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Taxation and Economic Growth

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Abstract

The development of endogenous growth theory has opened an avenue through which the effects of taxation on economic growth can be explored. Explicit modelling of the individual decisions that contribute to growth allows the analysis of tax incidence and the prediction of growth effects. This paper reviews the theoretical and empirical evidence to assess whether a consensus arises as to how taxation affects the rate of economic growth. It is shown that the theoretical models isolate a number of channels through which taxation can affect growth and that these effects may be very substantial. Although empirical tests of the growth effect face unresolved difficulties, the empirical evidence points very strongly to the conclusion that the tax effect is very weak.

JEL classification: E62, H20.

I. INTRODUCTION

Economic growth is the basis of increased prosperity. Investment in new capital (both human and physical), the implementation of new production techniques and the introduction of new products are the fundamentals of the growth process. Through its effect on the return to investment or the expected profitability of research and development, taxation can affect what choices are made and, ultimately, the rate of growth. In most developed countries, the level of taxes has risen steadily over the course of the last century. An increase from about 5–10 per cent of GDP at the turn of the century to 20–30 per cent at present is typical. Such significant increases in taxation raise serious questions about the effect they have had upon economic growth.

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Until recently, economic models that could offer insight into this question were lacking. Much of the growth literature focused on the steady state where output per head was constant, whilst those that did have sustained growth introduced this through a process exogenous to the model. By definition, such exogenous growth could not be affected by taxation. It is only since the development of endogenous growth theory that a tool has existed for investigating how taxation affects growth. These new models explicitly model the processes through which growth is generated and, by doing so, can trace the effects of taxation upon the individual decision-making that lies behind them. Thus, tax incidence can be understood and predictions made about growth effects.

The models provide a perspective from which to interpret and understand historical data. They should also generate insights into the consequences of future policy changes. This latter role is especially important in current policy debates, given the significance attached to ‘green taxes’ as a solution to environmental problems. The carbon tax, for example, has been proposed as a solution to increases in greenhouse gases. The introduction of this and other similar instruments will have the effect of raising the level of taxation even higher. This immediately focuses attention on how detrimental the implementation of such a tax will be for economic growth.

The purpose of this paper is to draw recommendations for tax policy from a review of the endogenous growth literature. It considers both the theoretical research, which shows how taxation might affect the economy, and the empirical evidence, which seeks to evaluate these effects. The consequences of extending the analysis to incorporate environmental issues are also addressed. The paper offers the conclusion that the structure of taxation is probably more important than the level.

The remainder of the paper is organised as follows. In Section II, a brief introduction to growth theory is provided. This notes the limitations of assuming exogenous growth and describes the features of major endogenous growth models. This is followed in Section III by a study of theoretical predictions of the effect of taxation on growth in the simplest closed-economy endogenous-growth setting. 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 IV. The theoretical results are contrasted with empirical evidence in Section V. The inclusion of environmental aspects into the models and the double dividend hypothesis are analysed in Section VI. Section VII provides some conclusions.

II. MODELS OF ECONOMIC GROWTH

This section describes the distinctions between models of exogenous and endogenous growth. It looks at the limitations of early growth models to show why endogenous growth models were an important development. The various endogenous growth models are introduced to provide a perspective for the later discussion. The important distinction between level and growth effects is also explained.

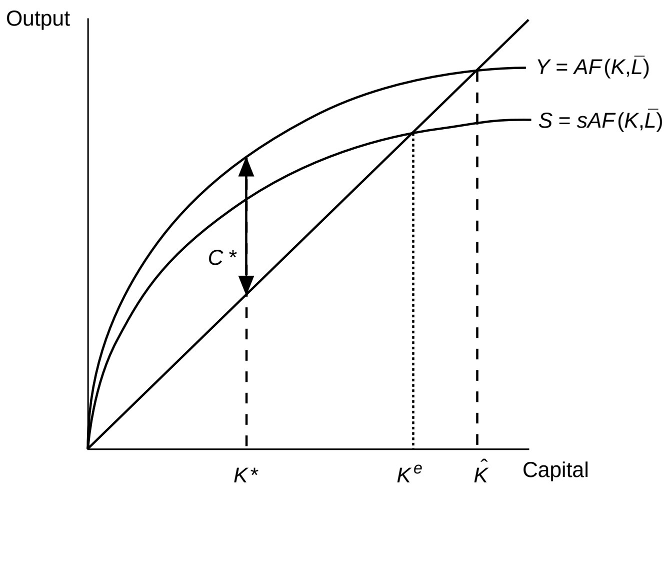
1. Exogenous Growth

The growth theory of the 1950s and 1960s, typified by Solow (1956) and Swan (1956), was based on a production function that had capital and labour (with labour measured in man-hours) as the inputs into production. Constant returns to scale were assumed, as was diminishing marginal productivity of both inputs. Growth occurred in the model through the accumulation of capital but, without any exogenous changes, there had to be a limit to this process.

To see this, consider an economy with a fixed population in which each person works a fixed number of hours and 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. With fixed labour supply $\bar{L}$, the production function $Y = AF\left(K, \bar{L}\right)$ shows the level of output as capital is increased, with its shape a consequence of diminishing marginal productivity. Since $Y = C + K$, the height of the curve above the 45° line shows the quantity of consumption. Let saving, *S*, be a constant fraction of output, so $S = sY$. Since capital is the only repository for savings, this is also the level of

FIGURE 1

Output, Saving and Capital



investment. The equilibrium for the economy occurs when net additions to the capital stock are zero and investment matches depreciation. With the total depreciation, this implies $K = sY = sAF\left(K, \bar{L}\right)$. This equilibrium level of capital is shown as K^e in Figure 1.

As well as the equilibrium level, two other levels of capital are important. Capital level K^* in Figure 1 shows the point where consumption per capita is at its maximum of C^*. This is the optimal outcome for the economy and no amount of investment will ever allow consumption to exceed C^*. In contrast, at $\hat{K}$, consumption is zero and all output is being used to replace the depreciated capital stock. This cannot be sustained as an equilibrium. More importantly, Figure 1 shows why there is a natural limit to the level of consumption per capita due to the limited supply of labour and the diminishing marginal productivity of capital. Putting more and more capital to work with a limited supply of labour is eventually self-defeating, as a point is reached at which all production is used just to maintain the level of the capital stock. Removing the fixed population assumption does not help. Although this permits the total size of the economy to grow without limit (i.e. as population increases, so does total output), it does not allow consumption per capita to grow beyond C^*. Relaxing the assumptions of fixed labour supply and of complete depreciation does not help either — doing so simply moves the points K^* and $\hat{K}$.

To circumvent this conclusion, the assumption of 'exogenous growth' was introduced. Under this assumption, labour or capital (or both) would, for exogenous reasons summarised as 'technical progress', become more productive over time. If the technical progress were capital-augmenting, this would mean that the curve in Figure 1 shifted upwards over time, thus raising the maximum attainable level of consumption. The drawback of this approach is that the mechanism for growth — the 'growth engine' — is exogenous, so preventing the models from explaining the most fundamental factor of what determines the rate of growth. Furthermore, because it is exogenous, the rate of economic growth cannot be affected by policy. As such, exogenous growth models have limited value for exploring the determinants of growth. This explains why interest in growth theory declined in the 1960s and did not revive until the development of endogenous growth theory almost 25 years later.

2. Endogenous Growth

Models that both allow sustained growth *and* determine its level are said to have 'endogenous growth'. To achieve this requires circumventing the decreasing marginal product of capital in a way that is determined by choices made by the agents in the economy. There have emerged in the literature four basic methods by which this can be achieved. All of these approaches achieve the same end — that of sustained growth — but by different routes.

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 model's name. Output will then grow at the same rate as net investment in capital. Whilst simple, this model is limited due to the fact that it overlooks the obviously important role of labour.[1]

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. Doing so allows labour time to be made more productive by investments in education and training which raise human capital. There are then two investment processes in the model: investment in physical capital and investment in human capital. If the production function has constant returns to scale in human capital and physical capital jointly, then investment in both can raise output without limit. 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 latter approach is able to incorporate different human and physical capital intensities in the two sectors, so making it consistent with the observation that human capital production tends to be more intensive in human capital — through the requirement for skilled teaching staff etc.

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 and 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 results in better-quality inputs which are more productive. Over time, old inputs are replaced by new inputs and total productivity increases. Firms are driven to innovate in order to exploit the position of monopoly that goes with ownership of the latest innovation. This is the process of 'creative destruction' which was seen by Schumpeter (1934) as a fundamental component of technological progress.

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[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 final approach to ensure sustained 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 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 flow 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 translate into constant returns for the economy.

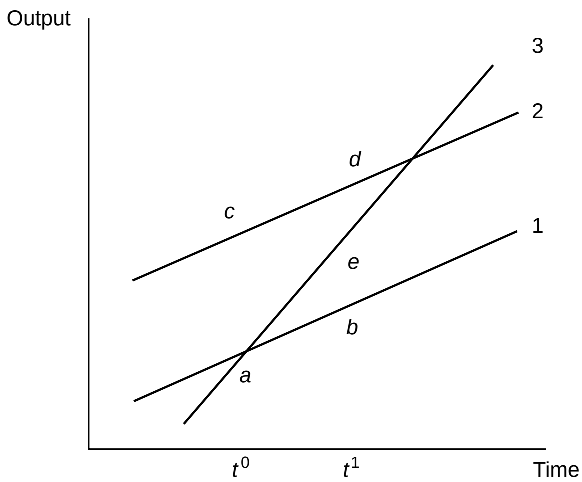
3. Level and Growth Effects

Before assessing the effects of taxation, it is worth clarifying an important distinction — the distinction between the effect of a change in taxation on the *level* of output and its effect on the rate of *growth* of output. This distinction is illustrated in Figure 2, which shows three different growth paths for the economy. Paths 1 and 2 have the same rate of growth — their slopes are the same. In contrast, path 3 has a steeper slope and therefore captures a faster rate of growth.

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

FIGURE 2

Distinguishing Level and Growth Effects



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'. Naturally, most policy changes will have both level and growth effects. It is also worth noting that, in exogenous growth models, only level effects can arise, but that both level and growth effects are possible with endogenous growth.

III. ANALYTICAL RESULTS

This section will consider analytical results on the relationship between taxation and growth. It begins with a discussion of the optimal structure of taxation, which describes the form that the tax structure should possess. This can be compared with the actual structure to assess whether there is a possibility for improvement. A discussion of the gains that can be made through reform of the tax system then follows. The results are a combination of analytical predictions and numerical predictions developed from calibrated models.[2]

1. Optimal Taxation

In a static economy, the efficient structure of taxation is found by following Ramsey rule principles. Under the assumption that there are no substitutability or complementarity relations between the goods in the economy, this translates into the simple prescription that the tax on a good should be inversely proportional to its elasticity of demand (see Myles (1995)). A formal treatment of taxation in an overlapping-generations model of growth (see Ihori (1996)) shows that, on the steady-state growth path, a slightly modified version of the Ramsey rule applies. This is not too surprising since it is only a small step from a static economy to a steady-state growth path. If a source of exogenous growth were to be added to the overlapping-generations economy, there is no reason why the conclusion should change. However, in a growth model, this conclusion represents only one aspect of the problem. To the within-period treatment of different commodities captured by the Ramsey rule must be added an analysis of taxation as it affects intertemporal choices, in particular the decision to invest.

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[2]The process of calibration involves choosing key parameters in models (such as the share of capital in GDP) to match those in the data and setting other parameters (such as the elasticity of substitution between capital and labour in production) at values consistent with econometric estimates.

There are two different strands to the literature on the taxation of capital in growth models which are distinguished by the time-horizon of households. The early work (such as Atkinson and Sandmo (1980)) assumed that households have finite horizons. Under this assumption, income from capital should be taxed at a positive rate. This result is extended by Park (1991), who shows that the tax rate is dependent upon the rate of social time preference and individual preferences over consumption in different periods of life. There are cases, though, in which capital income should not be taxed. As shown by Ordover and Phelps (1979), if preferences are separable between consumption and labour, then the use of an optimal non-linear income tax makes a tax on capital income redundant.

The outcome is significantly different when households have infinite horizons.[3] In this case, Chamley (1986) showed that the long-run tax rate on capital should be zero. This finding was extended to an endogenous growth model by Lucas (1990). The basic intuition behind this result is that a capital income tax distorts the investment decision, so, in the long run, should be replaced entirely by an income tax. This is an important result since the optimal tax structure that it describes is significantly different from that which is observed in practice. As such, the model on which it is based requires further consideration.[4]

Given its effect, the assumption that households have infinite horizons is critical. 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.[5] On this interpretation, the assumption can become acceptable. Even so, it must be treated with caution since the way in which the care between generations is expressed can affect the outcome. The zero-tax result is dependent on each generation caring about the utility of the following generation. If instead they care about the size of the bequest they leave, which can be interpreted as an indirect concern about the later generation's welfare, then, as Chamley (1986) noted, it once more becomes optimal to tax capital.

Two further situations in which the zero tax will not apply have been identified. Correia (1996) assumes that there are one or more factors of production that the government cannot tax (or cannot tax optimally). Then the tax upon capital income will be dependent on the relationship between capital

[3]A comprehensive survey of this area can be found in Chari and Kehoe (1998).

[4]There is also the issue of commitment. Once the government has announced a zero tax, it can always raise additional revenue by reneging and imposing a positive tax. This can be resolved by assuming either that there is some mechanism available that allows commitment or else that commitment can be sustained by reputation effects.

[5]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 (1984). It has been challenged empirically by Kotlikoff and Summers (1982), amongst others.

and the non-taxable factors. Zhu (1992) extends the Chamley model to incorporate stochastic shocks to government spending and to technology. In this setting, there is no presumption that the long-run tax rate on capital should be zero.

The result of Chamley offers an intriguingly simple policy proposal. As a practical suggestion, it is open to questions about the interpretation of the long run and about the cases in which it has been shown not to hold. But the assumptions that some factors cannot be taxed and that the economy is subject to a series of stochastic shocks are both very open to criticism. That almost all people care about their descendants is clearly true, but the precise way in which this enters utility is not easily investigated. Consequently, these objections are not fundamentally damaging to the result. By demonstrating what should be the case, the result permits an understanding of how reforms will affect the economy.

2. Policy Reform

If the zero tax on capital is accepted, actual tax systems are revealed to be far from this ideal. This raises the possibility that reforms in these systems can raise the rate of growth and the level of welfare. The most obvious policy to consider is budget-balanced replacement of the capital tax by taxes on consumption or labour.

The first major contribution in this respect was by Lucas (1990), who analysed an endogenous growth model with investment in human capital driving growth. The fundamental assumptions of Lucas, 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; and
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 since the single household can always be interpreted as a representative of many identical households. Its role is to eliminate issues concerning distribution between households of differing abilities and tastes (the ‘equity’ role of policy) and to focus entirely upon efficiency. The second part of the assumption, that the household has an infinite life, has already been discussed above. Accepting this, there is still one further shortcoming of the assumption. In practice, the consumption and saving of a household follow the pattern of the life-cycle hypothesis (Ando and Modigliani, 1963): income gradually rises until retirement, saving begins negative, then rises and again becomes negative in retirement. The model of infinite lifespan cannot capture this life-cycle behaviour. A model that can, and one that is discussed further below, is the overlapping-generations model of Samuelson (1958) and Diamond (1965).

The quantitative results of Lucas are obtained using data from the US economy and aim to show what would have happened if the tax on capital had been set to zero in 1985 with revenue-neutrality ensured by increasing the tax on labour. With an initial capital tax rate of 36 per cent, the rate of growth of output per capita before the tax reduction is 1.5 per cent p.a. The conclusions that emerge are that reducing the capital tax to zero causes a reduction in the growth rate to 1.47 per cent, an increase of over 30 per cent in the capital stock, and increases of 6 per cent in consumption and 5.5 per cent in welfare. Consequently, the policy change results in a significant *level* effect but an insignificant *growth* effect. The explanation for these findings is straightforward. Since time is the only input into the production of human capital, the cost (and return) 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. 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 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 per cent, to give a net increase in welfare of 3.3 per cent.

The analysis of Lucas is extended by King and Rebelo (1990), who consider both an open economy and a closed economy. The model differs from Lucas's through the use of a Cobb–Douglas production function, rather than Lucas's constant elasticity of substitution (CES),[6] 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 bench-mark case, where the share of physical capital in human capital production is a third, increases in the capital tax and the labour tax from 20 per cent to 30 per cent reduce the growth rate by 1.52 percentage points from its initial level of 1.02 per cent, to –0.5 per cent. The level effect is a 62.7 per cent decrease in welfare. A 10 percentage point increase in the capital tax alone reduces growth by 0.52 of a percentage point to 0.5 per cent. When the share of physical capital in human capital

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

production is decreased to a twentieth, the figure of 0.52 of a percentage point falls to 0.11 of a percentage point. 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 percentage point increase in the capital tax reduces growth by 8.6 percentage points. Further comments upon the open-economy results will be made in Section IV(1).

The model of Jones, Manuelli and Rossi (1993) combines elements of those of Lucas and of 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

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

where c is consumption, ℓ is leisure and α and σ are constants. Lucas takes σ=2 and α=0.5. In contrast, Jones et al. find the value of α by calibrating the model with the data. For instance, 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. 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 cent p.a. to 4 per cent.[7] For lower values of σ, and hence greater values of α, the effect is even more marked. A value of σ=1.1 (and α=7.09) gives an increase in growth of 8.3 percentage points. The reason for this increase in growth can be seen in the response of labour supply to the tax changes. For σ=1.1, the quantity of time used for work increases by 47 per cent and time devoted to human capital formation by 50 per cent. For σ=2, the figures are 11 per cent and 0 per cent respectively.

At this point, it seems worth summarising 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. King and Rebelo use a much lower share of human capital in its own production than Lucas and a depreciation rate of 10 per cent p.a. 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 explaining the divergence between the results is confirmed in Stokey and Rebelo (1995). Using a model that encompasses the previous three, they show that the elasticity of substitution in

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[7]Since this entails a loss of government revenue, the implicit assumption is made that revenue is not spent on any productive activity.

production matters little for the growth effect but does have implications for the level effect — with a high elasticity of substitution, a tax system that treats inputs asymmetrically will be more distortionary. The elimination of the distortion then leads to a significant welfare increase. 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 are 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's claim that the growth effect is small.

Rather than test the effects of variations in the tax structure, Pecorino (1993) asks the question 'What combination of taxes results in the highest level of growth?'. The model used by Pecorino has the feature that capital is a separate commodity from the consumption good.[8] This permits different factor intensities in the production of human capital, physical capital and consumption good. Numerical analysis of the model, assuming that 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 quite small. Compared with a baseline system where the tax rates on income from human and physical capital are equal, optimal taxes raise growth by 0.1 of a percentage point to 0.12 per cent p.a. Endogenising labour supply makes the effects slightly larger but growth is still raised by less than 0.2 of a percentage point.

For σ=2, α=0.5 (as in Lucas) and a share of physical capital in production in all three sectors of 0.24, the complete elimination of the capital tax raises the growth rate by 1.23 percentage points. Under the original Lucas specification, this experiment leads to a marginal reduction in the growth rate. There are two reasons for the different results. First, in the Pecorino model, it is human capital itself that is the input and the earnings of this are taxed. This gives the wage tax a more significant role. Second, the share of physical capital in human capital production is 0 in Lucas and 0.24 in Pecorino. This is one of the factors that Stokey and Rebelo identified as crucial for the growth effect.

[8]In the previous four contributions, capital is simply output that is not consumed.

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.[9] The experiment of replacing the tax on income from physical capital with a wage tax reduces growth from 1.5 per cent to 1.37 per cent — 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 per cent.

Before describing extensions of the basic model, it is worth summarising the discussion so far. A range of estimates have been given for the effects of taxation upon growth, involving several different policy experiments. However, all the policy experiments involve proportional taxes whereas tax systems in practice involve numerous non-linearities. Proportionality is employed for analytical simplicity but limits applicability. Some of the models predict that the growth effect is insignificant; others predict it could be very significant. What distinguish the models are a number of key parameters, particularly the share of physical capital in human capital production, the elasticities in the utility function and the depreciation rates. In principle, these could be isolated empirically and a firm statement of the size of the growth effect given. To do so and thus claim an 'answer' would be to overlook several important issues about the restrictiveness of the model. 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, after a brief review of some extensions to the model in Section IV, Section V considers empirical evidence.

IV. EXTENSIONS

Due to its simplicity, there are a number of directions in which the basic model underlying the previous discussion can be extended. Several of these extensions will now be considered and their effects upon the relationship between taxation and growth discussed. Effectively, the consequence of these is to open up further channels through which taxation can affect growth.

1. Open Economy

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

[9]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.

its effects. This outcome has already been noted in the discussion of King and Rebelo (1990) — their growth decrease of 0.52 of a percentage point for a 10 percentage point increase in the tax on physical capital in a closed economy became an 8.6 percentage point decrease in the open economy. These figures suggest that a moderate tax increase would turn the initial growth rate of 1.02 per cent into an annual decline in output of 7.58 per cent — a figure that just does not seem credible.

The model of Asea and Turnovsky (1998) combines an open-economy setting with uncertainty. The uncertainty arises because both asset prices and output are assumed to be stochastic. Endogenous growth is achieved by adopting a production function that 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 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. The model thus has two transmission mechanisms which are not completely tied down by the assumptions made. This leads to theoretical uncertainty about the direction of the effect that 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 rates of output and of output per capita (which are different due to the endogenous fertility) are both very sensitive to the rate of capital taxation. The results given show that a reduction in the capital tax from 30.000 per cent to 29.996 per cent reduces growth of per capita output by 0.038 of a percentage point — a growth decrease about 10 times the magnitude of the tax reduction! This leads to the conclusion that a tax decrease both lowers growth and does so at a dramatic rate. This occurs because the parameters used for the analysis ensure greater weight in utility is placed on the number of children than on the welfare of each offspring. Since a cut in taxation raises the rate of population growth, output is happily sacrificed.

2. Life Cycles and Bequests

The next extension to the model returns to an issue that was discussed earlier: the role of life-cycle saving behaviour. The nature of life-cycle 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 save more 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 of the model was the overlapping generations of consumers, who each have a lifespan of two periods. Over the life cycle, each 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. In the first period, they undertake work and divide the income between consumption and saving. The central result is a demonstration that an increase in capital taxation will raise the growth rate (via the inducement it gives the young to increase saving) 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 it applies when λ is large, so that labour supply is concentrated in the first period of life.

It is important to note that the effect just described depends strongly 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, in each period, there is a constant probability of death. The conclusion of the analysis is to emphasise that the Uhlig and Yanagawa result of growth-increasing taxation does not hold unless labour supply declines rapidly in the later stages of life.

3. Multiple Growth Mechanisms

A further extension is to consider a combination of endogenous growth processes. Einarsson and Marquis (1997) construct a model that can have growth both through investment in human capital and through research and development 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 of tax reductions. For instance, a 10 percentage point reduction in the labour income tax from 25 per cent to 15 per cent causes a 2.77 per cent increase in welfare in the human capital model and a 19.01 per cent increase in the intermediate good model. For a 10 percentage point reduction in the capital tax, the corresponding figures are 2.14 per cent and 16.4 per cent. 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 percentage point reduction in labour income tax raises the growth rate by 0.28 of a percentage point for both models, whereas the 10 percentage point reduction in capital tax raises growth by 0.28 of a percentage point in the intermediate good model but only by 0.08 of a percentage point in the human capital model.

4. Government Expenditure

The simulation analyses reported in Section III(2) typically evaluate the effect of a balanced-budget shift from one tax instrument to another. In this way, they focus upon the consequences of distortions caused by the tax instruments and avoid the need to address the role of government expenditure. This perspective provides a slightly unbalanced view of taxation since there are several ways in which the expenditure to which it gives rise can raise the growth rate.

In Barro (1990), the government is modelled as providing productively useful infrastructure and it is shown that, for low tax rates, the return from additional infrastructure more than offsets the distortionary cost of higher taxes. Thus, up to a point, increased taxes will raise the rate of growth. Similar conclusions would apply if the government invested in education and so increased the level of human capital. Even if government expenditure is non-productive and only involves transfer payments, it may still affect growth. The consequences of income redistribution are considered by Galor and Zeira (1993) and Perotti (1993). If capital markets are imperfect and there are indivisibilities in investment in human capital, the poor will not be able to borrow to fund investments in human capital. A transfer that increases their wealth sufficiently will then permit the purchase of education and so may raise the rate of growth.

5. Summary

Several conclusions emerge from these extensions. It is clear that the open economy is important and the models are helpful in identifying additional channels through which taxation can affect growth. This benefit is offset by the quantitative magnitudes of some of the tax effects: they are simply too large to be credible.[10] As a basis for policy recommendations, the models generate issues for debate but cannot be trusted to provide meaningful quantitative guidance. This casts some doubt upon the structure of the models that have been used. The other extensions (uncertainty, endogenous fertility, life-cycle behaviour and government expenditure) all have the effect of reducing the growth rate effect of taxation and can even overturn the normal expectation.

V. EMPIRICAL EVIDENCE

The theoretical evidence has produced a wide 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 are displayed in Figure 3 for the UK (a very similar figure for the US is given in Stokey and Rebelo (1995)). The dashed line is the growth rate and the solid line the (least squares) trend line for taxation as a share of GDP.[11] The figure shows the steady rise in taxation and the relative constancy of the mean growth rate. Although the variance of the growth process appears to reduce after 1940, statistical tests by Stokey and Rebelo on the US data (which exhibit very similar behaviour) found no statistical difference between the average rates of growth prior to 1942 and after 1942.

The message from this figure appears compelling but it is not completely convincing. There are two reasons for this. First, a contrast between tax 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 study involving countries with different regimes. Second, there are substantive issues that have to be resolved about the definition of the tax rates that should be used in any such comparison.

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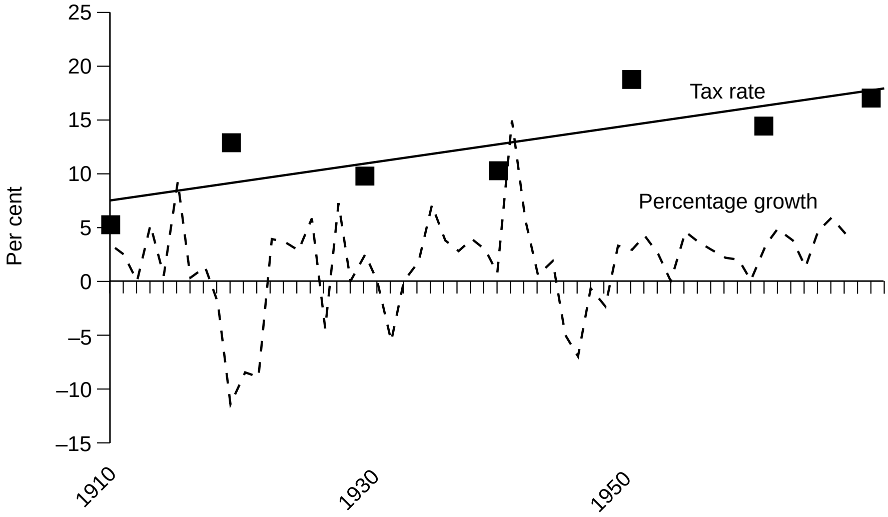
[10]The sensitivity of the Razin and Yuen model in particular makes one wonder about the stability and uniqueness properties of equilibrium. The steady state defined seems not to be robust to large parametric variation.

[11]Tax revenue is defined as 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 3

Taxation and Growth in the UK



Sources: *UK Revenue Statistics*; Feinstein, 1972; *Economic Trends*.

To understand the problem of definition, consider Figure 4, which illustrates a typical progressive income tax.[12] 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, where $t^2>t^1$. What is important about the figure is that it shows how the marginal rate of tax (the proportion of an extra pound of income that is paid in tax) differs from the average rate of tax (the proportion of total income that 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.

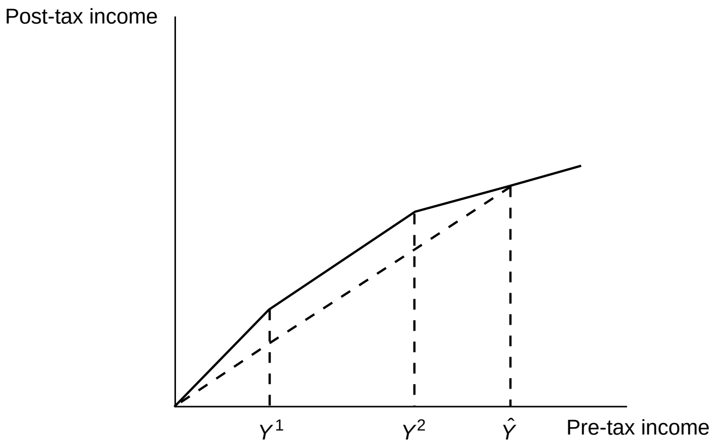
The data displayed in Figure 3 are tax revenue as a fraction of GDP, i.e. they capture the average tax rate. However, what matters for economic behaviour is the marginal tax rate — the decision about whether or not to earn an additional pound depends on how much of that pound can be kept. This suggests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

The difficulty with undertaking the analysis comes in determining what the marginal rate actually is. Figure 4 illustrates this problem: the marginal rate is 0,

[12]Progressive tax here means one with an increasing marginal rate. Other definitions are possible; see Lambert (1993).

FIGURE 4

Average and Marginal Tax Rates



t^1 or t^2 depending on where on the graph a consumer chooses to locate.[13] In practice, income tax systems typically have several different levels of exemption (for example, married and single person's allowances) and several marginal rates and interact with taxes such as National Insurance (or social security) 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 to VAT, 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.

One approach designed to circumvent these difficulties can be found in Easterly (1993). Rather than look at tax rates directly, Easterly places the focus on the distortions generated by those tax rates. These distortions are found by using the data of Summers and Heston (1988) on 1980 prices 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 percentage points. This is clearly an

[13]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.

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. Second, 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. 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).[14] Taking account of this, Easterly and Rebelo (1993b) showed that the negative relationship all but disappears when the effect of initial income is accounted for. This observation makes the claims of Plosser rather doubtful.

Easterly and Rebelo (1993a) 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.[15] 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 similar conclusion is derived by Agell, Lindh and Ohlsson (1997).[16]

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 1980–95 against three measures of the tax rate (average tax rate, marginal tax rate and average direct tax rate) showed that a 10 percentage point increase in tax rates would be accompanied by a 0.5 percentage point reduction in the rate of growth, with direct taxation reducing growth marginally more than indirect taxation.

An alternative line of literature (Barro, 1991; Dowrick, 1993; de la Fuente, 1997) has considered the more general issue of how fiscal policy has affected

[14]A higher level of initial income is associated with a lower level of growth in later periods.
[15]The concepts for the second and fourth measures are taken from Easterly and Rebelo (1993b) and Koester and Kormendi (1989) respectively.
[16]See also the exchange between Fölster and Henrekson (1999) and Agell, Lindh and Ohlsson (1999).

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 if public spending (measured as the share of total government expenditure in GDP) increases, growth is reduced (a reduction in government spending of 5 per cent of GDP reduces growth by 0.66 of a percentage point) whereas an increase in public investment will raise growth. There are four significant points to be made about these findings. First, 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 it may be these, not expenditure, that actually reduce growth. Second, 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: government expenditure is seen as being determined by the preferences of the population as expressed through the political system. An extreme version of this view is captured in Wagner's law, which relates government expenditure to national income via the income elasticity of demand for government-provided goods and services. 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 of taxation on labour supply, investment and productivity, and then summing these to obtain a total measure. Doing this suggests that cuts of 5 percentage points in all marginal rates of tax and 2.5 percentage points in average rates would raise the growth rate by 0.22 of a percentage point.

This review of the empirical evidence leads to the following observations. A visual inspection of tax rates and growth rates suggests that there is little relationship between the two. This is weak evidence but it does find support in some more detailed investigations in which regression equations that include previously identified determinants of growth, especially initial income, reveal 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 by their lack of an equilibrium relationship.

VI. ENVIRONMENTAL ISSUES

An issue that has not yet been discussed is the environmental impact of growth. Environmental issues are important because taxation is seen as a potential means of combating problems such as greenhouse gases. One prominent example is the ‘carbon tax’, whose introduction would represent a major increase in taxation. A significant issue for policy is whether the ‘double dividend’ implies that environmental taxes can raise revenue without harming growth. Although there is a small literature addressing these issues, it is not as yet well developed nor well focused. There are probably two reasons for this situation. First, there seems to be no convincing modelling of the role of environment. Second, the concentration upon the demonstration of ‘double dividend’ effects has directed attention away from more substantive issues.

Environmental effects operate in the models through two different channels. One channel is the appearance of environmental quality in the utility function of the consumer 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 that is dependent on such things as the level of output. Such a model is developed by Mohtadi (1996), who shows that the highest level of welfare is achieved by the use of a combination of taxes and quantity controls.[17] The second possibility is that environmental quality is an argument of the production function. Bovenberg and de Mooij (1997) 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.[18] Bovenberg and de Mooij study the effect of an increase in the tax rate on pollution with the government budget balanced by an offsetting change in the output tax. This lowers the level of pollution but the effect on the growth rate depends on a number of elasticities,[19] and there is no obvious reasoning or available data that can evaluate these or resolve the competing effects. This should be contrasted to the basic growth models, where data are easily available on the important parameters such as the shares of capital and labour in production.

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[17]Before weight can be given to this conclusion, it should be noted that the quantity controls modelled directly affect the relationship between capital stock and environment (i.e. they reflect (undefined) abatement regulations etc.), which is not the same as controlling how much capital is used. Such controls must be connected with additional costs elsewhere, which if introduced would reduce the benefits gained.

[18]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.

[19]Actually, the elasticities of environmental quality in production, pollution in production, abatement in production and pollution in determining environmental quality.

Mabey and Nixon (1997) assess the effect of environmental taxes in two different macroeconometric models. 'EGEM' employs three factors of production: capital, labour and energy. Employment is determined via profit maximisation at the given wage rate and energy intensity is reduced by an autoregressive trend so that the effects of policy change will accumulate over time. 'SLEEC' uses four inputs (the three already introduced plus imported inputs) and 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 and provides the tantalising suggestion that taxation can essentially provide a real 'free lunch'. Whilst there are many alternative ways the double dividend can be formalised (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. Since this seems such a potentially important result for policy design, it is worth commenting upon it.

A first reaction to 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 from those not causing environmental damage. This is wrong on at least two counts. First, the analysis of environmental taxes is often developed in a framework (partial equilibrium, single household) that 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, Green and Sheshinski (1976) construct an example in which the tax on a good damaging the environment should be zero whilst goods that cause no damage have positive taxes. Hence, the simple intuition is misleading. Second, 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 that is taxed too little.[20] Raising the tax on this good will reduce consumption toward

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

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.

VII. CONCLUSIONS

Endogenous growth theory provides models that can assess the effects of taxation upon economic growth. This paper has described the available models and has discussed the results that have been obtained. Numerous channels were identified through which taxation can affect growth. In quantitative terms, a wide range of theoretical predictions arose for the size of the tax effect. These range from insignificant to dramatically large. The size of the growth rate effect depends just about equally on the structure of the model and on parameter values within the model. The growth-reducing effect of taxation is increased in open-economy models and reduced, and possibly even reversed, if life-cycle behaviour is considered. The production process for human capital is also critical, as are the elasticities in the utility function and the rates of depreciation. A fair summary would say that the theoretical models introduce a range of issues that must be considered, but that they do not provide any convincing or definitive answers.

The conclusions of the empirical evidence are not quite as diverse as those of the theory. Although there are some disagreements, the picture that emerges is that the effect of taxation, if there is any at all, is relatively minor. However, the estimates are dogged by the difficulty of defining the appropriate measure of the tax rate and the choice of appropriate regressors. These problems may prove to be significant but that is unlikely. As far as policy is concerned, the conclusion is reassuring since it removes the need to be overly concerned about growth effects when tax reforms are being planned.

Given these findings, what principles should guide the design of taxes? The empirical evidence can be interpreted as supporting the argument that the level of taxes is not that significant (with the obvious and important caveat that this claim does not extend to levels outside the range observed in the data) but the structure of taxation is important. When growth is endogenous, taxation can influence the factors that determine the growth rate. In general, appealing to the logic of the Ramsey rule, this would suggest that the design of optimal taxes should trade off inelasticity in demand against the effect on the growth rate (aiming to distort choice as little as possible whilst helping growth). Effectively, taxation would be predominantly on commodities that were inelastic in demand and had no effect upon the growth rate. This conclusion would be somewhat modified if there were initial inefficiencies in the economy such as imperfect competition (due to increasing returns) or suboptimal levels of research and development (due to public good problems).

How these observations translate into a policy proposal for an economy such as the UK depends, to an extent, upon how satisfactory endogenous growth models are in representing the UK economy and upon how sensitive the factors that cause growth are to taxation. At this point, it is worth noting that the calculations of the consequences of policy reform discussed in Section III(2) view all growth-enhancing changes as coming from within the economy that is under analysis. If human capital and R&D are the major factors generating growth, this is probably not too unrealistic a view of the US, which dominates by a very long way the production of new patents. On the other hand, it may not be such a good view of the UK, whose generation of patents, although credible for the size of economy, is far behind that of the US. As a result, the UK benefits from advancements that are made elsewhere — a situation that is outside the scenario of these simple models. More convincing evaluations would need at least to take account of international spillovers of knowledge.

These arguments suggest that, if endogenous growth models are to be applied to the UK, then human capital investment should assume more prominence than R&D. Consequently, the design of taxation should be considered in view of how it affects human capital investment. Given that the facilities for the development of human capital are provided, the decision to invest in human capital is an individual one driven by the expectation of future returns. There is no obvious reason why these returns should be reduced by employing a tax system based on the Ramsey principles (but they might well be if the tax system takes account of equity considerations). So, again, the argument would point in the direction of taxes based on the Ramsey formula.

In summary, the Ramsey rule principles apply in the static economy. They apply, with minor modification, in exogenous growth models. In general, they probably require more modification in endogenous growth models, particularly those involving R&D or increasing returns as the growth engine. However, if the contention that the endogenous component of growth in the UK comes primarily from human capital investment can be supported, then it is likely that the Ramsey principles would again apply with only minor modification.

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