_t + \zeta_t \qquad (5.6a)$$

(where we have neglected the direct effect of z_t on output for convenience as very small; where $\psi = \frac{1-\gamma-\zeta}{1-\gamma}$ and where $-\frac{\gamma}{1-\gamma} \ln r_t = \xi_t$ is the effect of world real interest rates – this is assumed to be picked up by the time effects in the panel estimation process (as is $\phi_0' t$) while $(1-\psi)\ln X_t$ is assumed to be picked up by the country and time effects).

Thus (5.10a) and (5.6a) are our two equations of the model to be taken to the data.

These equations have been chosen for tractability in the context of our panel set-up and data set. Forward-looking terms for example must be substituted out because we are in practice unable to solve each country model separately over the sample period. Other variables, such as wages, we have no data for. We have substituted out consumption in order to simplify the model to be estimated to its essentials. Thus one of our two equations (5.6a) contains the production function which is essentially structural, an 'engineering relationship' with capital solved out in terms of its first-order condition; productivity in it is a function of the business or other taxes. The other equation is (5.10a) the labour supply equation derived from first order conditions as partially solved out. The resulting two error terms include what the data and model imply are the omitted effects of the exogenous errors. These effects do not include the direct effects of interest in the model, of tax rates on productivity growth and on labour supply; these are explicitly included in the model.

Thus the two equations constitute a 'structural model' in the sense that they jointly exactly replicate the data country by country in a way entirely constrained by the model and its solution method; and that they can be solved to give the paths of output and labour supply.

5.3 A New Testing Approach

When it comes to empirical economics in general and economic growth in particular, a central question is which explanatory variables to include and which to exclude. In fact, this problem is caused by different reasons. **First**, economic theories sometimes are not precise enough to pinpoint the exact determinants of growth. **Second**, the theories tend not to be mutually inconsistent – it is reasonable that human capital accumulation matters for growth and, at the same time, that technological progress, taxation, infrastructure investment matter as well. **Third**, many studies are just loosely related to specific underlying structural model to be tested. In fact, we cannot include all potential explanatory variables in one regression and let the data speak, because the number of potential variables can exceed the number of countries in the world, which means all-inclusive regression is computationally impossible. The approach used by empirical growth analysts often involves trying the variables that are thought to be possibly significant determinants of growth – 'data-mining'. The typical economic growth paper starts by presenting a theory, then proceeds to empirical work in which it is shown that the variable that captures the phenomenon highlighted by the theory is correlated with growth when a number of other regressors are controlled for. However, once we start running regressions including the various variables, we often find that x_1 is significant when we include x_2 and x_3 but it becomes insignificant when x_4 is added in. Since we do not know a priori the 'true' variables to include, we are left with the question – Which variables are 'truly' correlated with growth? **Fourth**, perhaps most important, is that many different models could give rise to the same relationships between the chosen regressors and growth. Let us suppose a model has been estimated appropriately. Say too that its parameter values have not been rejected by the data, in the usual sense that they exceed twice their standard errors. Such a test of a model is rather limited; many rival models can be fitted to data acceptably in this way. For example if the regressors are correlated (due to transmission within the model) with the true causal mechanisms whatever they are one could obtain significant regression coefficients on the chosen regressors which in fact come from a quite different set of causes. Furthermore, tests of models against each other through non-nested or encompassing tests are often found to be inconclusive. The reason is easy to see: different theories can be pushed to explain the same facts by structuring the unexplained errors differently. **Finally**, the causative relations between various variables and growth are usually complex and nonlinear. This means that the correlation being tested is too simple and leaves out important extra dimensions which could bias the estimated correlation. Thus it is better to calibrate the model according to economic theory, under the assumption that the theory is correct; then test it against the 'facts' of the economy.

We suggest that a way forward is, in line with Popper's original ideas, to set up as the 'null' (strictly, the 'working') hypothesis the structural model to be tested and derive from this null the relevant restrictions.

Another suggestion is that we should use all available data in our tests. Thus the structural model implies what the structural errors are and their values are in general supplied by the actual data; thus testing against the data should allow for the data's restrictions under the structural model on the errors being used in generating the structural model's simulated performance.

A further, related, suggestion is that we should use bootstrapping rather than the theoretical asymptotic error distributions postulated by the model to represent the true source of sampling variability since distributions will in general mislead in small samples. Bootstrapping under small sample conditions can be carried out by using the actual data on the errors just mentioned.

As for this thesis, consider a) a panel data set for 76 countries from 1970 to 2000; b) a micro-founded structural theory of its behaviour stating that it behaves according to certain parameters whose values are to be estimated by some means.

Our starting point is the assertions to the effect that the model is to be regarded as 'the truth', that is as a null hypothesis. We shall use 'truth' and 'true' to mean that the model is to be taken as an assertion of how the economy in question works. Such an assertion is made in order for testing to be done of a concrete hypothesis. Thus the 'truth' is the same as the economist's null hypothesis.

The theory being specified is then calibrated or estimated on the data so that its structural equations have an implied set of errors. Under the null these errors are the true errors, warts of approximation and all. Thus these errors contain vital information about the model's implications; different models 'slice reality (data)' between model and error differently. We exploit this fact in what follows; this exploitation we may note in passing crucially distinguishes what we do from methods of simulation in widespread use (such as the Simulated Method of Moments- see Minford, Theodoridis and Meenagh (2005)) where errors are typically imposed. Our concern is to use the information in the data to the maximum in the testing process.

We use approximative techniques to derive the structural equations to the full non-linear model. The implication is that the errors contain the terms omitted via the approximation — these will include second and higher order terms of Taylor series expansion when only first order approximation is done as is our practice here. In addition there may be other terms in the error that have deliberately been omitted even after first-order approximation; an example would be where a variable cannot be explicitly solved for (such as previously mentioned the ratio of consumption to GDP). Thus the error terms contain all the information about the effect of variables in the model but omitted from an equation as well as of pure error terms such as productivity or preference shocks. (Notice that they will in general all be simultaneously correlated for this reason). When drawing policy conclusions this must be carefully taken into account — Lucas' critique — provided the policy change does not alter the stochastic processes of the model it can be evaluated.

Notice that in the course of estimation various tests of the model will probably have been performed- notably whether the parameters are statistically significant, that is are sufficiently large to reject the null hypothesis that they are zero. But let us assume that the model has either passed such tests or is in any case asserted to be a reasonable null hypothesis. Thus we consider models that have already been estimated or calibrated, by whatever means.

Now consider the idea for the following steps. This idea has been to reorganise the facts in the form of correlations, where the facts are metamorphosed into 'stylised facts' which describe the data in a relevant way but one that is entirely theory-free. We can think of the facts against which the model is being measured as being like the 'reduced forms' discussed above. These are not true reduced forms of any relevant model; but they are descriptions of relationships between variables. In business cycle studies the facts are often represented by VARs. However in growth studies the facts of interest are naturally represented by panel relationships between growth and various regressors. Many such descriptions are possible; the empirical studies referred to earlier exemplify a wide variety. One thing we can say is that the true model will 'predict these facts' in a certain sense: these facts must lie within the statistical distribution implied by the model. That is, if we can derive the distribution of possible results for such relationships implied by the model, then we can ask whether the relationship found in the actual facts lies within some agreed (say 95%) set of confidence limits. We can derive these confidence limits by bootstrapping the errors in the model. For these errors represent the true source of sampling variability under the null hypothesis. Thus by replicating these errors in repeated random draws from them and inputting these draws into the model we may replicate the sampling variability of the model and hence the statistical distributions implied for our 'relationship facts'. It is this procedure that underlies our testing of the model against the facts. We derive a pure test of the model in this way.

Notice that the model may not fit the 'facts of correlation between variables'. This could be so even with a model estimated carefully on the data at a 'structural equation by equation' level; the reason for example could be that it is mis-specified in some way. As we know a mis-specified model may still fit at the equation level with the error term picking up the mis-specification.

Thus in summary the Popperian testing approach with bootstrap consists of four major steps:

First, one takes the estimated equation errors that the model implies and treats them as the stochastic shocks hitting the model. They will usually obey some stochastic process (usually autoregressive) which forms part of the model.

Second, the random elements in the shocks are then repeatedly resampled and used to generate model 'scenarios' or 'pseudo-samples'. The idea is that if the model is correct then the estimated shocks will also be the true shocks hitting the model; therefore one may ask what samples could have been produced in the period of estimation had the shocks been different but nevertheless drawn randomly from the same distribution. From this we have the actual sample shocks; if we repeatedly resample these ('bootstrapping') we obtain new samples from the same distribution. These samples, input into the model, generate new samples of the data, the pseudo-samples that together indicate a complete range of samples that could have occurred.

Third, we ask what these pseudo-samples (the world according to the model, as it were) imply for the possible range of relationships in the data. These relationships are often represented by the reduced form consists of either a single variable or a group of selected variables of interest. We take these relationships and estimate them on all the pseudo-samples to see what the sampling variability implies for their possible estimated values.

Fourth, we take the same relationship and estimate it on the actual sample. The statistical test asks whether the values estimated on the actual data lie within say the 95% limits from the range of estimates that the model implies should be found. Of course matters do not end there. If the model is rejected we have to decide on an alternative and test that in turn; if it is accepted we still must discover whether an alternative would also be accepted or whether it is rejected.

Thus the null defines the model, the structural 'error' data and restricts the reduced form in possible ways. We can then estimate the reduced form on the data and compare it with the bootstrapped predictions of the structural model. Our suggested test is thus designed to reject the null hypothesis of the model at some specified confidence level (say 95%). Under the null hypothesis the model stochastic error processes are defined within the sample period. We may then ask whether this model and these processes could have generated the facts as captured by the reduced form estimated over the same sample period. Thus under the null hypothesis, the sampling variation would be given by bootstraps of the stochastic errors with the model; these bootstraps would provide us with a large number of pseudo-samples on which we can estimate the same reduced form.

It is not our major concern here that the models should be estimated or calibrated to fit the data as closely as possible. Estimation and calibration of the model can only be the first stage of this Popperian approach, and as we will show we have used both estimation and parameter imposition at the structural testing level. Our testing procedure takes as a primary assertion that certain model is 'true' (or provisionally believed hypothesis). How this model is arrived at is not the key issue at the first stage. We then check whether the 'facts' can be explained by this model through bootstrapping – the second stage. In this new testing approach, instead of using the theoretical error distributions postulated by the model to compute the model's correlations with the facts, we suggest using the actual error distributions implied by the data to compute them, using the bootstrap. This allows us to derive small sample distributions, rather than rely on asymptotic ones which are inappropriate in general given the small size of economic data samples. Approaches such as Generalised Method of Moments (GMM) and Simulated Method of Moments (SMM) rely on asymptotic distributions which can cause a lot of bias (rejecting the null) in small samples.

Tests of this particular type are new; but experiments based on similar ideas are now becoming more common — see Minford, Theodoridis and Meenagh (2005) for a preliminary survey (a recent example applying the method to models of inflation persistence is Minford, Sofat, Nowell and Srinivasan (2006)). Thus as yet the results for the test here are preliminary. However, they are interesting precisely because, being new, they do challenge much of the normal process currently employed in empirical research. So we present them below in this spirit of challenge and to stimulate debate. Our view is that this test provides a statistical method for rejecting the null of a particular model, in the sense that it answers the question "could the facts of the economy have been produced by this model?"

5.4 Empirical Work – Incentivism: the Model with Business Tax Alone

We begin by considering a model in which business tax alone, out of the three we have identified, is operative. Later we consider the addition of the other taxes. In this model the production function error should be purged of all effects of business taxation since this is explicitly entered in the estimated equation. Hence the model attributes a causal role to business taxation in creating growth.

The procedure we follow to test the model we have set out is that of bootstrapping. The idea is that we treat the model – in the form of the two equations set out above – as the true or 'null' hypothesis. We estimate this model on the available post-war annual data, for 76 countries from 1970–2000. The resulting 2 structural errors for each country-period are thus the implied 'true errors' under the model. These errors and the tax rates have time-series properties which we assume differ country by country; we estimate a time-series process for each country error and tax process, which in turn implies a set of 4 random errors (structural and tax) for each country over the period 1970–2000. Our bootstrapping procedure is then to draw the whole vector of random errors as a 76-country bloc repeatedly with replacement for a 30-year sample period (we draw them as a vector to retain any patterns of simultaneous correlation); input them into the country time-series processes to generate a resulting set of 30-year errors; input these in turn into the model to generate a 30-year sample of data for the endogenous variables. Such a 30-year sample of data is one pseudo-sample. We generate 1000 of these pseudo-samples. The idea is that these 1000 pseudo-samples represent the sampling variation that would occur according to the model.

We then investigate whether data descriptions that would emerge from the model are rejected by the data. We do this by estimating the descriptive form on the actual data and also on the pseudo-samples; if the estimate generated on the actual data lie within the 95% confidence limits given by the pseudo-samples, then we say that the model is not rejected by the data and vice versa.

Algorithmically, our bootstrapping procedure involves 6 major steps: First we fit process to the two structural errors ζ_t and v_t in equations (5.6a) and (5.10a) as well as two exogenous tax variables τ_t and π_t (for activism this will be e_t and ρ_t) for each of the 76 countries as:

$\zeta_t = \alpha_1 \zeta_{t-1} + \alpha_2 \zeta_{t-2} + \varepsilon_t$

$v_t = \beta_1 v_{t-1} + \beta_2 v_{t-2} + k_t$

$\tau_t = \gamma_1 \tau_{t-1} + \gamma_2 \tau_{t-2} + m_t$

$\pi_t = \lambda_1 \pi_{t-1} + \lambda_2 \pi_{t-2} + n_t$ (for activism this will be e_t and ρ_t instead of π_t)

which in turn implies a set of random errors for each country over the period 1970-2000, then:

1. Add shocks to ε_{jt}, k_{jt} , m_{jt} and n_{jt} (j reprensents country, j = 1, 2……, 76);

2. Input them into the country time-series processes to generate a resulting set of 30-year errors ζ_{jt} and v_{jt} and two exogenous variables τ_{jt} and π_{jt} ;

3. Add v_{jt} in equation (5.10a) to generate $\ln(1\text{-}x_{jt})$, then add $\ln(1\text{-}x_{jt})$, ζ_{jt} , τ_{jt} and π_{jt} in equation (5.6a) to generate $\ln y_{jt}$;

4. Put all the countries into one vector per variable, and then put all results into a matrix which has each variable in the columns and pooled data for the countries in the rows;

5. Repeat steps 1-4 one thousand times to generate 1000 pseudo-samples, which represent the sampling variation that would occur according to the model;

6. Run the reduced form regression on the 1000 pseudo-data samples; the tails of the parameter distributions then gives 95% limits, then run the same regression on the actual data to see whether its parameters lie within those limits.

Therefore the two structural error terms as well as the two exogenous variable errors include the omitted effects of non-systematic factors implied by the data and model. The two equations constitute a 'structural model' in the sense that they jointly replicate the data country by country in a way entirely constrained by the model and its solution method; and that they can be solved to give the paths of labour supply and output.

Variables and data

The data for all the variables in the empirical work in this chapter is panel annual data for 76 countries, in contrast to the panel decadal data used in the previous chapter as a preliminary test.

1. Growth ($\Delta \ln y$, 1970~2000). Growth in real GDP per capita expressed in Purchasing Power Parities (PPP) from Penn World Table 6.1 (2002).
2. General tax (τ, 1970~2000). The general marginal tax rate which we take to be approximated by the average overall share of public spending in GDP from Penn World Table 6.1 (2002). We assume that citizens anticipate the tax effects of policies and react to the present value of taxation. Taxation here includes the 'inflation tax' if that is chosen by the authorities (i.e. they choose to print money as a financing mechanism). This general tax variable in our model not only enters the labour supply function, it is also a component of business tax that influences entrepreneurial activity.
3. Business tax ($\tau+\pi$, 1970~2000). Business tax is general tax plus particular imposts levied on business activities, and for the latter we use the index data compiled by the World Bank on the costs of doing business, which consists of the costs of starting and closing a business. The text of the Company Law, the Commercial Code, and specific regulations and fee schedules are used to calculate the costs of starting a business; while the costs of closing a business include court costs, as well as fees of insolvency practitioners, independent assessors, lawyers, accountants, etc.
4. Government subsidy to education (e, 1970~2000). This subsidy is approximated by government spending on education (primary, secondary, and tertiary) as the share of total GDP, from the World Bank Database (2003). As it is subsidy it is counted as negative tax rate and referred to as 'tax' symmetrically with the business tax (counted as negative value only for comparison purpose). We did attempt to get more appropriate data on direct subsidy by government to education, but annual international panel data on this variable seems to be a luxury.

5. Government subsidy to R&D (ρ, 1970~2000). We treat this subsidy exactly the same way as the subsidy to education: the negative value of the government expenditure on R&D as the percentage of total GDP, from UNESCO yearbook (1971-2001).
6. Infrastructure (*infra*, 1970~2000) is the negative indexed value (i.e. also counted as negative tax) of government spending on infrastructure (airports, electricity, telephones, and roads) as the share of total GDP, from the World Bank Database (2003).

The results for the model equations are as follows (with fixed country and time effects on each equation). We estimate equation (5.6a) as:

$\ln y_t = c^{\bullet} + 0.38\ln(1-x_t) - 0.017\sum_{i=1970}^{t}(\tau_i + \pi_i')$	Number of obs	= 2280
(0.085) (0.0015)	F(105, 2174)	= 869.93
	R-squared	= 0.9770
	Adj R-squared	= 0.9759
	Root MSE	= 0.1605

We estimate the structural labour supply equation, (5.10a) as:

$\ln(1-x_t) = c_2 + 0.0128\ln(1-\tau_t)$.	Number of obs	= 2280
(0.01)	F(103, 2024)	= 278.53
	R-squared	= 0.9308
	Adj R-squared	= 0.9275
	Root MSE	= 0.0442

The error term from this equation is a combination of labour supply preferences and the log of the consumption/income ratio.

Notice that the business tax term in the production function has the right sign and is highly significant, while the general tax rate in the labour supply function also has the right sign, though at a low level of significance. Hence we may say that this Incentivist theory is not rejected at the structural model level.

Bootstrapping this model as described above generates 1000 pseudo-samples. With it we then investigate a data description for growth. In it growth depends on the (general plus entrepreneurial) tax rate and the rate of change of the general tax rate (the latter because growth in output not caused by productivity depends of the growth in labour supply which in turn depends on the rate of change of the general tax rate).

5.4.1 Growth Rate and Taxation – Descriptions of Data with Model-Generated 95% Confidence Bands

We now turn to our test of this above model against the growth regressions. We proceed as follows. First we regress the data for growth on a set of potential regressors with a view to capturing the best (linear reduced form) description of the data. We consider four sets of regressors suggested by the theory: the level of the different special taxes; the rate of change of personal tax, $\Delta\tau_t$; country dummies; and time dummies.

In these growth regressions $\Delta\tau_t$ was insignificant though of the right sign. This term picks up the temporary effect on growth of the change in the personal tax rate (which affects labour supply); this effect however is very poorly determined, which is perhaps not surprising as it works through labour supply and we know from other work that labour supply effects depend on expected tax and other variables. Here we are unable to pick up expectations effects (which could introduce a lead or a lag in the tax variable).

Table 5.1: Regression of Growth on Business Tax and the Rate of Change of Personal Tax With Fixed Time and Country Effects

With fixed country and time effects				
$\Delta \ln y_t = a_1(\tau_t + \pi_t') + a_2\Delta\tau_t$			Number of obs	= 1748
			F(100,1648)	= 3.87
	Actual	'Reduced form' standard errors	R^2	= 0.1903
a_1	-0.043	0.027	Adj. R^2	= 0.1411
a_2	-0.039	0.043	Root MSE	= 0.0506

We therefore decided to look also at an equation with solely the business tax effect whose level should directly determine growth on a permanent basis; we would expect this effect to come through powerfully in the data description and indeed it seems to do so.

The resulting equation is:

Table 5.2: Regression of Growth on Business Tax with Fixed Time and Country effects

With fixed country and time effects				
$\Delta \ln y_t = a_1(\tau_t + \pi_t')$			Number of obs	= 1748
			F(99,1648)	= 3.90
	Actual	'Reduced form' standard errors	R^2	= 0.1899
a_1	-0.050	0.026	Adj. R^2	= 0.1412
			Root MSE	= 0.0506

Using panel data with fixed effects may not be the most efficient model to run. Estimating the model with random effects will give a more efficient estimator (the reason for this is that the estimator saves degrees of freedom by not using the fixed country dummies but instead using the regression with fixed country dummies with a weight, to correct the regression with time dummies only). The results for the random effects estimator are shown in Table 5.3.

Table 5.3: Regression of Growth on Business Tax with Random Effects

With random effects			Number of obs	= 1748
$\Delta \ln y_t = a_1(\tau_t + \pi'_t)$			Wald $\chi^2(1)$	= 9.91
	Actual	'Reduced form' standard errors	R^2 within	= 0.0035
a_1	-0.043	0.014	R^2 between	= 0.0615
			R^2 overall	= 0.0088

To test whether we should use the fixed or random effects model we run a Hausman test, the results from this test are shown in Table 5.4.

Table 5.4: Hausman Test

$\Delta \ln y_t = a_1(\tau_t + \pi'_t)$	Fixed	Random	Difference	Standard error	$\chi^2(1)$	P-value
a_1	-0.050	-0.043	-0.007	0.022	0.10	0.751

From Table 5.4 we find that we can use either fixed or random effects in the actual data sample without serious risk of inconsistency. However it can be seen that the fixed effects regression, which we can be sure is free of inconsistency, gives effects essentially no different from the random effects regression.

We now turn to the bootstrapping exercise where we wish to establish the sampling distributions of the growth regression coefficients according to our model. For this exercise it is essential that the estimator used is consistent in all the potential data samples; otherwise the distribution of 'potentially estimated' coefficients will be wrongly measured. Hence in what follows we use the fixed effects estimator throughout the bootstrapping process, since it is known definitely to be consistent in all samples; thus each sample estimate will give us a 'central' value for the coefficients.

We now report how our chosen growth regression – with the business tax rate only – compares with our basic model. We take the growth regression and run it on our bootstrap data for each model. As noted earlier, this allows us to find the 95% confidence interval implied by the model. In addition it gives the overall 'M-metric', that is the percentile in the bootstrap distribution of all parameters[13] jointly where the actual data regression lies; the higher the percentile, the further into the tail the actual regression lies. As it happens, in this case with only one parameter of interest the M-metric is directly related to the distribution of this one parameter.

Table 5.5: Bootstrap Results for Model with Estimated Tax Effects

$\Delta \ln y_t = a_1(\tau_t + \pi_t')$ with fixed country and time effects

95% interval for basic model	Actual	Lower	Upper	M-metric
a_1	-0.050	-0.05680	0.0112	90.4%

[13] In assessing whether the model is rejected or not we need to use the joint distribution of all the parameters in the description. The 95% confidence intervals shown by each parameter apply to that parameter taken on its own, that is holding the other parameters as given by their estimated values. For the model as a whole the question is whether the joint values of the estimated parameters lie within the '95% contour' of the joint distribution. The idea here is that the model generates a joint distribution of the descriptive ('reduced form') parameters around the mean of the bootstrap distribution. This is assumed to be symmetric and the Mahalanobis distance of each parameter combination from the bootstrap mean is computed. The bootstrap distribution over this distance value – the 'M-metric' – can be used to compute their percentile values. The model as a whole is then rejected if the actual M-metric estimated on the data exceeds say the 95th percentile, this being the 95th percentile 'contour line' on the joint distribution. Clearly such a rejection is related somehow to the rejection on the parameters individually; however, this relationship depends on the covariance matrix of these parameters which is a crucial ingredient of the joint distribution. Thus there is no simple link from the individual rejections to the overall rejection of the model.

What we see is that the model is accepted at the 95% level. This is itself of some interest. However, we do not know whether the data will also accept other models that contradict our model. To assess this we create an alternative model of this sort: in this we set the tax coefficients to zero. Thus the alternative model asserts that taxes have no effect; the only identified effects are of labour in the production function, the rest is the effect of country and time dummies. The model is re-estimated in this way and new error terms extracted and bootstrapped in just the same way as for the principal model. We obtain new bootstrap distributions for the data descriptive equation as follows:

Alternative (no-tax-effect) model

Table 5.6: Bootstrap Results for Model with Zero Business Tax Effect

Coefficient on Business Tax Set to 0

$\Delta \ln y_t = a_1(\tau_t + \pi_t')$ with fixed country and time effects				
	Actual	Lower	Upper	M-metric
a_1	-0.0500	-0.0485	0.0241	96%

We see that this alternative model is rejected, with an M-metric of 96%. Thus our model is accepted by the data at the 95% level, whereas the alternative model with no tax effect is rejected.

So far we have tested the basic model from the zero side, so to speak – to see whether it dominates a no-tax-effect model. It is also of interest to test it from the other side: to see whether a business tax effect higher than freely estimated would satisfy the data description. So we also re-estimated the model imposing an increased coefficient on business tax and retrieving the implied new errors. We used two cases, one in which we set the coefficient to -0.02 and another in which we set the coefficient to -0.04. The results for the -0.02 case are shown in Table 5.7 and the -0.04 case in Table 5.8.

Table 5.7: Bootstrap Results for Model with Tax Effects and Coefficient on Business Tax set to -0.02

Coefficient on Business Tax Set to -0.02

$\Delta \ln y_t = a_1(\tau_t + \pi'_t)$ with fixed country and time effects				
	Actual	Lower	Upper	M-metric
a_1	-0.050	-0.0580	0.0083	87.2%

Table 5.8: Bootstrap Results for Model with Tax Effects and Coefficient on Business Tax set to -0.04

Coefficient on Business Tax Set to -0.04

$\Delta \ln y_t = a_1(\tau_t + \pi'_t)$ with fixed country and time effects				
	Actual	Lower	Upper	M-metric
a_1	-0.0500	-0.0729	-0.0034	47.5%

What is interesting about this is that there is an improvement in the model's performance vis-a-vis the data description as the model's business tax effect is raised. Thus if it is raised in absolute size by two standard errors to -0.02 (from the estimated -0.017) the M-metric falls from 90.4% to 87.2%. This parameter imposition on the production function is not rejected by the F-test (3.06); hence we can happily accept the higher effect from both the structural and the simulation viewpoints.

The improvement in the simulation test continues from here on up. If the parameter is raised further to -0.04 the M-metric improves to 47.5%. However of course this higher coefficient is massively outside the two standard error range on the production function estimate; thus it fails to fit the structural model quite badly (the F-test value is a massive 225). Hence the data estimation of the model itself combined with the data description tells us that a business tax parameter of around -0.02 is the most compatible with the data.[14]

5.4.2 A Discussion of the Empirical Results on the Incentivist Model (Business Tax Rate Alone)

We may start by discussing the 'conventional' way of testing the model using the standard reduced form approach. Thus we note that the model implication – viz that the level of business tax and the rate of change of general tax both affect growth – meets a mixed reception. The business tax effect alone is fairly significant against the usual zero alternative; the general tax effect is not. We concluded from this that the data description should not include the general tax effect as it does not contribute to explaining growth. We might also have concluded that there was reduced form evidence

[14] If we use the general data description with both variables entered, the distribution is not so tightly defined. We obtain:

$\Delta \ln y_t = a_1(\tau_t + \pi_t') + a_2\Delta\tau_t$ with fixed country and time effects

and

$\Delta \ln y_t = a_1(\tau_t + \pi_t') + a_2\Delta\tau_t$ with fixed country and time effects

Here we see that neither model is rejected. But if we compare the no-tax-effect model with the basic model we see that its M-metric at 73.5% lies well above the 62.5% of the basic model. We can interpret this as a measure of relative likelihood of each model, conditional on the data. That is, the data regression is closer to the most likely parameter combination according to our model than according to the alternative model. If we could assume a particular likelihood distribution --- e.g. multi-variate normal --- then we could translate the M-metrics into exact likelihoods.

We also find that the model with the higher business tax effect (of -0.02) performs better than the one with the estimated tax effect, just as in the case focused on in the text. Hence if we were to use this data description, we would get essentially the same results if we were to set the confidence level higher, at say 65%. We would reject the no-tax-effect model and accept the two tax-effect ones, with the likely tax effect lying somewhere between the two. If we maintain the 95% confidence level it still remains the case that this is the likely tax effect range.

$\Delta \ln y_t = a_1(\tau_t + \pi_t') + a_2\Delta\tau_t$ with fixed country and time effects of a business tax effect. However as we have argued above this is not a persuasive test for two reasons. First, the error terms in the reduced form will include omitted nonlinear effects of tax on growth that can bias the reduced form coefficient. Second, other models in which tax plays no part could also generate this reduced form result.

So we reviewed next the evidence from the bootstrapping method, where instead of the confidence intervals generated by the 'reduced form' we look at those produced by bootstrapping the structural model. We found here that the model was accepted by the data description and furthermore that an alternative model with no tax effects was rejected by it and thus also dominated in likelihood by our model. In fact a model with a higher business tax coefficient of -0.02 is also accepted and with a lower M-metric by the growth regression (and still compatible with the production function as checked by an F-test).

What is also striking is the insight afforded by the bootstrapping procedure into the biases in the linear reduced form coefficients under the null hypothesis. Thus we suggest from the combination of the structural estimates and from simulating the model for a shock to the business tax rate that growth (in steady state) increases by some 0.2% for every 0.1 (i.e. 10 percentage point) fall in the business tax rate under the model. However the reduced form coefficients give a value for this business tax effect that is up to two and a half times as big. This indicates a possible bias in these linear reduced form coefficients; these values bear little relation to what the model would produce as the simulated effect. The model when bootstrapped reveals that the correlation of the tax shocks with the errors creates massive bias in the 'reduced form' estimates. To put it in concrete terms, for example when the business tax rate is cut this causes a rise in consumption and labour supply as well as in productivity growth; the former two create an independent source of output increase over and above the steady state increase; this association raises the estimated effect of a business tax cut on growth.

A further point of interest is that there is some tension between what the structural model will tolerate in estimation and what gives the best results when simulated results are compared with the linear reduced form. The simulated method of moments would give all the weight to the latter comparison; here we treat the structural estimation results as a separate Popperian hurdle or source of potential rejection, on a par with the growth regressions hurdle. The results here suggest that we were unable to change the structural coefficients on the business tax upwards beyond a certain point, even though the 'reduced form' results would have been better fitted by a large business tax coefficient, ceteris paribus. What we found was that the data forced the structural model errors to offset the effect of raising the business tax coefficient beyond a certain point. Had we kept the freedom to 'make up' the structural errors we would have been able to fit the 'reduced form' results easily. But because we forced the structural model to fit the data through the implied errors used in the bootstrapping, the fitting of the 'reduced form' was constrained. It is as if our results can only emerge satisfactorily if they can go through two mincers, each of a different shape; a structural mincer and a 'reduced form' mincer; only if the model can force its way through both are its results to be believed.

5.5 Empirical Work – Activism: Adding Other Potential Sources of Growth

From here on we expand the model to include, besides or instead of the business tax, tax/subsidies to education and R&D. Each of these we think of as constructed of the general tax rate and the direct tax or (usually) subsidy on this element. We measure the subsidy to education as the share of GDP spent by government on education at all levels; that to R&D by the government expenditure on R&D as a percentage of total

GDP. As these are subsidies they are counted as negative tax rates and referred to as 'taxes' symmetrically with business taxes; hence the sign of their effect in our regressions should be negative. Our procedure is the same as before except that now we replace the (cumulant of the) business tax rate in the production function with the cumulant of these other tax rates. As our estimate of the effect of these direct tax rates we use the freely estimated coefficient on each entered on its own with the general tax rate; the only exception is education discussed below. In the growth regressions we enter the general tax rate and the direct tax/subsidy separately, to allow the effect of the direct element to be freely determined.

5.5.1 The Education Tax/Subsidy

We obtain a nonsensical positive and significant effect of the cumulated education tax rate in the production function when we allow it to be freely estimated, with the cumulated business tax rate (and insignificant education tax effect without the cumulated business tax rate). Hence the presence of an education tax/subsidy effect is rejected at the structural level.

(a) without business tax

$\ln y_t = c\bullet + \underset{(0.081)}{0.792}\ln(1-x_t) + \underset{(0.005)}{0.011}\sum_{i=1970}^{t}\tau_i +$	Number of obs	= 2280
	F(107, 2172)	= 814.09
	R-squared	= 0.9757
$\underset{(0.032)}{0.002}\sum_{i=1970}^{t}e_i^t$	Adj R-squared	= 0.9745
	Root MSE	= 0.1651

(b) with business tax

$\ln y_t = c\bullet + 0.38\ln(1\text{-}x_t) - 0.019\sum_{i=1970}^{t}(\tau_i + \pi_i') +$ (0.085) (0.0015) $0.024\sum_{i=1970}^{t}\tau_i + 0.055\sum_{i=1970}^{t}e_i'$ (0.0049) (0.0313)	Number of obs = 2280 F(108, 2171) = 864.07 R-squared = 0.9773 Adj R-squared = 0.9761 Root MSE = 0.1596

However, for completeness we did go on to consider whether the education tax could have a marginal effect at some (imposed calibrated) level in the growth regressions test. So our procedure was to impose on the production function the same coefficient as for the business tax rate: -0.02. The table below shows that the education tax cannot predict any of the growth regressions, either on its own or when combined with the business tax.

The table can be understood as follows. In the first Table we show the model with the education tax/subsidy alone. Then the table shows the relevant growth regressions in the actual data in the first line of each pair, with the standard errors of the coefficients in brackets. In the second line of each pair we show the 95% confidence limits of the same coefficients derived from running the same regression on the bootstrapped data from the model; the final column shows the M-Metric which indicates what level of confidence we would need to accept the model overall. In the second Table we show the equivalent for the model with both education and business tax operative.

Table 5.9: Bootstrap Results for Model with Education Tax

$\Delta \ln y_t = \alpha_0(\tau_t + \pi_t') + \alpha_1 \tau_t + \alpha_2 e_t'$ +country/time dummies (stand errors) – Model has education tax alone				
	$\tau_t + \pi_t'$	τ_t	e_t'	M-metric
Growth regression		-0.0329(0.0270)	0.3934(0.1663)	100%
Bootstrap 95% limits		-0.0621,0.0101	-0.1873,0.1673	

Table 5.10: Bootstrap Results for Model with Education Tax and Business Tax

$\Delta \ln y_t = \alpha_0(\tau_t + \pi_t') + \alpha_1 \tau_t + \alpha_2 e_t'$ +country/time dummies (stand errors) – Model has education tax with bus. tax				
	$\tau_t + \pi_t'$	τ_t	e_t'	M-metric
Growth regression	-0.0481(0.0105)	0.0152(0.0294)	0.3934(0.1663)	100%
Bootstrap 95% limits	-0.0302,0.0003	-0.0529,0.0134	-0.1490,0.1543	

Hence we can say that any role for the education tax in the model is strongly rejected at both the structural and the growth regression levels. We therefore eliminate the education tax/subsidy from any further consideration.

5.5.2 Government Subsidy to R&D:

When we turn to the Government R&D tax/subsidy (GOVRD) we find a different picture. This (cumulated) is now significant and of the right sign at the structural level. The coefficient is -0.003 with a standard error of 0.001 on its own though when entered with the cumulated business tax it drops to insignificance. Thus at the structural level it is rejected if we assume that the business tax rate is operating. We would only accept it if we could reject the business tax rate in favour of the R&D model alone. We proceed to test the R&D model on the growth regressions.

Table of structural equation with GOVRD on its own and with bus tax.

(a) without business tax

$\ln y_t = c\bullet + 0.768\ln(1-x_t) + 0.009\sum_{i=1970}^{t}\tau_i -$ (0.081) (0.004) $0.003\sum_{i=1970}^{t}\rho_i'$ (0.001)	Number of obs F(107, 2172) R-squared Adj R-squared Root MSE	= 2280 = 815.71 = 0.9757 = 0.9745 = 0.1649

(b) with business tax

$\ln y_t = c\bullet + 0.36\ln(1-x_t) - 0.019\sum_{i=1970}^{t}(\tau_i + \pi_i') +$ (0.085) (0.0016) $0.019\sum_{i=1970}^{t}\tau_i + 0.0005\sum_{i=1970}^{t}\rho_i'$ (0.0039) (0.0013)	Number of obs F(108, 2171) R-squared Adj R-squared Root MSE	= 2280 = 862.9 = 0.9772 = 0.9761 = 0.1597

If we now test the Government R&D Model on the growth regressions we find that it is rejected. The Table below shows first the Model with the R&D tax/subsidy on its own, and it is rejected by the growth regression. Secondly we show the Model with both tax rates; again it is rejected by the growth regression with both.

Table 5.11: Coefficient on GOVRD -0.003(structural production function estimate)

$\Delta \ln y_t = \alpha_0(\tau_t + \pi_t') + \alpha_1\tau_t + \alpha_2\rho_t'$ +country/time dummies (stand errors) – Model has R&D tax alone

	$\tau_t + \pi_t'$	τ_t	ρ_t'	M-metric
Growth regression		-0.0674(0.0270)	-0.0269(0.0110)	100%
Bootstrap 95% limits		-0.0626, 0.0002	-0.0144, 0.0058	

Table 5.12: Coefficient on GOVRD -0.003(structural production function estimate)

$\Delta \ln y_t = \alpha_0(\tau_t + \pi_t') + \alpha_1 \tau_t + \alpha_2 \rho_t'$ +country/time dummies (stand errors) – Model has R&D tax with bus.tax

	$\tau_t + \pi_t'$	τ_t	ρ_t'	M-metric
Growth regression	-0.0025(0.0126)	-0.0649(0.0312)	-0.0269(0.0110)	99.9%
Bootstrap 95% limits	-0.0312,-0.0018	-0.0525, 0.0063	-0.0113, 0.0074	

These results indicate that the R&D tax/subsidy is rejected on the growth regressions whether business tax is included in the structural model or not and also whether or not it is included in the growth regression. However notice that in the growth regression the negative coefficient on R&D is higher in absolute value than the bootstrap range, indicating that a structural coefficient that is more negative would do better. Accordingly we subtracted two standard errors from the -0.003 estimated and reran the bootstraps; the results are shown in the next table.

Table 5.13: Coefficient on GOVRD changed to -0.005

$\Delta \ln y_t = \alpha_0(\tau_t + \pi_t') + \alpha_1 \tau_t + \alpha_2 \rho_t'$ +country/time dummies (stand errors) – Model has R&D tax alone

	$\tau_t + \pi_t'$	τ_t	ρ_t'	M-metric
Growth regression		-0.0674(0.0270)	-0.0269(0.0110)	99.8%
Bootstrap 95% limits		-0.0649, 0.0051	-0.0171, 0.0050	

Table 5.14: Coefficient on GOVRD changed to -0.005

$\Delta \ln y_t = \alpha_0(\tau_t + \pi_t') + \alpha_1 \tau_t + \alpha_2 \rho_t'$ +country/time dummies (stand errors) – Model has R&D tax with bus.tax

	$\tau_t + \pi_t'$	τ_t	ρ_t'	M-metric
Growth regression	-0.0025(0.0126)	-0.0649(0.0312)	-0.0269(0.0110)	100%
Bootstrap 95% limits	-0.0302,-0.0015	-0.0538, 0.0078	-0.0126, 0.0049	

What we see in this Table is that the GOVRD coefficient of -0.005 still fails to match up with the growth regression. We found that it needed to be put at -0.017 before the structural model with R&D would be accepted (Table following). This is fourteen standard errors above the estimated coefficient and the F-test on this in the structural equation is 122, implying massive rejection.

Table 5.15: Coefficient on GOVRD changed to -0.017

$\Delta \ln y_t = \alpha_0(\tau_t + \pi_t') + \alpha_1 \tau_t + \alpha_2 \rho_t'$ +country/time dummies (stand errors) – Model has R&D tax alone

	$\tau_t + \pi_t'$	τ_t	ρ_t'	M-metric
Growth regression		-0.0674(0.0270)	-0.0269(0.0110)	97.8%
Bootstrap 95% limits		-0.0612, 0.0071	-0.0280, -0.0081	

What this evidence is telling us is that the government share of R&D does have a moderate effect on output in the production function estimate when business tax is not included but that this coefficient cannot explain the growth regressions with this factor in it, with or without business tax. These growth regressions show a much larger effect of this GOVRD factor than can be explained by the only model with this factor accepted at the structural stage, viz one with the GOVRD factor on its own. Thus this model must be rejected. This implies that the apparent role of the GOVRD factor in the growth regression is the result of some other causal factor than the GOVRD factor itself – i.e. it is spurious.

For completeness we finally consider whether the infrastructure tax (*infra*) could have some effects on growth. At the structural level, the cumulated *infra* is significant and of the right sign. The coefficient is -0.16 with a standard error of 0.0167 on its own and when entered with the cumulated business tax it remains significant. Thus at the structural level it is not rejected.

Table of structural equation with *infra* on its own and with bus tax.

(a) without business tax

$\ln y_t = c\bullet + 0.298\ln(1\text{-}x_t) - 0.0019\sum_{i=1970}^{t}\tau_i -$ (0.094) (0.0039) $0.16\sum_{i=1970}^{t} infra_i$ (0.0167)	Number of obs = 2280 F(107, 2172) = 849.64 R-squared = 0.9767 Adj R-squared = 0.9755 Root MSE = 0.1617

(b) with business tax

$\ln y_t = c\bullet + 0.216\ln(1\text{-}x_t) - 0.015\sum_{i=1970}^{t}(\tau_i + \pi_i') +$ (0.092) (0.0018) $0.011\sum_{i=1970}^{t}\tau_i - 0.075\sum_{i=1970}^{t} infra_i$ (0.004) (0.0194)	Number of obs = 2280 F(108, 2171) = 868.99 R-squared = 0.9774 Adj R-squared = 0.9763 Root MSE = 0.1592

If we now test the infrastructure tax model on the growth regressions we find it has a wrong sign, also it is rejected when entered with the business tax. The Table below shows first the model with the infrastructure tax/subsidy on its own and second the model with both tax rates, and it is rejected by the latter. The full bootstrap results for various growth specifications are shown in Appendix 5B.

Table 5.16: Coefficient on *infra* -0.16(structural production function estimate)

$\Delta \ln y_t = \alpha_0(\tau_t + \pi_t') + \alpha_1\tau_t + \alpha_2 infra_t$ +country/time dummies (stand errors) – Model has infrastructure tax alone

	$\tau_t + \pi_t'$	τ_t	$infra_t$	M-metric
Growth regression		-0.0510(0.0262)	0.1436(0.3331)	92.8%
Bootstrap 95% limits		-0.0525, 0.0086	-0.6067, 0.2752	

Table 5.17: Coefficient on *infra* -0.16(structural production function estimate)

$\Delta \ln y_t = \alpha_0(\tau_t + \pi_t') + \alpha_1 \tau_t + \alpha_2 infra_t$ +country/time dummies (stand errors) – Model has infrastructure tax with bus.tax				
	$\tau_t + \pi_t'$	τ_t	$infra_t$	M-metric
Growth regression	-0.0514(0.0229)	0.0004(0.0334)	0.1436(0.3331)	98.2%
Bootstrap 95% limits	-0.0412, 0.0111	-0.0524, 0.0163	-0.4337, 0.3283	

5.6 Discussion of the Empirical Results

The theory we are investigating is in terms of the level of output, labour supply and productivity. These levels depend on the history of people's diversion of effort into productivity-raising activities. In the Incentivist Barriers to Riches theory people's incentive to do this depends on the barriers erected to it in the form of taxes and regulations. In the Activist theory people's incentive to acquire education and do R&D depends on direct government encouragement of these activities. To test the two theories on our panel data we have first estimated a production function whose productivity level depends on the accumulated history of these factors; also a labour supply function of an ordinary sort from the households' first order condition. At this structural stage we are mirroring Parente and Prescott's emphasis on the need for the theory to explain the level of living standards. This first 'structural-stage' test is then complemented by the test on growth regressions – the second stage. Each theory implies that the growth regression should include only factors it identifies.

Our findings are that the model with only tax variables both fits at the structural level and predicts the parameters of the implied growth on tax variables. Plainly growth regressions can be done on other variables; but according to this theory any correlations with such variables is spurious, i.e. the result of reverse or joint causation – that is, the tax causal mechanism of growth also causes these other variables' movement either directly or via some link from growth to them. However this is not in this model but in some extended model. Thus for example we find that there is a partial correlation between growth and GOVRD, in addition to the one with business tax. According to the Incentivist model this is spurious.

When we turned to the Activist model focused on the government subsidy to R&D, we find that it fits at the structural stage. However, the growth regression it implies has a rather weak partial correlation with GOVRD which is inconsistent with the much stronger one in the data. Thus this model is rejected at the second stage; by implication the strong partial correlation with growth is spurious, in terms of the only model (the Incentivist) that survives both test stages.

How could this partial correlation come about in practice? It may well be that when growth is rapid it induces governments to participate directly in the process by paying for R&D – in defence or strategic industries for example. Perhaps it sees opportunities for more tax revenue; or the politicians involved see opportunities for personal gain. There are many possible avenues in political economy for such processes.

Another way of looking at the matter is that the true relationship is in levels; differences of accumulated government GOVRD for example should show up in differences in living standards. If they do not, because there is no effect, then it is nevertheless possible for a relationship to show up in the growth rate of living standards and the levels of government R&D, should there be some process that causes growth to affect the latter. Of course this has nothing to do with the model. This echoes the point emphasised by Parente and Prescott that a theory must explain the difference of living standards as well as the difference of growth rates. Our double-stage test should check out this capacity of the theory. Where a theory fails, it should reveal the existence of a spurious relationship coming from outside the causal model driving growth and living standards.

Appendix 5A: the non-stationarity of {ln c_t – ln y_t}

Start with the household budget constraint after substituting out tax and transfer terms via the government budget constraint and wage and dividends from the firm's first order conditions; this is line 4 of footnote 12:

$$c_t + k_{t+1} - (1-\delta)k_t + b_{t+1} = y_t + (1+r_t)b_t \qquad \text{(A1)}$$

In expectational form the household's consumption plan must satisfy this constraint as follows after an infinite forward recursion in the value of future bonds:

$$(1+r_t)b_t = c_t - y'_t + E_t\sum_{i=0}^{\infty}\left\{\left[\prod_{j=1}^{i}(1+r_{t+j})\right]^{-1}(c_{t+i} - y'_{t+i})\right\} \qquad \text{(A2)}$$

where $y'_t = y_t - [k_{t+1} - (1-\delta)k_t]$

Now note that from the household's first order condition

$$E_t\left[\prod_{j=1}^{i}(1+r_{t+j})\right]^{-1} c_{t+i} = \beta^i c_t \text{ since for example } c_t = \frac{1}{\beta}E_t\frac{c_{t+1}}{1+r_{t+1}} = \frac{1}{\beta^2}E_t\frac{c_{t+2}}{(1+r_{t+1})(1+r_{t+2})}$$

(A3)

It follows that

$$c_t = (1-\beta)\left\{(1+r_t)b_t + y'_t + E_t\sum_{i=0}^{\infty}\left\{\left[\prod_{j=1}^{i}(1+r_{t+j})\right]^{-1} y'_{t+i}\right\}\right\} \qquad \text{(A4)}$$

The term inside the braces is the household's spendable wealth hence the whole RHS expression is permanent net income or

$$c_t = (1-\beta)(1+r_t)b_t + \overline{y}'_t \qquad \text{(A5)}$$

In steady state (at T) we have (where g is the growth rate)

$$c_T = (1-\beta)\left\{(1+r^*)b_T + \sum_{i=0}^{\infty}\left(\frac{1+g}{1+r^*}\right)^i\left(1+\frac{\gamma\delta}{r^*+c}\right)y_T\right\} = (1-\beta)(1+r^*)\left\{b_T + \frac{1}{r^*-g}\left(1+\frac{\gamma\delta}{r^*+c}\right)y_T\right\}$$

$$= (1-\beta)(1+r^*)b_T + \overline{y}_T' \qquad \text{(A6)}$$

in which all of c_T, b_T , y_T will be growing at g.

Now consider the movement of $\frac{c_t}{y_t}$ which from (A5) is:

$$\frac{c_t}{y_t} = (1-\beta)(1+r_t)\frac{b_t}{y_t} + \frac{\overline{y}_t'}{y_t} \qquad \text{(A7)}$$

Hence using the approximation that $\ln(x+y) = \frac{x}{x+y}\ln x + \frac{y}{x+y}\ln y$

$$\ln c_t - \ln y_t = (\text{share of net income from abroad})\ln\frac{b_t}{y_t} + \ln\frac{\overline{y}_t'}{y_t} \qquad \text{(A8)}$$

From the balance of payments (footnote 12)

$$\frac{b_{t+1}}{y_{t+1}}\frac{y_{t+1}}{y_t} - \frac{b_t}{y_t} = r_t\frac{b_t}{y_t} - \frac{m_t}{y_t} \qquad \text{(A9)}$$

or

$$\frac{b_{t+1}}{y_{t+1}} - \frac{b_t}{y_t} = (r_t - g_t)\frac{b_t}{y_t} - \frac{m_t}{y_t}$$

We know that in steady state $\frac{b_t}{y_t}$ will tend to some steady level because of household behaviour. However until this has occurred it is driven by a difference equation of the form:

$$x_{t+1} = (1 + q_t)x_t + \xi_t \qquad \text{(A10)}$$

where $q_t = r_t - g_t$ will vary from positive to negative and $\xi_t = -\, m_t / y_t$ will move randomly between steady states. Plainly $x_t = b_t / y_t$ will for at least some of the periods between steady states will be a randomly disturbed explosive (or unit root) difference equation and will therefore be non-stationary (in other words it will end up at a new steady state randomly different from its initial value). So therefore will (ln c_t – ln y_t) which contains its log.

In summary, consumption in steady state equals home income (y) plus net income from abroad (NIA). NIA depends on accumulated foreign assets (which in turn are equal to accumulated net exports and past NIA as given by equation A9). To put it in concrete terms, imagine for example a temporary shock to the economy which lowers income for just one period. Consumers will smooth consumption so that net exports fall (i.e. they use imports to supplement the lower home output) and therefore net foreign assets will also fall. Next period income goes back to normal, but now since NIA is lower consumption is permanently slightly lower. Hence the ratio of c/y falls.

The point can be put another way. Imagine $c_t = y_t + \alpha w_t$ where net foreign assets $w_t = \sum_{i=0}^{\infty} \varepsilon_{t-i}$ is the accumulation of shocks to the current account. Therefore $c_t - y_t = \alpha w_t$. By construction $\Delta w_t = \varepsilon_t$ is a random walk. It is true that at time 0, $E[c_t - y_t - \alpha w_0] = 0$, i.e. all expected future shocks are zero, so that expected future c/y ratio is the same as at time 0. But w_0, current net foreign assets, continue to have an effect on the ratio for ever. This is because consumers spend their permanent income which is equal to GDP plus interest on net foreign assets. (The best forecast of a random walk is the current value). Once you have accumulated a certain amount of net foreign assets, you do not expect to run it down but rather to spend the interest from it; this is the optimum strategy in infinite time. But each period a shock will change your net foreign assets and this will change your interest income.

Appendix 5B: Full Bootstrap Results for Different Specifications

dln $y_t = a_1 t + a_2 bus + a_3 edu + a_4$GOVRD + a_5 *infra* with fixed country and time effects

	t	*bus*	*edu*	GOVRD	*infra*	M-metric
Bootstrap 1		-0.050(0.026) -0.0580, 0.0083 IN				87.2%
Bootstrap 2	-0.0329(0.0270) -0.0621, 0.0101 IN		0.3934(0.1663) -0.1873, 0.1673 OUT			100%
Bootstrap 3	-0.0674(0.0270) -0.0626, 0.0002 OUT			-0.0269(0.0110) -0.0144, 0.0058 OUT		100%
Bootstrap 4	-0.0510(0.0262) -0.0525, 0.0086 IN				0.1436(0.3331) -0.6067, 0.2752 IN	92.8%
Bootstrap 5	0.0152(0.0294) -0.0529, 0.0134 OUT	-0.0481(0.0105) -0.0302, 0.0003 OUT	0.3934(0.1663) -0.1490, 0.1543 OUT			100%
Bootstrap 6	-0.0649(0.0312) -0.0525, 0.0063 OUT	-0.0025(0.0126) -0.0312,-0.0018 IN		-0.0269(0.0110) -0.0113, 0.0074 OUT		99.9%
Bootstrap 7	0.0004(0.0334) -0.0524, 0.0163 IN	-0.0514(0.0229) -0.0412, 0.0111 OUT			0.1436(0.3331) -0.4337, 0.3283 IN	98.2%
Bootstrap 8	-0.0502(0.0277) -0.0622, 0.0037 IN		0.4254(0.1664) -0.1702, 0.1523 OUT	-0.0290(0.0110) -0.0116, 0.0078 OUT		100%
Bootstrap 9	-0.0339(0.0271) -0.0578, 0.0074 IN		0.3976(0.1665) -0.1562, 0.1420 OUT		0.1809(0.3329) -0.4586, 0.3954 IN	99.9%
Bootstrap 10	-0.0682(0.0270) -0.0571, 0.0050 OUT			-0.0269(0.0110) -0.0117, 0.0067 OUT	0.1333(0.3326) -0.4600, 0.3066 IN	100%
Bootstrap 11	-0.0366(0.0331) -0.0534, 0.0092 IN	-0.0136(0.0133) -0.0269, 0.0019 IN	0.4254(0.1664) -0.1421, 0.1446 OUT	-0.0290(0.0110) -0.0092, 0.0069 OUT		100%
Bootstrap 12	0.0255(0.0349) -0.0516, 0.0210 OUT	-0.0594(0.0231) -0.0392, 0.0105 OUT	0.3976(0.1665) -0.1307, 0.1549 OUT		0.1809(0.3329) -0.4080, 0.3476 IN	100%
Bootstrap 13	-0.0548(0.0402) -0.0546, 0.0136 OUT	-0.0134(0.0301) -0.0357, 0.0132 IN		-0.0269(0.0110) -0.0088, 0.0064 OUT	0.1333(0.3326) -0.4307, 0.3303 IN	99.9%
Bootstrap 14	-0.0511(0.0278) -0.0565, 0.0055 IN		0.4294(0.1666) -0.1424, 0.1522 OUT	-0.0289(0.0110) -0.0101, 0.0079 OUT	0.1729(0.3324) -0.4034, 0.3618 IN	100%
Bootstrap 15	-0.0232(0.0420) -0.0398, 0.0247 IN	-0.0279(0.0306) -0.0338, 0.0119 IN	0.4294(0.1666) -0.1208, 0.1418 OUT	-0.0289(0.0110) -0.0078, 0.0059 OUT	0.1729(0.3324) -0.3849, 0.3001 IN	100%
Bootstrap 16	-0.0232(0.0420) -0.0483, 0.0181 IN	-0.0279(0.0306) -0.0534,-0.0082 IN	0.4294(0.1666) -0.1389, 0.1306 OUT	-0.0289(0.0110) -0.0084, 0.0046 OUT	0.1729(0.3324) -0.4742, 0.1934 IN	100%

Note: 1) Besides the estimated coefficients are their standard errors in parentheses, and underneath them are bootstrap limits.

2) Weight of 1 on general tax for all 16 bootstraps

3) Bootstraps 1~4: weight of 1 on each one alone of the four remaining taxes, and weight of zero on the other three.

4) Bootstraps 5~10: weight of 0.5 on each two alone of the four remaining taxes, and weight of zero on the other two.

5) Bootstraps 11~14: weight of 0.33 on each three alone of the four remaining taxes, and weight of zero on the other one.

6) Bootstraps 15: weight of 0.25 on each of the four remaining taxes.

7) Bootstraps 16: all unweighted for the four remaining taxes.

8) *t* is general tax; *bus* is general tax rate plus (setup cost + bankruptcy cost); *edu* is the negative education subsidy; GOVRD is the negative government share in R&D/GNP%; *infra* is the negative index of infrastructure.

Appendix 5C: Data Description

Country	dlny			General tax			Business tax			Education tax			Infra tax			R&D tax			Labour supply		
	70s	80s	90s	70s	80s	90s	70s	80s	90s	70s	80s	90s	70s	80s	90s	70s	80s	90s	70s	80s	90s
argentina	0.012	-0.029	0.037	0.140	0.142	0.143	0.258	0.260	0.261	-0.019	-0.017	-0.035	-0.065	-0.070	-0.074	-0.812	-0.388	-0.339	0.385	0.378	0.388
australia	0.015	0.020	0.022	0.201	0.240	0.247	0.237	0.275	0.282	-0.052	-0.051	-0.050	-0.087	-0.094	-0.100	-0.773	-0.703	-0.933	0.446	0.476	0.504
austria	0.036	0.022	0.019	0.322	0.382	0.398	0.406	0.466	0.482	-0.054	-0.056	-0.056	-0.070	-0.078	-0.087	-0.352	-0.613	-0.739	0.435	0.455	0.465
belgium	0.029	0.021	0.017	0.435	0.521	0.476	0.488	0.575	0.530	-0.063	-0.056	-0.041	-0.074	-0.079	-0.089	-0.454	-0.540	-0.535	0.388	0.403	0.411
bolivia	0.026	-0.026	0.012	0.137	0.137	0.212	0.808	0.809	0.884	-0.040	-0.026	-0.041	-0.046	-0.051	-0.054	-0.500	-0.680	-1.400	0.376	0.386	0.401
botswa	0.108	0.049	0.038	0.266	0.310	0.351	0.369	0.412	0.454	-0.052	-0.054	-0.078	-0.003	-0.016	-0.026	-0.150	-0.195	-0.200	0.442	0.436	0.440
brazil	0.056	0.010	0.005	0.235	0.248	0.294	0.304	0.317	0.363	-0.030	-0.030	-0.039	-0.059	-0.070	-0.076	-0.272	-0.380	-0.571	0.373	0.415	0.454
burki faso	0.019	0.007	0.012	0.097	0.122	0.164	0.660	0.685	0.726	-0.022	-0.022	-0.024	0.011	0.001	-0.003	-0.132	-0.132	-0.133	0.562	0.533	0.506
burundi	-0.004	0.000	-0.019	0.212	0.252	0.285	0.945	0.986	1.018	-0.034	-0.031	-0.040	0.024	0.017	0.010	-0.070	-0.110	-0.150	0.553	0.544	0.536
cameroon	0.042	0.006	-0.022	0.167	0.203	0.162	0.869	0.905	0.864	-0.033	-0.030	-0.028	-0.024	-0.031	-0.027	-0.500	-0.600	-0.600	0.437	0.411	0.404
canada	0.033	0.018	0.013	0.198	0.237	0.248	0.215	0.255	0.265	-0.075	-0.066	-0.064	-0.096	-0.099	-0.099	-0.566	-0.553	-0.539	0.451	0.511	0.532
chad	0.049	-0.050	-0.015	0.118	0.186	0.250	1.589	1.656	1.721	-0.012	-0.012	-0.016	0.001	0.006	0.003	-0.150	-0.195	-0.200	0.500	0.492	0.483
chile	0.010	0.014	0.045	0.343	0.284	0.213	0.441	0.382	0.311	-0.042	-0.040	-0.031	-0.050	-0.055	-0.071	-0.333	-0.298	-0.495	0.328	0.360	0.394
colombia	0.033	0.013	0.011	0.120	0.143	0.146	0.219	0.242	0.245	-0.021	-0.026	-0.030	-0.059	-0.065	-0.071	-0.083	-0.082	-0.084	0.317	0.363	0.416
congo rep	0.049	0.044	-0.026	0.340	0.395	0.351	1.584	1.639	1.595	-0.062	-0.054	-0.059	-0.024	-0.032	-0.034	-0.280	-0.089	-0.007	0.427	0.420	0.415
costa rica	0.031	-0.012	0.018	0.202	0.237	0.220	0.355	0.390	0.373	-0.064	-0.051	-0.043	-0.054	-0.058	-0.066	-0.197	-0.192	-0.119	0.327	0.362	0.388
cote divoire	0.027	-0.031	-0.012	0.312	0.273	0.249	0.843	0.803	0.779	-0.061	-0.068	-0.054	-0.007	-0.014	-0.011	-0.057	-0.110	-0.022	0.410	0.390	0.390
denmark	0.017	0.016	0.018	0.324	0.397	0.396	0.352	0.425	0.424	-0.071	-0.070	-0.077	-0.083	-0.088	-0.093	-0.530	-0.630	-0.725	0.507	0.546	0.562
dominica	0.036	0.016	0.040	0.170	0.145	0.151	0.287	0.262	0.268	-0.024	-0.017	-0.018	-0.040	-0.043	-0.038	-0.100	-0.150	-0.171	0.354	0.384	0.419
egypt	0.011	0.035	0.027	0.521	0.438	0.331	0.804	0.722	0.614	-0.050	-0.052	-0.045	-0.037	-0.048	-0.056	-0.653	-0.220	-0.197	0.351	0.350	0.362
el salvador	0.014	-0.028	0.022	0.118	0.143	0.158	0.594	0.619	0.634	-0.032	-0.029	-0.022	-0.037	-0.042	-0.056	-0.954	-1.144	-1.009	0.334	0.355	0.402
ethiopia	0.005	-0.012	0.004	0.223	0.236	0.176	0.522	0.535	0.475	-0.026	-0.031	-0.039	-0.011	-0.015	-0.019	-0.020	-0.050	-0.053	0.457	0.447	0.438
fiji	0.036	0.000	0.014	0.239	0.272	0.284	0.460	0.493	0.505	-0.045	-0.056	-0.055	-0.037	-0.040	-0.047	-0.200	-0.218	-0.238	0.308	0.332	0.371
finland	0.029	0.032	0.010	0.259	0.294	0.379	0.267	0.302	0.386	-0.058	-0.052	-0.070	-0.082	-0.090	-0.095	-0.444	-0.617	-1.069	0.491	0.509	0.510
france	0.030	0.020	0.011	0.341	0.423	0.453	0.373	0.454	0.485	-0.049	-0.054	-0.058	-0.081	-0.090	-0.097	-0.998	-1.099	-1.076	0.434	0.439	0.444
germany	0.028	0.019	0.016	0.237	0.267	0.322	0.286	0.315	0.370	-0.043	-0.043	-0.046	-0.080	-0.086	-0.095	-1.035	-0.985	-0.884	0.467	0.489	0.501
ghana	-0.002	-0.006	0.005	0.184	0.119	0.197	0.553	0.488	0.566	-0.048	-0.027	-0.041	-0.028	-0.027	-0.026	-0.900	-0.800	-0.935	0.470	0.471	0.469
greece	0.039	0.002	0.016	0.265	0.398	0.340	0.417	0.549	0.491	-0.018	-0.021	-0.027	-0.073	-0.081	-0.086	-0.144	-0.190	-0.227	0.389	0.400	0.422
guatemala	0.029	-0.009	0.008	0.103	0.129	0.115	0.386	0.412	0.398	-0.017	-0.018	-0.016	-0.027	-0.027	-0.038	-0.100	-0.191	-0.080	0.344	0.344	0.355
india	0.003	0.039	0.039	0.108	0.147	0.155	0.309	0.348	0.356	-0.026	-0.031	-0.032	-0.028	-0.038	-0.046	-0.407	-0.658	-0.606	0.437	0.431	0.432
indonesia	0.053	0.042	0.027	0.180	0.209	0.172	0.701	0.730	0.692	-0.024	-0.014	-0.013	-0.023	-0.040	-0.054	-0.352	-0.294	-0.103	0.387	0.415	0.460
iran	-0.006	-0.029	0.042	0.428	0.258	0.232	0.481	0.312	0.286	-0.079	-0.044	-0.044	-0.047	-0.052	-0.064	-0.325	-0.278	-0.351	0.304	0.295	0.298
ireland	0.033	0.027	0.062	0.352	0.459	0.365	0.416	0.523	0.429	-0.054	-0.056	-0.049	-0.072	-0.078	-0.091	-0.414	-0.425	-0.743	0.375	0.372	0.396
israel	0.027	0.016	0.023	0.653	0.687	0.466	0.753	0.787	0.566	-0.069	-0.074	-0.072	-0.071	-0.076	-0.083	-1.094	-1.494	-0.936	0.371	0.383	0.413
italy	0.030	0.026	0.013	0.330	0.455	0.479	0.449	0.574	0.599	-0.041	-0.047	-0.044	-0.077	-0.082	-0.090	-0.397	-0.516	-0.747	0.396	0.413	0.439
jamaica	-0.003	0.006	-0.005	0.337	0.367	0.295	0.454	0.484	0.412	-0.055	-0.057	-0.052	-0.058	-0.059	-0.068	-0.085	-0.053	-0.040	0.416	0.468	0.508
japan	0.032	0.032	0.013	0.145	0.173	0.231	0.196	0.224	0.282	-0.052	-0.051	-0.036	-0.086	-0.092	-0.098	-0.510	-0.595	-0.537	0.500	0.503	0.530
jordan	0.058	-0.002	0.006	0.392	0.358	0.325	0.602	0.568	0.535	-0.045	-0.051	-0.071	-0.041	-0.061	-0.062	-0.237	-0.216	-0.220	0.256	0.250	0.281
kenya	0.049	0.005	-0.005	0.213	0.264	0.277	0.462	0.514	0.527	-0.061	-0.061	-0.065	-0.025	-0.029	-0.034	-0.633	-0.495	-0.450	0.479	0.474	0.496
korea rep	0.066	0.060	0.048	0.157	0.164	0.167	0.233	0.240	0.243	-0.029	-0.038	-0.038	-0.052	-0.068	-0.088	-0.287	-0.317	-0.385	0.382	0.430	0.485
lesotho	0.053	0.001	0.004	0.291	0.480	0.486	0.523	0.713	0.719	-0.062	-0.071	-0.099	0.003	-0.011	-0.005	-0.053	-0.080	-0.088	0.428	0.412	0.406
malawi	0.047	-0.011	0.027	0.241	0.308	0.257	0.762	0.829	0.778	-0.030	-0.031	-0.044	-0.005	-0.006	-0.007	-0.211	-0.260	-0.300	0.513	0.498	0.486
malaysia	0.051	0.028	0.043	0.241	0.306	0.240	0.392	0.457	0.391	-0.053	-0.061	-0.048	-0.055	-0.069	-0.081	-0.017	-0.065	-0.108	0.364	0.388	0.400
mali	0.028	-0.021	0.016	0.100	0.263	0.396	0.819	0.982	1.115	-0.029	-0.031	-0.027	0.004	0.003	0.003	-0.005	-0.012	-0.015	0.522	0.509	0.494
mexico	0.031	-0.002	0.011	0.142	0.232	0.155	0.264	0.354	0.276	-0.036	-0.039	-0.049	-0.059	-0.069	-0.074	-0.176	-0.214	-0.188	0.311	0.345	0.389
morocco	0.030	0.017	0.008	0.308	0.318	0.312	0.414	0.424	0.418	-0.050	-0.062	-0.052	-0.036	-0.040	-0.053	-0.111	-0.150	-0.110	0.346	0.366	0.385

nepal	0.014	0.015	0.026	0.106	0.174	0.169	0.393	0.461	0.456	-0.014	-0.023	-0.029	-0.006	-0.018	-0.029	-0.050	-0.080	-0.044	0.500	0.476	0.463
netherlands	0.022	0.016	0.023	0.437	0.533	0.484	0.487	0.583	0.534	-0.075	-0.066	-0.051	-0.080	-0.085	-0.093	-0.968	-0.942	-0.893	0.384	0.427	0.465
n. zealand	0.004	0.014	0.012	0.325	0.414	0.357	0.340	0.429	0.371	-0.054	-0.053	-0.068	-0.089	-0.092	-0.098	-0.635	-0.619	-0.632	0.407	0.451	0.491
nicaragua	-0.022	-0.040	-0.030	0.164	0.489	0.376	0.787	1.112	1.000	-0.035	-0.035	-0.034	-0.036	-0.031	-0.027	-0.116	-0.208	-0.266	0.332	0.350	0.381
norway	0.040	0.023	0.028	0.321	0.361	0.396	0.335	0.375	0.410	-0.060	-0.063	-0.076	-0.093	-0.101	-0.106	-0.861	-0.744	-0.779	0.445	0.487	0.511
pakistan	0.015	0.047	0.013	0.171	0.207	0.230	0.311	0.347	0.370	-0.020	-0.024	-0.027	-0.029	-0.039	-0.048	-0.148	-0.791	-0.884	0.350	0.355	0.363
panama	0.020	0.008	0.019	0.308	0.295	0.257	0.529	0.516	0.478	-0.053	-0.045	-0.048	-0.056	-0.056	-0.061	-0.072	-0.072	-0.030	0.343	0.367	0.404
p/n guinea	0.019	-0.009	-0.004	0.327	0.324	0.303	0.567	0.565	0.543	-0.044	-0.044	-0.044	-0.026	-0.032	-0.033	-0.005	-0.009	-0.010	0.505	0.491	0.490
paraguay	0.045	0.011	0.001	0.113	0.097	0.113	0.692	0.677	0.693	-0.017	-0.015	-0.032	-0.030	-0.040	-0.045	-0.100	-0.055	-0.090	0.359	0.366	0.368
peru	0.003	-0.023	0.016	0.160	0.177	0.184	0.315	0.333	0.339	-0.031	-0.030	-0.032	-0.047	-0.052	-0.054	-0.184	-0.101	-0.374	0.307	0.325	0.356
philippines	0.031	-0.006	0.011	0.139	0.137	0.190	0.340	0.338	0.391	-0.021	-0.020	-0.030	-0.046	-0.048	-0.053	-0.065	-0.040	-0.019	0.382	0.396	0.410
portugal	0.036	0.030	0.027	0.293	0.359	0.403	0.368	0.434	0.478	-0.031	-0.037	-0.052	-0.066	-0.070	-0.082	-0.212	-0.241	-0.390	0.432	0.479	0.498
romania	0.063	0.040	-0.021	0.481	0.375	0.336	0.535	0.429	0.390	-0.034	-0.025	-0.036	-0.052	-0.061	-0.060	-0.276	-0.220	-0.363	0.517	0.477	0.468
senegal	-0.004	-0.004	0.004	0.188	0.291	0.390	0.611	0.714	0.813	-0.038	-0.038	-0.039	-0.020	-0.022	-0.025	-0.024	-0.014	-0.004	0.467	0.453	0.446
singapore	0.075	0.048	0.058	0.181	0.251	0.187	0.189	0.259	0.195	-0.032	-0.038	-0.033	-0.072	-0.084	-0.092	-0.071	-0.250	-0.357	0.407	0.485	0.506
south africa	0.012	0.003	-0.005	0.226	0.276	0.310	0.321	0.371	0.405	-0.055	-0.054	-0.062	-0.065	-0.070	-0.074	-0.300	-0.300	-0.301	0.374	0.380	0.391
spain	0.026	0.021	0.022	0.205	0.300	0.344	0.291	0.386	0.429	-0.018	-0.030	-0.045	-0.078	-0.084	-0.091	-0.134	-0.272	-0.451	0.375	0.389	0.424
sri lanka	0.013	0.031	0.027	0.278	0.325	0.271	0.379	0.425	0.371	-0.030	-0.026	-0.032	-0.015	-0.027	-0.038	-0.064	-0.140	-0.151	0.358	0.383	0.417
sweden	0.015	0.021	0.011	0.306	0.409	0.437	0.336	0.440	0.467	-0.073	-0.076	-0.076	-0.090	-0.097	-0.100	-0.697	-1.056	-1.144	0.486	0.522	0.541
switzerland	0.005	0.017	0.002	0.169	0.203	0.262	0.213	0.247	0.306	-0.048	-0.050	-0.055	-0.088	-0.093	-0.098	-0.432	-0.504	-0.678	0.476	0.505	0.534
syria	0.054	0.009	0.032	0.393	0.343	0.238	0.540	0.491	0.385	-0.041	-0.052	-0.033	-0.037	-0.045	-0.050	-0.050	-0.062	-0.097	0.286	0.282	0.296
thailand	0.042	0.050	0.039	0.156	0.184	0.176	0.313	0.340	0.332	-0.034	-0.036	-0.042	-0.036	-0.049	-0.066	-0.286	-0.204	-0.094	0.503	0.543	0.588
tunisia	0.053	0.015	0.033	0.285	0.357	0.327	0.351	0.424	0.393	-0.054	-0.055	-0.065	-0.041	-0.051	-0.057	-0.189	-0.188	-0.188	0.321	0.347	0.371
turkey	0.026	0.016	0.019	0.181	0.188	0.256	0.302	0.308	0.377	-0.021	-0.019	-0.024	-0.046	-0.053	-0.069	-0.420	-0.259	-0.266	0.438	0.427	0.455
uk	0.022	0.022	0.017	0.356	0.385	0.398	0.380	0.409	0.423	-0.062	-0.051	-0.050	-0.088	-0.093	-0.099	-1.061	-0.960	-0.669	0.469	0.487	0.498
u.s.a.	0.030	0.020	0.020	0.198	0.227	0.217	0.228	0.257	0.247	-0.071	-0.059	-0.051	-0.109	-0.113	-0.117	-1.286	-1.215	-1.060	0.455	0.493	0.507
uruguay	0.023	-0.003	0.029	0.235	0.252	0.289	0.432	0.449	0.486	-0.028	-0.027	-0.026	-0.053	-0.057	-0.062	-0.200	-0.154	-0.200	0.396	0.416	0.448
venezuela	-0.023	-0.022	-0.005	0.191	0.211	0.195	0.376	0.396	0.380	-0.045	-0.050	-0.046	-0.065	-0.074	-0.074	-0.426	-0.327	-0.403	0.320	0.356	0.388
zambia	-0.004	-0.016	-0.018	0.331	0.343	0.334	0.439	0.450	0.442	-0.054	-0.039	-0.022	-0.042	-0.038	-0.035	-0.244	-0.180	-0.150	0.436	0.414	0.415
zimbabwe	0.014	0.017	-0.006	0.229	0.290	0.319	1.358	1.419	1.449	-0.033	-0.062	-0.085	-0.046	-0.045	-0.047	-0.100	-0.120	-0.150	0.451	0.456	0.463

Data definitions and sources:

1. y is GDP per capita from the Penn World Table;
2. General tax is public spending–to–GDP rate, from the Penn World Table;
3. Business tax is general tax plus marginal costs levied by the country on firm closure & firm set-up, from the World Bank Database;
4. Education tax is the negative value of government spending on education (primary, secondary, and tertiary) as the share of total GDP, from the World Bank Database;
5. Infrastructure tax is the negative indexed value of government spending on infrastructure (airports, electricity, telephones, roads) as the share of total GDP, from the World Bank Database;
6. R&D tax is negative value of the government expenditure on R&D as the percentage of total GDP, from UNESCO yearbook;
7. Labour supply is workforce as the share of total population, from the World Bank Database.

6

CONCLUSIONS

6 CONCLUSIONS

The main purpose of this thesis has been to estimate and simulate a general equilibrium model of growing small open economies by taking a new testing approach. The effect of business tax and regulation on growth, together with potential effects of government spending on education and R&D, is embodied in this model. Growth does indeed depend on tax rates, particularly the business tax rate (interpreted as the tax, including regulative, burden on an individual businessman). But the usual estimates of this effect are unreliable and biased upwards. Instead one must construct the underlying ('structural') model, check whether its estimates cohere with the data using this bootstrap-based technique. Then the parameters in this structural construct, thus tested, can be used to estimate the effect of a shock to the tax rates. What we have found here is that the hypothesis of no effect can be rejected confidently and that the best estimate of a 10 percentage point reduction in business tax is a rise in the growth rate of between 0.14% and 0.2% per year. This is a substantial effect; it implies for example a marked 'dynamic effect' on what tax cuts can be afforded.

The main contribution of this thesis is that we abandon the wide-used method of regressing and propose to test theories by a two-stage Popperian procedure in which rejection can occur at each stage. As we have argued, 'conventional' way of testing growth on its supposed causes is not on its own persuasive evidence of these causes due to the problems of potential data-mining, biased estimation and lack of identification. In the first stage of our new approach the model as tightly specified must pass an estimation test in its structural form; in the second its bootstrapped implications must be consistent with the growth regressions it implies. It is as if our results can only emerge satisfactorily if they can go through two mincers, each of a different shape; a structural mincer and a 'reduced form' mincer; only if the model can force its way through both are its results to be believed. We tested two main classes of growth theory: one was the Activist theory that direct government intervention to stimulate particular activities – specifically education and R&D – caused growth, the other was the Incentivist theory in which growth is caused by incentives for people to engage in entrepreneurial activity. For the latter, we construct new data to measure business tax by incorporating general tax rate and the particular imposts levied on business activity. We were able to reject the Activist theory for education at both the structural and the bootstrap levels; and for R&D at the bootstrap level, though not the structural. We accepted the Incentivist theory at both levels.

While borrowing from the literature on endogenous growth, this thesis has quite different policy implications. Endogenous growth theory sees knowledge production and hence, R&D spending, as the key to obtaining increasing returns. We believe that, as our results show, it is removal of barriers that allow technology to be translated into economic growth. Thus policymakers aiming to foster economic growth should more concentrate on promoting incentives, rather than simply chasing policies to increase the quantity of economic inputs (subsidies for education, R&D, investment, etc.). Although institutional change is not easy, realising that institutions matter is the first step in the course of promoting entrepreneurial activity—the root source of economic growth and prosperity.

The major conclusions of the study are broadly reviewed here. Chapter 2 provides an overview of theories of endogenous growth involving human capital. The predictions generated from these models suggest to a large extent that human capital should matter for output growth. The following section builds on the endogenous growth framework laid out in the previous sub-section and compares the various effects of alternative tax policies on growth. These theoretical models do not reach a consensus – whether a tax policy has negative, zero, or even positive effects on economic growth hinges on model specifications. The final part of this chapter surveys the empirical evidence of the effects of both human capital and taxation on economic growth. The overall evidence is somewhat mixed. This chapter also indicates some statistical and methodological problems to which various studies are subject.

We start chapter 3 by reviewing Parente and Prescott's work and discuss how conventional endogenous growth models fail to account for the income differences across countries. Then we study how Parente and Prescott tackle this problem through productivity differences and 'barriers to riches'. In what follows we extend Parente and Prescott's idea to a broader context and discuss the missing link in endogenous growth literature. We emphasise the role of entrepreneurship as a crucial link between knowledge creation and economic growth. We also point out the research gap at the macroeconomic level linking entrepreneurship to growth. Finally, we argue how government can facilitate the link.

In chapter 4 we sketch out two rival models of the effects of public spending: the 'activist' according to which spending raises growth via its effects in subsidising R&D, and the 'incentivist' according to which it reduces it by penalising incentives through higher taxes; then we conduct a preliminary test by estimating reduced form equations on panel data in the form of decade averages from 1970-2000. What we have found is that there appears to be no significant effect of R&D and other capital subsidies on growth but that there is an effect of taxation depressing growth — in this we join a growing literature that finds similar negative tax effects on growth. However, such reduced form relationships can only be a first approach to the empirical testing of these theories. We need to develop and test structural micro-founded models of general equilibrium to predict these effects with greater assurance.

We start chapter 5 by building a general equilibrium model of a small open economy with growth choices. We go on to show that this economy for our purposes can be summarised in two equations: (1) an equation relating employment (the supply of labour) to the personal tax rate; (2) an equation relating output to employment, other 'resource factors' (such as natural resources), the world interest rate, and finally the history of business taxation. Resource factors are assumed to be picked up by country dummy variables and the world real interest rate by time dummies. These countries and time dummies are also used in equation (1) for analogous reasons. We first estimate the model in which business tax alone, out of the three we have identified, is operative. Then we consider the addition of the other two taxes, namely, education and R&D. It is in this way that we test the two rival theories. To avoid the problems in 'conventional' testing method, we propose a two-stage Popperian procedure in which rejection can occur at each stage. Here we treat the structural estimation results as a separate Popperian hurdle or source of potential rejection, on a par with the growth regressions hurdle. We found here that the Incentivist model was accepted at both stages and that an alternative model with no tax effects was firmly rejected. In fact a model with a higher business tax coefficient of -0.02 is also accepted, but we were unable to change the structural coefficients on the business tax further upwards. When we turned to the Activist model focused on education, we were able to reject it at both the structural and the bootstrap levels. Finally, we found that the Activist model featuring R&D failed at the second stage; by implication its strong partial correlation with growth in the data is spurious, in terms of the only model (the Incentivist) that survives both test stages.

We suggest that these methods of testing are a useful way to proceed when there are many competing theories which are hard to distinguish in their reduced form. Further work would be interesting, for example both to test other theories of growth and to consider different measures of the relevant tax incentives. Finally we emphasise, as we began, that this sort of econometric testing can only complement and not replace the wide-ranging investigation of the historical evolution and particular case-studies of growth in terms of other methods.

Bibliography

Acemoglu, D., S. Johnson, and J. A. Robinson. (2001), "The colonial origins of comparative development: An empirical investigation", *American Economic Review* 91(5), 1369-1401.

Acemoglu, D. and J. A. Robinson (2000), "Political Losers as a Barrier to Economic Development," *American Economic Review*, 90, 126-130.

Acs, Z. (2002), *Innovations and the Growth of Cities*, Edward Elgar, Cheltenham (UK) and Northampton, Ma. (U.S.).

Acs, Z. and D. B. Audretsch (1989), "Patents as a Measure of Innovative Activity," *Kyklos*, Blackwell Publishing, vol. 42(2), pages 171-80.

Agell, J., P. Englund and J. Södersten. (1995), "The Swedish tax reform: an introduction." *Swedish Economic Policy Review*, Vol. 2: 219-228.

Aghion, P. and P. Howitt (1992), "A Model of Growth Through Creative Destruction", *Econometrica*, 60 (2), 323-352.

——— (1998), *Endogenous Growth Theory*. Cambridge, MA: MIT Press.

Alesina, A., S. Ardagna, R. Perotti and F. Schiantarelli. (2002), "Fiscal Policy Profits and Investment." *American Economic Review*, June, 92: 571-89.

Alogoskoufis, G. and F. Van Der Ploeg. (1990), "Endogenous Growth and Overlapping Generations," *Papers* 9072, *Tilburg - Center for Economic Research.*

Arauzo-Carod, J. M. and A. Segarra-Blaso (2005), "The Determinants of Entry are not Independent of Start-up Size: Some Evidence from Spanish Manufacturing", *Review of Industrial Organization*, 27, 147-65.

Audretsch, D. B. (1995), *Innovation and Industry Evolution*, MIT Press, Cambridge, MA.

Audretsch, D. B. and M. P. Feldman (1996). "R&D Spillovers and the Geography of Innovation and Production." *American Economic Review*, 86: 630-640.

Audretsch D. B. and M. Fritsch (2002), "Growth regimes over time and space", *Regional Studies* 36: 113–124.

Audretsch, D. B. and M. Keilbach (2003), "Entrepreneurship Capital and Economic Performance", *CEPR Discussion Paper* No. 3678.

Audretsch, D. B. and R. Thurik (2002), "Linking Entrepreneurship to Growth" *OECD STI Working Paper* 2081/2.

Azariadis, C. and A. Drazen (1990), "Threshold Externalities in Economic. Development." *Quarterly Journal of Economics* 105: pp.501-526.

Barro, R.J. (1991), "Economic growth in a cross-section of countries." *Quarterly Journal of Economics*, 106(2):.407 433.

——— (1996), "Democracy and growth", *Journal of Economic Growth* 1, 1-27.

——— (1998), "Human capital and growth in cross-country regressions." *Manuscript*, Harvard University.

——— and X Sala-i-Martin (1992), "Public finance in models of economic growth." *Review of Economic Studies*, 59, 645-661.

——— and X Sala-i-Martin (1995), *Economic growth*, New York: McGraw-Hill.

——— and J.W. Lee. (1993), "International comparisons of educational attainment." *Journal of Monetary Economics*, Vol. 32, 3, pp. 363-394.

——— and J.W. Lee. (1994), "Sources of economic growth." *Carnegie-Rochester Conference Series on Public Policy*, Vol. 40, pp. 1-46.

——— and J.W. Lee. (2001), "International Data on Educational Attainment: Updates and Implications." *Oxford Economic Papers*, 53(3): 541-563.

Bassanini, A. and S. Scarpettta. (2001), "Does human capital matter for growth in OECD countries? Evidence from PMG estimates." *OECD Economics Department Working Papers*, No. 282.

Baumol, W. J. (1990), "Entrepreneurship: Productive, unproductive and destructive", *Journal of Political Economy* 98(5), 893-921.

Becker, Gary. S. (1964), *Human Capital*, 1st ed. New York: Columbia University.

Benhabib, J. and M. Spiegel. (1994), "The Role of Human Capital in Economic Development: Evidence from Aggregate Cross-Country Data", *Journal of Monetary Economics*, 34, pp.143-173.

Benson, B., and R. Johnson. (1986), "The Lagged Impact of State and Local Taxes on Economic Activity and Political Behaviour." *Economic Inquiry*, 24 (July): 389-401.

Bleaney, M., N. Gemmell and R. Kneller. (2000), "Testing the endogenous growth model: public expenditure, taxation and growth over the long run." *Canadian Journal of Economics*, 34(1): 36-57.

Boettke, P. B., and C. J. Coyne. (2003), "Entrepreneurship and development: Cause or consequence?" In R. Koppl (Ed), *Advances in Austrian economics* vol. 6: *Austrian economics and entrepreneurial studies* (pp. 67-87). New York: Elsevier Science.

——— (2006), "Entrepreneurial behaviour and institutions", In M. Minniti (Ed), *Praeger perspectives series* vol. 1: *Entrepreneurship: The engine of growth* (pp. 119-134). Praeger Press: Portsmouth.

Braunerhjelm, P. (1996) "The Relation Between Firm-Specific Intangibles and Exports", *Economic Letters*, 53, 213-219.

Callejon, M. and A. Segarra (1999), "Business Dynamics and Efficiency in Industries and Regions: The Case of Spain", *Small Business Economics* 13: 253-271.

Case, A. C. and L. F. Katz. (1991), 'The Company You Keep: The Effects of Family and Neighborhood on Disadvantaged Youths," *NBER Working Paper* #3705.

Caselli, F., G. Esquivel, and F. Lefort (1996), "Reopening the convergence debate: a new look at cross-country growth empirics." *Journal of Economic Growth*, Vol. 1, 3, pp. 363-389.

Cashin, P. (1995), "Government spending, taxes and economic growth." *IMF Staff Papers*, 42(2), 237-69.

Caves, R. E. (1998), "Industrial Organization and New Findings on the Turnover and Mobility of Firms", *Journal of Economic Literature*, 36(4), December, pp. 1947-1982.

Chao, J.C.P., and H. Grubel. (1998), "Optimal Levels of Spending and Taxation in Canada." In *How to Use the Fiscal Surplus: What is the Optimal Size of Government? ed.* Herbert Grubel. Vancouver: Fraser Institute.

Coe, D. T. and E. Helpman (1995), "International R&D spillovers", *European Economic Review,* 39 (5), 859-887.

Cohen, W. M. and S. Klepper (1992), "The trade-off between firm size and diversity in the pursuit of technology progress", *Small Business Economics*, 4, pp. 1-14.

Cohen, W. M. and D. A. Levinthal (1989), "Innovation and learning: the two faces of R&D", *Economic Journal*, Vol. 99 pp.569-96.

Dar, A. and S. AmirKhalkhali. (2002), "Government size, factor accumulation, and economic growth: evidence from OECD countries." *Journal of Policy Modeling*, 24(7-8): 679-692.

Easterly, W. and S. Rebelo. (1993), "Marginal income tax rates and economic growth in developing countries." *European Economic Review*, 37(2-3): 409-417.

Easterly, W. (2001), *The Elusive quest for growth*: *Economists' adventures and misadventures in the tropics*. Cambridge, MA, MIT Press.

Engen, E. M., and J. Skinner. (1996), "Taxation and Economic Growth." *NBER Working Papers* 5826, National Bureau of Economic Research, Inc.

Evans, D. and L. S. Leighton (1990), "Small Business Formation by Unemployed and Employed Workers", *Small Business Economics*, 2(4), pp. 319-330.

Evans, D. and B. Jovanovic (1989), "Estimates of a Model of Entrepreneurial Choice under Liquidity Constraints", *Journal of Political Economy*, 97(3), pp. 808-827.

Feldman, M. P. and D. B. Audretsch (1999), "Innovation in Cities: Science-Based. Diversity, Specialization and Localized Monopoly", *European Economic Review* 43, 409-429.

Fölster, S. (2000). "Do entrepreneurs create jobs?" *Small Business Economics*, 14, 137-148.

Folster, S. and M. Henrekson. (2000), "Growth Effects of Government Expenditure and Taxation in Rich Countries." *European Economic Review*, 45(8): 1501-1520.

Frankel, M. (1962), "The Production Function in Allocation and Growth: A Synthesis." *American Economic Review*, 52(5) pp. 995-1022.

Frye, T. and A. Shleifer (1997), "The Invisible Hand and the Grabbing Hand", *American Economic Review*, Papers and Proceedings 87, 354--58.

Gemmell, N. (1996), "Evaluating the impacts of human capital stocks and accumulation on economic growth: some new evidence." *Oxford Bulletin of Economics and Statistics*, Vol. 58, 1, pp. 9-28.

Gillman, M. and M. Kejak. (2005), "Inflation and Balanced-Path Growth with Alternative Payment Mechanisms." *Economic Journal*, 115(January): 247-270.

Glaeser, E., H.D. Kallal, J.A. Scheinkman and A. Schleifer (1992), "Growth in Cities", *Journal of Political Economy* 100, pp.1126-1152.

Green, S., A. Melnyk, and D. Powers. (2002), "Is economic freedom necessary for technology diffusion?" *Applied Economics Letters* 9(14): 907 – 910.

Grier, K., and G. Tullock. (1989), "An Empirical Analysis of Cross-national Economic Growth, 1951-80." *Journal of Monetary Economics*, 24: 259-76.

Grossman, P. (1988), "Government and Economic Growth: A Non-Linear Relationship." *Public Choice*, 56: 193-200.

——— and E. Helpman, (1991) *Innovation and growth in the global economy.* Cambridge, Mass.: MIT Press.

Gwartney, J. D., R. Holcombe, and R. Lawson. (1998), "The Scope of Government and the Wealth of Nations", *Cato Journal* 18, 163-90.

——— (2004), "Economic freedom, institutional quality, and cross-country differences in income and growth", *Cato Journal* 24(3), 205-233.

Hansen, G. and E. C. Prescott (1999), "From Malthus to Solow", Unpublished Manuscript, University of Minnesota.

Hansson, P. and M. Henrekson. (1994), "A new framework for testing the effect of government spending on growth and productivity." *Public Choice*, 81: 381-401.

Hart, M. and E. Hanvey (1995), "Job Generation and New and Small Firms: Some Evidence from the Late 1980s", *Small Business Economics*, Vol. 7, pp 97-109.

Hart, P. E. and N. Oulton (2001), "Galtonian Regression, Company Age and Job Generation 1986-95", *Scottish Journal of Political Economy,* 48, 82-98.

Hébert, R. F. and A. N. Link (1999), "In Search of the Meaning of Entrepreneurship", *Small Business Economics*, 1, 39-49.

Heston, A., R. Summers and B. Aten. (2002), "Penn World Table Version 6.1." Center for International Comparisons at the University of Pennsylvania (CICUP), October.

Hirschman, A. O. (1970), *Exit, Voice, and Loyalty: Responses to Decline in Firms, Organizations, and States.* Cambridge, MA: Harvard University Press.

Holcombe, R. (2003), "The Origins of Entrepreneurial Opportunities", *The Review of Austrian Economics*, 16(1): 25–43.

Holmes, T. J. and J. A. Schmitz (1990), "A Theory of Entrepreneurship and its Application to the Study of Business Transfers," *Journal of Political Economy*, University of Chicago Press, vol. 98(2), pages 265-94, April.

Islam, N. (1995), "Growth empirics: a panel data approach." *Quarterly Journal of Economics*, Vol. 110, 4, pp. 1127-1170.

Jacobs, J (1969), *The Economy of Cities*. New York: Vintage.

Jaffe, A., M. Tratjenberg, and R. Henderson (1993), "Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations." *Quarterly Journal of Economics*. pp. 577-598.

Johnson, S., J. McMillan, and C. Woodruff (2000), "Entrepreneurs and the Ordering of Institutional Reform: Poland, Slovakia, Romania, Russia and the Ukraine Compared", *Economics of Transition* 8, 1-36.

Jones, C. (1995), "R&D-Based Models of Economic Growth", *Journal of Political Economy*, 103 (2): 759-84.

King, R.G. and S. Rebelo. (1990), "Public policy and economic growth: developing neoclassical implications." *Journal of Political Economy*, 98(5): 5216-5150.

Kirzner, I. M. (1985), *Discovery and the Capitalist Process*. Chicago: The University of Chicago Press.

——— (1999), "Creativity and/or Alertness: A Reconsideration of the Schumpeterian Entrepreneur", *The Review of Austrian Economics* 11, 5--17.

Klette, T. J. and S. Kortum. (2004), "Innovating firms and Aggregate Innovation." *Journal of Political Economy*, 112 (5), 986-1018.

Koester, R. and R. Kormendi. (1989), "Taxation, aggregate activity and economic growth: cross-country evidence on some supply-side hypotheses." *Economic Inquiry*, 27(3): 367-386.

Kreft, S. F., and R. S. Sobel (2005), "Public policy, entrepreneurship, and economic growth", *Cato Journal* 25(3), 595-616.

Krueger, A., and M. Lindahl. (2001), "Education for growth: why and for whom?" *Journal of Economic Literature*, Vol. 39, pp. 1101-1136.

Krugman, P. (1991), *Geography and Trade*, MIT Press, Cambridge.

Krusell, P. and J.-V. Rios-Rull (1996), "Vested Interests in a Positive Theory of Stagnation and Growth", *Review of Economic Studies* 63(2), 301–329.

Leach, G. (2003), *The negative impact of taxation on economic growth*. London: Reform. September.

Leibfritz, W., J. Thornton and A. Bibbee. (1997), "Taxation and economic performance." *OECD Working paper* No. 176.

Levine, R. and D. Renelt. (1992), "A sensitivity analysis of cross-country growth regressions." *American Economic Review*, 82(4): 942-963.

Lucas, R.E. (1988), "On the mechanics of economic development." *Journal of Monetary Economics*, 75(4), 321-334.

——— (1990), "Supply Side Economics: An Analytical Review", *Oxford Economic Papers*, 42, 293-316.

Mackness, W. (1999), "Canadian Public Spending: The Case for Smaller, More Efficient Government." *Public Policy Source* 13. Vancouver, BC: The Fraser Institute.

Mankiw, N. G., D. Romer, and D. N. Weil. (1992), "A contribution to the empirics of economic growth", *Quarterly Journal of Economics*, Vol. 107, 2, pp. 407-437.

Martin, R. and P. Sunley. (1998). "Slow convergence? The new endogenous growth theory and regional convergence", *Economic Geography* 74(3), 201-227.

Michelacci, C. and O. Silva (2005), "Why so Many Local Entrepreneurs?", *CEMFI Working Paper 0506*, Madrid, CEMFI.

Minford, P., P. Sofat, E. Nowell and N Srinivasan (2006), "UK Inflation Persistence: Policy or Nature?", *CEPR Discussion Paper No 5608*, available on Minford Cardiff University webpage.

Minford, P., K. Theodoridis and D. Meenagh (2005), "A Bootstrap Test for the dynamic performance of Macroeconomic Models - an outline and some experiments", available on Minford Cardiff University webpage.

Ngai, R. (2000), "Barriers and the Transition to Modern Growth", Unpublished Manuscript, University of Pennsylvania.

Nelson, R., and E. Phelps. (1966), "Investment in humans, technological diffusion, and economic growth", *American Economic Review*, Vol. 61, pp. 69-75.

North, D. C. (1990), *Institutions, institutional change, and economic performance.* Cambridge: Cambridge University Press.

Parente, S. and E. Prescott. (1993), "Changes in the wealth of nations." *Federal Reserve Bank of Minneapolis Quarterly Review*, 17 (Spring), 3-16.

——— (1994), "Barriers to technology adoption and development." *Journal of Political Economy*, 102(2), 298-321.

——— (1999), "Monopoly rights: a barrier to riches." *American Economic Review*, 89(5), 1216-1233.

——— (2000), *Barriers to Riches*, Cambridge, MA, MIT Press.

Peden, E. (1991), "Productivity in the United States and Its Relationship to Government Activity: An Analysis of 57 Years, 1929-1986." *Public Choice*, 69: 153-73.

——— and M. Bradley. (1989), "Government Size, Productivity, and Economic Growth: The Post-War Experience." *Public Choice*, 61: 229-45.

Plosser, C. I. (1992), "The search for growth", in *Policies for Long-Run Economic Growth*, Federal Reserve Bank of Kansas City.

Pritchett, L. (2001), "Where has all the education gone?" *World Bank Economic Review*, Vol. 15, 3, pp. 367-391.

Popper, K. (1934), "The Logic of Scientific Discovery." reprinted Routledge Classics.

Porter, M. (1990), *The Competitive Advantage of Nations*. New York: The Free Press.

Rebelo, S. (1991), "Long-Run Policy Analysis and Long-Run Growth," *Journal of Political Economy*, University of Chicago Press, vol. 99(3), pages 500-521.

Reynolds, P. D. (1997), "Who Starts New Firms?", *Small Business Economics* 9, pp. 449-462.

——— (1999), "Creative Destruction: Source or Symptom of Economic Growth?" In *Entrepreneurship, Small and Medium-sized Enterprises and the Macroeconomy*. Cambridge, UK: Cambridge University Press.

———, B. Miller and W. R. Maki (1995), "Explaining Regional Variation in Business Births and Deaths: US 1976-1988", *Small Business Economics* 7, pp. 389-407.

———, D. J. Storey and P. Westhead (1994), "Cross National Comparison of the Variation on the New Firm Formation Rates", *Regional Studies* 27, pp. 443-456.

Romer, D. (2001), *Advanced macroeconomics*, 2nd edition, New York: McGraw-Hill.

Romer, P. M. (1986), "Increasing returns and long-run growth", *Journal of Political Economy*, Vol. 94, 5, pp. 1002-1037.

——— (1989), "Human capital and growth: theory and evidence." *National Bureau of Economic Research* Working Paper no. 3173.

——— (1990), "Endogenous technological change", *Journal of Political Economy*, Vol. 98, 5, pp. 71-102.

——— (1994), "The Origins of Endogenous Growth", *Journal of Economic Perspectives*, 8(1), Winter, pp. 3-22.

Santarelli, E. (2006), Introduction, in E. Santarelli (ed.), *Entrepreneurship, Growth, and Innovation: The Dynamics of Firms and Industries*, New York, Springer, xiii-xx.

Sarquis, J. B. and J. S. Arbache (2002), "Human Capital, External Effects and Technical Change", *London School of Economics Working Paper*.

Schleifer, A. (1997), "Schumpeter Lecture: Government in Transition", *European Economic Review* 41, 385-410.

——— and R.W. Vishney (1994), “Politicians and Firms ”, *Quarterly Journal of Economics* 109, 995-1025.

Scully, G. W. (1989), ‘The Size of the State, Economic Growth and the Efficient Utilization of National Resources.’ *Public Choice*, 63: 149-64.

——— (1991), ‘Tax Rates, Tax Revenues and Economic Growth.’ *Policy Report* 98. Dallas, TX: National Center for Policy Analysis.

——— (1995), “The ‘Growth Tax’ in the United States.” *Public Choice*, 85: 71-80.

Slemrod, J. (1995), “What do cross-country studies teach about government involvement, prosperity, and economic growth?” *Brookings Papers on Economic Activity*: 373-431.

Smith, D. B. (2001), *Public Rags or Private Riches? High Public Spending Makes Us Poor*. Politeia, London.

Snowdon, B. (2007), *Globalisation, development and transition: conversations with eminent economists*, forthcoming, Cheltenham and Northampton, MA, Edward Elgar.

Soto, H. de. (1989), *The Other Path: The Invisible Revolution in the Third World*. New York: Harper & Row Publishers.

——— (2000), *The Mystery of Capital: Why Capitalism Triumphs in the West and Fails Everywhere Else*. New York: Basic Books.

Steckbeck, M., and P. Boettke. (2004). “Turning lemons into lemonade: Entrepreneurial solutions to adverse selection problems in e-commerce”. In J. Birner and P. Garrouste (Eds), *Markets, information and communication: Austrian perspectives on the internet economy* (pp. 218-230). New York: Routledge.

Stokey, N. L. and S. Rebelo (1993), "Growth Effects of Flat-Rate Taxes," *NBER Working Papers 4426*, National Bureau of Economic Research, Inc.

Thurik, R. (1999). “Entrepreneurship, Industrial Transformation and Growth”, in G.D. Libecap (ed.), *The sources of entrepreneurial activity*, Standford, CT: JAI Press, 29-65.

——— (2003), “Entrepreneurship and Unemployment in the UK”, *Scottish Journal of Political Economy*, 50, 264-90.

Van Stel, A. J., M. Carree, and A. R. Thurik (2005), "The Effect of Entrepreneurial Activity on National Economic Growth", *Small Business Economics,* 24, 311-21.

Varga, A. and J. Schalk (2004), "Knowledge Spillovers, Agglomeration and Macroeconomic Growth: An Empirical Approach", *Regional Studies*, 38, 977-89.

Vedder, R. K. and L. E. Gallaway. (1998), "Government Size and Economic Growth." Paper prepared for the Joint Economic Committee of the US Congress.

Young, A. (1998), "Growth Without Scale Effects", *Journal of Political Economy,* 106 (1), 41-63.