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**Working Paper**

Permanent International Productivity Growth Differentials in an Integrated Global Economy. The Roles of Households, Non-Tradedness, Self-Financing and Fiscal Policy

Center Discussion Paper, No. 664

**Provided in Cooperation with:**

Yale University, Economic Growth Center (EGC)

*Suggested Citation:* Buiter, Willem Hendrik; Kletzer, Kenneth M. (1992) : Permanent International Productivity Growth Differentials in an Integrated Global Economy. The Roles of Households, Non-Tradedness, Self-Financing and Fiscal Policy, Center Discussion Paper, No. 664, Yale University, Economic Growth Center, New Haven, CT

This Version is available at:

<https://hdl.handle.net/10419/160586>

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CENTER DISCUSSION PAPER NO. 664

PERMANENT INTERNATIONAL PRODUCTIVITY GROWTH  
DIFFERENTIALS IN AN INTEGRATED GLOBAL ECONOMY.  
THE ROLES OF HOUSEHOLDS, NON-TRADEDNESS,  
SELF-FINANCING AND FISCAL POLICY.

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June 1992

**Note:** Center Discussion Papers are preliminary materials circulated to stimulate discussions and critical comments. The original version of this paper was presented at the Conference on Fiscal Policies in Open Macro Economies on January 7 and 8, 1991.

We would like to thank the participants of the Conference on Fiscal Policies in Open Macro Economies organized by the National Bureau of Economic Research Inc., the Centre for Economic Policy Research and the Tokyo Center of Economic Research for their helpful comments. Special thanks are due to our discussants Akihisa Shibata and Tohru Inoue and to Takatoshi Ito, George Alogoskoufis, Charles Bean, Allan Drazen, Assaf Razin, Paul Romer, Rick van der Ploeg and Xavier Sala-i-Martin. Two anonymous referees provided very helpful comments on an earlier version of this paper.

### Abstract

This paper develops a role for differences in household tastes and policies that influence household behavior as sources of persistent or permanent differences between national or regional productivity growth rates, under perfect international financial capital mobility. We show that when households are constrained in the trade of some essential input into the production of nontraded human capital, productivity growth differentials arise even with common technologies and industrial structures and with constant returns from scale. We discuss two alternative sources of nontradedness. One is that there are essential "home-grown" inputs to human capital augmentation (represented by time spent in education). The other is that households cannot borrow against future labor income to finance education and training. In a two-country overlapping generations model, we show that intergenerational redistributions, using either balanced-budget policies or the issuing of public debt, that reduce private financial saving as conventionally defined tend to increase human capital formation. We also analyze the effects of residence-based taxes on savings, subsidies to borrowing for human capital formation and public provision of inputs into education and training.

Key Words: Endogenous growth, productivity growth differentials, fiscal policy.

JEL Classification Numbers: O4, F43, H6

## (1) INTRODUCTION.

Much of the rapidly growing literature on endogenous growth has emphasized increasing returns to scale and/or differences in technology, factor endowments, initial conditions and industrial structure as explanations for persistent and permanent differences in productivity growth rates between nations and regions<sup>1</sup>. Where a two-or multi-country approach is adopted, the richness of the specification of technology and firm behavior stands in stark contrast to the sparseness of the specification of the household sector, which seldom ventures beyond the identical representative consumer.

When differences in technology and industrial structure are not present, as in some of the work of Barro [1989a,b] and in Barro and Sala-i-Martin [1990b], differences in tastes and in other determinants of household behavior can yet account for permanent productivity growth differentials, as long as international or interregional factor mobility is restricted<sup>2</sup>.

The first objective of this paper is to restate and develop the role of differences in household behavior as a source of persistent and permanent differences between national or regional productivity growth rates, in a world with perfect international mobility of financial capital. We present our argument about the importance of household tastes and of policies influencing household behavior when there are constant returns to scale with common technologies and industrial structures between nations or regions. We do not deny that increasing returns or asymmetries in technology and industrial structure may be an important part of the story of unequal growth and development. For expository reasons, however, we abstract from these possible sources of permanent productivity growth differentials.

Under the assumptions of free international technology transfer, constant returns to scale, perfect international financial capital mobility and no non-traded essential growth inputs, most existing growth models (of both the exogenous and the endogenous variety) would imply global convergence of output per worker. Differences in national savings rates would not account for differences in national rates of accumulation of augmentable factors of production. In the simplest version of the model (absent adjustment costs) convergence would be immediate.

The implication that levels and growth rates of output per worker should be equalized across the globe, is a source of empirical embarrassment<sup>3</sup>. This remains true even if its sharp edges are dulled somewhat by allowing for

political and administrative restrictions on the international mobility of financial capital and for adjustment costs in the accumulation of augmentable factors of production. Our approach starts from the recognition that there are important "local" or national essential complementary inputs into the production process that cannot be imported but have to be "home-grown". We are thinking of the social, political, cultural, legal and educational infrastructure without which modes of production and economic organization conducive to high productivity cannot be realized.

In our formal model, we try to capture some of the essence of these "home-grown" inputs by including in the production function a non-traded capital good ("human capital") whose production requires a non-traded input (efficiency units of labor time devoted to education and training) that has an alternative use in consumption as intrinsically valued leisure.

An alternative (or complementary) derivation of the household decision rules of our model starts from the assumption that expenditures for education and training must be self-financed and shows how this requirement can act as a constraint on national economic growth. In this approach, the income from future human capital cannot be used as collateral for borrowing (including international borrowing) to finance education and training when young.

We realize that our non-traded human capital good whose production requires a non-traded current input that has alternative uses as a consumption good, captures but very partially our notion of "home-grown" infrastructure. Some elements of the home-grown infrastructure (the rule of law, the clear definition and defense of property rights, the enforcement of contracts and general popular attitudes towards entrepreneurship, business and private profit) possess aspects of "zero-one" dummy variables (or of variables with a bounded range of variation) rather than of capital-like augmentable inputs whose quantity can be varied (given time and effort) without upper bound. Other "home-grown" inputs such as a skilled and educated labor force fit quite easily into our formal straight jacket. It is true that countries can send their citizens abroad to advance their education and that the processes of education and training within a country can make use of imported inputs. This, however, is and has been historically, of second-order importance.

In our formal model, human capital cannot be traded at all. This, however, is but an analytically convenient simplifying assumption. Our key non-convergence result goes through even if human capital can be traded, as

long as the importable human capital goods are not perfect substitutes for the domestically produced ones. Similarly, in the alternative interpretation of our model, the self-financing constraint on education and training expenditures can be relaxed without affecting the main qualitative conclusions, as long as human capital is inferior to physical capital and financial claims as collateral for borrowing.

The second objective of our paper is the analysis of the role of policies that affect human capital formation and private financial saving. Among the policies we consider are those that effect direct lump-sum intergenerational redistribution, either in balanced-budget fashion or through the issuing of public debt. A two-country OLG model is the natural vehicle for investigating these issues<sup>4</sup>. We show that intergenerational redistribution policies that cause "financial crowding out" and reduce conventionally measured private saving are likely to boost human capital formation.

The conventional system of national income, expenditure and product accounts fails to register most of a key input into the human capital formation process: time spent in education and training. In addition, it fails to record altogether the output of that process: the increase in the stock of human capital. It does register (correctly) as negative household saving the borrowing by households in order to finance purchases of marketed inputs into human capital formation. The purchase of these traded inputs is, however, erroneously classified as consumption rather than as household investment. This has the important implication that it is not necessarily true that any policy which reduces conventionally measured domestic saving is growth-unfriendly. Even in the real world, loans taken out by younger households need not be consumption loans, but may instead be used to finance growth-enhancing unrecorded human capital formation.

In addition to considering the effects on growth differentials of direct intergenerational redistribution, we also consider the effects of residence-based taxes on savings, of subsidies to borrowing for human capital formation and of the free provision of public sector inputs into the education and learning process<sup>5</sup>.

The outline of the rest of the paper is as follows. Section 2 develops the model. Section 3 contains the main results concerning the effects of international differences in household tastes and in budgetary policies on international productivity growth differentials. Section 4 addresses in some

detail the issue of intergenerational redistribution policies, human capital formation and financial crowding out. Section 5 concludes.

## (2) THE MODEL.

### a. Household behavior.

The decisions concerning consumption, labor supply, human capital formation and financial portfolio allocation are taken by households. The household sector in each country is modeled through a three period overlapping generations model. We only derive the household decision rules for the home country. The corresponding decision rules for the foreign households are obtained attaching the superscript \* to foreign taste parameters and household choice variables. The same notational convention will be followed for firms and governments. While there are many identical consumers in each generation, we will only use an additional subscript to designate individual consumers where this is required to avoid ambiguity.

In the first period of her life ('youth'), a consumer born in period  $t$  has an endowment of time,  $h_t^0$  when measured in efficiency units, which she can either choose to consume as leisure,  $l_t$  in period  $t$  or to allocate to an alternative use, which we shall call education,  $e_t$ . This education process during the first period of the household's life adds to the endowment of labor time in efficiency units  $h_t^1$  during the second period ('middle age'), that is during period  $t+1$  for a household born in period  $t$ .

While young the household can also choose to spend private resources other than time on human capital formation. Such private spending on education  $m_t$  will have to be financed by borrowing, since the household is born without financial endowment and does not earn any income in the first period of its life. Public spending on the education of an individual young household,  $g_t$  also boosts  $h_t^1$ . For simplicity the young are assumed not to pay any taxes or to receive any transfer payments other than the benefits from the "transfer in kind"  $g_t$ , which cannot be resold by the recipient.

Endogenous growth is permitted in our model because of two features of the technology. First, the production function of traded output is constant returns to scale in two inputs that can be accumulated, human and physical

capital. Second, the production of the two augmentable inputs is itself subject to constant returns to scale in the traded good and the augmentable inputs<sup>6</sup>.

Human capital lives on after death. Formally we model this by assuming that  $h_{jt}^0$ , the amount of time measured in efficiency units (human capital) which the  $j^{\text{th}}$  household of generation  $t$  is endowed with at birth, is given by the average amount of human capital achieved by the previous generation during middle age, that is, letting  $N_t$  denote the number of households-consumers in period  $t$ ,

$$h_{jt}^0 = \frac{1}{N_{t-1}} \sum_{i=1}^{N_{t-1}} h_{it-1}^1$$

Each member of a new generations stands, as regards its starting level of human capital (knowledge, education), on the shoulders of the average member of the previous generation. We also assume, although this is not essential to obtain endogenous growth, that there is an externality in the human capital formation process. From the definition of  $h_{jt}^0$ , it is clear that  $h_{jt-1}^1$  is *non-rival* with respect to the levels of human capital achieved in period  $t$  by members of generation  $t$ . If generation  $t$  is larger, more members of generation  $t$  will benefit from the higher average level of education achieved by the previous generation.

The externality and source of inefficiency occurs because we also assume that the effect of  $h_{jt-1}^2$  on  $h_{it}^1$ , is *non-excludable*. Those in generation  $t$  who benefit from the knowledge accumulated by generation  $t-1$  cannot be made to pay for these benefits. By permitting the use of purchased inputs in the human capital accumulation process, our human capital accumulation mechanism extends the one developed by Lucas [1988], following Razin [1972] and Uzawa [1965]. Azariadis and Drazen [1990] developed a very general specification of the intergenerational transmission of human capital, which encompasses ours<sup>7</sup>. Borjas [1992] presents empirical evidence for human capital externalities by showing that the average level of human capital of an individual's ethnic group for the previous generation positively affects the individual's productivity level.<sup>8</sup>

The per capita stock of human capital used in employment by generation  $t$  during period  $t+1$ ,  $h_t^1$ , is assumed to be a constant returns to scale function



of the current inputs  $e_t$ ,  $m_t$  and  $g_t$  and the inherited per capita stock of human capital  $h_t^0$ , which equals the per capita level of human capital achieved by the previous generation  $h_{t-1}^1$ .

We believe our assumption of an intergenerational externality in human capital accumulation to be realistic. It also solves the technical problem, first highlighted by Jones and Manuelli [1990b], of endowing new generations in an OLG model with an asset whose value will grow at the endogenously determined growth rate.

During middle age, the only household choice concerns how much to consume,  $c_t^1$ . The entire endowment of labor time services in efficiency units  $h_t^1$  is supplied inelastically in the labor market. Lump-sum taxes (transfers if negative)  $\tau_t^1$  are paid.

In the last period of life ('old age' or 'retirement') households do not work or educate themselves. The old consume  $c_t^2$ , which equals the value of the resources they carried into old age through saving in the first two period of their lives, minus any lump-sum taxes  $\tau_t^2$  paid in their last period.

Formally, each competitive<sup>9</sup> household of generation  $t$ , ( $t \geq 0$ ) maximizes its lifetime utility function  $U_t$ , given in (1) with respect to  $l_t$ ,  $e_t$ ,  $m_t$ ,  $h_t^1$ ,  $c_t^1$  and  $c_t^2$ , subject to (2), (3) and (4) and the usual non-negativity constraints.

$$(1) \quad U_t = \beta^2 u(c_t^2) + \beta u(c_t^1) + v(l_t) \quad 10$$

$$(2) \quad (1+r_{t+1}^{-\theta_{t+1}-\varphi_{t+1}})m_t - h_t^1 w_{t+1} + c_t^1 + \tau_t^1 + (1+r_{t+2}^{-\theta_{t+2}})^{-1}(c_t^2 + \tau_t^2) \leq 0$$

$$(3) \quad l_t = h_t^0 - e_t$$

$$(4) \quad h_t^1 = h_t^0 \left[ 1 + \psi \left( \frac{e_t}{h_t^0}, \frac{m_t + g_t}{h_t^0} \right) \right]$$

$$c_t^1, c_t^2, m_t \geq 0; 0 \leq l_t, e_t \leq h_t^0. \text{ At the initial date, } t = 0, h_0^0 > 0.$$

Equation 2 is the lifetime budget constraint of a representative member of generation  $t$ .  $w_{t+1}$  is the wage paid per unit of efficiency labor in period  $t+1$ . The before-tax interest factor on loans from period  $t$  to period  $t+1$  is  $1 + r_{t+1}$ .  $\theta_t$  is the period  $t$  residence-based tax rate on all non-human asset

income in the home country. It is therefore also the subsidy rate to all domestic borrowing, including borrowing by the young. We also consider the subsidization of "student loans" (borrowing by the young to finance expenditures on traded goods used in human capital formation) as a policy instrument.  $\varphi$  is the subsidy rate on these loans. We assume that  $r_t^1$  and  $r_t^2$  are such that (2) can be satisfied for non-negative values of  $c_t^1$ ,  $c_t^2$  and  $m_t$ .

$\psi(\cdot, \cdot)$ , the constant returns to scale production function for the growth of the household's human capital stock, is positive when both its arguments assume positive values, has positive but diminishing marginal products to both inputs and is strictly concave and twice continuously differentiable.

Our assumption of perfect substitutability of public and private traded inputs into the human capital formation process has two virtues. The first is analytical simplicity. The second is that it avoids an all too easy (and not very convincing) way of creating a role for government in the human capital formation process: assuming  $m$  and  $g$  to be imperfect substitutes<sup>11</sup>. Note that there is no externality in the  $\psi$  process: public expenditure on education benefiting the  $i^{\text{th}}$  individual can only be enjoyed by the  $i^{\text{th}}$  individual: it is excludable and rival. It also cannot be resold by the recipient.

Equation (5) gives the intergenerational transmission of human capital.

$$(5) \quad h_t^0 = h_{t-1}^1$$

Population grows at a constant proportional rate:

$$(6) \quad N_t = (1 + n)N_{t-1} \quad n > -1; N_0 > 0.$$

The solution to the household optimization problem is given by equations (2) through (5) and the first-order conditions given in (7), (8) and (9).

$$(7) \quad u'(c_t^1) = (1 + r_{t+2} - \theta_{t+2})\beta u'(c_t^2)$$

$$(8) \quad v'(\ell_t) = \beta u'(c_t^1) w_{t+1} \psi_1 \left( \frac{e_t}{h_t}, \frac{m_t + g_t}{h_t} \right)$$

$$(9) \quad 1 + r_{t+1} - \theta_{t+1} - \varphi_{t+1} = w_{t+1} \psi_2 \left( \frac{e_t}{h_t}, \frac{m_t + g_t}{h_t} \right)$$

Equation (7) is the familiar martingale condition for the discounted marginal utility of consumption. Equation (8) equates the marginal utility of leisure in period  $t$  to the discounted marginal utility of the extra consumption permitted in period  $t+1$  by allocating an additional unit of time

to education in period  $t$ . Equation (9) equates the marginal cost of borrowing to finance additional traded inputs into the education process to the value of the marginal product of the traded education input. Note that (9) does not involve the utility function of the household. Borrowing to finance the purchase of additional traded inputs into the education process can be decided by the household as if it were a profit maximizing firm, that is with reference to the productive efficiency criterion alone.

With perfect international integration of financial markets, the use of traded productive inputs alone will therefore not result in taste differences generating permanent differences in human capital accumulation rates and in productivity growth rates. It is equation (8) that accounts for the dependence of the optimal value of the non-traded human capital accumulation input on the parameters of the utility function and thus for the possibility of permanent productivity growth differentials.

The household decision rules for the foreign country are completely analogous to those for the home country and will not be reproduced here. Parameters, variables and functions with the superscript <sup>\*</sup> will characterize the foreign country. Note that while all taste and policy parameters can differ between the two countries, the human capital accumulation technology ( $\eta$ ,  $a$ ,  $\rho$  and  $\delta$ ) is the same in both countries.

#### Self-financing vs. non-tradedness.

The essential implications of this paper do not depend on the specific details of the human capital accumulation mechanism we assume, which relies heavily on education-leisure choice. An alternative (or complementary) mechanism giving rise to the same qualitative conclusions is based on plausible constraints on households' abilities to borrow against labor earnings to finance educational expenditures. For simplicity, assume that the young can allocate their endowment of efficiency time  $h_t^0$  either to leisure,  $l_t$ , or to work. To make the point as clearly as possible, the role of non-traded education in human capital accumulation is omitted. Only private traded inputs and public traded inputs enter in the human capital formation process, as given in (10).

$$(10) \quad h_t^1 = h_t^0 \left[ 1 + \xi \left( \frac{m_t + g_t}{h_t^0} \right) \right]$$

The proportional growth function  $\xi$  is positive when its argument is positive, increasing, strictly concave and twice continuously differentiable.

The key capital market imperfection in this alternative model is that private traded inputs in human capital formation can be financed only out of concurrent labor income. Borrowing against expected future labor income in order to finance the purchase of  $m_t$  is not permitted. The belief that capital market imperfections constrain human capital accumulation by households is widespread and supported by empirical studies of educational attainment<sup>12</sup>. Becker [1975] discusses borrowing constraints in theoretical models of human capital accumulation at length. Barro, Mankiw and Sala i Martin [1992] also discuss the importance of self-financing constraints for convergence of growth rates under international capital mobility.

This gives us the following self-financing constraint

$$(11) \quad m_t \leq w_t (h_t^0 - \ell_t)$$

The revised household budget constraint for this model is

$$(12) \quad (1+r_{t+1}-\theta_{t+1})[(h_t^0 - \ell_t)w_t - m_t] + h_t^1 w_{t+1} - c_t^1 - \tau_t^1 \\ - (1+r_{t+2}-\theta_{t+2})^{-1}(c_t^2 + \tau_t^2) \geq 0$$

The competitive household maximizes (1) subject to (10), (11) and (12).

When the self-financing constraint (11) is not binding, the first-order conditions of the household are:

$$(13) \quad u'(c_t^1) = (1 + r_{t+2} - \theta_{t+2})\beta u'(c_t^2)$$

$$(14) \quad v'(\ell_t) = w_t(1 + r_{t+1} - \theta_{t+1})\beta u'(c_t^1)$$

$$(15) \quad 1 + r_{t+1} - \theta_{t+1} = \xi' \left( \frac{m_t + g_t}{h_t^0} \right) w_{t+1}$$

It is apparent from equation (15) that, when the self-financing constraint for human capital formation is not binding, the household's optimal choice of  $m_t$  is, for given values of the interest rate and the wage rate, independent of taste parameters (time preference, intertemporal elasticity of substitution, labor-leisure choice). With perfect international capital mobility equalizing interest rates and wage rates world-wide (ignoring distortionary taxes), international differences in the growth rates of human capital can therefore not be attributed to international differences in household preferences or to international differences in policies influencing

saving or labor-leisure choice.

When the self-financing constraint (11) binds, the return to financial saving in the first period of life  $(1+r_{t+1}-\theta_{t+1})$  is less than the return to investing in human capital  $(\xi'w_{t+1})$ . The first-order conditions of the household are given by (13) and

$$(16) \quad m_t = w_t(h_t^0 - l_t)$$

$$(17) \quad v'(l_t)/w_t = \xi' \left( \frac{m_t + g_t}{h_t^0} \right) w_{t+1} \beta u'(c_t^1)$$

The utility-of-leisure cost of increasing  $m_t$  (on the left-hand-side of (17)) is equated to the additional utility of consumption in period  $t+1$  permitted by the rise in  $h_t^1$  caused by the increase in  $m_t$  (on the right-hand-side of (17)). The growth rate of human capital will therefore be a function of the parameters characterizing household preferences.

Comparing equations (8) and (9) with equations (16) and (17), the qualitative properties of our model will be the same when we assign a key role to the non-tradedness of an essential growth input, as when we invoke a binding self-financing constraint for a traded growth input (one difference is noted later). In the version of the self-financing constraint presented here, it is labor-leisure choice rather than education-leisure choice that causes the growth rate of human capital to depend on household preferences and on policies affecting household behavior. Both mechanisms may well be operative in practice.

If the model is generalized slightly by permitting the household to consume traded goods when young, a binding self-financing constraint on the sum of consumption when young and educational expenditures causes the growth rate of human capital to depend on the time preference rate and other characteristics of household preferences, even if labor supply is exogenous. For expositional simplicity we restrict our formal analysis in what follows to the case of the essential non-traded growth input.

#### b. Firm behavior.

Firms face competitive output and input markets and maximize profits. Non-negative quantities of the two factors of production, human capital (or efficiency units of labor) and physical capital, can be varied costlessly.

All firms are identical. The representative firm's production function is linear homogeneous in the two factors of production, increasing in both its arguments, strictly concave, twice continuously differentiable and satisfies the Inada conditions. Capital depreciation is ignored.

The aggregate production function for the home country is given in equation (18). It exhibits constant returns to scale in the two inputs, human and physical capital, is increasing, strictly concave and satisfies the Inada conditions. The representative domestic firm's first-order conditions equating the real interest rate to the marginal product of capital and the real wage to the marginal product of efficiency labor are given in equations (19) and (20) respectively.  $Y$  denotes aggregate output,  $K$  the aggregate physical capital stock,  $H$  the aggregate stock of human capital and  $k \equiv K/H$ .

$$(18) \quad Y_t = H_t f(k_t)$$

$$(19) \quad r_t = f'(k_t)$$

$$(20) \quad w_t = f(k_t) - k_t f'(k_t) = \omega(k_t), \quad \omega' = -k_t f''(k_t) > 0.$$

The derivation of foreign country output, interest rate and wage rate is analogous. Note that the two countries also have identical production technologies for traded output  $f(\cdot)$ . At the initial date,  $t = 0$ ,  $K_0 + K_0^* > 0$ .

### c. Government.

In both countries the government spends on the education of its young, levies lump-sum taxes on the middle aged and the old, taxes all asset income of its residents at a proportional rate  $\theta$ , subsidizes education loans at a proportion rate  $\varphi$ , pays interest on its debt and borrows to finance any excess of current outlays over current revenues. Government debt is single-period debt denominated in the traded output. The outstanding stock of home country government debt outstanding is  $B_t$ . The home country government single-period budget identity is given in equation (21). The conventional solvency constraints, given in (22a) is assumed to apply<sup>13</sup>. The foreign country counterparts are obvious and have been omitted.

$$(21) \quad B_{t+1} = (1 + r_t)B_t + g_t N_t - \tau_{t-1}^1 N_{t-1} - \tau_{t-2}^2 N_{t-2}$$

$$(22a) \quad \lim_{T \rightarrow \infty} \prod_{i=0}^T (1 + r_{t+i})^{-1} B_{t+1+T} = 0$$

$$- \theta_t \left\{ \left[ \frac{c_{t-2}^2 + \tau_{t-2}^2}{1 + r_t - \theta_t} \right] N_{t-2} - m_{t-1} N_{t-1} \right\} + \varphi_t m_{t-1} N_{t-1}$$

$B_0$  and  $B_0^*$  are given.

The budget identity and the solvency constraint of the home government together imply the present value budget constraint given in (22b).

$$(22b) \quad B_t = \sum_{i=0}^{\infty} \Lambda_{t+i} \left[ \tau_{t+i-1}^1 N_{t+i-1} + \tau_{t+i-2}^2 N_{t+i-2} + \theta_{t+i} \left[ \frac{c_{t+i-2}^2 + \tau_{t+i-2}^2}{1 + r_{t+i} - \theta_{t+i}} \right] N_{t+i-2} \right. \\ \left. - (\theta_{t+i} + \varphi_{t+i}) m_{t+i-1} N_{t+i-1} - g_{t+i} N_{t+i} \right]$$

$$\Lambda_{t+i} \equiv \prod_{j=0}^i (1 + r_{t+j})^{-1}$$

This says that the outstanding value of the public debt should be equal to the present discounted value of the future primary (non-interest) public sector budget surpluses.

For future use, we introduce the following notation:

$$(23) \quad T_t \equiv \tau_t^1 + \frac{\tau_t^2}{1 + r_{t+2} - \theta_{t+2}}$$

$-T_t$  is the present value (discounted to period  $t+1$ ) of the net lifetime lump-sum fiscal transfer to a member of generation  $t$ . Note that  $(1 + r_{t+1} - \theta_{t+1} - \varphi_{t+1}) g_t$ , the period  $t+1$  value of the public educational inputs spent on a member of generation  $t$ , can be viewed as income-in-kind, it is not a lump-sum transfer.

#### d. Market equilibrium.

There is perfect international mobility of financial capital. In the absence of distortionary source-based taxes on capital income, the domestic and foreign before-tax interest rates and rates of return on fixed capital will be equalized.

$$(24) \quad r_t = r_t^* = f'(k_t) = f'(k_t^*)$$

The after-tax rates of return to private saving,  $1 + r_t - \theta_t$  in the home country and  $1 + r_t - \theta_t^*$  in the foreign country, however, can differ.

From the production function, equalization of capital-human capital ratios in the two economies implies that the wage rates (of efficiency labor) in the two countries are also equalized, although labor itself is not traded internationally and workers are not internationally mobile.

$$(25) \quad w_t = w_t^*$$

The fact that both countries' labor markets clear each period means that

$$(26a) \quad H_t = h_{t-1}^1 N_{t-1}$$

$$(26b) \quad H_t^* = h_{t-1}^{*1} N_{t-1}^*$$

Home country private financial wealth at the beginning of period  $t+1$ ,  $A_{t+1}$ , is given by (27a).  $F_{t+1}$  denotes the net foreign assets of the home country at the beginning of period  $t+1$ . Note that  $F = -F^*$ .

$$(27a) \quad A_{t+1} \equiv [w_t h_{t-1}^1 - c_{t-1}^1 - \tau_{t-1}^1 - (1 + r_t - \theta_t - \varphi_t) m_{t-1}] N_{t-1} - m_t N_t$$

$$(27b) \quad F_{t+1} \equiv A_{t+1} - K_{t+1} - B_{t+1}$$

The old (those born in period  $t-2$ ) will not be holding any assets: they have at the end of period  $t$  just exhausted the last of their lifetime savings. The savings of the middle aged (those born in period  $t-1$ ) will be the sum of their primary (non-interest) current surpluses during middle age ( $w_t h_{t-1}^1 - c_{t-1}^1 - \tau_{t-1}^1$  per person of generation  $t-1$ ) and their compounded primary current surpluses from their youth ( $-(1 + r_t - \theta_t - \varphi_t) m_{t-1}$  per member of generation  $t-1$ ). The young at the end of period  $t$  will have negative per capita savings equal to  $-m_t$ , the value of their borrowing to finance their education (student loans).

The condition for equilibrium in the world capital market is given in equation (30), where equalization of domestic and foreign interest rates and wage rates has already been imposed.

$$(28) \quad K_{t+1} + K_{t+1}^* + B_{t+1} + B_{t+1}^* = A_{t+1} + A_{t+1}^*$$

Equation (28) states that the total stock of non-human assets at the beginning of period  $t+1$ ,  $K_{t+1} + K_{t+1}^* + B_{t+1} + B_{t+1}^*$ , has to be willingly held by the private sectors of the two countries.



We define  $b \equiv B/H$ ,  $b^* \equiv B^*/H^*$  and  $\sigma_t^* \equiv \frac{h_t^1 N_0^* (1+n^*)^t}{h_t^1 N_0 (1+n)}$ .  $\sigma^*$  is a measure of

the relative size of the foreign country. Equation (28) can now be rewritten as:

$$(29) \quad (1 + \sigma_t^*)k_{t+1} + b_{t+1} + \sigma_t^* b_{t+1}^* \\ = \frac{(c_{t-1}^2 + \tau_{t-1}^2)}{1 + f'(k_{t+1}) - \theta_{t+1}} [(1+n)h_t^1]^{-1} - \frac{m_t}{h_t^1} \\ + \sigma_t^* \left[ \frac{(c_{t-1}^{*2} + \tau_{t-1}^{*2})}{1 + f'(k_{t+1}) - \theta_{t+1}^*} [(1+n^*)h_t^{*1}]^{-1} - \frac{m_t^*}{h_t^{*1}} \right]$$

We note that there are two different kinds of steady state solutions. In the first, the long run growth rate of aggregate human capital differs between the two countries. This implies that the relative size of the country with the lower growth rate decreases steadily. In the second the long run growth rates are the same. In this case, a steady state can exist in which  $\sigma^*$  is positive and finite.

### (3) INTERNATIONAL PRODUCTIVITY GROWTH DIFFERENTIALS.

With perfect financial capital mobility leading to equalization of physical capital intensities and of wage rates per unit of efficiency labor, it is easily seen that international differences in the growth rate of output per worker are due solely to differences in the growth rate of human capital per worker. Noting that  $Y_t = H_t f(k_t) = h_{t-1}^1 N_{t-1} f(k_t)$ , output per worker  $\Pi$  in the home country is given by

$$\Pi_t \equiv Y_t / N_{t-1} = h_{t-1}^1 f(k_t)$$

The rate of growth of home country output per worker,  $\pi$  is given by

$$\pi_t \equiv \frac{\Pi_{t+1}}{\Pi_t} - 1$$

Similarly, with a common technology and free capital mobility, we have for the foreign country:

$$\Pi_t^* \equiv Y_t^* / N_{t-1}^* = h_{t-1}^{*1} f(k_t)$$

$$\pi_t^* \equiv \frac{\Pi_{t+1}^*}{\Pi_t^*} - 1.$$

It follows that the differences in the growth rate of output per worker are given by:

$$(30) \quad \pi_t - \pi_t^* = \left[ \frac{h_t^1}{h_{t-1}^1} - \frac{h_t^{*1}}{h_{t-1}^{*1}} \right] \frac{f(k_{t+1})}{f(k_t)}$$

In steady state <sup>14</sup>, the labor productivity growth differential is given by:

$$\pi - \pi^* = \frac{h_t^1}{h_{t-1}^1} - \frac{h_t^{*1}}{h_{t-1}^{*1}}$$

Equations (4) and (30) imply that the productivity growth differential is given by

$$(33) \quad \pi_t - \pi_t^* = \left[ \psi \left( \frac{e_t}{h_{t-1}^1}, \frac{m_t + g_t}{h_{t-1}^1} \right) - \psi \left( \frac{e_t^*}{h_{t-1}^{*1}}, \frac{m_t^* + g_t^*}{h_{t-1}^{*1}} \right) \right] \frac{f(k_{t+1})}{f(k_t)}$$

When the constraint  $m_t \geq 0$  is not binding, the optimal program of the home country generation  $t$  household and the factor market equilibrium conditions yield equations (34) through to (37). These can be solved for  $c_t^1$ ,  $c_t^2$ ,  $e_t$  and  $m_t$  as functions of  $k_{t+1}$ ,  $k_{t+2}$ ,  $h_{t-1}^1$ , the home country fiscal policy parameters  $\theta_{t+1}$ ,  $\theta_{t+2}$ ,  $\varphi_{t+1}$ ,  $\tau_t^1$ ,  $\tau_t^2$  and  $g_t$  and the home country subjective discount factor  $\beta$  <sup>15</sup>.

$$(34) \quad u'(c_t^1) = [1 + f'(k_{t+2}) - \theta_{t+2}] \beta u'(c_t^2)$$

$$(35) \quad v'(h_{t-1}^1 - e_t) = \beta u'(c_t^1) \omega(k_{t+1}) \psi_1 \left( \frac{e_t}{h_{t-1}^1}, \frac{m_t + g_t}{h_{t-1}^1} \right)$$

$$(36) \quad 1 + f'(k_{t+1}) - \theta_{t+1} - \varphi_{t+1} = \omega(k_{t+1}) \psi_2 \left( \frac{e_t}{h_{t-1}^1}, \frac{m_t + g_t}{h_{t-1}^1} \right)$$

$$(37) \quad [1 + f'(k_{t+1}) - \theta_{t+1} - \varphi_{t+1}] m_t - h_{t-1}^1 [1 + \psi \left( \frac{e_t}{h_{t-1}^1}, \frac{m_t + g_t}{h_{t-1}^1} \right)] \omega(k_{t+1}) \\ + c_t^1 + \tau_t^1 + (1 + f'(k_{t+2}) - \theta_{t+2}) (c_t^2 + \tau_t^2) = 0.$$

A set of four equations analogous to (34) through to (37) can be derived

for the foreign country, allowing us to solve for  $c_t^{1*}$ ,  $c_t^{2*}$ ,  $e_t^*$  and  $m_t^*$  as functions of  $k_{t+1}$ ,  $k_{t+2}$ ,  $h_{t-1}^{1*}$ , the foreign fiscal policy parameters  $\theta_{t+1}^*$ ,  $\theta_{t+2}^*$ ,  $\varphi_{t+1}^*$ ,  $\tau_t^{1*}$ ,  $\tau_t^{2*}$  and  $g_t^*$  and the foreign subjective discount factor  $\beta^*$ . If we restrict ourselves to the analysis of small perturbations away from *symmetric* equilibria (that is, equilibria characterized by identical values of all parameters and identical initial conditions across the two countries), the effect on the productivity growth differential of small differences in these parameters can be analyzed without having to consider the effect of the perturbations on  $k_{t+1}$  and  $k_{t+2}$ . We impose this restriction in what follows. The effect of changes in taste and policy parameters and in initial conditions on the international productivity growth *differential* can then be found by considering the effect on the domestic productivity growth *level* of changes in domestic taste and policy parameters and in domestic initial conditions, at given values of  $k_{t+1}$  and  $k_{t+2}$ . These effects are found from total differentiation of equations (34)-(37). The appendix provides the resulting set of equations simplified to allow straightforward derivation of the effects reported below. We know what happens to domestic productivity growth when we know what happens to  $e_t$  and to  $m_t + g_t$ . To conserve space, we only report the results for the case where the constraint  $m_t \geq 0$  is binding when the effects of variations in  $g_t$  are discussed.

#### A reduction in the time preference rate.

The signs of the effects of an increase in  $\beta$  are the following:

$$\frac{dm_t}{d\beta} > 0 \quad \frac{de_t}{d\beta} > 0 \quad \frac{d(\pi_t - \pi_t^*)}{d\beta} > 0 \quad \frac{dc_t^1}{d\beta} \text{ is ambiguous} \quad \frac{dc_t^2}{d\beta} > 0 .$$

The intuition is clear. Reduced impatience lowers the demand for early consumption of leisure,  $l_t$ , and therefore increases the amount of time spent in education while young,  $e_t$ . Since the two inputs in the human capital growth function are complements ( $\psi_{12} > 0$ ), the use of the traded input,  $m_t$ , also increases. The productivity growth differential therefore moves in favor of the country with the lower rate of time preference. A higher value of  $\beta$  also increases the demand for consumption when old,  $c_t^2$ , while the effect on

consumption when middle-aged,  $c_t^1$ , is ambiguous.

Note that with borrowing by the young to finance the purchase of traded inputs into the human capital accumulation process, the effect of a lower rate of time preference on home country relative private financial wealth is ambiguous. This is true even if there is no government debt and the government budget is balanced continuously. While a higher value of  $\beta$  will cause the middle-aged to save more, it will also cause the young to dissave more by taking out more "student loans" ( $m_t$  increases). Since the increased value of the human capital assets acquired by the young is not counted in conventionally measured saving, the net effect of an increase in  $\beta$  on conventionally measured private financial wealth is ambiguous.

#### **An increase in the present value of life-time lump-sum taxes.**

Note that an increase in lump-sum taxes paid when middle-aged had the same effects as an increase in the discounted lump-sum taxes paid when old. We therefore only discuss the impact of changes in  $T_t = \tau_t^1 + (1+r_{t+2} - \theta_{t+2})^{-1} \tau_t^2$ , which are as follows:

$$\frac{dm_t}{dT_t} > 0 \quad \frac{de_t}{dT_t} > 0 \quad \frac{d(\pi_t - \pi_t^*)}{dT_t} > 0 \quad \frac{dc_t^1}{dT_t} < 0 \quad \frac{dc_t^2}{dT_t} < 0 .$$

Any change in the government's policy concerning borrowing and lump-sum taxes and transfers that increases the net life-time lump-sum tax burden on generation  $t$ , will reduce human capital formation by that generation. The negative effect of an increase in  $T_t$  on life-time income will reduce consumption of leisure while young and consumption of traded goods during middle age and old age. The increase in  $e_t$  induces (because  $e$  and  $m$  are complementary inputs,  $\psi_{12} > 0$ ) an increase in  $m_t$ . Human capital formation and productivity growth in the home country are boosted relative to their foreign counterparts.

#### **Higher public spending on the traded human capital accumulation input.**

When the constraint  $m_t \geq 0$  is not binding, the effects of an increase in public education expenditure are the following:

$$\frac{d(m_t + g_t)}{dg_t} < 0 \quad \frac{de_t}{dg_t} < 0 \quad \frac{d(\pi_t - \pi_t^*)}{dg_t} < 0 \quad \frac{dc_t^1}{dg_t} > 0 \quad \frac{dc_t^2}{dg_t} > 0 .$$

As long as the non-negativity constraint on private spending on education is not binding, an increase in  $g_t$ , public spending on education will lead to a *reduction* in  $m_t + g_t$ , the total amount spent on education by the private and public sectors combined. Time spent on education,  $e_t$ , will also be reduced and the relative growth rate of home country human capital will decline unambiguously. Consumption when middle-aged and when old increase, despite the reduction in  $h_t^1$ , because of the smaller amount of educational debt carried into middle age.

As a profit maximizing *firm* facing a given wage and interest rate, the young worker would respond to the in-kind free gift of  $g_t$  by reducing his private input of  $m_t$  one for one. The free gift of  $g_t$ , however, also has an income effect on the young worker as a consumer the same as would a decrease in  $T_t$  by  $(1+r_{t+1}^{-\theta_{t+1}} - \varphi_{t+1}) g_t$ . The net result is the more than 100 percent crowding out of private education spending by public spending on education.

If the increase in public spending on the education of a member of generation  $t$ ,  $g_t$ , is matched by a corresponding increase in the present discounted value of the life-time lump-sum taxes paid by generation  $t$ ,  $T_t$ , so as to be distributionally neutral between generations there is no income effect associated with the increase in public spending on education, and the "direct crowding out" (Buiter [1977]) of private by public spending is exactly one-for-one.

If an aim of policy is to boost human capital formation, this model suggests that increasing public spending on education while the private sector still engages in private spending on education, would not be very effective. An obviously superior policy is one pursued (up to a point) by most governments: the removal of the education decision from the realm of private decision making. Compulsory school attendance up to a certain age is indeed the rule in most societies. It can be checked easily that with administrative assignment of  $e$  and of  $g$  and access to non-distortionary taxes, Pareto-efficient equilibria can be supported<sup>16</sup>.

When the  $m_t \geq 0$  constraint is binding, the effect of an increase in public spending on education,  $g_t$ , on private time spent on education is ambiguous. The increase in the quantity of the complementary factor of production  $g_t$  raises the marginal return to another hour spent in education. The income effect, however, goes the other way and suggests an increase in the demand for leisure. Even when  $e_t$  declines, however, the net effect on the growth rate of human capital is positive. The intuition for this is that the positive income effect of the increase in public spending also raises the demand for  $c_t^1$  and  $c_t^2$ . The net effect of an increase in  $g_t$  on  $h_t^1$  and on the home country productivity growth rate is therefore positive when the non-negativity constraint on  $m_t$  is binding.

The two alternative household models differ with respect to the effects of an increase in public spending on private educational inputs. In the version in which the household cannot borrow against future labor income to finance its educational expenditures, an increase in  $g_t$  also raises demand for leisure when young and demand for consumption during middle age and old age. When the self-financing constraint (11) is binding, this leads to a net increase in the household's investment in human capital. This happens because an increase in  $g_t$  and an equal discounted present value increase in  $T_t$  are not equivalent when the constraint on household borrowing while young remains binding. In that case, raising consumption while middle aged and old requires a rise in the household's accumulation of human capital. If the constraint does not bind, then an increase in  $g_t$  and equal value increase in  $T_t$  have the same effect (however, crowding out is one-for-one if  $k_{t+1}$  and  $k_{t+2}$  are constant in that case).

#### **An increase in the student loan subsidy rate.**

The analysis of the effects of a change in  $\varphi_{t+1}$ , the subsidy rate on student loans taken out in period  $t$ , is straightforward. Note that the effect on generation  $t$  of a change in  $\varphi_{t+1}$  is the same as the effect on generation  $t$  of a change in  $\theta_{t+1}$ , the general subsidy to borrowing (tax on lending)

undertaken in period  $t$ . In addition, a change in  $\theta_{t+1}$  will affect the marginal cost of borrowing or lending in period  $t$  by generation  $t-1$ . We consider this below, when we report the effects of a change in  $\theta_{t+2}$  on generation  $t$ .

An increase in  $\varphi_{t+1}$  or  $\theta_{t+1}$  reduces the marginal cost of borrowing to finance the purchase of traded inputs in the accumulation of human capital. The substitution effect of an increase in the subsidy rate on student loans works to increase  $m_t$ ,  $e_t$ ,  $c_t^1$  and  $c_t^2$ . When  $m_t$  is positive, the positive income effect of an increase in  $\varphi_{t+1}$  or  $\theta_{t+1}$  will reinforce the substitution effects as regards  $c_t^1$  and  $c_t^2$ . Since leisure is a normal good, however, the income effect will tend to reduce  $e_t$ . If the net effect on  $e_t$  is negative, it is possible, since  $e_t$  and  $m_t$  are complementary inputs, that  $m_t$  also declines, despite the reduction in the marginal cost of borrowing. The household as consumer of leisure overwhelms the household as producer in this case. If both  $m_t$  and  $e_t$  fall, the home country productivity growth rate declines. Even in this case, the total amount of resources carried into middle age will be larger as a result of the increase in  $\varphi_{t+1}$  or  $\theta_{t+1}$ , because of the increased subsidy. If income effects are small, the productivity growth differential will increase.

If we compensate for the increased educational subsidy with an increase of equal value in  $T_t$  (the present discounted value of life-time lump-sum taxes paid by generation  $t$ ) in a way that is distributionally neutral between generations, only the marginal incentive effects will be present and  $m_t$ ,  $e_t$  and  $\pi_t - \pi_t^*$  will increase unambiguously.

#### An increase in the tax on saving during middle age.

The effects of an increase in  $\theta_{t+2}$  by one unit on the behavior of generation  $t$  are the same as the effects of an increase in  $T_t$  of magnitude

$$\hat{T}_t = \frac{\tau_{t+2} + c_{t+2} + u'(c_t^2)/u''(c_t^2)}{(1+r_{t+2}-\theta_{t+2})^2},$$

which has an ambiguous sign. This is the sum of a real income effect from the reduction in the marginal return to saving during middle age (changing the present value of  $c_{t+2} + \tau_{t+2}$ ) and an intertemporal substitution effect. If  $c_t^2 + \tau_t^2$  is positive, an increase in  $\theta_{t+2}$  represents a loss of real income. This at least partially offset by the negative substitution effect on  $c_t^2$ . If  $\tau_t^2$  is zero, then the signs of the effects of an increase in  $\theta_{t+2}$  on the choices of generation  $t$  depend on whether the equilibrium intertemporal elasticity of substitution is greater than, equal to or less than unity.

If we compensate for the increased tax on saving by the middle-aged (that is, for the real income effect of  $\theta_{t+2}$  only) with a reduction of equal value in lump-sum taxes,  $T_t$ , in a way that is distributionally neutral between generations, then the only effects of an increase in  $\theta_{t+2}$  are the marginal incentive effects for generations  $t$  and  $t+1$ . The substitution effect for generation  $t$  works to reduce investment in human capital while the substitution effect for generation  $t+1$  works in the opposite direction, so that the net impact on productivity growth rate differentials is ambiguous. We can, however, reduce life-time lump-sum taxes for generation  $t$  by  $-\hat{T}_t$  to compensate for the entire effect of an increase in  $\theta_{t+2}$  on that generation (as part of a distributionally neutral policy), so that the net effect on home country productivity growth relative to foreign productivity growth is just the positive substitution effect for generation  $t+1$ .<sup>17</sup>

#### Steady-state productivity growth differentials.

When the preference ordering generating  $U_t$  in equation (1) is homothetic<sup>18</sup>, the steady state version of equations (34) to (37) can be written as in equations (38) to (41).

$$(38) \quad u'(c^1/h_{-1}^1) = (1+f'(k)-\theta)\beta u'(c^2/h_{-1}^2)$$

$$(39) \quad v'(1-(e/h_{-1}^1)) = \beta u'(c^1/h_{-1}^1) \omega(k) \psi_1\left(\frac{e}{h_{-1}^1}, \frac{m+g}{h_{-1}^1}\right)$$

$$(40) \quad 1+f'(k)-\theta-\varphi = \omega(k) \psi_2\left(\frac{e}{h_{-1}^1}, \frac{m+g}{h_{-1}^1}\right)$$



$$(41) \quad (1+f'(k)-\theta-\varphi)m/h_{-1}^1 - [1+\psi(\frac{e}{h_{-1}^1}, \frac{m+g}{h_{-1}^1})]\omega(k) \\ + (c^1 + \tau^1)/h_{-1}^1 + (1 + f'(k) - \theta)(c^2 + \tau^2)/h_{-1}^1 = 0.$$

For a steady state to exist, each exogenous flow variable must be constant when expressed as a fraction of human capital per member of the young generation, that is,  $g/h_{-1}^1$ ,  $\tau^1/h_{-1}^1$  and  $\tau^2/h_{-1}^1$  must be constant. Equations (38) to (41) then determine the steady-state values of  $m/h_{-1}^1$ ,  $e/h_{-1}^1$ ,  $c^1/h_{-1}^1$  and  $c^2/h_{-1}^1$  as functions of  $\beta$ ,  $\theta$ ,  $\varphi$ ,  $g/h_{-1}^1$ ,  $\tau^1/h_{-1}^1$ ,  $\tau^2/h_{-1}^1$  and  $k$ . An analogous set of equations applies to the foreign country. If we restrict ourselves again to perturbations of a *symmetric* stationary equilibrium (identical values of all parameters in the two countries), we can analyze the effects of changes in taste and policy parameters without having to work out the effect of these parameter changes on the steady-state ratio of physical to human capital,  $k$ . Furthermore, the steady state effects of  $\beta$ ,  $\theta$ ,  $\varphi$ ,  $g/h_{-1}^1$ ,  $\tau^1/h_{-1}^1$  and  $\tau^2/h_{-1}^1$  on  $m/h_{-1}^1$ ,  $e/h_{-1}^1$ ,  $c^1/h_{-1}^1$  and  $c^2/h_{-1}^1$  (and therefore on the steady state productivity growth differential), are exactly the same as the impact effects of  $\beta$ ,  $\theta_t^{19}$ ,  $\varphi_t$ ,  $g_t$ ,  $\tau_t^1$  and  $\tau_t^2$  on  $m_t$ ,  $e_t$ ,  $c_t^1$  and  $c_t^2$ , given  $h_{t-1}^1$ , derived in the previous subsections.

#### Only traded inputs into human capital accumulation.

Inter-country differences in productivity growth rates disappear in our model when all inputs into human capital accumulation are tradable. This effectively is the case analyzed in Alogoskoufis and van der Ploeg [1991]. Consider, for example, the following human capital accumulation function in which only traded inputs enter:

$$h_t^1 = h_t^0 \{1 + \eta[(m_t + g_t)/h_t^0]^\lambda\} \quad 0 < \lambda < 1.$$

With this strictly concave accumulation function the first order condition for  $m_t$  becomes, when the non-negativity constraint on  $m_t$  is not binding

$$1 + r_{t+1} - \theta_{t+1} - \varphi_{t+1} = \eta\lambda[(m_t + g_t)/h_t^0]^{\lambda-1} w_{t+1}$$

With perfect international mobility of financial capital and no differential source-based taxes on capital rentals, the before-tax interest

rate will be equalized in the world economy. With a common production function the wage rate (per unit of efficiency labor) will also be equalized throughout the world economy. With a common human capital accumulation technology (common values of  $\eta$  and  $\lambda$  in this example) and common distortionary tax rates, the equilibrium value of  $(m_t + g_t)/h_t^0$  is equalized throughout the world economy. Taste parameters (such as  $\beta$  and  $\beta^*$ ) therefore no longer matter for differences in productivity growth rates. Neither do redistributive lump-sum taxation or public sector deficits. The only aspect of fiscal policy in our model that matters for growth differentials are the tax rates on non-human asset income and student loan subsidy rates ( $\theta$ ,  $\theta^*$ ,  $\varphi$  and  $\varphi^*$ ). Different source-based capital rental tax rates would *cet. par.* cause different wages to be generated in the parts of the world where they apply. By raising the return to human capital accumulation a higher home country relative real wage would *cet. par.* increase  $m_t$  and thus the relative growth rate of home country human capital.

Note that a permanently higher value of  $\varphi$  will *cet. par.* be associated with a permanently higher home country relative growth rate of human capital and a permanently higher relative rate of growth of output per worker. An increase in  $\theta$  will have the same effects.

Also, higher public spending on education would *cet. par.* (i.e. without allowing for possible consequences for the world rate of interest and the wage rate of the financing decisions associated with higher public spending) crowd out private spending on education one-for-one:  $d(m_t + g_t) = 0^{20}$ . If  $m$  and  $g$  were imperfect substitutes, crowding out would be less than one-for-one.

If the non-negativity constraint  $m_t \geq 0$  on private expenditure on education is binding, the government can of course boost the growth rate of human capital simply by raising  $g_t$ , its own expenditure on education.

#### **(4) GOVERNMENT BORROWING AND LUMP-SUM INTERGENERATIONAL REDISTRIBUTION: MUST WHAT HELPS SAVING HURT HUMAN CAPITAL FORMATION?**

The discussion of the effect on human capital formation of changes in  $T_t$ , the present discounted value of life-time lump-sum taxes paid by generation  $t$  raises a number of important policy issues. We saw that an increase in  $T_t$

raises human capital formation by generation  $t$ . The mechanism is either the income effect on time spent in education while young or (in our alternative model) the income effect on work performed while young in order to relax a binding self-financing constraint on human capital formation.

One obvious question is whether it is possible to alter  $T_t$  systematically in the same direction for a (long) sequence of generations, so as to have a systematic and lasting influence on the rate of human capital formation through lump-sum intergenerational redistribution. The answer will turn out to be affirmative, even in steady state. It is possible even when the government is restricted to balanced-budget strategies.

A second question is whether in our model, intergenerational redistribution policies that boost human capital formation are necessarily also policies that hurt national saving (and thus, in a closed economy, physical capital formation). Consider home country financial wealth (private plus public) at the beginning of period  $t+1$ .

$$(42) \quad A_{t+1} - B_{t+1} = \left[ \frac{c_{t-1}^2 + \tau_{t-1}^2}{1+r_{t+1} - \theta_{t+1}} \right] N_{t-1}^{-m_t} N_t^{-B_{t+1}}$$

$$= [w_{t-1}^h c_{t-1}^1 - \tau_{t-1}^1 - (1+r_t - \theta_t - \phi_t) m_{t-1}] N_{t-1}^{-m_t} N_t^{-B_{t+1}}$$

It is clear that any policy that increases  $T_t$  will, by boosting borrowing to finance the purchase of traded inputs into human capital formation,  $m_t$ , reduce financial saving in period  $t$  by the young. Unless it increases financial saving by the middle aged in period  $t$  or by the government, conventionally measured national saving falls in period  $t$  as a result of the credible announcement of the same fiscal action that increases human capital formation.

Even if conventionally defined national financial saving declines, there is no necessary policy dilemma. The reason is that the conventional national income accounts do not record and value much of the time spent in education and training. The savings data correctly record borrowing in order to finance the purchase of marketed educational inputs as dissaving, but fail to register the associated acquisition of intermediate inputs by the household sector as a form of investment. Such loans are therefore by default classified as consumption loans. Thus the current resources devoted to human capital formation are either not recorded at all (in the case of  $e_t$ ) or recorded as

consumption (in the case of  $m_t$ ).

It is easily seen that balanced-budget intergenerational redistribution can increase the present discounted value of life-time lump-sum taxes for all generations. Consider, for instance, a permanent balanced-budget tax increase imposed on the middle-aged with the proceeds used to finance a tax cut for the old, that is, a permanent increase in the scale of an unfunded social security retirement scheme.<sup>21</sup> For simplicity let the stock of public debt  $B_t$  equal zero for all  $t$ , and let all distortionary tax rates be zero as well. During middle age each person pays a tax increase worth  $\mu$  and during old age she receives a tax reduction worth  $(1+n)\mu$ . That is:

$$d\tau_{t+i}^1 = -(1+n)^{-1} d\tau_{t+i-1}^2 = \mu > 0 \text{ for all } i \geq -2.$$

The present discounted value of lifetime taxes falling on generation  $t+i$  changes by  $\mu \left[ \frac{r_{t+2+i} - n}{1 + r_{t+2+i}} \right]$  which is positive if the interest rate exceeds the rate of growth of population, as we shall assume<sup>22</sup>. With leisure a normal good, this policy therefore increases forever more the home country allocation of time to education and thus the rate of growth of the stock of human capital relative to that in the rest of the world.

This example also illustrates the point that intergenerational redistribution that favors human capital formation will tend to reduce conventionally measured financial saving (and vice-versa). As noted before, the increase in  $T_t$  (for all  $t$  in our example) will increase  $m_t$  together with  $e_t$ . This increase in financial dissaving by the young is reinforced by a reduction in saving by the middle-aged, for familiar life-cycle reasons. The increase in the scale of the home-country unfunded social security retirement scheme reduces saving by the middle aged and therefore reduces further the total national stock of non-human assets held by domestic residents<sup>23</sup>.

Next consider an example with an unbalanced government budget, in which intergenerational redistribution favors financial saving but hurts human capital formation. In period  $t$  an (unexpected) one-time tax is levied on the old. The revenues from this one-time wealth levy,  $\Omega_t$ , are used to retire public debt. Following the wealth levy, the present discounted value of net future tax receipts is therefore reduced by  $\Omega_t$ . This "present value tax

"dividend" can be distributed across generations in such a manner that the present discounted value of lifetime taxes for all current and future generations (except the unfortunate current old) is lower. For instance, one could give the middle-aged each period, beginning in period  $t$ , the same size tax cut, with the value of the per capita tax cut determined by the requirement that its present discounted value be equal to  $\Omega_t$ .

This policy would clearly raise the permanent income (at given wages and interest rates) of all generations born in period  $t-1$  or later. It would therefore reduce the expenditure of time and traded goods on human capital formation (and the associated borrowing) during youth by all generations born in period  $t$  or later.. Current and future middle-aged all increase their saving for life-cycle purposes. Again, human capital formation and financial saving move in opposite directions.

These two examples make it clear that the proposition, that any intergenerational redistribution policy that raises  $T_t$  for all  $t$  will have a positive effect on human capital formation and a negative effect on conventionally measured financial saving, is perfectly general when the interest rate exceeds the growth rate of population. Without much loss of generality, consider balanced-budget redistribution policies only<sup>24</sup>. The lower permanent income represented by the increase in  $T_t$  increases human capital formation while young and reduces consumption while old. Increased human capital formation implies increased dissaving (borrowing) by the young. A lower value of  $c_t^2$  is only consistent with *increased* saving by generation  $t$  during middle age, if  $\tau_t^2$  increases by more than  $c_t^2$  falls. In fact, balanced-budget redistribution that increases  $T_t$  requires  $\tau_t^2$  to fall if the interest rate in period  $t$  exceeds the population growth rate, that is, the redistribution scheme has to be from the middle aged ( $\tau_t^1$  increases) to the old ( $\tau_t^2$  decreases).

How worried should policy authorities interested in boosting economic growth be, in our model, about the reduction in private saving associated with an increase in  $T_t$ ? Clearly, to the extent that the reduction in private saving represents a reduction in saving by the middle-aged, it is at the expense of the growth of national non-human wealth (at the expense of fixed

capital formation in a closed economy) without any compensating increase in human wealth. If the reduction in conventionally measured financial saving is instead due to increased dissaving by the young, there is a matching unrecorded increase in the value of human capital. Depending on whose private saving is reduced and on the relative social yields on human and non-human assets, the financial crowding out of private saving by public borrowing (or by policies with equivalent intergenerational redistribution effects) may be growth-promoting rather than growth-inhibiting.

#### (5) CONCLUSION.

The literature on endogenous growth models has emphasized economies of scale, differences in technology and in industrial structure, and barriers to trade in factors and/or commodities as sources of persistent and permanent international productivity growth rate differentials. In a fully integrated global economy with free technology transfer and financial capital mobility, constant returns to scale implies global convergence of the level and growth rate of output per worker despite differences in national savings rates. Our paper offers a complementary (and non-rival) approach to those discussed elsewhere for differences in household characteristics and in fiscal policies affecting household behavior to lead to permanent international productivity growth rate differentials.

Non-tradedness of an essential growth input or the presence of a binding self-financing constraint on expenditures for education and training suffice to create a role for differences in household behavior (and thus for policies influencing household behavior) as sources of persistent and even permanent international differences in productivity growth rates. This holds even though there is perfect international mobility of financial<sup>25</sup> and physical capital and even though industrial structure and technology are identical across the world and returns to scale are constant.

In our model, a higher rate of time preference will lower a country's relative rate of growth by reducing its rate of accumulation of human capital.

A higher public debt burden will, to the extent that it represents a net intergenerational redistribution towards the old, increase a country's growth rate of human capital and output relative to the rest of the world. More generally, deficit financing policies and lump-sum intergenerational redistribution policies that boost conventionally measured financial saving

will reduce human capital accumulation. The level of the growth rate of the country that raises its public debt burden could of course decline, since a higher public debt burden also lowers financial saving and physical capital formation.

Since human capital accumulation involves positive external effects, Pareto-efficiency requires subsidies to education or, in our model, a tax on leisure or a wage subsidy. The same result can of course also be achieved through administrative assignment of time and resources spent on schooling, overriding individual choice. Improvements over the unassisted decentralized equilibrium that fall short of full Pareto efficiency can be achieved by subsidizing private borrowing for educational expenditure (student loans).

In our model with an essential non-traded input in education, when public spending on education is equally efficient as private spending, an increase in public spending on education will crowd out private spending more than one-for-one, because this public transfer in kind is equivalent to an increase in the life-time lump-sum transfer received by each generation receiving it. In the alternative model with a binding self-financing constraint on education expenditures, an increase in public spending on education and an equal present value increase in life-time lump-sum transfers are not equivalent since the household is unable to borrow against future resources to finance current expenditures while young. If the household's borrowing constraint remains binding, then public spending for education raises the growth rate.

A distributionally neutral increase in the subsidy rate to student loans and increase in lump-sum taxes will raise the relative growth rate of productivity. A distributionally neutral increase in a general residence-based tax on lending (subsidy to borrowing) has the same effect. The effects of a residence-based tax increase on the middle-aged can be fully offset by a suitable change in the net lump-sum transfer to this generation.

## APPENDIX

This appendix provides the information necessary to derive the effects of taste and policy parameter perturbations on household choices of  $e_t$ ,  $m_t$ ,  $c_t^1$  and  $c_t^2$  reported in the text. Totally differentiating equations (34) - (37) and substituting out the result for (34) to eliminate  $dc_t^2$  yields the following equation system:

$$\begin{bmatrix} -\omega\psi_1\beta u''(c_t^1) & -(v''(\ell_t) + \omega\psi_{11}\beta u''(c_t^1)) & -\omega\psi_{12}\beta u'(c_t^1) \\ 0 & \omega\psi_{12} & \omega\psi_{22} \\ -\left(1 + \frac{u''(c_t^1)}{(1+r_{t+2}-\theta_{t+2})^2\beta u''(c_t^2)}\right) & \omega\psi_1 & 0 \end{bmatrix} \begin{bmatrix} dc_t^1 \\ de_t \\ dm_t \end{bmatrix}$$

$$= \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} d\tau_t + \begin{bmatrix} \omega\psi_1 u'(c_t^1) \\ 0 \\ \frac{-u'(c_t^2)}{(1+r_{t+2}-\theta_{t+2})\beta u''(c_t^2)} \end{bmatrix} d\beta + \begin{bmatrix} \omega\psi_{12}\beta u'(c_t^1) \\ -\omega\psi_{22} \\ -\omega\psi_2 \end{bmatrix} dg_t$$

$$+ \begin{bmatrix} 0 \\ -1 \\ -m \end{bmatrix} (d\theta_{t+1} + d\varphi_{t+1}) + \begin{bmatrix} 0 \\ 0 \\ (1+r_{t+2}-\theta_{t+2})^{-2} [c_t^2 + r_t^2 + \frac{u'(c_t^2)}{u''(c_t^2)}] \end{bmatrix} d\theta_{t+2}$$

We assume that  $u(c)$  and  $v(\ell)$  are strictly concave and that  $\psi$  satisfies  $\psi_1, \psi_2 > 0$ ,  $\psi_{11}, \psi_{22} < 0$ ,  $\psi_{12} > 0$  and  $\psi_{11}\psi_{22} - \psi_{12}^2 \geq 0$ . It is straightforward to invert the first matrix.



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## FOOTNOTES

<sup>1</sup>See e.g. Romer [1986, 1987, 1989, 1990a,b,c], Lucas [1988], Grossman and Helpman [1989a,b,c,d; 1990; 1991], Young [1989], Azariadis and Drazen [1990], Feenstra [1990] and Quah and Rauch [1990].

<sup>2</sup>In the macroeconomic literature Lucas [1988, pp.14-17] recognizes and emphasizes the importance of factor mobility assumptions for the predictions of neo-classical growth theory. It is equally important for endogenous growth theory with constant returns (of which our paper is an example) and for endogenous growth theory with increasing returns.

<sup>3</sup>Recent examples of studies that investigate national differences in per capita output levels and growth rates using as (one of) the technological maintained hypotheses the constant or decreasing returns to augmentable factors of production model and the common global technology of production include the empirical studies of Barro [1989a,b], King and Rebelo [1989], Benhabib and Jovanovic [1989] and Cohen [1990]. For more on the facts on convergence see Baumol [1986] and Baumol, Blackman and Wolff [1987]. Easterly [1989] has a technology that can exhibit increasing returns to scale but focuses on the case of constant returns to reproducible factors and either a constant value for the irreproducible factor or independence of output from the irreproducible factor in steady state. In Easterly [1990] the model is simplified to exhibit constant returns to reproducible factors. Irreproducible factors play no role. Finally, Edwards [1989] develops and tests a simple model of growth in developing countries in which the assumption of access to a common global technology is abandoned. It is replaced by one of gradual catching up by a technologically backward nation to the higher external level of technology. The rate at which a country catches up is postulated to be an increasing function of the degree of external orientation in the country's international trade relations.

Barro and Sala-i-Martin [1990b] use a model without factor mobility to analyze convergence of growth rates among regions within a nation state (the states of the USA). They recognize that this framework is unrealistic for countries and especially for the U.S. states and note that extensions of the neoclassical growth model that allow for features of an open economy tend to speed up the predicted rate of convergence.

<sup>4</sup>Two-country exogenous growth models with a Samuelson [1958]-Diamond [1965] OLG household sector include Buitier [1981] and Buitier and Kletzer [1990, 1991a]. Two-country exogenous growth models with a Yaari-Blanchard uncertain lifetimes OLG household sector include Frenkel and Razin [1987] and Buitier [1989]. A very simple two-country endogenous growth model with the Samuelson-Diamond OLG household sector is developed in Buitier and Kletzer [1991b]. A two-country endogenous growth model with the Yaari-Blanchard OLG household sector is studied by Alogoskoufis and van der Ploeg [1991]. Closed economy endogenous growth models with a Samuelson-Diamond OLG household sector have been developed by Azariadis and Drazen [1990] and by Jones and Manuelli [1990b]; the Yaari-Blanchard version has been studied by Alogoskoufis and van der Ploeg [1990a,b].

<sup>5</sup>Other papers analyzing the consequences of the use of distortionary taxes in (closed) endogenous growth models with a representative agent household sector are Rebelo [1990], King and Rebelo [1990] and Barro and Sala i Martin [1990a]. The latter also consider productive public spending. Jones and Manuelli [1990a] analyze an infinite-lived representative agent version

of the open economy endogenous growth model with distortionary taxes.

<sup>6</sup>In general, non-decreasing returns in both production processes is necessary for endogenous growth.

<sup>7</sup>We were not aware of the contribution of Azariadis and Drazen (henceforth A&D) when the first version of this paper was written. The focus of the A&D paper is quite different from ours. Using a model of a closed economy, they emphasize nonconvexities in the production and accumulation of human capital as a source of possible multiple locally stable stationary equilibria. When there are no traded inputs in the human capital production technology, our specification of the human capital accumulation technology can be written as follows:

$$h_t^1/h_{t-1}^1 = 1 + \eta e_t/h_{t-1}^1, \quad \eta > 0.$$

A special but informative case of the human capital accumulation technology of A&D (given in their equation (13b)) can, using our notation, be written as

$$h_t^1/h_{t-1}^1 = 1 + \gamma(h_{t-1}^1)e_t, \quad \text{where } \gamma \text{ is an increasing function of}$$

$h_{t-1}^1$  with a finite upper bound. The non-convexity in the human capital production function of A&D can generate "threshold externalities" (radical differences in dynamic behavior arising from local variations in social returns to scale). Multiple steady states with significantly different levels of education and training can be associated with small differences in initial conditions, giving rise to "development traps".

Our constant returns to scale production function of human capital rules out this particular source of multiplicity of steady states. Like any Diamond OLG mode, however, our model may well possess multiple stationary equilibria for the global economy. We do not study the behavior of the aggregate global economy but instead focus on permanent *differences* between the growth rates of labor productivity of the two countries that make up the global economy. These can occur, in or out of steady state, despite the assumption of identical, constant returns technologies and despite the equalization of the ratio of physical to human capital brought about by perfect international mobility of financial capital and the absence of source-based capital income taxation.

<sup>8</sup>Note that unless, through vigorous intermarriage a la Bernheim and Bagwell [1988], all of society effectively constitutes one big happy family, the human capital formation externality, whose domain is both intergenerational and across families or dynasties, will not be fully internalized even if one assumed universal operative intergenerational gift motives.

<sup>9</sup>Each household of each generation  $t$  takes  $w_{t+1}$ ,  $r_{t+1}$ ,  $r_{t+2}$ ,  $h_t^0$ ,  $\tau_t^1$ ,  $\tau_t^2$ ,  $\theta_{t+1}$ ,  $\theta_{t+2}$ ,  $\varphi_{t+1}$  and  $g_t$  as given.

<sup>10</sup> $u(\cdot)$  and  $v(\cdot)$  are increasing, strictly quasi-concave, twice continuously differentiable and satisfy the Inada conditions  $\lim_{x \rightarrow \infty} u(x) = \lim_{x \rightarrow \infty} v(x) = 1/\lim_{x \rightarrow 0} u(x) = 1/\lim_{x \rightarrow 0} v(x) = 0$ ;  $\beta > 0$ .

<sup>11</sup>Assuming imperfect substitutability between  $m$  and  $g$  would result in

additional tedious algebra, but would not qualitatively change the effects of  $g$  on human capital formation and private financial saving, as long as an increase in  $g$  does not reduce the marginal products of education and private traded inputs.

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Recent empirical evidence that capital market imperfections constrain individuals' educational attainments is given by Behrman, Kletzer, McPherson and Schapiro [1992] and by Cameron and Heckman [1992], who find that family financial resources are a significant determinant of education levels.

<sup>13</sup>See Buiter and Kletzer [1992] for an analysis of the conditions under which the conventional government solvency constraint (22a) is implied by more robust notions of feasibility of government tax, spending and financing plans.

<sup>14</sup>For a steady state to exist, preferences must be homothetic.

<sup>15</sup>When the constraint  $m_t \geq 0$  binds, the value of the marginal product of traded inputs in the human capital accumulation process is below the after-tax rate of interest ( $1 + f'(k_{t+1}) - \theta_{t+1} - \varphi_{t+1} > w_{t+1} \psi_2$ ). Equation (36) is dropped and  $m_t = 0$  in this case.

<sup>16</sup>To achieve an equilibrium for this 2-country economy that is Pareto efficient, the two governments are required to subsidize human capital formation in order to internalize the externality and to forswear the use of distortionary taxes. They also should refrain from choosing values of their human capital accumulation inputs  $g$  and  $g^*$  that make the constraints  $m \geq 0$  or  $m^* \geq 0$  binding. In addition one of the governments may have to use lump-sum taxes and transfers to ensure dynamic efficiency. The first-best policy to internalize the externality is to subsidize time spent by the young in education,  $e_t$ . In our model such an education subsidy is equivalent either to a subsidy on the wage earned by the middle aged or to a tax on leisure.

If in our model we also permitted the young to work (in addition to choosing between leisure and education), and if work did not produce a human capital externality, then the equivalence between a subsidy to education, a tax on leisure and a wage subsidy to the middle-aged would break down. Efficiency would then require a subsidy to education or a tax both on leisure and on time spent working while young. The equivalence between an education subsidy and a tax on leisure would also break down when the middle-aged can choose leisure, unless age discrimination can be built into the leisure tax. A subsidy to borrowing by the young for educational expenditures is not needed in the first best. If a tax on leisure or a wage subsidy are not feasible, then subsidizing student loans will be a second-best policy. Subsidizing private borrowing in general will be next best.

<sup>17</sup>It is easy to consider the difference made by the existence of national source-based taxation (say at a constant rate  $\hat{\theta}$  in the home country and  $\hat{\theta}^*$  in the foreign country) of the rental income from capital instead of national residence-based taxation of the income from all non-human wealth. Student loan subsidies are also omitted for simplicity. With free international mobility of financial capital we now have equalization of after-tax rates of return to physical capital, that is  $r_t = r_t^* = (1 - \hat{\theta}_t) f'(k_t) = (1 - \hat{\theta}_t^*) f'(k_t^*)$ .

With source-based capital taxation, perfect capital mobility and a common technology, the home country wage rate will be above the foreign wage rate if and only if  $\hat{\theta}$  is below  $\hat{\theta}^*$ . Even if all other private and policy parameters are identical, different wage rates will be associated with different productivity growth rates. A higher wage rate during middle age increases the rate of return to education. Unless the income effect of a higher wage on the demand for leisure is very strong, the country with the higher real wage will have the higher growth rate of productivity.

<sup>18</sup>If the preference ordering generating  $U_t$  defined in equation (1) is homothetic, it follows that

$$\beta^2 u(c_t^2) + \beta u(c_t^1) + v(\ell_t) = \lambda [\beta^2 u(c_t^2/\lambda) + \beta u(c_t^1/\lambda) + v(\ell_t/\lambda)] \text{ for all } \lambda > 0.$$

<sup>19</sup>The steady-state effects of a change in  $\theta$  are the same as the impact effects of equal changes in  $\theta_{t+1}$  and  $\theta_{t+2}$ .

<sup>20</sup>In the framework of this paper, any consequences of lump-sum financing of, say, increased home country public spending on education would affect domestic and foreign interest rates and wage rates equally. This would therefore not alter productivity growth differentials.

<sup>21</sup>In period  $t$  the government can only change  $\tau_{t-1}^1$ , the tax on the middle aged, and  $\tau_{t-2}^2$ , the tax on the old. Period  $t$  human capital formation is performed by the young in that period, that is by generation  $t$ . Human capital formation in period  $t$  will only be a function of expectations at time  $t$  concerning  $\tau_t^1$  and  $\tau_t^2$ . The behavior of members of generation  $t$  during period  $t$  is therefore only affected by tax changes in period  $t$  to the extent that such changes in  $\tau_{t-1}^1$  and  $\tau_{t-2}^2$  carry *announcement effects* concerning  $\tau_t^1$  and  $\tau_t^2$ , the taxes they will pay when middle-aged and old. Of course, if the changes in  $\tau_{t-1}^1$  and  $\tau_{t-2}^2$  are news with respect to the information set of period  $t-1$ , then the saving behavior of the middle-aged in period  $t$  will be affected. The scope for time-inconsistent policy behavior in a model like ours is clearly considerable. For reasons of space these issues will not be considered further.

<sup>22</sup>While the competitive equilibria of OLG models such as the one we are considering may be dynamically inefficient, we shall consider the consequences of a cut in lump-sum taxes during period  $t$  when the interest rate is above the growth rate of physical capital in each period, which is sufficient for dynamic efficiency in our non-stochastic model. Any government, acting unilaterally, could issue debt or vary lump-sum taxation to achieve a national Pareto improvement if dynamic inefficiency prevailed (see Buiter and Kletzer [1990a, 1990b]). In steady state, the growth rate of physical capital equals the growth rate of population,  $n$ , plus the growth rate of per capita human capital. The latter is non-negative in our model. If the interest rate exceeds the steady-state growth rate of aggregate human capital it therefore also exceeds  $n$ .

<sup>23</sup>This does not require the interest rate to be above the population



growth rate.

<sup>24</sup>If the government could also levy lump-sum taxes on the young, there would not be any loss of generality in restricting ourselves to balanced budget redistribution schemes. See Buiter and Kletzer [1992].

<sup>25</sup>In the self-financing constraint interpretation of our model, financial markets are clearly imperfect. The inability to borrow in order to finance education and training, however, excludes the young equally from the domestic and from the international financial markets.