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CAPITAL TAXATION AND ECONOMIC PERFORMANCE

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Capital Taxation and Economic Performance*

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Abstract

A new technology is a bold new combination of production factors that potentially yields a higher level of total factor productivity. The optimal combination of input factors is unknown when an innovation is pursued. A larger targeted innovation may require a greater change in the optimal combination of production factors employed and increases volatility alongside with economic growth. We show that economic policy can interfere in this relationship with by adjusting source based capital income taxes.

Keywords: Economic Growth, Cycles, Innovation, Capital Taxation, Tax Coordination, Automatic Stabilizers

JEL-Code: H87, E32, O31, O41

1 Introduction

An innovation is the active pursuit of entrepreneurs out of a profit motive to find a new and more productive technology. This new technology may require a different combination of inputs in production. The uncertain change in the optimal combination of production factors generates a cost for firms, if they are required to write employment contracts one period in advance. If firms set an optimal combination of production factors different from the optimal combination of production factors, output will fall below its potential level. This will result in lower revenues, which can be interpreted as volatility costs. Both economic growth and volatility are thus produced endogenously by firms decisions, and, in contrast to traditional theories of economic growth and the business cycle, can therefore be instrumentalized by economic policy.

The driving force for growth is innovation and technical progress. In this respect, it does not differ from existing theories of economic growth. (for a survey, see Aghion and Howitt (1998)). In contrast to existing theories of economic growth, this paper differs in identifying a different boundary to economic

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growth. Previous models of economic growth have focused on accumulation (Solow (1956), Harrod (1948), Domar (1946), Rebelo (1991), Romer (1986), Lucas (1988), Barro (1990)) and on resource constraints (Romer (1990), Grossman and Helpman (1991), Aghion and Howitt (1992)). In the prior, growth was bound as (capital) accumulation could only be finite. In the latter, growth was bound by the amount of workers available in the innovation process. Indeed, the dependence of growth on resources led to the Jones critique (Jones (1995)), which essentially states that current growth rates are unsustainable, as they have required an ever increasing number of workers in research and development (R & D). Here, by contrast, growth will be constrained by the amount of risk entrepreneurs are willing to accept. As the cost associated with innovation risks increases exponentially, there appears a natural boundary to economic growth that is not related to the amount of resources devoted to the growth process.

Despite the novelty of the approach, the paper is related to several strands of literature. Technological change as a source of economic growth has been addressed early on in growth theory. The rate of technical progress is the only source of long-run growth in per capita GDP in the Solow model (Solow (1956)). Still, technical progress only affected total factor productivity (TFP), but held the optimal factor input combination for given prices constant. Harrod (1953) suggested that technical progress is embodied entirely in the factor labor as the only possibility consistent with the facts. Thus the "great ratio" of capital to efficiency units of labor remains constant along the balanced growth path. However, labor augmenting technical progress leads to a permanently growing wage, and hence a constant but foreseeable shift in the optimal factor input combination away from labor and toward capital.

The first wave of endogenous growth models, which all have in common constant returns to scale with respect to reproducible factors of production, retain the "great ratio" properties of factor shares (Rebelo (1991), Romer (1986), Lucas (1988)). In principle, one could introduce a cost of adjustment to a higher level of production. If these costs are exponential and significant, the economy may grow at a permanently lower growth path, or the growth rate may increase or decrease over time, in accordance with the specific properties of adjustment costs. Under a balanced growth path, the factor shares will remain constant even under these assumptions. In some respect, these adjustment costs mimic the costs of employing a suboptimal factor mix, as proposed here. However, no model of adjustment cost would be able to generate a cyclical behavior of the economy.

Technical change that favors one factor of production over another was later introduced under the heading of skill-biased technical change (Sanders and Ter Weel (2000)), in order to explain the growing wage gap between skilled and unskilled workers (Katz and Murphy 1992). Of the several hypotheses brought forward in the debate, the one closest related to this paper simply claimed that technical change somehow favored one factor over another (Acemoglu (1998)). This paper, too, allows for change in relative wages between two groups of workers. However, here the movement of relative wages need not be unidirectional and certainly will not be predictable.

None of the above papers have been able to draw the attention to the common determinants of economic growth and economic cycles. However, there is a number of empirical papers suggesting a relationship between economic growth and cycles. Campbell and Mankiw (1987) were amongst the first to report permanent effects on the level of GDP from shocks to output growth, first for the US and later on for a selected sample of various countries (Campbell and Mankiw (1989)). Hall (1988) and Burnside et al. (1993) show that the Solow residual is correlated economic variables, and can therefore not be purely exogenous, as suggested by the real business cycle literature, suggesting that trend and fluctuation of output should be investigated jointly.

Several authors have attempted to model the joint determination of growth and cycles. A noteworthy first attempt was by King and Rebelo (1988). They argue that the business cycle indeed affects augmented factor productivity through the quality of capital and labor, capacity, energy and natural resources, foreign trade and structural effects. Nested within real business cycle theory, temporary stochastic shocks only cause temporary deviations from potential output. Given on average positive productivity gains, trend growth itself is stochastic but remains exogenous. While the fluctuations around average movements in productivity can be interpreted as the business cycle, movements in trend itself remain unexplained within the theory of real business cycles.

As business cycle shocks are exogenous, policy can only make things worth. In the model presented below, where both growth and volatility are determined endogenously by the choice of economic actors, policy will be influential. We will illustrate this with an important special case. Using a model of a small open economy, we can show source based capital income taxation can alter the trade-off between economic growth and volatility. An increase in capital income taxation will reduce the economies proneness to volatility and stabilize the economy, albeit on a slower growth path. Capital income taxation therefore plays a role in this model, inducing stability. This is in stark contrast to conventional models of capital taxation, where one typically finds that with fully mobile capital, taxing capital will be inferior to taxing immobile labor (Sinn (2003)). This paper thus suggest a role for capital income taxation, the stability motive, and prescribes it the role of an automatic stabilizer.

There are several recent papers that try to model both growth and cycles endogenously. Matsuyama (1999) and Waelde (1999) argue that changes in productivity happen only sporadically, either because there is a stochastic element of failure intrinsic in innovation, or because firms prefer to invest in capital accumulation after periods of high productivity growth. Within an elaborate endogenous growth model, Aghion et al. (2005) investigate the effect of exogenous shocks on growth and volatility. The interesting feature is that policy choices (in their case concerning credit market regulation) may work on the trade-off between economic growth and fluctuations. Comin and Mulani (2006) present an innovation model, with firm specific and general innovations. The prior lead to volatility, the latter to economic growth. Here, too, the growth and volatility are endogenous, and the trade-off depends primarily on market structure. Closest to this proposal is a recent paper by Jovanovich (2006). There the choice of a growth rate leads to a positively correlated stochastic cost. However, Jovanovich fails to motivate the source of the stochastic cost.

2 The Model

We will analyze the relationship between economic growth and volatility in a partial equilibrium[1] model of a small open economy[2], where capital is fully mobile internationally with a world market prize of ρ, whereas labor is fully immobile and comes at fixed supply $L = 1$. Aggregate output is assembled by homogeneous inputs from n firms[3], with productivity of the assembly equal to A_t,

$$Y_t = A_t \sum_{i=1}^{n} y_{i,t} \tag{1}$$

Each firm in the economy strives to gain a competitive advantage over others by implementing new technologies and rendering the factor labor more efficient. This will yield a productivity gain of $a_{i,t} > 1$, which will last for one period[4]. There are no direct costs associated with this productivity gain. However, firms will face uncertainty over the optimal factor input combination, which is increasing in the size of the productivity gain[5]. These individual productivity gains will generate non-appropriable public knowledge[6], that is used in the assembly of the output good (1), so that the average of all $a_{i,t}$ will be the rate of technical progress in the economy,

$$A_t = \frac{A_{t-1}}{n} \sum_{i=1}^{n} a_{i,t} \tag{2}$$

An new technology will only have a transitory effect for the single firm, but will have a permanent effect on the economy on the whole. We can think of any successful innovation, or implementation of a new technology, as being copied with a one period lag by all other firms in the economy. Firm specific technological knowledge thus turns into general knowledge, with the added advantage that the uncertainty about the optimal factor input combination will vanish, too. This is in stark contrast to the innovation literature, where patent protection for innovation lasts forever (Grossman and Helpman (1991)) or at least until a new innovation comes around (Aghion and Howitt (1992)), but coincides with actual patenting practice and open source innovations. Clearly it applies more to process innovations than to product innovations[7].

Aggregate economic growth will therefore be driven by two sources, disembodied technical progress (2) and output growth of individual firms (3). As the prior will have no impact on volatility, all cyclical components will derive from the later term. This is in accordance with Comin and Mulani (2006), who postulate that firm specific knowledge predominantly drives volatility, whereas

[1] It should not be very difficult to extend the model to a full equilibrium model.

[2] Wildasin (1995) shows that this assumption is not fully innocent, as a shift from a closed to an open economy may shift risk from capital to labor.

[3] The number of firms n is exogenously given, but could well be determined by product market regulations and national competition policy. We will analyze changes to the number of firms in this light below.

[4] We can think of $a_{i,t}$ as efficiency gains. If the firm engages in productivity enhancing activities, they will extract labor efficiency above unity, otherwise not.

[5] As shown below, this will induce firms to choose a finite level of productivity increases.

[6] This is a knowledge externality typical for endogenous growth models.

[7] For this reason, we have refrained from modeling differentiated products in the first place.

general knowledge is responsible for economic growth. Firms[8] produce output with a constant elasticity of substitution technology,

$$y_{i,t} = (1-\phi_{i,t})k_{i,t}^{\sigma} + \phi_{i,t}a_{i,t}l_{i,t}^{\sigma} \tag{3}$$

where $k_{i,t}$ and $l_{i,t}$ are capital and labor, respectively. We assume that firms must hire capital and labor at the beginning of the period, and before any shock realizes[9]. Labor augmenting technical progress will therefore equal $a_{i,t}^{1/\sigma}$. The elasticity of substitution between capital and labor is given by $1/(1-\sigma)$. In order to ensure substitutability between production factors, we must have $\sigma < 1$. In this case, the production function exhibits decreasing returns to scale, with a scale factor equal to σ. In order to ensure a positive marginal product for both capital and labor, this requires $0 < \sigma < 1$.

We will introduce the above mentioned uncertainty over the optimal factor input combination by assuming that the parameter determining factor shares, $\phi_{i,t}$, changes with the size of the innovation. To simplify matters, we assume that for a positive rate of innovation, $\phi_{i,t}$ has a bivariate distribution that depends on the size of the technological innovation implemented by the firm,

$$\phi_{i,t} = \begin{cases} \phi_{i,t-1} + \frac{a_{i,t}-1}{a_{i,t}}(1-\phi_{i,t-1}) & \text{with probability } p, \\ 0 & \text{with probability } 1-p, \\ \tilde{\phi}_{i,t} & \text{if } a_{i,t} = 1. \end{cases} \tag{4}$$

Several things are worth mentioning at this point. First, firms can choose to innovate or remain with an ex-ante known factor share parameter $\tilde{\phi}_{i,t}$, to be defined below (5). If they innovate, with probability p, firms are hit by a "positive" shock, i.e. the factor share parameter $\phi_{i,t}$ will be larger than before, and with probability $1-p$, firms are hit by a "negative" shock, i.e. the factor share parameter $\phi_{i,t}$ will be smaller than before[10]. We shall assume that whether we are faced with a positive or a negative shock to $\phi_{i,t}$ is drawn once for the entire economy, in order to exclude pooling of resources of groups of large firms. If firms choose an infinite level of innovation, $\phi_{i,t}$ will go to unity with probability p and to zero with probability $1-p$. In that case, either the entire amount of capital or the entire amount of labor employed will be completely unproductive and therefore only costly for the firm. Note that if firms choose no innovation, we set the ex-ante known factor share parameter equal to the expected factor share parameter in case they would innovate, in order not to influence the results. The one period ahead expected value of $\phi_{i,t}$ takes the form

$$\tilde{\phi}_{i,t} = E_{t-1}[\phi_{i,t}] = \frac{p}{a_{i,t}}[\phi_{i,t-1} + a_{i,t} - 1] \tag{5}$$

It is noteworthy that $E_{t-1}[\phi_{i,t}] = \phi_{i,t-1}$ if and only if $\phi_{i,t-1} = (a_{i,t}-1)p/(a_{i,t}-p)$. With $a_{i,t}$ set close to unity, $\phi_{i,t-1}$ will converge to zero, whereas an infinite rate of technical progress sets the equilibrium value of $\phi_{i,t-1}$ to unity.

[8] We assume that the number of firms n is large, so that firms need not consider the choice of others in their optimization problem.

[9] We will normalize the price of input goods to unity. This implies that the price of the output good (1) will equal $1/A_t$ and falls with technical progress.

[10] The assumption that $\phi_{i,t}$ falls to zero is rather extreme, but adopted for matters of simplicity only.

Otherwise, the factor share parameter will take a value somewhere between zero and unity.

Firms will choose capital, labor, and the level of productivity in order to maximize expected profits, taking market prizes for their product, capital and wages as given. Firms will pay a source based tax on capital income equal to τ. The first order condition with respect to labor states that the expected marginal product of labor will be equal to the domestic wage,

$$\sigma E_{t-1}[\phi_{i,t}]a_{i,t}l_{i,t}^{\sigma-1} = w_t \tag{6}$$

In equilibrium, labor demand of all n firms must equal supply, which has been normalized to unity. Labor demand is downward sloping, so the wage can ensure equilibrium in the labor market. The firm's decision to innovate will influence wages. Substituting the expected value of the factor share parameter $\phi_{i,t}$ from equation (5), we note that wages will increase with the size of the productivity gain $a_{i,t}$. The first order condition with respect to capital reads,

$$\sigma E_{t-1}[1-\phi_{i,t}]k_{i,t}^{\sigma-1} = (1+\tau)\rho \tag{7}$$

and holds that the marginal product of capital should equal the gross interest rate $(1+\tau)\rho$. Ceteris paribus, an increase in the tax on capital (or the world interest rate) will reduce the domestic demand for capital, given $\sigma < 1$. So capital taxation will lead to capital flight, and it has been proven elsewhere (Sinn 2003) that this has negative consequences both for the level and the distribution of national income. As the change in the price of the domestic capital stock will alter the optimal factor input combination, firms will wish to alter the factor share parameter $\phi_{i,t}$ by changing the rate of innovation. And it is this link which will ensure the role of capital income taxation on the trade-off between growth and volatility in this economy. The optimal degree of technical change is given by

$$\frac{E_{t-1}[\phi_{i,t}]}{a_{i,t}}\left[a_{i,t}l_{i,t}^{\sigma} + \epsilon a_{i,t}l_{i,t}^{\sigma} - \epsilon k_{i,t}^{\sigma}\right] = 0 \tag{8}$$

where the elasticity of the factor share parameter with respect to changes in productivity ϵ is defined as

$$\epsilon = \frac{\partial E_{t-1}[\phi_{i,t}]}{\partial a_{i,t}}\frac{a_{i,t}}{E_{t-1}[\phi_{i,t}]} = \frac{1-\phi_{i,t-1}}{p(\phi_{i,t-1}+a_{i,t}-1)}$$

There are three distinguished effects in the first order condition with respect to technical progress (8). The first is the direct effect of technical progress on labor productivity. The second and the third are indirect effects of technical progress on labor and capital productivity, and it is always positive. The two indirect effects have opposite signs. With the elasticity of the factor share parameter with respect to changes in productivity ϵ always positive, we find that an increase in innovation will indirectly foster labor productivity and reduce capital productivity.

Substituting the first (6) and second (7) first order conditions into the third (6), we obtain a solution for the rate of technical progress $a_{i,t}$, that depends on a single firm specific variable. Given $a_{i,t} \leq 1$, and under fairly mild parameter restrictions, we find that there is a unique solution for technical progress $a_{i,t} =$

a_t, and all firms will make the same choice of innovation. This implies that they will all choose the same capital stock k_t and the same number of employees, $L_{i,t} = L_t$, equal to $1/n$ due to labor market clearing. Substituting labor market clearing and the second first order condition (7) into the third (6), we obtain an implicit solution for the degree of technical progress[11],

$$\sigma n^{1-\sigma} a_t^{-1/\sigma}[a_t(1-p) + p(1-\phi_{t-1})] \left(1 - p + \frac{pa_t}{1-\phi_{t-1}}\right)^{\frac{1-\sigma}{\sigma}} = (1+\tau)\rho \quad (9)$$

This gives a unique and finite solution for technical progress a_t. Economic growth is bounded not by capital accumulation or innovation costs, which have been assumed to be zero. The capital stock will not grow without bound in this economy. Following equation (7), it will reach its minimum of zero if $E_{t-1}[\phi_t] = 1$, and a maximum value of $[(1+\tau)\rho/\sigma]^1/(\sigma-1)$ if $E_{t-1}[\phi_t] = 0$. The reason for bounded economic growth in this model is the fact that infinite growth would yield infinite costs due to a mismatch in the optimal factor input combination. Firms will therefore prefer to induce finite technical change to avoid exuberant costs.

3 Growth and Cycles

With a positive rate of technical progress a_t, the economy will exhibit volatility. Individual firms contribute to aggregate output (1) through its production y_t and through its contribution to public knowledge a_t. We will therefore use the measure $a_t y_t$ as a performance measure for the economy as a whole. In the case of a positive shock to the factor share parameter ϕ_t, the aggregate output share of a particular firm will equal

$$a_t y_t^+ = (1-\phi_{t-1})k_t^\sigma + (\phi_{t-1} + a_t - 1)a_t l_t^\sigma \quad (10)$$

where we can treat both capital and labor as given, as they have been chosen before the shock has realized. By contrast, if the factor share parameter is hit by a negative shock,

$$a_t y_t^- = k_t^\sigma \quad (11)$$

The difference between those two states is a good measure of volatility in the economy, and is equal to

$$a_t(y_t^+ - y_t^-) = (a_t - 1)a_t l_t^\sigma + \phi_{t-1}[a_t l_t^\sigma - k_t^\sigma] \quad (12)$$

It is important to note that volatility is monotonically increasing in the rate of technical progress a_t. A higher rate of technical progress will therefore also lead to a higher degree of volatility. Expected output is equal to

$$E_{t-1}(y_t) = \frac{1}{a_t}[(1-p\phi_t)k_t^\sigma + p(\phi_t + a_t - 1)a_t l_t^\sigma] \quad (13)$$

which is a weighted average between output under the current factor share parameter ϕ_t and the expected long-run distribution parameter p, where a larger

[11] The solution is unique, as argued above.

rate of technical progress a_t puts less weight on the current value. Costs in this economy are given by labor and capital costs

$$w_t L_t + (1+\tau)\rho k_t = \sigma E_{t-1}(y_t) \tag{14}$$

This allows us to determine profits in both states of the world,

$$\pi_t^+ = \frac{1}{a_t}[(1 - \phi_{t-1} - \sigma + \sigma p \phi_{t-1})k_t^\sigma + (1 - \sigma p)(\phi_{t-1} + a_t - 1)a_t l_t^\sigma] \tag{15}$$

which is a weighted average between profits in the absence of innovation and profits due to innovation, where the latter can be negative. Similarly, profits in the other state of the world equal

$$\pi_t^- = \frac{1}{a_t}[(1 - \sigma + \sigma p \phi_{t-1})k_t^\sigma - \sigma p(\phi_{t-1} + a_t - 1)a_t l_t^\sigma] \tag{16}$$

where the second part can once again be negative. Unless σ is very close to unity, we can ensure positive profits in both states of the world. Expected profits equal

$$E_{t-1}(\pi_t) = \frac{1-\sigma}{a_t}[(1 - p\phi_{t-1})k_t^\sigma + p(\phi_{t-1} + a_t - 1)a_t l_t^\sigma] \tag{17}$$

By contrast, in case of no innovation, profits will be known in advance and equal

$$\tilde{\pi}_t = (1-\sigma)[(1 - \tilde{\phi}_t)k_t^\sigma + \tilde{\phi}_t l_t^\sigma] \tag{18}$$

Substituting for $\tilde{\phi}_t$ from equation (5), we find that the difference between profits under no innovation and expected profits with innovation equals

$$E_{t-1}(\pi_t) - \tilde{\pi}_t = (1-\sigma)(a_t - 1)\left[\frac{p}{a_t}k_t^\sigma + \tilde{\phi}_t a_t l_t^\sigma\right] > 0 \tag{19}$$

This implies that expected profits will be higher than profits under certainty without innovation, hence firms will always choose to innovate, and we can exclude a solution $a_t = 1$. The economy will exhibit long-run growth. Economic growth will be bounded, not by capital accumulation or costs of innovation, but by the exponentially increasing cost generated by uncertainty of the optimal factor input combination. Alongside with economic growth, the economy will also exhibit volatility, which is do to the uncertainty over the optimal factor input combination, too.

4 Government Policy

The implicit solution (9) allows for ample policy analysis. We will look at four distinct policy experiments, an increase in the source based capital income tax τ, capital income tax coordination, automatic stabilizers, and an increase in product market liberalization, modeled through an increase in the number of firms n. We will also look at other forms of taxation in order to see why this model, as opposed to conventional theories, will give a role to source based capital income taxation, even in a world with perfectly mobile capital.

The first policy experiment that we introduce is an increase in the source based capital income tax. Whilst we cannot take a derivative of technical progress a_t with respect to the tax rate, we can do the opposite,

$$\begin{aligned}\frac{\partial(1+\tau)}{\partial a_t} &= -\Omega\left[\frac{1+\epsilon}{\epsilon}[a(1-\sigma)(1-p)+p(1-\phi_{t-1})]\right] \\ &\quad -\Omega\left[[a(1-p)+p(1-\phi_{t-1})](1-\sigma)\frac{a_t p}{1-\phi_{t-1}}\right] < 0\end{aligned} \tag{20}$$

where Ω is defined as,

$$\Omega = \frac{1}{\sigma\rho} n^{\sigma-1} a_t^{-\frac{1+\sigma}{\sigma}} \left(\frac{\epsilon}{1+\epsilon}\right)^{\frac{1}{\sigma}}$$

As the derivative of the tax rate with respect to the size of the innovation is negative throughout, we can infer the opposite as well. An increase in the source based tax on capital income τ will reduce the rate of technical progress in this economy. A capital income tax will therefore lead to lower growth and higher stability. If policymakers fancy both economic growth and economic stability, they are now faced with a dilemma. They can either increase the tax on capital, and thereby increase stability at the cost of lower economic growth, or vice-versa. Clearly, different policymakers, mimicking social preferences or their own, may choose different points along the trade-off, resulting in different tax rates across countries. Policymakers with a high preference for economic stability will favor higher taxes.

As an increase in world interest rates would lead to the same result, these policymakers would also favor efforts to coordinate capital income taxes at a higher level internationally, which would in effect raise the global interest rate. Whereas this policy would reduce government revenues, it would alter the distribution of factor income toward labor income internationally.Capital income tax coordination would therefore achieve both higher stability and redistribution at the expense of lower economic growth.

Noting from equation 9 above, the effect of an increase in the number of firms n is exactly opposite to an increase in capital income taxation. Countries may therefore wish to introduce product market regulations for the very same reason they introduce capital income taxes, in order to increase economic stability.

The automatic stabilizing effect obtained from capital income taxes cannot be easily achieved through other forms of taxation. Labor taxes will only alter the current wage rate, as labor is in constant supply, and change nothing in the relationship between growth and volatility. Residence based capital income taxes would tax worldwide capital income of domestic residents, and insofar as the economy is small, this would not influence world interest rates and innovation. Income taxes, which in this economy would be a combination of labor taxes, source and residence based capital income taxes, would only influence the trade-off through its effect on source based capital income taxes, but require a far larger amount of tax revenues to achieve the same effect. Finally, consumption taxes would tax output consumed at home. Given undifferentiated products, this would not influence domestic suppliers of products to the world market, and therefore have no influence, either.

5 Conclusions

This paper has established a link between economic growth and economic volatility. The idea was that a new technology is a new combination of production factors that yields a higher level of total factor productivity. However, the optimal combination of input factors is unknown when an innovation is pursued. A larger targeted innovation requires a greater change in the optimal combination of production factors employed and increases volatility alongside with economic growth.

Economic growth is bounded by the costs associated with uncertainty over the optimal factor combination. The further the economy will depart from the anticipated optimal factor input combination, the higher will be these factor costs. As these costs are increasing exponentially due to the convexity of the production function, firms will pursue only finite changes in productivity, thus inducing bounded economic growth.

We show that economic policy can interfere in this relationship by adjusting source based capital income taxes. An increase in capital income taxes will induce a slower targeted level of technical progress, but also lead to lower volatility. Capital income taxes can therefore be used to stabilize the economy, giving a motive why small open economy may still wish to introduce them, despite their negative allocative and distributive effects. No other form of taxation can achieve this goal equally.

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