THE WELFARE IMPLICATIONS OF TANSPORT IMPROVEMENTS IN THE PRESENCE OF MARKET FAILURE: REVIEWS AND FURTHER ANALYSIS

and

TAXATION, ECONOMIC GROWTH AND THE DOUBLE DIVIDEND

Reports to SACTRA

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Taxation, Economic Growth and the Double Dividend

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CONTENTS

1. Introduction

This report reviews the literature on economic growth, the environment and the effect of taxation. In Section 2 a brief introduction to growth theory is provided. This looks at the failings of exogenous growth models which motivated the development of the endogenous growth literature. This is followed in Section 3 by a study of theoretical predictions of the effect of taxation on growth in the simplest closed economy endogenous growth models. The factors responsible for the differences in predictions between models are identified. The consequences of making a number of extensions to the basic model are then considered in Section 4. The theoretical work is then contrasted with empirical evidence in Section 5. The inclusion of environmental aspects into the models and the double dividend are analysed in Section 6. Section 7 provides some summary conclusions.

2. Models of Economic Growth

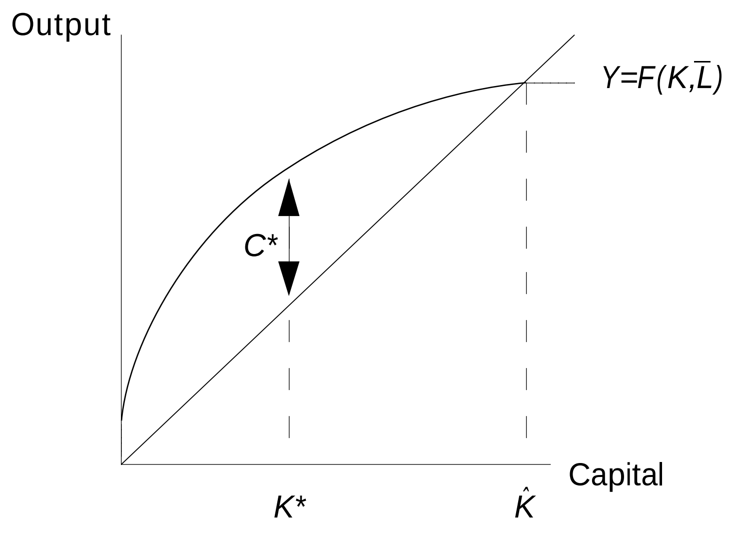
This section considers the distinctions between models of exogenous and endogenous growth. It provides the motivation for why endogenous growth models are an important development and provides a perspective for the later discussion. It also explains the important distinction between level and growth effects.

2.1 EXOGENOUS GROWTH

The growth theory of the 1950s and 1960s (Solow (1956), Swan (1956)) was based on a production function with capital and labour (in man-hours) as the inputs into production. Constant returns to scale and diminishing marginal productivity for both inputs were assumed. Hence, increasing the amount of capital whilst holding labour constant lead to gradually smaller increments in output.

To understand the consequences of this last assumption, consider an economy with a fixed population and let each person work a fixed number of hours. This gives a total labour supply $\bar{L}$. Assume further that all capital depreciates fully when used. Any output, Y, produced is divided between consumption, C, and replacement of the capital stock, K. Figure 1 illustrates such an economy. The curve $Y = F(K,\bar{L})$ shows the level of output as capital is increased holding labour supply fixed and the height of the curve above the $45°$ line shows the quantity of consumption. At K^* the level of consumption, C^*, is at its maximum and this is the optimal outcome for the economy. Consumption is zero at capital level $\hat{K}$ and all output is being used to replace the aging capital stock.

Figure 1: **Output with a fixed stock of capital**



This figure shows the essential feature of the early growth models: whilst growth can occur through the accumulation of capital, there is a natural limit to the level of consumption per capita. This result is a consequence of the limited supply of labour and the diminishing marginal productivity of capital. Removing the fixed population assumption and the assumptions of fixed labour supply and of complete depreciation do not markedly change the outcome – doing so simply moves the points K^* and $\hat{K}$. Consequently, such models were unable to explain sustained economic growth. To circumvent this, the assumption of "exogenous growth" was introduced under which labour or capital (or both) become more productive over time. The drawback of this approach is that the "growth engine" is not modelled, so that the rate of growth cannot be explained nor can it be affected by policy.

2.2 ENDOGENOUS GROWTH

Models that both allow continuous growth and determine its level are said to have "endogenous growth". To achieve continuous and unrelenting growth the decreasing marginal product of capital must be circumvented and in a way that is explained by the model. There have emerged in the literature four basic methods by which this can be achieved.

The simplest method, called the "AK model", is to assume that capital is the only input into production and that there are constant returns to scale. Under these assumptions the production function is given by $Y = AK$, hence the models name.[1] Output will then grow at the same rate as net investment in capital.

[1] It is possible for the model to be given a broader interpretation of including both physical and human capital. The argument is as follows. Assume that the production function $Y = F(K,H)$, where H is human capital, has constant returns to scale. Then it can be written $Y = Kf(H/K)$. If the output produced can be turned into consumption, physical capital or human capital equally easily then all three must have the same price. Profit maximisation by firms then fixes a value of H/K. This allows A to be defined by $A \equiv f(H/K)$.

The second approach is to match increases in capital with equal growth in other inputs. One interpretation of this is to consider human capital as the second input, rather than just raw labour. This allows labour time to be made more productive by investments in education and training which raise the level of human capital. If the production function has constant returns to scale in human capital and physical capital jointly, then investment in both can eventually raise output without limit. Such models can either have one sector, with human capital produced by the same technology as physical capital (Barro, Mankiw and Sala-i-Martin (1992)), or have two sectors with a separate production process for human capital (Lucas (1988), Uzawa (1965)). The advantage of the latter approach is that it is able to incorporate different human and physical capital intensities in the two sectors.

Alternatively, output can be assumed to depend upon labour use and a range of other inputs. Technological progress then takes the form of the introduction of new inputs into the production function without any of the old inputs being dropped Romer (1987, 1990). This allows production to increase since the expansion of the input range prevents the level of use of any one of the inputs becoming too large relative to the labour input. An alternative view of technological progress is that it takes the form of an increase in the quality of inputs (Aghion and Howitt (1992)). Expenditure on research and development can result in better quality inputs which are more productive. Over time, old inputs are replaced by new inputs and total productivity increases.

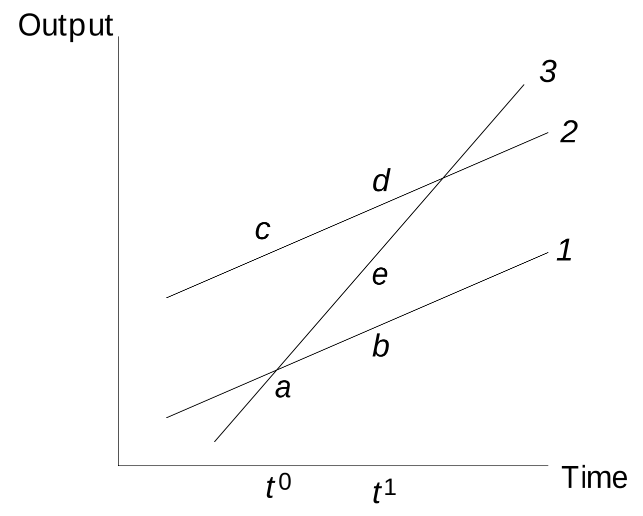
The final approach to ensure continuing growth is to assume that there are externalities between firms. The mechanism through which this externality operates is learning-by-doing (Arrow (1962), Romer (1986)): investment by a firm, and so an increase in its capital stock, leads to parallel improvements in the productivity of labour as new knowledge and techniques are acquired. Moreover, this increased knowledge is a public good so investment, and learning, by one firm flows into other firms. This makes the level of knowledge and hence labour productivity dependent upon the aggregate capital stock of the economy. Decreasing returns to capital for a single firm (given a stock of labour) then translates into constant returns for the economy.

The value of endogenous growth models is that because the rate of growth is determined by choices made within the model, it can be affected by policies that alter these choices. This is in contrast to the exogenous growth models where nothing would affect the rate of growth. It is this that makes exogenous growth models such a suitable vehicle for examining the effect of taxation.

2.3 LEVEL AND GROWTH EFFECTS

In assessing the effects of taxation it is first worth clarifying an important distinction. This distinction is between the effect of a change in taxation on the <u>level</u> of output (or consumption) and its effect on the rate of <u>growth</u> of output. This distinction is illustrated in Figure 2 which shows three different growth paths for the economy. Paths 1 and 2 have the same rate of growth – the slope of the two is the same. In contrast, path 3 has a steeper slope and therefore captures a faster rate of growth.

Figure 2: **Distinguishing level and growth effects**



Now consider beginning at time t^0 at point *a*. In the absence of any policy change, the economy is assumed to grow along path 1 so at time t^1 it will be at point *b*. The two distinct effects of policy can now be described. If policy were to be changed at time t^0 and the economy were to move to point *c* and then grow along path 2 up to point *d* at time t^1, there has been a change in the level of output but not in the rate of growth. If this occurs, policy is said to have a "level effect". Alternatively, the change in policy at t^0 may cause the economy to grow along path 3 so at time t^1 it arrives at point *e*. The change in policy has affected the rate of growth but not (at least initially) the level of output – of course, output eventually becomes higher because of the higher growth rate. Here the change in policy has had a "growth effect".

3. Theoretical Predictions

A commonly-recognised starting point for the literature that traces the effect of taxation in endogenous growth models is Lucas (1990). The work of Lucas was driven by two related observations. First, the work Feldstein (1978) and Boskin (1978) argued that the taxation of capital could have a significant effect upon the level of capital accumulation and hence upon growth. This was a conclusion in stark contrast to that founded in a Solow-Swan model with a fixed savings rate (since the level of saving is fixed, so must be capital). Second, Chamley (1986) showed that the long-run tax rate on capital should be zero. Essentially, in the model of Chamley a tax on labour income does not distort the decision to invest in human capital since both the cost and return are determined by the net-of-tax wage rate. In contrast, a capital income tax does distort the investment decision so in the long-run should be replaced entirely by the income tax. The purpose of Lucas was to quantify the effect of implementing the policy proposal of Chamley.

The model adopted in Lucas (1990) was an endogenous growth model with investment in human capital driving growth. The fundamental assumptions, which have been relaxed and modified in later work, were that:

1. Human capital is produced using only existing human capital and time;
2. There is a single, infinitely lived household;
3. The economy is closed;
4. There is no uncertainty.

Assumptions 1 – 3 will be discussed further below but 2 merits some attention here. The assumption that there is a single household is easily justified. Its role is to eliminate issues concerning distribution between households of differing abilities and tastes (the so-called "equity" role of policy) and to focus entirely upon efficiency. The single consumer can always be interpreted as a representative of many identical households. The second part of the assumption, that the household has an infinite life, is not so obviously acceptable. In literal terms it is clearly wrong. The argument used to justify it is that the household should be thought of as a sequence of generations stretching through time. If each generation cares about the one that follows, then they act as if they were a single unified decision maker.[2] Accepting this, there is still one further shortcoming of the assumption. In practice, the consumption and savings of a household follow the pattern of the lifecycle hypothesis (Ando and Modigliani (1963)): income gradually rises until retirement, savings begin negative, then rise and again become negative in retirement. The model of infinite lifespan cannot capture this lifecycle behaviour. A model that can, and one which is discussed further below, is the overlapping generations model of Samuelson (1958) and Diamond (1965).

The quantitative results of Lucas are obtained by using data from the US economy. Basically, the calculations aim to show what would have happened if the tax on capital had been set to zero in 1985 with revenue made up by increasing the tax on labour. With an initial capital tax rate of 36%, the rate of growth of output per capita before the tax reduction is 1.5% per annum. The conclusions that emerge are that reducing the capital tax to zero causes:

1. A reduction in the growth rate to 1.47%;
2. An increase of over 30% in the capital stock;
3. Consumption increases 6% and welfare 5.5%.

Consequently, the policy change results in a significant level effect but an insignificant growth effect. The explanation for these findings is straightforward. As already noted, since time is the input, the cost is just the forgone wage. This leaves the human capital choice unaffected by taxation and, since it is this that drives growth, there is no growth effect from the tax change. The level effect arises simply because of the replacement of a distortionary tax by a non-distortionary one.

Whereas Lucas considers only the differences between the steady state before the policy change and the steady state finally achieved after the policy change, Laitner (1995) explicitly models the transition process. Along the transition process there has to be an accumulation of physical capital, and hence a reduction in consumption, until the

[2] This idea was first exploited in Barro's (1974) analysis of Ricardian equivalence. Further discussion can be found in Burbidge (1983) and Buiter and Carmichael (1983). It has been challenged empirically by Kotlikoff and Summers (1982), amongst others.

permanently higher level is achieved. Taking account of this will lower the increase in welfare. The results of Laitner suggest that taking full account of the transition will reduce the welfare gain by about 40% to give a net increase in welfare of 3.3%.

A first extension of the Lucas analysis is King and Rebelo (1990). They consider both an open economy and a closed economy. The model differs from Lucas through the use of a Cobb-Douglas production function, rather than Lucas' Constant Elasticity of Substitution (CES)[3], and through having physical capital as an input into the production of human capital. In addition, King and Rebelo also permit depreciation of both capital inputs. In their benchmark case, where the share of physical capital in human capital production is 1/3, an increase in the capital tax and the labour tax from 20% to 30% reduces the growth rate by 1.52%. The level effect is a 62.7% decrease in welfare. A 10% increase in the capital tax alone reduces growth by 0.52%. When the share of physical capital in human capital production is decreased to 1/20, the figure of 0.52% falls to 0.11%. In the open economy version of the model, which is characterised by an interest rate fixed at the world level, the fall in growth is even greater: the 10% increase in the capital tax reduces growth by 8.6%.

The model of Jones, Manuelli and Rossi (1993) combines elements of both Lucas and King and Rebelo. Production is Cobb-Douglas but human capital requires only time and physical capital. Where it differs significantly from the Lucas model is in the parameters of utility. In both models, the utility function is given by:

$$U = \frac{1}{1-\sigma}\sum_{t=0}^{\infty}\left[c l^{\alpha}\right]^{1-\sigma}.$$

where c is consumption and l is leisure. Lucas takes σ = 2 and α = 0.5. In contrast, Jones et al find the value of α that makes the model consistent with the data – this is the process of "calibration". As a consequence, when they use a value of σ = 2, the implied α is 4.99. The consequence of this is that labour supply is much more elastic in Jones et al than in Lucas, implying in turn that taxation will have a greater distortionary effect.

This reasoning is supported by the quantitative results. For the value of σ = 2, Jones et al find that the elimination of all taxes (so distortions are completely removed) raises the growth rate from 2% per annum to 4%. For lower values of σ, and hence greater values of α, the effect is even more marked. A value of σ = 1.1 (and σ = 7.09) gives an increase in growth of 8.3%. The reason for this increase in growth can be seen in the response of labour supply to the tax changes. For α = 1.1 the quantity of time used for work increases by 47% and time devoted to human capital formation by 50%. For σ = 2, the figures are 11% and 0% respectively.

At this point it seems worth summarising and assessing these contributions. Lucas finds no growth effect but a significant level effect. In contrast, King and Rebelo and Jones et al find very strong growth and level effects. The differences in the models that explain this

3 The Cobb-Douglas production function is given by $Y = K^{\alpha}L^{1-\alpha}$ and the Constant Elasticity of Substitution by $Y = [\mu K^{p}+[1-\mu]L^{p}]^{1/p}$. The Cobb-Douglas is a special of the CES with p = 0. More generally, the elasticity of substitution (the rate at which capital can be substituted for labour keeping output constant is 1/1 – p, which equals 1 when p = 0.

sharp divergence have already been noted: King and Rebelo use a much lower share of human capital in its own production than Lucas and a depreciation rate of 10% per annum. For human capital especially, this rate would seem excessive. For Jones et al it is the degree of elasticity of labour supply that leads to the divergence with Lucas.

The importance of these elements in determining the different results is confirmed in Stokey and Rebelo (1995). Using a model that encompasses the previous three, they show that the elasticity of substitution in production matters little for the growth effect but it does have implications for the level effect – with a high elasticity of substitution, a tax system that treats inputs asymmetrically will be more distortionary. The elimination of the distortion then leads to a significant welfare increase. Hence, the use of a Cobb-Douglas production function rather than the more general CES is not of great significance for conclusions concerning growth rates. What is important are the factor shares in production of human capital and physical output, the intertemporal elasticity of substitution in utility (σ) and the elasticity of labour supply (α). While information on factor shares in the production of physical output is easily obtained, information is limited on the crucial issue of the factor shares in the production of human capital. Finally, Stokey and Rebelo also demonstrate that the rates of depreciation of human and physical capital are important but information on both of these is limited. Despite these caveats, Stokey and Rebelo find grounds for supporting Lucas' claim that the growth effect is small.

The results so far have described experiments which test the effects of variations in the tax structure. Pecorino (1993) takes an alternative approach and asks the question: what combination of taxes results in the highest level of growth? The model used has the distinguishing feature that capital is a separate commodity to the consumption good.[4] This allows for different factor intensities in the production of human capital, physical capital and the consumption good. Numerical analysis of the model, assuming that the level of labour supply is exogenous, shows that the tax on wage income should exceed that on physical capital income when both physical and human capital production use physical capital more intensively than the production of consumption. The converse result holds when the capital production is less physical capital intensive than consumption production.

The effect upon the growth rate of optimising the tax rates is actually quite small. Compared to a baseline system where the tax rates on income from human and physical capital are equal, the optimal taxes raise growth by between 0.1% and 0.12% per annum. Endogenising labour supply, makes the effects slightly larger but the optimal taxes still raise growth by less than 0.2%. The experiment of removing the capital tax entirely is then undertaken. For $\sigma = 2$, $\alpha = 0.5$ (as in Lucas) and the share of physical capital in production in all three sectors of 0.24, the elimination of the capital tax raises the growth rate by 1.23%.

Under the original Lucas specification it should be recalled that this experiment lad to a marginal reduction in the growth rate. The reasons for the different results have already been described but are worth noting again. Firstly, in the Lucas model the cost of time involved in human capital production is forgone earnings which are not taxed. In the Pecorino model it is human capital itself which is the input and the earnings of this are taxed. This gives the wage tax a more significant role in the Pecorino model. Secondly, the share of physical capital in human capital production is 0 in Lucas and 0.24 in Pecorino.

[4] In the previous four contributions, capital is simply output which is not consumed.

This is one of the differences which Stokey and Rebelo identified as crucial for determining the growth effect.

Pecorino (1994) returns to the specification of the model with physical capital as unconsumed output. The innovation here is to consider the effect of a tax on consumption, as well as taxes on income from physical and human capital.[5] The experiment of replacing the tax on income from physical capital with a wage tax reduces growth from 1.5% to 1.37% – a slightly larger fall than in Lucas (1990). However, the replacement of the wage tax with a consumption tax raises the growth rate to 2.56%.

This review has revealed a range of estimates for the effects of taxation upon growth involving several different policy experiments. Some of the models predict that the growth effect is insignificant, others predict it could be very significant. What distinguishes the models is a number of key parameters, particularly the share of physical capital in human capital production, the elasticities in the utility function and the depreciation rates. In principal, these could be isolated empirically and a firm statement of the size of the growth effect given.

To do so and thus claim an “answer” would be to overlook several important issues about the nature and structure of the model. Moreover, it would not be justifiable to provide an answer without consulting the empirical evidence. Tax rates have grown steadily over the last century in most countries and so there should be ample evidence for determining the actual effect. Consequently, the next section briefly considers some extensions to the models that have been discussed. This is then followed by a consideration of the empirical evidence.

4. Extensions

There are a number of directions in which the basic model underlying the previous discussion can be extended. A number of these extensions will now be considered and their effects upon the relationship between taxation and growth discussed.

A first extension is to consider the changes that arise when an open economy framework is considered. An open economy has the implication that capital flows between countries will respond to differences in rates of return. If tax policy changes these rates of return, then an open economy setting will amplify its effects. This outcome has already been noted in the discussion of King and Rebelo (1990) – their growth decrease of 0.52% for a 10% increase in the tax on physical capital in a closed economy became an 8.6% decrease in the open economy. These figures suggest that a moderate tax increase would turn the initial growth rate of 1.02% into an annual decline in output of 7.58% – a figure that just does not seem credible.

The model of Asea and Turnovsky (1998) combines both an open economy and uncertainty with both asset prices and output are assumed to be stochastic. Endogenous growth is achieved by assuming that the production function is a stochastic variant of the AK technology. The model has no human capital. The effects of taxation on growth can be understood by thinking about how taxation affects the return on a risky asset: an

[5] In Lucas (1990) the tax on wage income is effectively a consumption tax. Again the reason for this is that the cost of time in human capital formation is just forgone earnings.

increase in taxation reduces both the mean return and the variance. The first is bad from an investor's point of view but the second is good. Consequently, there is a theoretical possibility that taxation may encourage the holding of risky assets which increases the capital stock and ultimately leads to higher growth. This argument is echoed by the analysis of Smith (1996) for a closed economy model based on endogenous growth through learning-by-doing.

Even when this risk argument is assumed not to apply, Asea and Turnovsky identify another channel through which taxation can have perverse effects. In the model the rate of growth is dependent upon the proportion of wealth invested in "foreign" assets but the direction of this relationship is not signed. Hence a tax increase on income from "home" assets will encourage holding of foreign assets, which may raise growth. In summary, this model has a number of transmission mechanisms which are not completely tied-down by the assumptions made. This leads to theoretical uncertainty about the effect an increase in taxation may have.

The issue of international capital mobility is also addressed by Razin and Yuen (1996). Their model is essentially a version of King and Rebelo but with the added dimension that the rate of growth of population is made endogenous by making time spent at child-rearing a choice variable. With perfect capital mobility the growth rate of output (and output per capita which is different due to the endogenous fertility) are both very sensitive to the rate of capital taxation with a reduction in the capital tax from 30.000% to 29.996% reduces growth of per capita output by 0.038. This gives the conclusion that a tax decrease both lowers growth and does so at a dramatic (and unbelievable) rate.

The next extension to the model returns to an issue that was discussed earlier: the role of lifecycle savings behaviour. The nature of lifecycle behaviour results in income from capital being received almost entirely by those in the later stages of life. In contrast, income from wages is received by the young. Therefore a switch from wage taxation to capital taxation reduces the tax burden on the young and raises it on the old. This provides an inducement to make greater saving in order to prepare for old age. Thus, an increase in the capital tax can actually have the effect of raising the level of capital and hence the level of growth.

This argument was first developed by Uhlig and Yanagawa (1996) in an endogenous growth model based upon learning-by-doing externalities. The essential feature was that the model embodied overlapping generations of consumers, with each consumer living for two periods.[6] In the first period they undertake work. Income in the first period is divided between consumption and saving. Over the lifecycle the consumer is endowed with one unit of labour. This is divided exogenously between the two periods of life with a fraction λ in the first period of life.

The central result of the paper is a demonstration that an increase in capital taxation will raise the growth rate (*via* the inducement it gives the young to increase savings) if the ratio of capital income to labour income for the economy as a whole is "not too high". This theoretical possibility is supported by numerical simulations which show the theoretical prediction is supported whenever λ is large so that labour supply is concentrated in the first period of life.

[6] In the simplest overlapping generations model, consumers live for two periods. In each period a new generation is born and they overlap with the old from the previous generation. More complex patterns of population are easily introduced – see Myles (1995).

The effect just described is dependent upon the relative values of lifespan and working life. Increasing the length of life will make the growth effect of capital taxation even stronger if the number of periods in which labour can be supplied is held constant. Conversely, if length of life is held fixed and the number of periods of labour is increased, the effect can be reversed. This relationship is explored further by Bertola (1996) who considers the Blanchard (1985) model of perpetual youth in which the lifespan of each consumer is random rather than fixed. The randomness is driven by the assumption that each period there is a constant probability of death. The conclusion of the analysis is to emphasise the dependence that the Uhlig and Yanagawa result of growth-increasing taxation has upon the assumption that labour supply declines rapidly in the later stages of life.

Also working within the overlapping generations framework, but with a model in which growth is driven by human capital formation rather than externalities, Ihori (1997) considers the same issues. However, the focus is upon the role of bequests rather than the lifecycle effect itself. With the bequest motive operative, an increase in the capital tax always reduces the growth rate while a tax on human capital leaves it unchanged. The roles are reversed when bequests are constrained to be zero. Here the taxes cannot raise the growth rate because of the effect of human capital and educational expenditures.

A final extension is to consider an alternative process through which endogenous growth arises. Einarsson and Marquis (1997) consider a model which can have growth through both investment in human capital and through R+D generating new intermediate goods (as in Romer (1990)). Within this framework they contrast the predictions of the two formulations. With respect to the level of welfare, it is found that the intermediate good model predicts much greater increases as a result ot tax reductions. For instance, a 10% reduction in the labour income tax from 25% to 15% raises welfare by 2.77% in the human capital model and by 19.01% in the intermediate good model. For a 10% reduction in the capital tax, the corresponding figures are 2.14% and 16.4%. Einarsson and Marquis suggest that these differences are explained by the human capital model requiring relatively more time input to generate additional growth than the intermediate good model.

Further differences arise when the transition between steady states is incorporated. In both cases, accounting for the transition reduces the welfare gain from the cut in capital income tax (and by a relatively higher percentage in the human capital model). However, the gain from the cut in income tax is raised by the transition in the human capital model but reduced in the intermediate good model. These results for the human capital model are consistent with those of Laitner (1995). Turning to growth rate effects, the 10% reduction in labour income tax raises the growth rate by 0.28% for both models whereas the 10% reduction in capital tax raises growth by 0.28% in the intermediate good model but only 0.08% in the human capital model.

Several conclusions emerge from these extensions. In practical terms, it is clear that the open economy is important and the models are helpful in identifying additional channels through which taxation can affect growth. However the growth effects derived in that setting are apparently extreme and simply too large to be credible.[7] This finding is potentially important for the shadow of doubt it casts upon the structure of the models. As a basis for policy recommendations, they generate issues for debate but cannot be trusted

7 The sensitivity of the Razin and Yuen model in particular makes one wonder about the stability and uniqueness properties of equilibrium. The steady state defined seems not to be robust to large parametric variation.

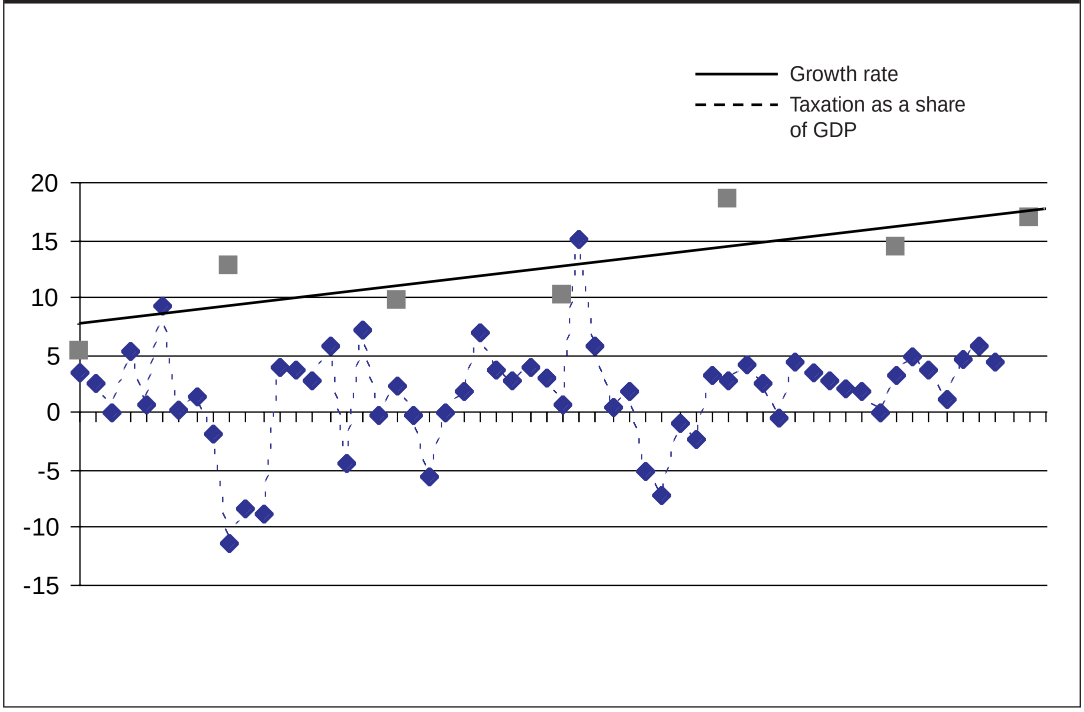
to provide meaningful quantitative guidance. Extending the model to include uncertainty, endogenous fertility and lifecycle behaviour has the effect of reducing the growth rate effect of taxation and can even overturn normal expectations. Finally, the analysis of the intermediate good model shows that the process for generating endogenous growth can have significant bearing on the conclusions. This is especially noticeable with respect to the level effect, rather less so for the growth effect.

5. Empirical Evidence

The theoretical evidence has produced a range of estimates for the effect of taxation upon economic growth. Since the theory is so inconclusive, it becomes paramount to consider the empirical evidence. At first glance, a very clear picture emerges from this: tax revenue as a proportion of GDP has risen significantly in all developed countries over the course of the last century, but the level of growth has remained relatively stable. This suggests the immediate conclusion that, in practice, taxation does not affect the rate of growth.

Data to support this claim is displayed in Figure 3 for the UK and Figure 4 for the US (the latter being taken from Stokey and Rebelo (1995)). In Figure 3, the dashed line is the growth rate and the solid line the (least squares) trend line for taxation as a share of GDP.[8] Both figures show the steady rise in taxation and the relative constancy of the mean growth rate. Statistical tests by Stokey and Rebelo on the US data found no statistical difference between the average rate of growth prior to 1942 and after 1942.

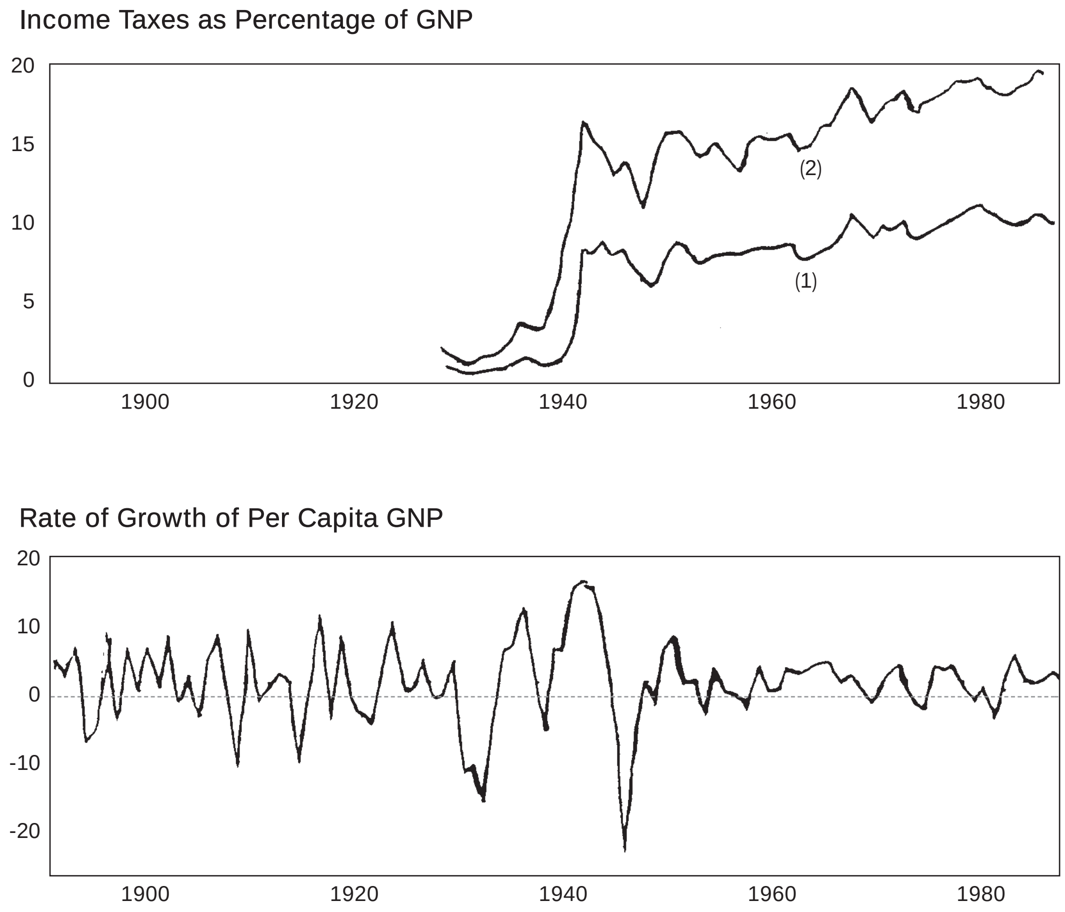
Figure 3: **UK Revenue Statistics**



Source: C.H. Feinstein, *National Income, Expenditure and Output of the United Kingdom*, 1855 – 1965, Economic Trends.

[8] Tax revenue is defined at the total receipts of the Inland Revenue, so it includes income tax and corporation tax plus other smaller taxes. It does not include National Insurance or Value Added Tax. Adding these would raise the trend line further.

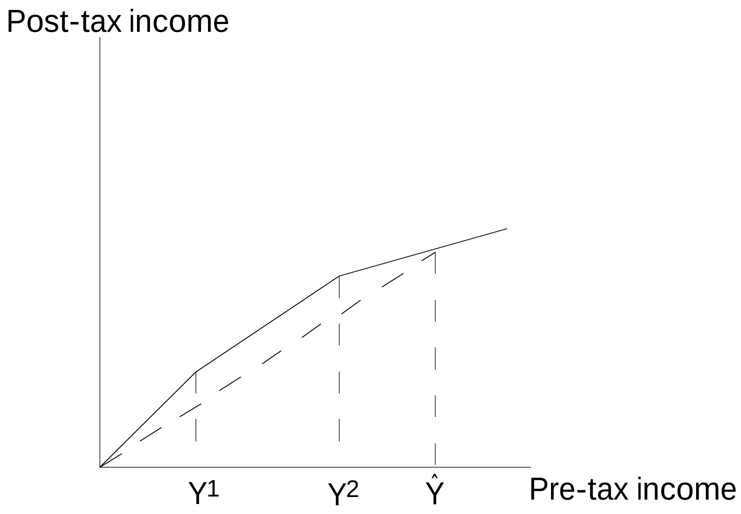
Figure 4: **Taxation and growth in the US**



The message from these figures is compelling but not completely convincing. There are two reasons for this. Firstly, a contrast tax between rates and growth across time cannot answer the counter-factual question "if taxes had been lower, would growth have been higher?" To do so requires a cross-country study. Secondly, there are substantive issues about the definition of the tax rates that should be used in any such comparison.

To understand the problem of definition, consider Figure 5 which illustrates a typical progressive income.[9] There is an initial tax exemption up to income level Y^1, then a band at tax rate t^1 and a final band at rate t^2, $t^2 > t^1$. What is important about the figure is that it shows how the marginal rate of tax (what proportion of an extra pound of income is paid in tax) differs from the average rate of tax (what proportion of total income is paid in tax). For instance at income $\hat{Y}$, the marginal rate is one minus the gradient of the graph whilst the average rate is one minus the gradient of the ray to the graph. With a progressive tax, the marginal rate is always greater than the average rate.

Figure 5: **Average and marginal tax rates**



The data displayed in Figures 3 and 4 are tax revenue as a fraction of GDP, i.e. they capture the average tax rate. However, what matters for economic behaviour is the marginal tax rate – the decision on whether or not to earn an additional pound depends on how much of that pound can be kept. This suggests that the link between growth and taxation should focus more on how the marginal rate of tax affects growth rather than on the average rate.

The difficulty with undertaking this is defining what the marginal rate actually is. Figure 5 illustrates this problem: the marginal rate is either 0, t^1 or t^2 depending where on the graph a consumer chooses to locate.[10] In practice, the income tax system has a number of different levels of exemption, several marginal rates and interacts with National Insurance contributions. All of this makes it difficult to assign any kind of value to the marginal rate of tax. The same comments apply equally to corporation tax, which has exemptions, credits and depreciation allowances, and Value Added Taxation which has exemptions, zero rated goods and lower rated goods. In brief, the rate of growth should be related to the marginal rate of tax but the latter is very ill-defined.

9 Progressive tax here means one with an increasing marginal rate. Other definitions are possible, see Lambert (1993).

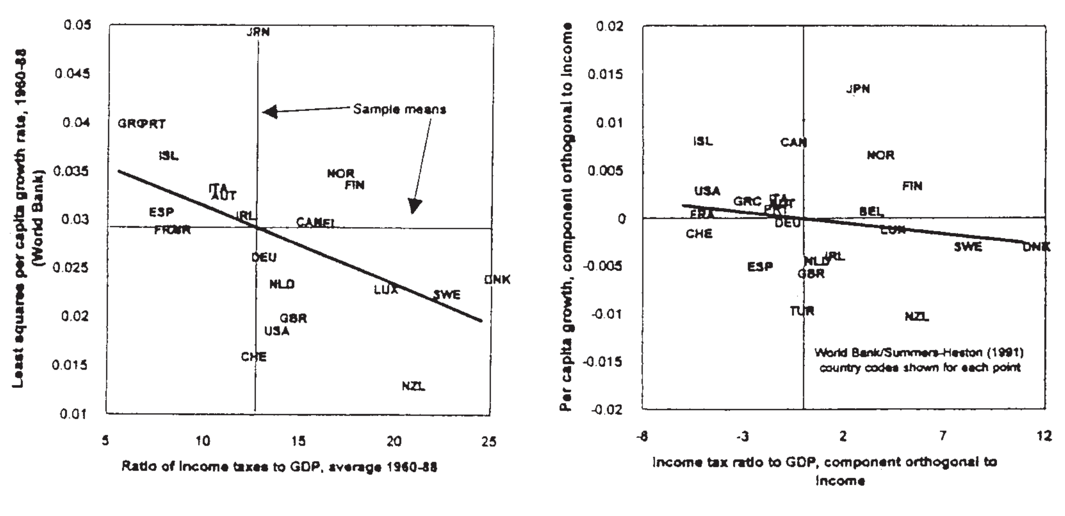
10 The theoretical models already reviewed avoided this issue by considering only flat rate tax systems (meaning a single marginal rate). The graph of a flat rate system is a straight line, so marginal and average rates are equal.

One approach designed to circumvent these difficulties can be found in Easterly (1993). Rather than look at tax rates directly, Easterly places the focus directly on the distortions generated by those tax rates. These distortions are found by using the data of Summers and Heston (1988) on 1980 price data for 151 commodities in 57 countries relative to the US. The variance of the prices within countries is then taken as a measure of the relative degree of distortion that exists in those economies due to taxation, quotas, price restrictions and other forms of intervention. Controlling for other determinants of growth (such as initial country income and school enrolment), the reported estimates show that the variance of input prices is a statistically significant variable in the determination of growth. In fact, increasing the variance of prices from the mean by one standard deviation lowers growth by 1.2%.

This is clearly an interesting approach but it does have two deficiencies. First, the variance of prices is not proven to be a good proxy for the degree of distortion in the economy, it is merely assumed to be so. Secondly, there is no immediately obvious way to translate from the effect of price variation into the effect of changes in tax rates. To do so would require knowledge of how taxes feed, through market equilibrium, into prices.

Some of the strongest evidence for an empirical link between taxation and growth is reported in Plosser (1993). Plosser regresses the rate of growth of per capita GDP on the ratio of income taxes to GDP for OECD countries and finds a significant negative relationship. This is shown in the left panel of Figure 6 (which is taken from Easterly and Rebelo (1993b)). The limitation of this finding is that the OECD countries differ in their income levels and income has been found to be one of the most significant determinants of growth (Barro (1991)).[11] The second panel of Figure 6 shows what happens to the negative relationship when the effect of initial income is accounted for: it all but disappears. This observation makes the claims of Plosser rather doubtful.

Figure 6: **Growth and taxes: OECD countries**



[11] A higher level of initial income is associated with a lower level of growth in later periods.

Easterly and Rebelo extend this analysis by using several different measures of the marginal rate of tax in regressions involving other determinants of growth, notably initial income, school enrolments, assassinations, revolutions and war casualties. In response to some of the difficulties already noted, four different measures of the marginal tax rate are used: statutory taxes; revenue as a fraction of GDP; income weighted marginal income tax rates; and marginal rates from a regression of tax revenue on tax base.[12] From a number of regressions involving these variables, Easterly and Rebelo conclude "The evidence that tax rates matter for economic growth is disturbingly fragile".

A very similar exercise is undertaken in Mendoza, Milesi-Ferretti and Asea (1997). In their regressions the tax variables are the marginal tax rates calculated in Mendoza, Razin and Tesar (1994). The clear finding is that when initial GDP is included in the regressions, the tax variable is insignificant. Evidence contrary to this is presented in Leibfritz, Thornton and Bibbee (1997). Their regression of average growth rates for OECD countries over the period 1980 – 1995 against three measures of the tax rate (average tax rate, marginal tax rate and average direct tax rate) showed that a 10% increase in tax rates would be accompanied by a 0.5% reduction in the rate of growth, with direct taxation reducing growth marginally more than indirect taxation.

An alternative line of literature (Barro (1991), Dowrick (1993) and de la Fuente (1997)) has considered the more general issue of how fiscal policy has affected growth. In particular, it has investigated how growth is related to the composition and level of public sector spending. The results of de la Fuente show that growth is reduced by increases in public spending (a reduction in government spending of 5% of GDP reduces growth by 0.66%) whereas an increase in public investment will raise growth. There are four significant points to be made about these findings. Firstly, government spending may just be a proxy for the entire set of government non-price interventions – including, for example, employment legislation, health and safety rules and product standards – and that it may be these, not expenditure, that actually reduce growth. Secondly, since the share of public spending in GDP is very closely correlated to the average tax rate, it is not clear which hypothesis is being tested.

The final points are more significant. Levine and Renelt (1992) have shown that the finding of a negative relationship is not robust to the choice of conditioning variables. Finally, as noted by Slemrod (1995), the method of the regressions is to use national income, Y, as the left-hand-side variable and government expenditure, G, as the right-hand variable. In contrast, economic theory usually views the causality as running in the opposite direction through, for instance, models such as that summarized by Wagner's law. If Y (or the growth of Y) and G are related via an equilibrium relationship, then a simple regression of one on the other will not identify this.

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

[12] The concepts for the second and fourth measures are taken from Easterly and Rebelo (1993) and Koester and Kormendi (1989) respectively.

This review of the empirical evidence has some clear conclusions. A visual inspection of tax rates and growth rates suggests that there is little relationship between the two. This is weak evidence but it does find support in some more detailed investigations in which regression equations that include previously identified determinants of growth, especially initial income, reveal that tax rates are insignificant as an explanatory variable. Other regressions find a small but significant tax effect. All of these results are dogged by the difficulties in actually defining marginal rates of tax and in their lack of an equilibrium relationship.

6. Environmental Issues

An issue that has not yet been discussed is the environmental impact of growth. Although there is a small literature on this subject, it is not as yet well developed nor well focused. There are probably two reasons for this situation. Firstly, there seems to be no convincing modelling of the role of environment. Secondly, the concentration upon the demonstration of “double dividend” effects has directed attention away from more substantive issues.

Environmental effects can operate in the models through two different channels. One channel is through the appearance of environmental quality in the utility function of the consumer (as in Mohtadi (1996)), coupled with the assumption that welfare is derived from high environmental quality. This can be linked with production by assuming that the quality of the environment is degraded over time at a rate which is dependent on such things as the level of output. This is a natural way to proceed and useful results could be expected. However the model is not developed convincingly in Mohtadi.[13]

Putting issues about specification aside, the results of Mohtadi claim to show that the highest level of welfare is achieved by the use of a combination of taxes and quantity controls. Before weight can be given to this, the nature of quantity controls has to be carefully analysed. Let the level of environmental quality at time *t* be given by:

$$E(t) = E_0 K(t)^{-\beta},$$

thus a quantity control in the sense of Mohtadi is a change in the value of *ß*. This is not a quantity control in any normal sense. *ß* controls the relationship between capital stock and environment. It could be changed by pollution abatement regulations etc. but this is not the same thing as, for example, controlling how much capital is used. Changes in *ß* must be connected with additional costs elsewhere, which would reduce the benefits gained, but these are not modelled.

[13] Mohtadi (1996) actually states that environmental quality “is assumed to be a “stock” that is gradually depleted over time by the flow of pollutants” but then writes *E = E(K)* the words and the equations are not reconcilable. No doubt the expression used was for mathematical convenience but it is does not have much intuitive appeal. There are also technical doubts about the existence of the steady state that is used to address policy.

The second possibility is that environmental quality is an argument of the production function. The way that this is undertaken in Bovenberg and de Mooij (1997) is to make environmental quality a multiplicative constant on the production function (it can be interpreted as a variable *A* in the *AK* production function). In addition, both pollution and abatement are also inputs into the production process.[14]

Bovenberg and de Mooij study the effect of an increase in the tax rate on pollution with the government budget balanced by a offsetting change in the output tax. A clear prediction is obtained that this will lower the level of pollution but the effect on the growth rate is uncertain. What it depends on is a number of elasticities[15], and there is no obvious line of reasoning or available data which can evaluate these or resolve the competing effects with any degree of confidence. This should be contrasted to the basic growth models where data is easily available on the important parameters such as the shares of capital and labour in production.

Mabey and Nixon (1997) assess the effect of environmental taxes in two different macroeconometric models. Unfortunately, the theoretical analysis presents only some unsubstantiated assertions and has little value.[16] The empirical results consider two different specifications of the “supply-side” and “wage-setting” and embeds these within macroeconometric models.

The first model (named EGEM) employs three factors of production: capital, labour and energy. Labour and capital are combined in a CES (sub)production function, and this aggregate then enters a Cobb-Douglas along with energy. Employment is determined via profit maximization at the given wage rate. More importantly, energy intensity is reduced by an autoregressive trend so that the effects of policy change will accumulate over time. The second model (SLEEC) uses four inputs (the three already introduced plus imported inputs) and represents technology via a trans-log cost function. Price is given by a mark-up on costs.

The simulated policy experiment involves the imposition of a flat rate tax of US $275 per ton of carbon. In both models the use of energy decreases initially. Whereas for EGEM it continues to do so, SLEEC eventually has energy use increasing again. Significant differences between the models are also apparent in the response of GDP when the tax revenue is recycled through either income tax or National Insurance reductions. For EGEM GDP rises initially then falls whereas for SLEEC it falls then rises. These direct conflicts between the outcomes for the two models lead Mabey and Nixon to conclude that the results “cast doubt on the possibility of supplying advice to policy-makers about the macroeconomic consequences of tax shifting”.

The double dividend (and sometimes the single and triple) appears frequently in the environmental tax literature so a comment on this seems appropriate. Whilst there are

14 It would seem more natural to think of pollution as an output, as in Gradus and Smulders (1993), for example. The best way to think of it as an input is to have abatement and pollution as determining together some kind of “working environment” which then has a bearing on the productivity of the firm. Pollution can be interpreted as an output in its effect upon environmental quality.

15 Actually the elasticities of: environmental quality in production; pollution in production; elasticity of abatement in production; and elasticity of pollution in determining environmental quality.

16 The theory has several deficiencies. First, it uses a representative consumer framework but enters “equity” as an argument in utility. Second, the optimisation apparently ignores any government budget constraints. Third, the optimisation of public good provision is not incorporated. If some of the public goods are complementary to a cleaner environment (e.g. parks), then the general level of taxation may rise after the carbon tax is employed to support greater provision of these complements.

many alternative ways in which the double dividend can be formalized (see Goulder (1995)), a loose statement of the double dividend is that taxes levied on goods causing environmental damage have the twin benefits of reducing the environmental damage and raising revenue. A first reaction to this statement of the double dividend is to accept it as implying that taxation should be focused on goods causing environmental damage and that these goods are somehow different to those not causing environmental damage. This is wrong on at least two counts.

The analysis of environmental taxes is often developed in a partial equilibrium framework which leads to the misleading conclusion that the taxes should only be levied on goods directly responsible for environmental damage. In a general equilibrium framework with many households, this conclusion depends on the ability to differentiate taxes across goods and across households. Restricting taxes to be uniform across households, examples can be constructed (see Green and Sheshinski (1976)) in which the tax on a good damaging the environment should be zero whilst other goods which cause no such damage have positive taxes. The simple intuition is misleading in a complex context. For there to be any dividend from changing tax policy, whether environmental issues are relevant or not, the initial tax system must be inefficient. If it is inefficient for the level of revenue being raised, there must be some good which is taxed too.[17] Raising the tax on this good will reduce consumption toward the efficient level, a first dividend, and raise some revenue, a second dividend so any commodity, whether it affects the environment or not, can yield a double dividend.

As a policy guide, the double dividend argument is vacuous. If the tax system is inefficient, it is obvious that it should be improved. The literature always assumes that the initial position is one where environmental effects have been ignored, so any improvement to the system involves correcting by introducing pollution taxes. Why this should be the starting point is never made clear. Given that in practice the tax system begins from an essentially arbitrary position, the double dividend literature is silent about what should be done – taxes on environmental goods may already be too high. Consequently, the double dividend hypothesis in itself has no useful policy implications.

7. Conclusions

In summary form, the conclusions that emerge from this report are:

1. There is a wide range of theoretical predictions about the effect on the growth rate of changes in taxation. This is as true within models as it is across models. Within models it is at least understood which parameters most affect the outcome but there is no evidence yet for how to choose between models.

2. The size of the growth rate effect is increased in an open economy and reduced if lifecycle behaviour is considered. However, the effects in the open economy are unreasonable large.

3. Empirical evidence provides mixed results. Some supports the hypothesis that taxation has no effect on growth, some that there is a small but significant effect. None of the work has fully resolved the data and specification problems involved in constructing a true test.

[17] This argument assumes that the economy is on the upward sloping part of the Laffer curve.

4. A satisfactory model incorporating the environment has not yet been constructed. Those that have been generate directly conflicting conclusions.

On issues of more direct concern to SACTRA the following comments are offered. Firstly, on the effects of a switch from direct to indirect taxation neither the theoretical or empirical evidence offers much guidance. The empirical work focuses on aggregate measures of taxation and generally does not look at individual components and the theoretical work is mainly concerned with experiments involving taxes on capital and labour income. Of the theoretical papers reviewed, only Pecorino (1994) (p. 10/11) contrasts a move to wage taxation with one to consumption taxation. The finding is that moving to consumption taxation is more beneficial to growth. This finding is supported by the empirical results of Leibfritz et al (1997) (p. 19). Consequently, what evidence there is points to indirect taxation being less harmful to growth than direct taxation. However, this is a claim which requires more substantiation before it is compelling.

Concerning the switch from direct taxation to optimal congestion charges, the literature reviewed is mostly silent on this. The research on growth in Sections 3 – 5 is conducted at too aggregate a level for such questions to be addressed. The Romer (1990) intermediate good model with one of the inputs being transport might prove a suitable vehicle for addressing this issue but this has not been pursued in the literature. Mabey and Nixon (1997) come closest to addressing the question but their two macroeconometric models have directly opposing conclusions. It would seem that an answer to this question will only be found if research is undertaken to investigate it in a framework designed for the purpose. Attempting to infer conclusions from the existing literature is not likely to provide an acceptable answer.

In conclusion, it is difficult to draw "micro conclusions" from what is a very aggregative, macro literature. There is some evidence that taxation may be harmful to growth, although the effect is most likely to be quite small, but this evidence is by no means overwhelming. There remain significant problems with the structure of the tests of this hypothesis. Models of the effect and design of environmental taxes which take account of growth effects are in their infancy. Those that do exist do not seem to provide any substantive conclusions.

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