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TAXATION AND ENDOGENOUS GROWTH IN OPEN ECONOMIES

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ABSTRACT

This paper examines the effects of taxation of human capital, physical capital and foreign assets in a multi-sector model of endogenous growth. It is shown that in general the growth rate is reduced by taxes on capital <u>and</u> labor (human capital) income. When the government faces no borrowing constraints and is able to commi: to a given set of present and future taxes, it is shown that the optimal tax plan involves high taxation of both capital and labor in the short run. This allows the government to accumulate sufficient assets to finance spending without any recourse to distortionary taxation in the long run. When restrictions to government borrowing and lending are imposed, the model implies that human and physical capital should be taxed similarly.

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1.INTRODUCTION

This paper studies the effects of taxation on economic performance, factor allocations and capital flows, and derives implications for the optimal taxation of factors of production (human and physical capital) in an open economy. In particular, it stresses the impact of factor income taxation on the private sector's decisions to accumulate physical capital and improve labor efficiency through human capital accumulation. It builds on three related strands of literature: the literature on endogenous economic growth, the literature on the effects of international taxation on capital flows, and the literature on dynamic optimal taxation. The positive analysis in this paper examines the effects of labor and capital income taxation on long-run growth; the normative analysis addresses the question of the optimal path of taxes on labor income, capital income and the income from foreign assets.

Following the seminal work of Romer (1986) the literature on economic growth has experienced a revival. Theoretical studies have developed models in which the rate of growth of an economy is determined endogenously, instead than by exogenous factors such as preferences, population growth and technical progress.[1] For example, Lucas (1988) considered human capital as an additional engine of economic growth, together with physical capital. This literature suggests that distortions (such as non lump-sum taxation) will affect the rate of growth of income, consumption and capital accumulation in an endogenous growth set-up, while they have only an effect on the level of such variables in a neoclassical exogenous growth model.

Traditionally, the normative analysis of optimal taxation of factor incomes was developed in neoclassical models of exogenous growth. One of the most remarkable results of this literature was obtained by Chamley (1985, 1986) and Judd (1985). These authors considered an infinite-horizon exogenous growth models with a representative agent deriving utility from consumption of final goods and leisure time, and showed that, in such models, the optimal tax rate on capital income is zero in the long run. Given an exogenous stream of public expenditures, the optimal tax plan consists in taxing capital income heavily in the short run, since the supply of capital is relatively inelastic; in the long run, however, capital income tax rates discourage capital accumulation: expenditures should be financed only with taxes on labor income since labor/leisure (i.e. the individual's time endowment) is the only factor in fixed supply. This asymmetry between the optimal long run taxation of capital income (zero) and labor income (positive) is quite surprising; one should then consider whether the result is robust and under which conditions it may or may not hold. In particular, it is important to assess whether the Chamley-Judd result hold in models of endogenous growth where both human and physical capital are engines of

[1] Indeed, some of the factors determining the long-run rate of growth are the same, but they are considered endogenous instead of exogenous.

accumulation and growth.

In such a context, we study the role of the technology for human capital accumulation; the nature of the "leisure" activity; and international capital markets in determining the effects of taxation on long-run economic growth. We also determine the optimal taxation of human capital, physical capital and foreign assets. The key characteristics of our model are the following. First, we consider a general set-up where both physical and human capital can enter in the production of new human capital.[2] We are therefore able to analyze whether and how the direct inclusion of physical capital inputs in the production of human capital affects the results about the effects of taxation of growth and the optimal long run taxation of factor incomes. Second, we study the implications of alternative specifications of leisure production for the optimal factor taxation results. Our specification is quite general and includes as sub-cases the conventional "raw time" specification (leisure is the fraction of time that is spent away from work and study), the "quality time" model (leisure is human capital times the fraction of the time endowment that is not spent working or studying), "home production" (leisure is a non-market good produced with human and physical capital) and the case of no leisure. Third, we develop an open economy model that allows us to discuss the optimal taxation factor incomes (including the income from foreign assets) in a context of international capital mobility.

Our main results, summarized in table I, are the following:

(1) The steady-state growth rate of the economy in models with no leisure is qualitatively similar to that in models where the leisure activity is modeled as "quality time" or "home production". This is because in the last two cases leisure is a non-market activity produced with constant returns to scale to reproducible factors. Leisure can therefore be reinterpreted as a non-market consumption good; consequently, the model is substantially equivalent to one in which there is no leisure.

(2) Under the three specifications for leisure described above (no leisure, quality time and home production), the human capital accumulation function has important implications for the dependence of growth rates on factor income taxes. In particular, if human capital is produced with *both* human and physical capital (with CRS in the two inputs), the steady state growth rate of the economy and the real rate of interest depend on *both* labor and capital income tax rates. In this case, a zero long-run taxation of both capital and labor income will be optimal. However, if human capital accumulation uses human capital *only* (with CRS), the steady state growth rate of the economy will not depend on either factor

[2] See Rebelo (1991) and Mulligan and Sala-i-Martin (1993) for similar specifications of the human capital accumulation equations. Our formulation includes, as subcases, the specification à la Lucas (1990) where only effective labor enters in the production of human capital.

income tax rate.

(3) When human capital is produced only with human capital, long-run growth does not depend on tax rates but the optimal long run taxation of labor and capital will depend on the model of leisure considered. If leisure is modeled as "quality time" or "home production", the growth rate of the economy does not depend on factor taxes but the steady state physical to capital ratio depends on both tax rates. Since tax rates on both factors create such an intertemporal distortion, the optimal long run tax on both human and physical capital will be zero in these cases. In the model without leisure, the tax on physical capital affects the steady state physical to human capital ratio but the tax on human capital does not. In this sense, the tax on labor is lump-sum and it is therefore optimal to tax only labor in the long run while the tax on physical capital is zero.

(4) Under a residence-based taxation system, the tax on net foreign assets can be derived residually once the tax rates on domestic factor incomes are set. Specifically, the tax rate on labor affects the equilibrium real after-tax rate of return on physical capital. Consequently, the tax rate on foreign assets will depend on both the tax rate on capital and on labor income. The optimal long-run tax on foreign assets is shown to be zero whenever the optimal tax on physical capital is zero.

(5) If the government has to balance its budget in every period because of borrowing and lending restrictions, capital and labor income should be taxed at the same positive rate in the long run whenever it is optimal to have zero long run taxation of labor and capital income with an unconstrained government.[3]

(6) When the leisure activity is modeled as "raw time", the balanced growth rate of the economy depends on both labor and capital income tax rates regardless of the way the human accumulation technology is specified. This dependence of the growth rate on both tax rates implies the optimal long run tax on both human and physical capital will be zero in the "raw time" model.[4]

In summary, our results imply that the optimal long run tax on both capital <u>and</u> labor income is zero (or symmetric if borrowing is not allowed) under very general conditions regarding the production

[3] See Roubini and Sala-i-Martin (1992a, 1992b) for optimal taxation analyses in which the government behavior is restricted to a balanced budget in every period.

[4] In order to minimize the number of models and cases considered, in this version of the paper we do not formally consider the case of leisure as "raw time". The positive and normative results about this case can be found in Milesi Ferretti and Roubini (1994). It can also be observed that the case of leisure as "raw time" with human capital produced with human capital only corresponds to the model in Lucas (1990). While Lucas did not derive the implications of his model for the optimal taxation of human capital, our results imply that the optimal long run tax on capital <u>and</u> labor income is zero in the Lucas (1990) model.

of human capital and the specification of the leisure activity. The only case in which the long run tax on capital is zero while the one on labor is positive is that of a model without leisure and with human capital produced only with human capital.

The rest of the paper is organized as follows. In Section 2 we discuss the existing literature on taxation, growth and international capital markets. In section 3 we present our general setup, and in Section 4 we solve for the competitive market equilibrium. In Section 5 we discuss the conditions under which the steady-state growth rate of the economy and factor allocations depend on the tax rates on capital and labor income. Section 6 presents the solution to the government's optimal taxation problem. Section 7 briefly discusses some policy implications, and Section 8 concludes.

2. A REVIEW OF THE LITERATURE

The modern literature on the optimal taxation of factors of production is based on the seminal work of Frank Ramsey (1927). Ramsey studied the problem faced by a government that needs to raise a given amount of revenue by using commodity taxation. The government would like to raise revenue as "efficiently" as possible, but needs to take into account that the behavior of the private sector is going to be influenced by the tax system in place. Formally, the problem is solved by determining the optimal behavior of private agents for a given tax system, and then choosing the tax system that maximizes private agents' welfare, subject to the constraints imposed by private agents' behavior and by the government's revenue needs.

Building on Ramsey's work, Chamley (1985, 1986) and Judd (1985) showed that in neoclassical models of exogenous growth the optimal long-run tax on capital is zero, while the optimal long-run tax on labor income is positive; capital should be taxed heavily in the short run, when it is in relatively inelastic supply. These results about the asymmetric long-run taxation of labor and capital may be significantly modified in models in which both human and physical capital are engines of endogenous growth. In this regard, Lucas (1990) presented a model of endogenous growth and showed that it is optimal not to tax capital income in the long run even when human capital accumulation is an additional source of long-run growth. He also showed that when the time devoted to human capital accumulation is *exogenous*, the Chamley-Judd result is obtained again -- all long-run taxation should fall on labor income. However, he does not derive the implications of his model for the optimal long run taxation of labor income when the accumulation of human capital is *endogenous*.

Recently, a number of authors have started to address this issue.[5] Jones, Manuelli and Rossi (1993a, 1993b) extend the specification of Lucas (1990) by modeling human capital as a non-market good and by assuming that a flow of final market goods, in addition to effective human capital, enters in the production of human capital. They show that, if human capital is accumulated with constant returns to its reproducible inputs (human capital and market goods), both capital and labor income taxes should be zero in the long run. Bull (1993a) argues that this result is obtained also in a two-sector model in which human capital can be "produced" using physical capital, human capital and intermediate goods as inputs, and/or accumulated through learning-by-doing in the final goods sector. Since government expenditure is positive, the implementation of this tax plan requires high short-run taxation on both factors, in order to accumulate government assets that will finance long-run government spending.

Our model contributes to this literature by studying the role of the technology for human capital accumulation, the nature of "leisure" and international capital markets in determining the effects of taxation on long-run economic growth.

Regarding the first issue, it is clear that the presence of human capital as a reproducible factor modifies the traditional Chamley-Judd results. If human and physical capital were symmetric goods, both perfectly substitutable with consumption and accumulated through savings, the impact of capital and labor taxation would of course be similar (Bull 1993a and the first model in Jones, Manuelli and Rossi 1993a). In this case there is nothing peculiar about human capital: it is just a second capital good that is reproducible with the same technology as physical capital. Assuming that human and physical capital are perfectly symmetric is, however, restrictive. Human capital differs from physical capital in at least three dimensions: (1) human capital is not substitutable with consumption; (2) it is a non-market good; and (3) its accumulation depends on a production function with inputs possibly different from those entering in the production of final goods and physical capital.

Concerning point (1), while most growth models specify physical capital as being perfectly substitutable with consumption (final goods can either be consumed or accumulated in physical capital), it is more realistic to assume that human capital cannot be consumed (we can consume cars instead of using them to produce final goods but we cannot "consume our brain").

Concerning point (2), human capital accumulation should be thought as a non-market activity

[5] A number of other contributions do not directly consider the optimal taxation of factor incomes but study the effects of exogenous changes in tax rate on labor and capital income on the growth rate of the economy and the welfare of the representative agent. These contributions include Rebelo (1990), King and Rebelo (1990), Stokey and Rebelo (1993) and Trostel (1993).

whose inputs are not subject to factor income taxation. Specifically, while the labor income deriving from the time spent in the production of final goods can be taxed, the time input (and implicit labor income) used in production of human capital is usually not taxed. Similarly, any implicit income of physical capital goods entering in the production of human capital cannot be taxed either (for example, a capital good such as a computer used in the production of final goods earns an income that is taxable but the same computer used for increasing one's own human capital earns an implicit income that is not taxable).

Concerning point (3), the production technology for human capital accumulation may use different inputs and/or have different capital intensity relative to the production technology for final goods. For example, Lucas (1988, 1990) assumes that human capital is a non-market good whose accumulation has only human capital (or effective labor, i.e. a time fraction of human capital) as its input. While Lucas assumes that physical capital inputs do not enter in the production of human capital, Rebelo (1991) and Mulligan and Sala-i-Martin (1993) consider two-sector models where human capital is produced using both human and physical capital, with factor intensities possibly different from those for the production of final goods/physical capital. Alternatively, Jones, Manuelli and Rossi (1993a. 1993b) consider models where human capital is a non-market good that is produced with effective human capital and a flow of market goods (but no direct physical capital input).[6]

The second issue regards the role of leisure specification and its implications for the optimal factor taxation. In all the recent models of optimal factor taxation (Lucas 1990, Jones, Manuelli and Rossi 1993a, 1993b and Bull 1993a, 1993b), leisure is considered as a non-market good that requires the use of "raw time" only. An older literature, however, considered leisure as a more complex non-market activity requiring the use of both human and physical capital inputs, in addition to raw time. For example, in Becker (1965) and Heckman (1976) leisure is modeled as "quality time" (defined as human capital times the fraction of the time endowment that is not spent working or accumulating human capital).[7] Extending this idea of leisure as being quality time, Greenwood and Hercowitz (1991) model leisure as a form of "home production" that uses effective labor and effective physical capital in its

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[6] This specification of the human capital accumulation goes back to Ben Porath (1967) and has been used recently by Trostel (1993) as well.

[7] Suppose that u_t and z_t are respectively the fraction of the time endowment spent working and accumulating human capital; then leisure is defined as $L_t = (1-u_t-z_t)H_t$. See Rebelo (1990) for such a formulation of leisure as "effective labor" in an endogenous growth model.

production.[8] The idea that leisure might be a physical capital intensive activity makes sense since most forms of leisure require the use of capital goods (think of video-stereo entertainment, sporting equipment and so on). Why should the specification of leisure matter? The answer is that when leisure consists of time off work and education only, it cannot be "increased" alongside consumption. If, however, it is an activity that uses reproducible factors, such as human and physical capital, in addition to time, it can be increased together with consumption; at the same time, the decisions to accumulate human and physical capital will take into account their impact on the future enjoyment of leisure as well.

Finally, international capital markets are important because domestic investors will consider the option of investing abroad (and vice versa for foreign investors). Consequently the rate of return that domestic residents can obtain on foreign assets will affect their decision whether to invest in physical capital domestically or buy foreign assets. Such a decision is clearly affected by the tax rates on domestic and foreign capital income. More subtly, it may be influenced by the tax rate on human capital as well should the latter affect the domestic rate of return on capital.

The literature on taxation and international capital flows has been developed in a large number of studies, such as Frenkel, Razin and Sadka (1990) and Razin and Slemrod (1990). These studies have stressed the importance of the principle governing taxation of foreign assets and liabilities held by agents of different countries; residence versus source-based taxation of foreign assets will have very different implications for the world allocation of savings and investment. A number of recent papers consider the positive and some normative effects of taxation on growth in open economy models of endogenous growth. Rebelo (1992) surveys the literature on endogenous economic growth in open economies; Buiter and Kletzer (1991) consider the effects of residence-based taxes on savings in a two-country OLG endogenous growth model; Correia (1992) addresses the issue of optimal taxation of capital income in an open economy while Razin and Yuen (1993 a, b) consider a two-country model with human and physical capital and endogenous fertility choice. These contributions do not, however, address the issue of the optimal relative taxation of physical <u>and</u> human capital in models of endogenous growth.

The literature on the effects of taxation on economic growth has examined a number of other interesting issues that are not addressed in our model. If government expenditure is endogenous and productive – for example, when it enters in the production function for final or capital goods – the long

[8] Tanzi and Zee (1993) go even further in blurring the distinction between consumption of final goods and leisure by modelling consumption as an activity that always requires the use of time (in a fixed proportion technology in their model). Benhabib, Rogerson and Wright (1991) distinguish "home production" from leisure, and model the latter as raw time.

run optimal tax on capital might not be zero. This issue has been addressed by Barro (1990), Jones, Manuelli and Rossi (1993a, 1993b), Judd (1990), Zhu (1991) and Corsetti (1992). If there are externalities in the production of final goods, as in Romer (1987) or in the production of human capital, as in Lucas (1988), the optimal tax plan might require subsidies to the activities with positive externalities (see Yuen (1991)). When the rate of time preference is endogenous, Zee (1994) shows that the growth effects of a tax on capital income in a standard *Ak* model are ambiguous. Judd (1990), King (1990), Chari, Christiano and Kehoe (1991a), Zhu (1991) and Corsetti (1992) study optimal taxation in stochastic settings. In the presence of rents generated by factors in fixed supply (such as labor in models without leisure) it may be optimal to tax capital in the long run if there are limits on the taxation of rents (Jones, Manuelli and Rossi 1993b). Finally, the effects of indirect taxation are examined, in Bull (1993a) and Jones, Manuelli and Rossi (1993b) among others.

3. THE MODEL

We consider a two-sector open economy: a final goods sector that produces consumption goods and physical capital, and an education sector that produces human capital.[9] The economy is small, and takes the world real interest rate as given. Physical capital is perfectly mobile across countries, while labor (human capital) is immobile.

3.1. Technology

Physical output is produced with a constant returns to scale (CRS) technology that uses human capital H and physical capital K as inputs. The technology is assumed to take the Cobb-Douglas form:

$$Y_t = A(v_t K_t)^{\alpha} (u_t H_t)^{1-\alpha} \tag{1}$$

where v (u) is the fraction of physical (human) capital devoted to the production of goods. the capital stock is assumed to depreciate at the rate δ.

Human capital is also produced with a CRS technology that uses both human and physical capital as inputs, as in Rebelo (1991). It depreciates at a rate δ, equal for simplicity to the rate of depreciation of physical capital. The production function is assumed to be Cobb-Douglas as well:

[9] See Rebelo (1991) and Mulligan and Sala-i-Martin (1993) for similar two-sector model formulations.

$$\dot{H}_t = B(x_t K_t)^{\beta} (z_t H_t)^{1-\beta} - \delta H_t \tag{2}$$

where x (z) is the fraction of physical (human) capital devoted to the accumulation of human capital. In equations (1) and (2) we have implicitly assumed that the "point-in-time technologies" are linear: if a fraction v of the capital stock is employed in the production of final goods, the "effective capital" is vK. This assumption is not necessary for our results: the crucial assumption is that there are CRS in physical and human capital, the reproducible factors.[10]

3.2. The government

The government needs to finance an exogenously given path of public expenditure, using domestic bond issues, factor income taxation and taxation of foreign assets, under the residence principle. Without loss of generality, we assume that the government borrows only domestically and that government bonds are tax-exempt. The instantaneous budget constraint of the government is given by:

$$\dot{B}_t = r_t B_t + G_t - T_t \tag{3}$$

where B_t are government bonds, r_t is their rate of interest and T_t is government revenue out of taxation. In every period, the resource constraint of the economy is given by the income-expenditure identity:

$$Y_t = C_t + \dot{K}_t + G_t + \dot{F}_t - r^* F \tag{4}$$

where Y is Gross Domestic Product, C is private consumption, G is government expenditure, F is net foreign assets and r^* is the world interest rate.

3.3. Private agents

The economy is inhabited by identical atomistic agents. They choose consumption, investment and the allocation of their human and physical capital with the purpose of maximizing an intertemporal utility function:

$$U = \int_0^{\infty} e^{-\rho t} u(C_t, L_t)\, dt \tag{5}$$

where ρ is the rate of time preference and L is a "leisure activity", that could include for example home

[10] Mulligan and Sala-i-Martin (1993) discuss more in detail the role of the point-in-time technologies.

production. This maximization is subject to the constraint on human capital accumulation given by (2) and an instantaneous budget constraint:

$$R_t^K(1-\tau_t^K)v_tK_t + R_t^H(1-\tau_t^H)u_tH_t + r_tB_t + r^*(1-\tau_t^F)F_t - C_t - \dot{K}_t - \dot{B}_t - \dot{F}_t - \delta K_t \geq 0 \qquad (6)$$

where R^K, R^H, r^*, τ^K, τ^H and τ^F are the rates of return and the tax rates on capital income, labor income and foreign assets, respectively. Equation (6) simply states that consumption and asset accumulation have to be financed with net income from capital, labor and current asset holdings. Clearly total tax revenues T are equal to $\tau^K R^K vK + \tau^H R^H uH + \tau^H r^* F$.

The leisure activity ("home production") uses time, human and physical capital as inputs, with a Cobb-Douglas technology:

$$L_t = [(1-v_t-x_t)K_t]^\gamma [(1-u_t-z_t)H_t]^{1-\gamma} \qquad (7)$$

where each individual's time endowment has been normalized to one.

For simplicity, we assume that the instantaneous utility function takes a Constant Intertemporal Elasticity of Substitution (CIES) form:

$$u(C_t, L_t) = \frac{(C_t L_t^\eta)^{1-\theta}}{1-\theta} - 1 \qquad (8)$$

where θ is the inverse of the intertemporal elasticity of substitution. This functional form has been shown to be consistent with the existence of a balanced growth path by King, Plosser and Rebelo (1988).

This utility function is similar to the one used in Greenwood and Hercowitz (1991). A special case of this occurs when $\gamma = 0$, so that leisure is "quality time", as in Becker (1965), Heckman (1976) and Rebelo (1991).

3.4. Firms

Firms rent capital from households at the rate of interest R^K and hire labor at the wage rate R^H. They will hire labor and capital up to the point at which their marginal product equals their marginal cost:

$$R_t^K = \alpha A \left(\frac{v_t K_t}{u_t H_t} \right)^{\alpha-1} \qquad (9)$$

$$R_t^H = (1-\alpha)A\left[\frac{v_t K_t}{u_t H_t}\right]^{\alpha} \tag{10}$$

4. THE COMPETITIVE EQUILIBRIUM

The representative consumer takes the paths of τ^K, τ^H and τ^F as given and chooses the paths of C, K, H, F, B, u, v, x, z to maximize (5) subject to (2) and (6). This case includes as its subcases three models of leisure: the "home production" model ($\eta > 0$ and $0 < \gamma < 1$); the "quality time" model ($\eta > 0$ and $\gamma = 0$) and the "no leisure" model ($\eta = 0$).[11]

We can define non-human wealth $W_t = K_t + B_t + F_t$, and re-write (6) as follows:

$$r_t W_t - [r_t + \delta - R_t^K(1-\tau_t^K)v_t]K_t + R_t^H(1-\tau_t^H)u_t H_t + [r^*(1-\tau_t^F) - r_t]F_t - C_t \geq \dot{W}_t \tag{11}$$

Next, we observe that since domestic bonds and foreign assets are perfect substitutes for the consumer, they should yield the same after-tax rate of return:

$$r_t = r^*(1-\tau_t^F) \tag{12}$$

This also implies that the consumer's maximization problem can only determine aggregate holdings of domestic and foreign bonds $(B_t + F_t)$; the amount of domestic bonds being held is determined by the supply from the government.

The first-order conditions with respect to C, W, K, H, v, x, u and z respectively can be expressed as follows:

$$e^{-\rho t} C_t^{-\phi} L_t^{\eta(1-\phi)} = \lambda_t \tag{13}$$

$$-\frac{\dot{\lambda}_t}{\lambda_t} = r_t = R_t^K(1-\tau_t^K) - \delta \tag{14}$$

$$-\frac{\dot{\mu}_t}{\mu_t} = (1-\beta)B\left[\frac{x_t K_t}{z_t H_t}\right]^{\beta} - \delta \tag{15}$$

[11] For the "raw time" model of leisure ($L = 1-u-z$) see Milesi-Ferretti and Roubini (1993).

$$R_t^K(1-\tau_t^K)K_t = \frac{\gamma\eta}{1-v_t-x_t}C_t \tag{16}$$

$$\frac{\gamma\eta}{1-v_t-x_t}e^{-\rho t}C_t^{1-\phi}L_t^{\eta(1-\phi)} = \mu_t B\beta K_t\left(\frac{x_t K_t}{z_t H_t}\right)^{\beta-1} \tag{17}$$

$$R_t^H(1-\tau_t^H)H_t = \frac{(1-\gamma)\eta}{1-u_t-z_t}C_t \tag{18}$$

$$\frac{(1-\gamma)\eta}{1-u_t-z_t}e^{-\rho t}C_t^{1-\phi}L_t^{\eta(1-\phi)} = \mu_t B(1-\beta)H_t\left(\frac{x_t K_t}{z_t H_t}\right)^{\beta} \tag{19}$$

The remaining two FOCs are the constraints (2) and (6). Equation (13) states that the shadow price of consumption (physical capital) must equal the marginal utility of consumption in every period. Equation (14) is the FOC for capital accumulation: the rate of change of the shadow price of consumption must equal the marginal product of capital net of tax, which must also equal the rate of return on government bonds. Equation (15) is the corresponding FOC for human capital accumulation, relating the change in the shadow price of human capital to its marginal rate of return. Equation (16) and (18) describe the optimal allocation of physical and human capital respectively between production of market goods and "home production". Finally, conditions (17) and (19) describe the optimal allocation of physical and human capital between the "education" sector and home production.

The transversality conditions are:

$$\begin{aligned} \lim_{t\to\infty} \lambda_t K_t &= 0 \\ \lim_{t\to\infty} \mu_t H_t &= 0 \end{aligned} \tag{20}$$

From (12) and (14) it is straightforward to obtain:

$$r_t = r^*(1-\tau_t^f) = R_t^K(1-\tau_t^K) - \delta \tag{21}$$

That is, under residence-based taxation the interest rate on domestic bonds must equal the net after-tax rate of return on capital and the after-tax rate of return on foreign assets. This result is clearly an implication of the assumption that in the absence of uncertainty domestic bonds, domestic capital and foreign assets are perfect substitutes.

Using equations (9), (10) and (16)-(19) we can express the sectoral allocation of factors as a function of technology parameters and taxes:

$$\frac{v_t}{u_t} = \frac{\alpha}{1-\alpha}\frac{1-\beta}{\beta}\frac{1-\tau_t^K}{1-\tau_t^H}\frac{x_t}{z_t} = \frac{\alpha}{1-\alpha}\frac{1-\gamma}{\gamma}\frac{1-\tau_t^K}{1-\tau_t^H}\frac{1-v_t-x_t}{1-u_t-z_t} \tag{22}$$

According to (22), when the tax on labor income (capital income) rises (falls), the capital/labor ratio in the sector producing goods rises with respect to the capital/labor ratio in the sector producing human capital and with respect to the capital/labor ratio in the home production sector. It is interesting to note that changes in tax rates do <u>not</u> cause changes in the relative capital intensity between the education sector and the home production sector, since both these sectors are not directly taxed.

This economy will exhibit a balanced growth path, along which consumption, physical capital and human capital grow at the same rate, while factor allocations (u, v, x and z) remain constant.[12] Log-differentiating (13) and using the fact that factor allocations are constant along the balanced growth path, we obtain:

$$\frac{\dot{C}}{C} = -\frac{1}{\theta-\eta(1-\theta)}\left(\rho+\frac{\dot{\lambda}}{\lambda}\right) \tag{23}$$

where time subscripts have been omitted. Along the balanced growth path, the shadow prices of physical and human capital must decline at the same rate. Equating (13) and (15) and using (9), (10), (17) and (19) we can determine the physical to human capital ratios in the three sectors along the balanced growth path:

$$\begin{aligned}\frac{vK}{uH} &= [D_0(1-\tau^K)^{1+\beta}(1-\tau^H)^{-\beta}]^{\frac{1}{1-\alpha+\beta}}\\ \frac{xK}{zH} &= [D_1(1-\tau^K)^{\alpha}(1-\tau^H)^{1-\alpha}]^{\frac{1}{1-\alpha+\beta}}\\ \frac{(1-v-x)K}{(1-u-z)H} &= [D_2(1-\tau^K)^{\alpha}(1-\tau^H)^{1-\alpha}]^{\frac{1}{1-\alpha+\beta}}\end{aligned} \tag{24}$$

where the terms D_i are constants involving the technology parameters α, β, A and B, reported in the Appendix. The ratio of "market" consumption to leisure can be determined in an analogous fashion, and

[12] Mulligan and Sala-i-Martin (1993) and Barro and Sala-i-Martin (1994) give the necessary conditions for the existence of a balanced growth path.

is given by:

$$\frac{C_t}{L_t} = [D_3\,(1 - \tau_t^H)^{(1-\gamma+\beta)(1-\alpha)}\,(1 - \tau_t^K)^{1-\alpha\gamma+\beta}]^{\frac{1}{1-\alpha+\beta}} \tag{25}$$

Clearly, higher factor income tax rates will tend to shift consumption from "market" goods to "home production".

Using (10), (13), (23) and (24) we obtain the balanced growth rate of the economy (equation 26) and the steady state net real interest rate (equation 27):

$$\frac{\dot{C}}{C} = \frac{1}{\theta - \eta(1-\theta)}\,[D_4(1 - \tau^K)^{\alpha\beta}\,(1 - \tau^H)^{\beta(1-\alpha)}]^{\frac{1}{1-\alpha+\beta}} - \rho - \delta) \tag{26}$$

$$r = [D_4(1 - \tau^K)^{\alpha\beta}\,(1 - \tau^H)^{\beta(1-\alpha)}]^{\frac{1}{1-\alpha+\beta}} - \delta \tag{27}$$

From equations (24), (25) and (26) it is clear that both tax rates on domestic factor incomes will in general distort the allocation of factors between sectors and reduce the rate of growth of the economy.

When will the economy reach the balanced growth path? In a closed economy, the economy has to accumulate physical and human capital until it reaches the capital-labor ratio that is associated with balanced growth. In an open economy, however, it is possible to augment (reduce) the domestic capital stock instantaneously by borrowing (lending) on international capital markets. This is what will happen, and therefore the balanced growth path will be reached immediately. In other words, if tax rates do not change over time a small open economy will exhibit no transitional dynamics.

5. TAXATION AND LONG-RUN GROWTH

We will now discuss the main results of the balanced growth solution of our model. In particular, we analyze the conditions under which the balanced growth solutions of the model depend on the tax rates on labor (τ^H), capital income (τ^K) and income from net foreign assets (τ^F).

First, note that the "quality time" model of leisure ($\gamma = 0$), the "home production" model of leisure ($\gamma > 0$) and the model with no leisure ($\eta = 0$) do not qualitatively differ from each other since the equilibrium after-tax real interest is identical in the three models (it does not depend on either γ or η). Moreover, the growth rate in the "quality time" and "home production" models is equal and its ratio relative to the growth rate in the "no leisure" model is a constant ($[\theta/(\theta-\eta(1-\theta))]$) that depends only on parameters of the utility function θ and η (see equation 26).[13]

This qualitative similarity of "quality time" and "home production" models of leisure with the case of no leisure results from the fact that leisure is modeled as a non-market activity produced with constant returns to scale to reproducible factors -- either human capital only (when $\gamma=0$) or both human and physical capital (when $\gamma > 0$). Therefore, leisure can be reinterpreted in these two cases as a non-market consumption good and the model is substantially equivalent to one in which there is no leisure.

Second, note that the assumption of perfect capital mobility and the hypothesis of residence-based taxation imply that the after-tax return on all investments (domestic capital, domestic bonds and foreign assets) are equal in every period (see equation 21). In the absence of taxation of foreign asset income, perfect capital mobility should lead to the equalization of domestic real rates of return with the world interest rate and the equalization of domestic and world growth rates. In fact, assume that in the absence of taxation of domestic capital and labor income, the domestic real interest rate is equal to the world rate ($r=r^*$); this would be the case if the technology and preference parameters in the world economy were equal to those in the domestic economy and if there were no distortionary taxes in the world economy. This would also imply that, in the absence of domestic distortionary taxes on capital and labor, the home growth rate of consumption and GNP would be equal to the world growth rate.[14]

Consider now the effects of residence-based taxation. This form of taxation allows the after-tax return earned by domestic residents to differ from the world interest rate: the net after-tax return on domestic capital will be equal to the world real interest rate net of the tax on domestic residents' income from foreign assets. This divergence between domestic and world interest rates under residence-based taxation implies that domestic and world growth rates will also differ (see Rebelo 1991, 1992 on this point).

Next, the solution (27) for the steady state net after-tax domestic real interest rate shows that, in general, this real return will depend both on the tax on domestic capital income and on labor income. Given the equality between this real return and the after-tax return on foreign assets, it follows that:

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[13] A similar result was derived by Rebelo (1991) who compared the growth rates in a model with leisure as "quality time" and in a model where an exogenous fraction of time is devoted to leisure.

[14] Buiter and Kletzer (1992) show that long run differences between home and world GNP growth rates can persist with perfect capital mobility if some goods are non-traded and are produced with non-traded goods only (this is the case of human capital in their model). See also Rebelo (1992) for a discussion of non-tradedness and growth equalization.

Proposition 1 *In the case of $\beta > 0$, the residence taxation principle implies that, for any given tax on labor and capital income, there is a unique feasible value for the tax on foreign assets so that the returns to domestic and foreign investments are equalized. Such a tax rate is equal to:*

$$\tau_t^f = 1 - \frac{r_t}{r^*} \tag{28}$$

where r is defined in equation (27).

Proof See equations (12) and (21). ‖

According to this proposition, once the tax rate on capital income and labor income are chosen, the equilibrium after-tax real interest rate is determined; therefore, there is only one value for the tax on income from foreign assets such that the returns to domestic and foreign investments are equal.

Proposition 2 *In the case of $\beta > 0$, since the equilibrium real interest rate is a negative function of the labor income tax, the equilibrium tax on foreign assets will be a positive function of the tax on labor income.*

Proof See equations (21) and (27). ‖

Intuitively, since an increase in the tax on labor income reduces the after tax real interest rate r, a higher tax on foreign asset income is required to maintain the parity between domestic and foreign returns.

Proposition 3 *When physical capital does not enter in the production of human capital ($\beta = 0$), the steady state growth rate of the economy and the equilibrium real interest rate are independent of the tax rates on capital and labor income regardless of how the leisure activity is modeled. In this case:*

$$\frac{\dot{C}}{C} = \frac{1}{\theta - \eta(1-\theta)} [B - \rho - \delta] \tag{29}$$

$$r = B - \delta \tag{30}$$

Proof See equations (26) and (27). ‖

The intuition for the result is simple. If human capital is produced with human capital only, an increase in the labor tax rate will reduce the return to current work effort but it will also reduce the return to human capital accumulation (and the return to the leisure activity) by the same amount. Therefore, the fraction of time spent working, studying and producing leisure will not be affected by a change in the labor tax rate and the rate of growth of the economy and the real interest rate will be unaffected as well.

It is known that equation (30) represents the steady state growth rate of economies à la Lucas (1988) where human capital accumulation is CRS in human capital only ($\dot{H} = BzH$) and there is no leisure ($\eta = 0$) (see Barro and Sala-i-Martin 1994). Our analysis generalizes that result by showing that, in the Lucas case of $\beta=0$, a qualitatively similar steady state solution is obtained when we consider economies where leisure is introduced and modeled as "quality time" or "home production". Specifically, the growth rate will be independent of the technological parameters for the production of final goods and physical capital (α and A) while the net real interest rate will be independent of preferences and equal to the productivity level of human capital minus depreciation (B-δ).

Proposition 4 *When $\beta = 0$, the steady state physical to human capital ratio in the production of final goods is independent of the tax rate on labor income but a negative function of the tax rate on capital income:*

$$\frac{vK}{uH} = [\alpha \frac{A}{B}(1 - \tau^K)]^{\frac{1}{1-\alpha}} \tag{31}$$

Proof See equation (24). ‖

The explanation for the independence of the capital ratio from the labor tax is the same as the one given in Proposition 3. A change in the capital income tax rate will instead reduce the return to physical capital accumulation while not affecting the return to human capital accumulation; therefore, the physical to human capital ratio in the production of final goods will fall.

Proposition 5 *When $\beta = 0$, the steady state physical to human capital ratio in the economy is independent of the tax rate on labor income but a negative function of the tax rate on capital income in* *the model with no leisure; in the models where leisure is "quality time" or "home production" such a capital ratio depends on both the tax on human and physical capital.*

Proof From (22), the equilibrium capital/labor ratio in the economy is given by

$$\frac{K}{H} = \frac{u}{v}\left[\alpha\frac{A}{B}(1-\tau^{K})\right]^{\frac{1}{1-\alpha}} \tag{32}$$

From Proposition 1, we know that when $\beta = 0$, the fraction z of time spent accumulating human capital is independent of both tax rates. When $\gamma > 0$, we can use the equality between the first and the third term in (22) to express v as a function of u and both tax rates. Using the economy's resource constraint (4), we can establish that u, v and v/u are a function of both tax rates. Since from (23) we know that vK/uH depends only on τ^{K}, it follows that K/H is a function of both tax rates. When $\gamma = 0$, $v = 1$; the resource constraint (4) establishes that u is a function of both tax rates. From equation (28) it follows that K/H is also a function of both tax rates. Finally, when there is no leisure $z = 1 - u$; since z is independent of both tax rates (Proposition 1), so is u. In this case (32) establishes that K/H depends only on the tax rate on physical capital. ‖

The explanation for the above proposition is the following. As discussed above, when there is no leisure in the model, the tax on labor income does not affect the fraction of time spent working (u) and studying (1-u) as long as $\beta = 0$. Then, since $v = 1$ in this case, equation (31) shows that the equilibrium physical to human capital ratio in the economy will also be independent of τ^{H} but dependent on τ^{K}. In the specifications where leisure is modeled as "quality time" or "home production", the tax on labor income does not affect the fraction of time spent studying (z) (and therefore does not affect growth) but it affects the allocation of time between work (u) and leisure activities ($1 - u - z$). In particular, an increase in the labor tax reduces the fraction of time spent working and increases the fraction of time spent in the leisure activity. Therefore, the equilibrium human and physical capital in the economy will be affected by the labor tax. The above proposition is important for the derivation of the optimal taxation of factors. In fact, when $\beta = 0$ and there is no leisure, the labor tax does not create any intertemporal distortion: it does not affect either the growth rate of the economy nor the capital labor ratio in the economy. Conversely, if leisure is modeled as "quality time" or "home production", the labor tax does not affect growth but it creates an intertemporal distortion since the economy wide K/H is affected. A tax on capital income is always distortionary when $\beta = 0$ because it affects the physical to human capital ratio regardless of whether there is leisure or not in the model.

Proposition 6 *When $\beta = 0$, the equilibrium tax on foreign asset income will not depend on the tax rates on labor and capital income. In this case:*

$$\tau^F = 1 - \frac{B - \delta}{r^*} \tag{33}$$

Proof See equation (27). ‖

The intuition for the proposition is clear. When $\beta = 0$, the real after-tax interest rate is a constant, $B - \delta$, that does not depend on either the tax rate on capital or labor income. Therefore, the unique value of the tax on foreign asset income that equalizes returns to domestic and foreign investments will be independent of the choice of the tax on capital and labor.

Proposition 7 *When physical capital enters in the production of human capital ($\beta > 0$) the steady state growth rate of the economy will negatively depend on the tax rate on both capital income and labor income. Moreover, the steady state physical to human capital ratios in the final goods and human capital sectors will also depend on both factor tax rates.*

Proof See equations (24) and (26). ‖

The intuition for the proposition is easier to present for the case of no leisure, but is the same in the equivalent cases of leisure as "quality time" or "home production". We showed above that when $\beta = 0$, the return to and the cost of human capital accumulation (i.e. the net of tax wage) are affected in the same proportion by a change in labor taxes, leaving the time allocation decision unchanged. In other terms, since the cost of human capital accumulation is effectively tax-deductible, labor income taxation does not affect the incentive to accumulate human capital.[15] However, if physical capital is also used in the production of new human capital ($\beta > 0$), the return to human capital is reduced more than its cost. In particular, the cost of physical capital inputs used in the production of human capital is not

[15] See Trostel (1993) for a detailed presentation of this argument.

reduced by the labor income tax since these inputs are not tax deductible. More generally, as suggested by Trostel (1993), if any other inputs in addition to human capital enter in the production of human capital, its return will be reduced by more than its cost. Therefore human capital accumulation will be reduced by an increase in the labor tax rate.

The above results imply that, for the three specifications of the leisure activity considered so far (the "quality time", the "home production" and the "no leisure" models), the specification of the human capital accumulation function has important implications for the dependence of growth rates on factor income taxes. In particular, if human capital is produced with <u>both</u> human and physical capital (with CRS in the two inputs), the steady state growth rate of the economy depends on both factor tax rates. However, if human capital accumulation uses human capital <u>only</u> (with CRS), the steady state growth rate of the economy will not depend on either factor income tax rate. Moreover, in this case the steady state ratio between effective human and physical capital will depend on the tax on capital income but not on the labor income tax.

The result that the dependence of the growth rate on factor tax rates has to do with whether physical capital enters in the production of human capital (i.e. on whether β is positive or zero) holds both when leisure does not enter the utility function and when it is produced with constant returns in reproducible factors. What happens in the case in which leisure is not produced with constant returns to reproducible factors ? One such case -- leisure modeled as a "raw time" activity -- is the one most studied in the literature.[16] In this case "raw time" is a non-reproducible factor that is constrained by the agent's total time endowment. In Milesi-Ferretti and Roubini (1994) we show that, if leisure is modeled as "raw time" -- or, more generally, as an activity not produced with CRS in reproducible factors -- the balanced growth rate of the economy will always depend on the tax rates on capital and labor income regardless of whether physical capital inputs enter or not in the production of human capital (i.e. regardless of whether β is positive or zero).[17]

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[16] See Chamley (1986), Lucas (1990), Jones, Manuelli and Rossi (1993a, 1993b) and Bull (1993a) for such a specification of leisure in optimal taxation analyses.

[17] The intuition for the result is the following (see Milesi-Ferretti and Roubini, 1994 for a formal proof). Regardless of the value of β, when leisure is modeled as "raw time", an increase in human capital will increase the productivity of time spent producing goods or accumulating human capital but will not affect the marginal utility of leisure. Therefore, the return to the accumulation of human capital will now depend on the time spent in leisure activities. Consider now the effects of an increase in the labor tax: while the relative cost and return to working versus accumulating human capital are unchanged by such a change in labor taxes, the return to the leisure activity is increased since the time spent in leisure is untaxed. The ensuing increase in time spent in leisure reduces the time spent accumulating human capital and therefore its return. The reduction in the return to investment in human

As discussed above, residence-based taxation allows the after-tax return earned by domestic residents to differ from the world interest rate. This divergence between domestic and world interest rates under residence-based taxation implies that domestic and world growth rates will also differ. Residence-based taxation therefore implies that the long-run equilibrium and growth rate of an open economy will be equal to that of a closed economy. The main difference relative to the closed economy case is the absence of transitional dynamics in an open economy. Starting from an initial equilibrium without international capital flows, the opening of international capital markets will imply that, given the initial conditions (the initial stock of physical and human capital), the country will borrow or lend from the rest of the world so as to instantaneously change the stock of domestic capital to the steady state desired ratio of physical and human capital. In the presence of perfect capital mobility, the economy will therefore jump to the long run allocation of resources and grow along the balanced growth path; while in a closed economy the transition to the balanced growth path will take time.

6. OPTIMAL TAXATION ANALYSIS

So far, we have discussed the conditions under which the growth rate of the economy and the capital ratios in the various sectors will depend on the tax rates on labor and capital income. We turn now to the analysis of the conditions under which it will be optimal to have a zero long run taxation of a factor of production.

6.1 Optimal Long-Run Taxation of Labor and Capital

While a formal analysis of optimal tax rates on the two factors require the solution of a "restricted Ramsey planner's problem" where the government chooses the path of tax rates with the purpose of maximizing the representative agent's welfare, taking into account the optimizing behavior of this agent, it is possible to get the intuition for the optimal taxation results by considering the link between growth rates and tax rates.[18] Without loss of generality, we shall assume that the revenue from taxation of foreign assets initially held by private agents is rebated lump-sum to consumers: otherwise, it is always optimal for the domestic government to "confiscate" initial foreign assets by setting the tax as high as possible.

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capital will then imply that the equilibrium real interest rate is reduced and therefore the rate of growth of the economy is reduced in the steady state. Therefore, in the model with leisure as "raw time" the growth rate of the economy will depend on the tax rates on both factors of production.

[18] In Milesi-Ferretti and Roubini (1994) we solve such a "restricted Ramsey planner's problem" in a closed economy and provide formal proof of the optimal taxation results presented below.

The optimal taxation analysis implies the following five results:

1. When both human and physical capital enter in the production of human capital ($\beta > 0$), the optimal long run tax on both capital and labor income is zero when leisure is CRS in reproducible factors ($\eta > 0$) or when there is no leisure ($\eta=0$).

2. The optimal long run tax on both capital and labor income is zero when leisure is modeled as "raw time" regardless of how human capital is produced (i.e. for any value of β).

3. When only human capital enters in the production of human capital ($\beta = 0$), the optimal long run tax on both capital and labor income is zero when leisure is modeled as "quality time" or "home production".

4. When only human capital enters in the production of human capital ($\beta = 0$), the optimal long run tax on capital is zero while the one on labor income is positive in the model with no leisure.

5. The optimal long-run tax on foreign assets income will be zero regardless of the value of β.

The intuition for the first result can be easily understood by considering the relation between the growth rate of the economy and the tax rates. The analysis of Chamley suggests that any tax that distorts a long run intertemporal decision should be set equal to zero. In an endogenous growth framework, any tax distortion that reduces the long run growth rate of the economy will have large and permanent costs (in terms of present discounted value of lost consumption and utility) and should therefore be set equal to zero. Since the balanced growth rate of the economy is dependent on both tax rates in models without leisure and in models where leisure is CRS in reproducible factors when $\beta > 0$, it follows that the optimal tax on labor and capital income should be zero in these cases.

The basic principle that any tax the affects long run growth should be set to zero in the long run is behind the second result regarding optimal taxation in the specifications of leisure as "raw time". In particular, in the "raw time" model of leisure, the optimal long run tax rate on capital and labor income is zero regardless of whether capital inputs enter or not in the production of human capital (i.e., regardless of the value of β) because in that model the long-run growth rate depends on both tax rates regardless of the value of β.

While a dependence of the long run growth rate on a tax rate implies that such a tax rate should be set equal zero in the long run, what can we say about the cases in which long-run growth is independent of the tax rate ? Such independence of growth from tax rates is obtained, in our model, in three models of leisure (when leisure CRS in reproducible factors and when there is no leisure) whenever $\beta = 0$. Moreover, in the models with leisure as "home production" and "quality time", the equilibrium physical to human capital ratio in the economy is affected by both tax rates; conversely, in the model without leisure the equilibrium physical to human capital ratio in the economy is affected by the tax on capital but is not affected by the tax on labor. Therefore, a steady state tax on capital income distorts the intertemporal choice of physical to human capital regardless of whether leisure brings utility. Not so for the labor tax: a steady state tax on labor income distorts the physical to human capital ratio when there is leisure but does not create any intertemporal distortion when there is no leisure in the model.

Since optimal taxation principles suggest that we should not distort intertemporal choices, it follows that when the two tax rates do not affect the long term growth rate and only one of the two tax rates affects the steady state capital ratio, the optimal long run tax plan will be the following: set to zero the tax rate on the factor that distorts both the growth rate and the capital ratio; set to a positive value the tax rate on the factor that does not distort the long run physical to human capital ratio. The third and fourth results therefore follow: when $\beta = 0$, the model specifications of the leisure activity as "quality time", "home production" imply that the optimal long run tax rate on both capital and labor income will be equal to zero; in the specification without leisure the optimal long run tax rate on capital income will be zero while the optimal long run tax rate on labor income will be positive.

Consider next the implications of the above optimal taxation analysis for the taxation of foreign asset income. We showed above that, in the absence of taxation of domestic capital and labor income, the domestic real interest rate is equal to the world rate ($r = r^*$) and the home growth rate of consumption and GNP would be equal to the world growth rate. However, residence-based taxation will lead to a difference between the after tax return earned by domestic residents and the world interest rate. Similarly, the domestic growth rate will differ from the world rate.

What will then be the optimal long run tax on foreign asset income ? If $\beta > 0$, the optimal tax on capital and labor income is zero; therefore, the optimal tax on foreign asset income will be zero as well and domestic growth will equal the world rate. Suppose now that $\beta = 0$; if there is no leisure in the model, the optimal long-run tax on capital income is zero while it is positive for labor income; the domestic real interest rate will equal the world rate. It follows that the optimal long-run tax on foreign asset income will be zero again. Finally, in the models with leisure and $\beta = 0$, the optimal tax on both capital and labor income is zero; therefore, the optimal tax on foreign asset income will be zero as well. It then follows that the optimal long-run tax on foreign asset income is zero regardless of the value of β; in this sense the long run taxation of foreign asset income is equal to that of domestic capital.

How do the above results about optimal taxation compare with those in the literature on open economy ? Rebelo (1992) considers the relation between taxation and growth in open economies but does not consider the optimal taxation of incomes. As in our analysis, he finds that the assumption of perfect capital mobility should lead to interest rate and growth rate equalization between the domestic economy and the world; he also shows that only residence-based taxation will allow a wedge between domestic and world interest rates and growth rates. Correia (1992) considers the optimal taxation of capital income in a simple Ak one-sector model of endogenous growth where human capital and leisure are not considered. She replicates the Chamley result on the zero optimal taxation of capital income; since she assumes residence-based taxation with equal tax rate on domestic capital income and foreign asset income, the optimal zero long-run taxation of capital income corresponds a zero tax on foreign asset income as well. Razin and Yuen (1993) consider a two-sector, two-country model of endogenous growth with endogenous fertility choice. Agent derive utility from consumption of goods and from the number of their offsprings. The number of offsprings is determined taking into account that child-rearing requires a fraction of the household time endowment. Human capital is increased with both physical and human capital inputs. They formally prove that, under residence-based taxation, the optimal tax on capital income and foreign asset income is positive in the short-run and zero in the long-run (an application of the Chamley result in the open economy).[19]

6.2 Growth-Maximizing Tax Policies with a Balanced Budget

Optimal taxation plans in dynamic growth models are generally of the following nature. Tax rates on factors are positive in the short run (when factors are in semi-fixed supply) and lower (possibly zero) in the long run. Given an exogenous path of government expenditures this optimal taxation plan consists

[19] They also argue, without a formal proof, that the optimal long-run tax on labor income should be positive. The latter claim is puzzling. Their model, in fact, corresponds to a two-sector model with $\beta > 0$ since both physical and human capital enter in the production of human capital. Moreover, their model is equivalent to a model where utility is obtained from leisure and leisure is produced with "raw time": in fact, agents get utility from children, and child-rearing requires "raw time" only. We know that a model with leisure being produced with raw time implies a dependence of the long run growth on capital <u>and</u> labor income taxes regardless of β; therefore the optimal long run tax on labor should be zero. Moreover, even if children had been produced with "quality time" rather than raw time, the assumption of $\beta > 0$ in their model would imply that the growth rate would still depend on the tax on labor income and that tax should therefore be equal to zero in the long run.

of taxing both factors in the short run, and financing spending in the long run through accumulated budget surpluses. This implies that the government should be able to accumulate enough assets in the short run to be able live off their return in the long run. Such an accumulation of assets by the government is clearly not empirically realistic.

It is therefore interesting to consider the nature of an optimal taxation plan when the ability of the government to borrow or lend is restricted. In the limiting case where no intertemporal borrowing is allowed so that the government has to balance its budget in every period, we can study which tax policies will be growth maximizing (i.e. welfare maximizing) in the long run. We will consider only the steady state and assume that the government spending is a constant fraction of output. We assume that the government has to run a balanced budget in every period; moreover we assume that the revenues from foreign asset are rebated in lump-sum form to private agents so that capital and labor income are the only two sources of financing of government spending.[20] Then, the budget constraint of the government will be:

$$g = \frac{G}{Y} = \alpha \tau^{K} + (1-\alpha)\tau^{H} \tag{34}$$

where g is the steady state ratio of government spending to output. We can then consider which steady state tax policies will maximize the growth rate by maximizing the growth solution (28) (for the general case of $\beta > 0$) subject to the above government budget constraint (34). The solution of this problem is:

$$\tau^{K} = \tau^{H} = g \tag{35}$$

The equation shows that the growth-maximizing capital and labor income tax rates are equal, i.e. a common income tax on all factor incomes is optimal. The result is interesting because it suggests that, as long as the growth rate of the economy is affected by both tax rates, the optimal long run tax policy is to tax both factors at the same rate. As we argued above, if the behavior of the government is not constrained (so that it can borrow and lend), labor and capital should be taxed at the <u>same</u> long run rate of zero. Similarly, if the government is constrained to run a budget balance in every period, the optimal long run tax on labor and capital will still be the <u>same</u> for both factors and equal to the government spending to output ratio that has to be financed in every period.

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[20] We make the assumption of a rebate of foreign asset income revenue in order to avoid having to solve explicitly for the equilibrium value of foreign assets. In practice, since the revenues from foreign asset income are quite small, assuming that they are rebated is of no qualitative consequence.

7. POLICY IMPLICATIONS

What are the policy implications of our results for the actual conduct of tax policy ? In recent years, the question of the optimal degree of taxation of capital income has been hotly debated in academic and policy circles. For example, in many industrial countries the issue of capital gains taxation has attracted a lot of attention. The results of Chamley (1985, 1986) and Judd (1985), derived in neoclassical exogenous growth models, provided a theoretical rationale for the widely held view that the taxation of capital income should be kept at a minimum, because such taxes can reduce capital accumulation. Our analysis suggests that while the taxation of capital income is distortionary and can have negative growth consequences when the growth rate of the economy is endogenous, a similar effect is caused by the taxation of labor income when human capital is an additional engine of economic growth. Such an effect of labor taxation is absent in exogenous growth models, where the labor factor cannot be accumulated in the form of human capital.

In this sense, the analysis suggests that distortionary taxes have in general negative growth effects and should be kept at a minimum in the long run. What are the short-run implications? Formally, in the absence of constraints on the ability of the government to borrow and lend, the optimal taxation problem yields a solution that involves initially high taxes on both human and physical capital. This allows the government to accumulate a sufficient quantity of assets to finance government expenditure in the long run without any further recourse to taxation. In practice, this is not a realistic solution, for a number of reasons.

The first practical problem is that the government is unable to commit to a given path of taxes from now on to the foreseeable future. Therefore, this optimal taxation scheme will be subject to time-consistency problems. In particular, in every period the government will have an incentive to tax more heavily existing capital, while refraining from taxing investment.[21]

A second problem is that in practice government expenditure is not exogenous, and high short-run rates of taxation may lead to more spending, rather than to the accumulation of assets to finance long-run expenditure.

A third problem is that in practice the ability of the government to borrow and lend is likely to be restricted. In the limit case in which the government has to balance its budget in every period, the

[21] Unlike other optimal taxation models, however, our model can allow us to determine a meaningful optimal path of taxation even when tax decisions have to be taken sequentially. The reason is that the supply of taxable physical capital is elastic even in the short run, because capital can have alternative uses in the home production or the human capital sector. This implies that setting the capital income tax to confiscatory levels is unfeasible.

model suggests that physical and human capital should be taxed in a similar fashion. In this sense, the important message of the paper is not that taxation of labor and capital income should be high in the short run and zero in the long run; it is rather that human and physical capital should be taxed similarly if they both contribute to accumulation and long-run growth.

With regard to the taxation of foreign assets, endogenous growth models suggest that differential taxation of domestic and foreign asset income is feasible only with a residence-based taxation scheme, provided, of course, that foreign asset income can effectively be recorded and taxed. With source-based taxation, return differentials would imply unlimited amounts of capital inflows or outflows. Under residence-based taxation, the tax on net foreign asset income should be set at the level that equates domestic and foreign post-tax returns on capital. If zero taxation of domestic capital is optimal and feasible, zero taxation of foreign assets would also ensue.

In this paper we have not considered indirect taxes. The relative merits of indirect versus direct taxation have been widely discussed in the literature; in the framework of neoclassical growth models, it has been suggested that consumption taxation is superior to direct factor income taxation. However, the results of Jones, Manuelli and Rossi (1993b) and Bull (1993a) suggest that in the long run all taxes, including a consumption tax, ought to be zero. The reason is that when growth is endogenous even a distortionary consumption tax affects long-run growth. It would, however, be interesting to consider the implications for indirect taxation of restrictions on the government's ability to borrow and lend.

Another interesting policy aspect that is captured with the "home production" specification is the notion that factors of production in the "market" sector may be elastically supplied even in the short run. In practice, the "home production" sector may be reinterpreted as the "informal" sector of the economy, where capital and labor income are not taxed. The analysis suggests that "excessive" taxation of incomes in the formal sector will lead agents to transfer capital and labor resources to the informal sector in order to avoid taxation.

8. CONCLUDING REMARKS

In this paper we have considered the role of the human capital accumulation technology and of the nature of "leisure" activity in determining the optimal taxation of labor, capital and foreign assets in a small, open economy. Traditional optimal taxation analyses in exogenous growth models stressed that the tax rate on capital income should be zero in the long run, while the one on labor should be positive. We have shown that in endogenous growth models this result is replicated only under restrictive specifications of human capital accumulation and leisure production. Under more general specifications of these processes, capital and labor income should be taxed similarly. Another implication of this paper is that the labor tax rate will affect the real after-tax rate of return on domestic capital. Therefore, in the presence of free capital mobility equalization of tax rates on domestic and foreign capital may not be sufficient to prevent capital flight.

A general but unrealistic feature of the optimal taxation solution is the accumulation of budget surpluses in the short run to finance government expenditure without recourse to distortionary taxation in the long run. This result is due to the fact that reproducible factors are supplied relatively inelastically in the short run but elastically in the long run. Future research should re-examine the issue of dynamic optimal taxation subject to a realistic set of restrictions on government's behavior.

APPENDIX

A1. VALUE OF PARAMETERS IN EQUATIONS (24)-(26)

The terms D_i (equations (24), (25) and (26)) are given by:

$$D_0 = \frac{\alpha A}{(1-\beta)B}\left[\frac{\alpha}{1-\alpha}\frac{1-\beta}{\beta}\right]^{\beta}$$

$$D_1 = \frac{\alpha A}{(1-\beta)B}\left[\frac{1-\alpha}{\alpha}\frac{\beta}{1-\beta}\right]^{1-\alpha}$$

$$D_2 = \frac{\alpha A}{(1-\beta)B}\left[\frac{1-\alpha}{\alpha}\right]^{1-\alpha}\left[\frac{1-\beta}{\beta}\right]^{\beta}\left[\frac{\gamma}{1-\gamma}\right]^{1-\alpha+\beta}$$

$$D_3 = \left[\left(\frac{(1-\alpha)A}{(1-\gamma)\eta}\right)^{1-\alpha+\beta}\left(\frac{\alpha A}{(1-\beta)B}\right)^{\alpha-\gamma}\left[\frac{\alpha}{1-\alpha}\right]^{\gamma(1-\alpha)+\alpha\beta}\left[\frac{1-\beta}{\beta}\right]^{\beta}\left[\frac{\gamma}{1-\gamma}\right]^{\gamma(1-\alpha+\beta)}\right]^{\frac{1}{1-\alpha+\beta}}$$

$$D_4 = (\alpha A)^{\beta}[B(1-\beta)]^{1-\alpha}\left[\frac{1-\alpha}{\alpha}\frac{\beta}{1-\beta}\right]^{\beta(1-\alpha)}$$

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TABLE I

Taxes, resource allocation and growth

LEISURE → HUMAN CAPITAL ↓	No Leisure $\epsilon = 0 \quad \eta = 0$	Quality Time $L = (1 - u - z)H$	Home Production $L = [(1-u-z)H]^{1-\gamma} * [(1-v-x)K]^{\gamma}$	Raw Time $L = (1 - u - z)$
$\dot{H} = B z H$ $(\beta = 0)$ (Human capital prod. requires only human capital)	$w \neq f(\tau^K, \tau^H)$ $\frac{K}{H} = g(\tau^K)$ $\tau^K_\infty = 0$ $\tau^H_\infty > 0$	$w \neq f(\tau^K, \tau^H)$ $\frac{K}{H} = g(\tau^K, \tau^H)$ $\tau^K_\infty = 0$ $\tau^H_\infty = 0$	$w \neq f(\tau^K, \tau^H)$ $\frac{K}{H} = g(\tau^K, \tau^H)$ $\tau^K_\infty = 0$ $\tau^H_\infty = 0$	$w = f(\tau^K, \tau^H)$ $\frac{K}{H} = g(\tau^K, \tau^H)$ $\tau^K_\infty = 0$ $\tau^H_\infty = 0$
$\dot{H} = B(zH)^{1-\beta}(xK)^{\beta}$ $(\beta > 0)$ (Human capital prod. requires both human and physical capital)	$w = f(\tau^K, \tau^H)$ $\frac{K}{H} = g(\tau^K, \tau^H)$ $\tau^K_\infty = \tau^H_\infty = 0$	$w = f(\tau^K, \tau^H)$ $\frac{K}{H} = g(\tau^K, \tau^H)$ $\tau^K_\infty = \tau^H_\infty = 0$	$w = f(\tau^K, \tau^H)$ $\frac{K}{H} = g(\tau^K, \tau^H)$ $\tau^K_\infty = \tau^H_\infty = 0$	$w = f(\tau^K, \tau^H)$ $\frac{K}{H} = g(\tau^K, \tau^H)$ $\tau^K_\infty = \tau^H_\infty = 0$

w = Balanced Growth Rate

τ^K_∞ (τ^H_∞) = Optimal long-run tax on physical (human) capital