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CONVERGENCE IN GROWTH RATES: THE ROLE OF CAPITAL MOBILITY AND INTERNATIONAL TAXATION

Assaf Razin

Chi-Wa Yuen

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ABSTRACT

We consider the role of capital mobility and international taxation in explaining the observed diversity in long-term growth rates. Our major finding is that, under capital mobility, international differences in taxes will not matter for total growth differentials. Policy differences have a role to play in per capita growth differentials, however, when they lead to a divergence in the after-tax rates of return on capital across countries, as when the residence principle is adopted universally. When this is the case, how tax differences affect the growth rates of population and human capital will depend on the relative preference of the individual household towards these two engines of growth. Optimal tax policies are found to be growth-equalizing with and without policy coordination.

Assaf Razin
Department of Economics
Tel Aviv University
Department of Economics, Tel Aviv
69978, ISRAEL
Fax:972-3-642-8074
and NBER

Chi-Wa Yuen
Finance and Economics
The Hong Kong University
of Science and Technology
Clear Water Bay, Kowloon
Hong Kong
Fax: 852-358-1749

I. Introduction

Recently, Lucas (1988) has posed the *problem of economic development* as the problem of accounting for the observed diversity in the *levels* and *rates of growth* of per capita income across countries. Investigating international cross-country data, Baumol (1986) argues that there has been *convergence* in long-run productivity levels among developed countries since 1870. Following this line, Barro and Sala-i-Martin (1992) examine the convergence issue for the 48 contiguous US states and provide some evidence of equalizing trends.[1] This literature, however, uses the closed economy neoclassical growth model as a framework to study convergence without considering the role of capital mobility and the complexity introduced by international (and interstate) taxation issues.[2] Evidently, these two factors are crucial in explaining both level and growth rate differentials across countries (or states). The taxation factor may also help solve another problem posed by Lucas (1990b), viz., why capital does not flow from rich to poor countries.

In this paper, we address the issue of convergence in long-run growth rates by incorporating international capital mobility and global taxation, taking for granted level differences, which the model proposed below is also capable of generating. In order to assess the qualitative effects of these two factors on the growth differentials in a context where government policies matter, we develop a two-country model of endogenous growth with

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[1]De Long (1988) shows that Baumol's analysis suffers from sample selection bias. Using a much more extensive data set, however, Baumol and Wolff (1988) successfully demonstrates that Baumol's (1986) *convergence* conclusion still holds for the richest (say, top 15) industrialized countries. But since larger samples do not display convergence, we shall conclude that there does exist diversity in levels. Moreover, the cross-state evidence for *convergence* found in Barro and Sala-i-Martin (1992) does not generalize easily to cross-country comparisons because labor mobility and coordination of tax policies are more common among states within a federal system than countries.

[2]Buiter and Kletzer (1992) have developed an open economy OLG model of endogenous growth to examine human capital as a non-traded good whose augmentation requires a non-traded time input as the source of growth diversity under capital mobility. Their analysis seems to have overlooked the balanced growth restriction stated in our Proposition 1 below, which may invalidate some of their results. Barro, Mankiw, and Sala-i-Martin (1992) examine *convergence* in a model with partial capital mobility. But they take long-run convergence for granted, and are more concerned about the speed of converging from the transition path to the steady state growth path.

income taxes.[3] Although we do not ignore transitional behavior altogether, our main focus is on *long*-term growth. One reason lies in the findings of King and Rebelo (1989) that transitional dynamics cannot give rise to cross-country differences in levels and rates of growth persistent enough to match the observed diversities.[4] Averaging out the year-to-year fluctuations, we can also interpret the pretty stable growth rates observed in many countries over long periods of time as evidence of steady state growth. Another reason is technical: the balanced growth path is analytically more tractable than its transitional counterpart.

When countries with identical preferences and technology but perhaps different endowments are treated as isolated islands, there is at least two explanations of diversity in long-run growth. One is existence of multiple equilibria. [See, e.g., Becker, Murphy and Tamura (1990) and Azariadis and Drazen (1990).][5] Another is differences in national policies. [See, e.g., Rebelo (1991) and Jones and Manuelli (1990) for a qualitative analysis, and King and Rebelo (1990) and Lucas (1990) for a quantitative assessment, of the growth effects arising from tax changes.] The question is whether such differences can be preserved when countries open themselves up to trade with one another. In particular, the validity of

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[3]It is now a well-known result that, without exogenous technical change and with fastly diminishing marginal productivity of capital as capital deepening approaches the limit, the Solow-Cass-Koopmans-type growth model cannot generate sustained growth. Besides, when growth is driven by an *exogenous* engine, government policies can only affect the growth rate of per capita income along the transition path, but have no effect on perpetual growth. In other words, government policies do not have *growth* effects—they only have *level* effects—in the long run. In what follows, we shall presume diversity in levels and focus our attention on the explanation of diversity in growth rates because differences in initial endowments, as we shall assume below, are sufficient to generate level differences in endogenous growth models.

[4]This is not a very valid justification since their results are based on an exogenous growth model whereas ours will be derived from a model of endogenous growth. A more complete analysis shall examine both short-run and long-run differences.

[5]Assuming that the private rate of return on human capital rises with the stock of human capital, Becker, Murphy and Tamura (1990) obtain two stable steady states: one with large families and little human capital, and the other with small families and perhaps growing human and physical capital. They leave unanswered the question of what produces diversity in long-run growth rates among the low-growth and high-growth countries separately. Growth diversity to a more widespread degree—in terms of the number of multiple stationary states at various levels of income—is obtained in Azariadis and Drazen (1990) by assuming increasing social returns to scale with local variations (what they call "threshold externalities") in the accumulation of human capital.

the *convergence* hypothesis hinges critically on whether (1) capital mobility will lead countries to trade to the same—hopefully, high growth—equilibrium, and (2) growth rate differentials produced by policy differences will be washed out by international policy spillovers.[6] Since the closed economy version of our model will produce a unique equilibrium, we shall focus only on (2) in this paper and relegate (1) to a different paper.

To understand why capital mobility (intertemporal consumption trade) can be growth-equalizing, just recall from international trade theory how the marginal rates of substitution and marginal rates of transformation can be brought to equality through a common set of relative prices faced by consumers and producers in all countries under free trade. In an intertemporal setting, the intertemporal marginal rates of substitution (IMRSs) in consumption and the marginal productivities of capital (MPKs) become the relevant objects of interest. To see how these two objects are related to one another, and how they determine the rate of growth of per capita consumption, consider the familiar marginal condition for the intertemporal choice of consumption: $IMRS_{t,t+1} = 1+r_{t+1}$ where $IMRS_{t,t+1} \equiv U_{ct}/\beta U_{ct+1}$ and $r_{t+1} \equiv MPK_{t+1}-\delta_k$ (β is the subjective discount factor, U_c the marginal utility of consumption, δ_k the capital depreciation rate, and t the time index). Specializing the utility function to the isoelastic form, assuming people are altruistic towards each other, and allowing for taxes on capital levied by either government, we can rewrite the above condition as:

$$1+g_{ct} = [\beta(1+g_{Nt})^{\xi-1}(1+\bar{r}_t)]^{1/\sigma}$$

where ξ ($\leq$ 1) is the degree of interpersonal altruism, σ (> 0) the reciprocal of the intertemporal elasticity of substitution in consumption, $\bar{r}$ the after-tax rate of return on capital

[6]Jones and Manuelli (1990) give an example where the tax-driven growth diversity can be preserved in an open economy. Their example is special because the tax principles/policies they consider are so designed that the resulting equilibrium is autarky (i.e., zero net capital flows).

(ATROROC), N the population size, and $1+g_{xt} \equiv x_t/x_{t-1}$ the gross growth rate of variable x. [See equation (8) of Rebelo (1992) for the same formula.] This formula suggests that if two countries have identical preferences (β, ξ, and σ)[7], then their rates of consumption growth can differ only if they have either different population growth rates or different ATROROCs. This explains why it is important to endogenize the fertility choice (except when $\xi = 1$) and to highlight the role of international taxation (which can potentially break the free trade equalization result).[8]

Although there is probably no country which adheres to a pure principle of international income taxation, two polar principles with a wide application can be detected. They are the *residence* (of taxpayer) principle and the *source* (of income) principle. They have also been labelled the *worldwide* tax system and *territorial* tax system respectively. According to the residence principle, residents are taxed on their worldwide income uniformly, regardless of the source of income (domestic or foreign), while nonresidents are not taxed on income originating in the country. According to the source principle, all types of income originating in the country are taxed uniformly, regardless of the place of residence of the income recipients. Thus, residents of the country are not taxed on their foreign-source income, and nonresidents are taxed equally as residents on income originating in the country.[9]

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[7]Rebelo (1992) and Ogaki (1992) propose respectively that wealth-varying intertemporal elasticity of substitution [$\sigma = \sigma(y)$] and wealth-varying rate of time preference [$\beta = \beta(y)$] can explain diversity in growth rates without assuming asymmetric preferences as long as countries have different income levels, as are borne out by endogenous growth models even in the long-run. The problem with these preference specifications is that they both converge to a constant asymptotically [$\sigma(y) \to \sigma$ and $\beta(y) \to \beta$ as y gets big] so growth diversity cannot be sustained forever.

[8]Rebelo (1992) touches marginally on these issues. Since he implicitly assumes population growth to be exogenous and equal across countries and makes no distinction between short and long runs (given his example economy always grows along the balanced path), possibilities of international differences in growth rates along the transition path under the source principle and the asymmetric impact of taxes on the growth of human capital versus population are dismissed in his analysis. We can view his example as a special case of our more general setup.

[9]See Frenkel, Razin and Sadka (1991) for a more detailed explanation of these two international income tax principles and their implications for the viability of world equilibrium and the efficiency in the cross-country allocation of investment and savings.

Whether capital mobility implies equalization of the ATROROCs will depend on the choice of international tax principle, i.e., how foreign-source capital incomes are taxed by the home and foreign governments individually. With foreign investment as another channel for savings and foreign-source capital income as a common tax base, domestic tax policy can be nullified by counteracting foreign tax policies. The source principle implies asymmetric tax treatments of domestic-source and foreign-source incomes, but the ATROROCs will be equalized through arbitrage. It is thus a growth-equalizing force. The residence principle implies symmetric tax treatment of domestic-source and foreign-source incomes for residents of each country separately, but asymmetric treatment across countries. It can thus be growth-diverging if countries impose different capital income tax rates.

A brief description of the basic features of our model is in order. We use the simple representative household framework with two kinds of capital goods in each country: human and physical capital. The household is endowed with one unit of time in each period, and some units of human and physical capital in the initial period. He/she can split the unit time among child-rearing, schooling and work. Human capital is accumulated through forgone domestic consumption and schooling, and physical capital through forgone consumption and capital inflow. Labor is internationally immobile and taxed only at home, but physical capital is mobile and can thus be subject to double taxation by the two national tax authorities. As in the real world, tax policies are assumed to be uncoordinated internationally. We also assume that population growth is endogenously determined through altruistic motives which are constrained by the time costs of raising children. The human capital and endogenous population (the bi-*engines of growth*) features are important for accounting for long-run differences in growth rates across countries. The tradeoff between investment in human capital and fertility, the linchpin of our growth model, seems to explain the remarkable drop in fertility rates among the world's fastest growing countries in the last three decades.[10]

The paper is organized as follows. Section II lays out the theoretical framework. Positive tax analysis is carried out in Section III. Normative tax analysis is conducted in Section IV to characterize the national-welfare-maximizing tax structures under tax competition, and to derive the implications of optimal uncoordinated tax policies for *convergence*. Section V concludes.

II. The Analytical Framework

Our simplifying perfect foresight model is based on the Uzawa (1965)-Razin (1972a,b)-Lucas (1988,1990a)-type human capital growth framework augmented with endogenous population and mobility of physical capital. Population, human capital, and physical capital are the only (endogenous) state variables that drive the dynamics of the system. We make several assumptions about the factors that govern the evolution of these variables to ensure the existence of an endogenous steady state growth equilibrium.

Consider a two-country[11] dynastic world, where each country i (i = A,B) is populated by N_t^i identical agents at each date t. Following the growth-based endogenous fertility literature of Razin and Ben-Zion (1975) and Becker and Barro (1988), we represent the preferences of the typical consumer in country i by: [12]

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[10]Comparing the 1966-70 and the 1981-86 periods reveal the following changes in percentage rates of fertility. China: from 5.9 to 2.3; Hong Kong: from 3.4 to 1.7; Chile: from 3.7 to 2.5; Japan: from 2.6 to 1.8; Mexico: from 6.9 to 4.0; and Singapore: from 3.5 to 1.6. See United Nations (1990).

[11]In what follows, one can imagine more countries (say, i = 1, 2, ..., N, $2 < N < \infty$), each behaving as a price-taker in the global economy, without affecting our analysis.

[12]The altruism function in Becker and Barro (1988) contains both the discount factor β^t and the number of children $\Pi(v_\tau^i)N_\tau^i$, and can thus be expressed as $\beta^t a(\Pi(v_\tau^i)N_\tau^i)/\Pi(v_\tau^i)N_t^i$ in our notations. The advantage of our formulation is that we can disentangle the effects of intertemporal (via β) and intratemporal (via the function a(.)) altruism. Implicit in our a(.) function is an extreme form of altruism with everybody alive in the same period being treated as equal irrespective of their dates of birth. One can think of this as a reduced form representation of the kind

$$\sum_{t=0}^{\infty} \beta^t a(N_t^i) U(c_t^i) \qquad (2)$$

where c_t^i = consumption of the agent at date t,

β = the common subjective discount factor of time preference applied to future utilities of both the dynastic head and his offspring,

a(.) is an increasing and concave intratemporal altruism function, with a(1) = 1 and $a_N(N) \to +\infty$ as $N \to 0$,

U(.) is the momentary utility function that satisfies the standard properties.

To avoid the vintage problem, we assume that live agents of different ages all look alike in terms of their preferences and productivities. It is then natural to assume a complete equity rule in the allocation of resources within the representative family. Each agent is endowed with one unit of time, and possesses h_t^i of human capital and S_t^i/N_t^i of physical capital carried over from date t−1, at each date t ≥ 1 (given S_0^i/N_0^i at t=0). Under capital mobility and absent adjustment costs, new stocks of physical capital can freely be transformed into financial capital and invested abroad.[13] We denote the amount of physical capital invested abroad by S_t^{ij}, and that at home by S_t^{ii} (i = A,B and j = B,A), then $S_t^i \equiv S_t^{ii} + S_t^{ij}$ is the total savings accumulated from time t−1. A fraction η_t^i of S_t^{ii} is used as inputs in the production of final output, and the residual as inputs in the production of human capital, $(1-\eta_t^i)S_t^{ii}/N_t^i$ for each agent. Since the property rights problem as to how one can capture the returns from

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of altruism that results from the complex networks of family linkages, in which each individual may belong to many dynastic groupings, a la Bernheim and Bagwell (1988). Our preference specification would be the same as that in Razin and Ben-Zion (1975) if utility were multiplicatively separable between consumption c_t^i and population growth λ_t^i (= N_{t+1}^i/N_t^i) and the fertility function $\Pi(.)$ described below were a nonlinear function of the total child-rearing time $v_t^i N_t^i$ with v_t^i fixed in each period so that λ_t^i is a function of N_t^i only. The nonlinearity of $\Pi(.)$ in N_t^i will nonetheless violate balanced growth. A more general specification along the lines of Razin and Ben-Zion that preserves balanced growth will incorporate altruism as part of the utility function, i.e., $V(c_t^i, N_t^i)$, say, instead of $a(N_t^i)U(c_t^i)$. In any case, the degree of altruism towards one's contemporaries is inversely related to the degree of concavity of V(.) or a(.) in N_t^i. Time separability ensures that choices made by the dynastic head on behalf of his offspring are time consistent, i.e., such choices will also maximize the utilities of his offspring.

[13]Perfect substitutability between physical and financial capital implies that there is no nontrivial distinction between foreign direct investment and foreign portfolio investment. In reality, the tax treatment of and efficiency implications for these two forms of investment can be very different. So also are the effects of capital control on their relative sizes. For an empirical examination of these issues, see Gordon and Jun (1992).

investing in the human capital of foreign residents is very real, we assume that the whole of the capital invested abroad S_t^{ij} will only be devoted to final goods production. However, this does not preclude people in the home country from substituting foreign for domestic capital one for one as an input in human capital investment. Concerning the unit endowment of time, a fraction n_t^i is allocated to producing final output, e_t^i (e for education) to accumulating human capital (say, through schooling), and $1-n_t^i-e_t^i \equiv v_t^i$ to rearing children.

In every period t, $\Pi(v_t^i)N_t^i$ people are born and $\delta_N N_t^i$ people pass away. In the absence of cross-border migration, the size of population in the following period is given by,

$$N_{t+1}^i = \Pi(v_t^i)N_t^i + (1-\delta_N)N_t^i \tag{3}$$

where the 'fertility function' $\Pi(.)$ is increasing and concave in the amount of time devoted to raising children, with $\Pi(0) = 0$, and δ_N is the mortality rate ranging between zero and one. A more correct interpretation of v_t^i is the time required to maintain harmonious human relationship (including child-raising, brotherhood, friendship, marriage, old-age care and the like), which increases at an increasing rate with the size of the population N_t^i through an increasing and convex function $\pi(.)$. We can then think of $\Pi(.)$ as an inverse function of $\pi(.)$. For convenience, we shall continue to label v_t^i as the child-rearing time.

Knowledge and skills are 'produced' with both physical capital $k_{ht}^i = (1-\eta_t^i)S_t^{ii}/N_t^i$ and effective schooling time $e_t^i h_t^i$. Unlike Becker, Murphy and Tamura (1990), we make no distinction between 'raw' and 'refined' human capital. $\delta_h h_t^i$ disappears at each date t through death, obsolescence, illness or memory loss. The human capital of each agent thus evolves according to:

$$h_{t+1}^i = G(k_{ht}^i, e_t^i h_t^i) + (1-\delta_h)h_t^i \tag{4}$$

where the human capital production function G(.) is increasing and concave in both inputs, and δ_h is the rate of depreciation of human capital. We further assume that G(.) is linearly homogeneous to guarantee the existence of sustained growth.

There is one single malleable consumption good produced with physical capital K_{yt}^i and effective labor $H_t^i \equiv N_t^i n_t^i h_t^i$ via a standard production function F(.). Under perfect capital mobility, the capital input in country i can be obtained in one of two ways: either through forgone domestic consumption or through inflow of capital from abroad, i.e., $K_{yt}^i = \eta_t^i S_t^{ii} + S_t^{ji}$. [Total capital installed in country i can be defined as $K_t^i \equiv K_{yt}^i + K_{ht}^i$ (= $S_t^{ii} + S_t^{ji}$ in equilibrium), where $K_{ht}^i = k_{ht}^i N_t^i$.] Since capital can flow in either direction, GNP_t^i equals GDP_t^i plus net capital income from abroad, i.e., $F(K_{yt}^i, H_t^i) + (r_t^j S_t^{ij} - r_t^i S_t^{ji})$ where r_t^i is the rate of return on capital in country i. Part of this income G_t^i is absorbed by the government; this stream of spending is given exogenously, standing for the supply of public consumption goods. The remaining portion is left to the private sector either for private consumption $N_t^i c_t^i$ or accumulation of physical capital $I_t^i = S_{t+1}^i - (1-\delta_k)S_t^i$. Country i's resource constraint can therefore be written as:

$$N_t^i c_t^i + S_{t+1}^i - (1-\delta_k)S_t^i + G_t^i = F(K_{yt}^i, H_t^i) + r_t^j S_t^{ij} - r_t^i S_t^{ji} \tag{5}$$

where δ_k is the rate of depreciation of physical capital. Since there exists essentially only one good in each period, we can add up the resource constraints of both countries to get the total world resource constraint:

$$C_t + S_{t+1} - (1-\delta_k)S_t + G_t = Y_t$$

where $C_t = N_t^A c_t^A + N_t^B c_t^B$, $S_t = S_t^A + S_t^B$, $G_t = G_t^A + G_t^B$, and $Y_t = F(K_{yt}^A, H_t^A) + F(K_{yt}^B, H_t^B)$.

Thus far, we have indexed most of the variables with a country-specific superscript i without explaining what the source(s) of heterogeneity is(are) between the two countries. We shall assume the simplest world in which they are identical in terms of preferences, (production, human capital accumulation, and fertility) technology and time endowment, but different in terms of the initial population N_0^i and endowment of the initial stocks of human capital h_0^i and physical capital S_0^i owned by the two dynastic heads. When we introduce the two governments later in the next section, their different choices of national tax rates will form another source of heterogeneity that may make international capital flows—the only kind of (intertemporal) trade between the two countries—mutually beneficial.

III. World Equilibrium with Distortionary Taxes

Suppose each national government can levy four kinds of taxes (on labor income, domestic residents's domestic-source and foreign-source incomes, and non-residents's capital income originating from the home country) to finance its exogenous streams of spending and transfers in each period. We can write the time-t fiscal budget constraint facing the government in country i as: [14]

$$G_t^i + T_t^i = \tau_{wt}^i w_t^i H_t^i + (r_t^i - \delta_k)(\tau_{rDt}^i \eta_t^i S_t^{ii} + \tau_{rNt}^i S_t^{ji}) + \tau_{rFt}^i (1 - \tau_{rNt}^j)(r_t^j - \delta_k) S_t^{ij} \qquad (5)$$

where T_t^i = lump-sum transfer payments (including interest payments on the public debt outstanding),

τ_{wt}^i = tax rate on labor income $w_t^i H_t^i$,

τ_{rDt}^i = tax rate on domestic-source capital income net of the tax-deductible depreciation allowances $(r_t^i - \delta_k)\eta_t^i S_t^{ii}$,

τ_{rNt}^i = tax rate on non-residents's net capital income $(r_t^i - \delta_k) S_t^{ji}$,

τ_{rFt}^i = tax rate on foreign-source net capital income after deducting taxes paid to the foreign government $(1 - \tau_{rNt}^j)(r_t^j - \delta_k) S_t^{ij}$.

τ_{wt}^i, τ_{rDt}^i, τ_{rFt}^i and τ_{rNt}^i are linear, though not necessarily time-invariant, taxes. Equation (5) assumes that the government observes a period-by-period budget balance. If it is allowed to

[14] Our multiplicative specification of double taxation $(1-\tau_{rF}^i)(1-\tau_{rN}^j)r_t^j$ on foreign-source capital income implies that non-residents's taxes on capital income paid to the foreign government by home residents are deducted from their foreign-source capital income tax base in the home country. The additive specification $(1-\tau_{rFt}^i-\tau_{rNt}^j)r_t^j$ is actually more in line with the credit system. The reader can, however, rest assured that all the qualitative results in this paper carry over straightforwardly to the latter specification.

issue new debt, (5) can be replaced by a present value budget constraint:

$$\sum_{t=0}^{\infty} d_t^i \Big\{ \tau_{wt}^i w_t^i H_t^i + (r_t^i - \delta_k)(\tau_{rDt}^i \eta_t^i S_t^{ii} + \tau_{rNt}^i S_t^{ji}) + \tau_{rFt}^i (1 - \tau_{rNt}^j)(r_t^j - \delta_k) S_t^{ij} - (G_t^i + T_t^i) \Big\} = 0, \tag{5'}$$

where $d_t^i \equiv \prod_{\tau=0}^{\infty}(1+r_{b\tau}^i)^{-1}$ with the interest rate on debt r_{bt}^i equal to $(1-\tau_{rDt}^i)(r_t^i-\delta_k)+\delta_k$ by the no-arbitrage condition.

We assume, as in the real world, that tax policies are uncoordinated internationally, so each government has to take the tax policies of the other government as given while designing its own policies. We shall first discuss the private agents's optimization problems and the world equilibrium, and leave the analysis of the optimal policy choices of the two national governments to the next section.

In our world economy, the household-producer runs a representative firm in his own country, renting capital K_{yt}^i at the given rental rate r_t^i from the domestic capital market and hiring labor H_t^i from the domestic labor market at the going wage rate w_t^i to produce output $F(K_{yt}^i, H_t^i)$. (Firms are therefore purely production units. As explained below, investment decisions are carried out at the household level.) $r_t^i K_{yt}^i$ is paid out as rental cost, and $w_t^i H_t^i$ as labor cost. By the linear homogeneity of F(.) in K_y and H and the familiar profit-maximizing conditions, profit of the firm ($\equiv F(K_{yt}^i, H_t^i) - r_t^i K_{yt}^i - w_t^i H_t^i$) is zero in equilibrium. We can thus ignore the taxation of corporate profits and the distribution of after-tax profits.

The household-consumer splits up the one unit of time he/she has at each date, spending n_t^i at work, e_t^i at school, and $1-n_t^i-e_t^i$ at home raising children. He/she earns $(1-\tau_{wt}^i)w_t^i n_t^i h_t^i$ of after-tax labor income, $[(1-\tau_{rDt}^i)(r_t^i-\delta_k)+\delta_k]\eta_t^i S_t^{ii}/N_t^i$ of domestic-source after-tax capital income, $[(1-\tau_{rFt}^i)(1-\tau_{rNt}^j)(r_t^j-\delta_k)+\delta_k]S_t^{ij}/N_t^i$ of foreign-source capital income, gets back $(1-\delta_k)S_t^i/N_t^i$ of undepreciated capital from all sources, and receives T_t^i/N_t^i of transfer payments from its government. The household uses part of his/her income to consume c_t^i of final goods, and saves what remains S_{t+1}^i/N_t^i. Division of the latter into investment at home S^{ii}/N^i (to be sub-divided into inputs in final goods production and inputs in human capital formation) and investment abroad S^{ij}/N^i is as explained in the previous section. The family budget constraint is thus given by:

$$\begin{aligned} N_t^i c_t^i + S_{t+1}^i = (1-\tau_{wt}^i) w_t^i H_t^i + [(1-\tau_{rDt}^i)(r_t^i - \delta_k) + \delta_k] \eta_t^i S_t^{ii} \\ + [(1-\tau_{rFt}^i)(1-\tau_{rNt}^j)(r_t^j - \delta_k) + \delta_k)] S_t^{ij} + (1-\delta_k) S_t^i + T_t^i. \end{aligned} \tag{6}$$

By Walras's Law, the consumer and government budget constraints in each country sum to the economy-wide resource constraint. In the presence of taxes on non-residents's income, (4) has to be revised as follows:

$$\begin{aligned} N_t^i c_t^i + S_{t+1}^i - (1-\delta_k) S_t^i + G_t^i \\ = F(K_{yt}^i, H_t^i) + [(1-\tau_{rNt}^j)(r_t^j - \delta_k) + \delta_k] S_t^{ij} - [(1-\tau_{rNt}^i)(r_t^i - \delta_k) + \delta_k] S_t^{ji}. \end{aligned} \tag{4'}$$

This modification does not affect the world resource constraint, though, because the net capital income from abroad in the two countries will cancel each other out in the summation.

Let us now consider the familiar concept of a non-cooperative Nash equilibrium in the global economy.[15] In such an equilibrium, equations (2), (3) and (4)' will hold together with the following:

[15] A *non-cooperative global taxed equilibrium* is a sequence of prices $\{w_t^i, r_t^i\}_{t=0}^{\infty}$ and allocations $\{c_t^i, n_t^i, e_t^i, \eta_t^i, S_{t+1}^{ii}, S_{t+1}^{ij}, h_{t+1}^i, N_{t+1}^i\}_{t=0}^{\infty}$ (i = A,B and j = B,A) such that given the policy paths $\{g_t^i, T_t^i, \tau_{wt}^i, \tau_{rDt}^i, \tau_{rNt}^i, \tau_{rFt}^i\}_{t=0}^{\infty}$ satisfying the government budget constraint,

(1) $\{K_{yt}^i, H_t^i\}$ maximize the firm's profits $F(K_{yt}^i, H_t^i) - r_t^i K_{yt}^i - w_t^i H_t^i$, given $\{w_t^i, r_t^i\}$ where $K_{yt}^i \equiv \eta_t^i S_t^{ii} + S_t^{ji}$ and $H_t^i \equiv N_t^i n_t^i h_t^i$;

(2) $\{c_t^i, n_t^i, e_t^i, \eta_t^i, S_{t+1}^{ii}, S_{t+1}^{ij}, h_{t+1}^i, N_{t+1}^i\}$ maximize the dynastic head's utility (1) subject to the budget constraint (6), the population growth equation (2), and the human capital accumulation equation (3), given $\{w_t^i, r_t^i\}$, S_0^i, h_0^i and N_0^i; and

(3) The labor markets ($n_t^{id} = n_t^{is}$), capital markets ($K_t^i = S_t^{ii} + S_t^{ji}$) and goods markets (i.e., the world resource constraint holds) all clear at the equilibrium wage rate w_t^i and interest rate r_t^i.

$$(1-\tau^i_{wt})F^i_{Ht}N^i_t h^i_t = \left(\frac{\Pi^i_{nt}}{\Pi(1-n^i_t-e^i_t)+(1-\delta_N)}\right)\left(\frac{\mu^i_{Nt}N^i_{t+1}}{\mu^i_{ct}}\right), \tag{7}$$

$$(1-\tau^i_{wt})F^i_{Ht}N^i_t h^i_t = \left(\frac{G^i_{Et}}{G(k^i_{ht}/h^i_t, e^i_t)+(1-\delta_h)}\right)\left(\frac{\mu^i_{ht}h^i_{t+1}}{\mu^i_{ct}}\right), \tag{8}$$

$$(1-\tau^i_{rDt})(F^i_{kt}-\delta_k)+\delta_k = \left(\frac{G^i_{kt}}{G(k^i_{ht}/h^i_t, e^i_t)+(1-\delta_h)}\right)\left(\frac{\mu^i_{ht}h^i_{t+1}}{\mu^i_{ct}}\right), \tag{9}$$

$$(1-\tau^i_{rDt+1})(F^i_{kt+1}-\delta_k) = \frac{\mu^i_{ct}}{\beta\mu^i_{ct+1}}-1 = (1-\tau^i_{rFt+1})(1-\tau^j_{rNt+1})(F^j_{kt+1}-\delta_k), \tag{10}$$

$$\begin{aligned}\sum_{t=0}^{\infty}\beta^t\mu^i_{ct}\Big\{(N^i_t c^i_t-T^i_t)+[1+(1-\tau^i_{rDt})(F^i_{kt}-\delta_k)]S^i_t-[(1-\tau^i_{rDt})(r^i_t-\delta_k)+\delta_k](1-\eta^i_t)S^{ii}_t \\ -(1-\tau^i_{wt})F^i_{Ht}H^i_t\Big\} = [1+(1-\tau^i_{rD0})(F^i_{k0}-\delta_k)]\mu^i_{c0}S^i_0,\end{aligned} \tag{11}$$

$\mu^i_N N^i_{t+1}$ and $\mu^i_{ht} h^i_{t+1}$ are the time-t utility values of population and human capital (quantity and quality of children) chosen for time-(t+1) respectively, and μ^i_{ct} is the marginal utility of individual consumption at date t; so that the ratios of the former to the latter represent the values of population and human capital in terms of consumption at date t. These shadow unit values can be expressed as follows:

$$\mu^i_{Nt}N^i_{t+1} = \sum_{s=t+1}^{\infty}\beta^{s-t}\Big\{\mu_{cs}[(1-\tau^i_{ws})F^i_{Hs}H^i_s-N^i_s c^i_s]-\mu^i_{hs}G^i_{ks}k^i_{hs}+N^i_s a_{Ns}U(c^i_s)\Big\},$$

$$\mu^i_{ht}h^i_{t+1} = \sum_{s=t+1}^{\infty}\Big\{\beta^{s-t}\varepsilon^i_{Es-t}\mu^i_{cs}(1-\tau^i_{ws})F^i_{Hs}H^i_s\Big\},$$

$$\mu^i_{ct} = a(N^i_t)U^i_{ct}/N^i_t,$$

where ε^i_E is the elasticity of human capital formation with respect to the schooling input. The transversality conditions require that the limiting values of $\mu_N^t N_{t+1}^t$ and $\mu_{h1}^t h_{t+1}^t$ be zero when appropriately discounted (by β^t).

Equations (7)–(10) are the marginal conditions that govern the agent's optimizing behavior–(7) for the work-'fertility' choice, (8) for the work-schooling choice, (9) for the choice of allocating capital between the output and education sectors, and (10) for the consumption-investment choice. From equation (7), a higher current wage tax will reduce the marginal benefit from work, and provide an incentive to devote more time to raising children. Higher wage taxes in the future will lower future family labor income from having a bigger family work force, and will thus have an opposite effect on the time allocation between work and child-rearing. The effects of the labor income tax on both child-rearing and schooling are not much clearer—while the current wage tax lowers the marginal cost of schooling in terms of forgone labor income, future taxes will also reduce the marginal benefit in terms of future (after-tax) labor income. Equation (8) implies that a progressive wage tax or a wage tax profile that rises through time will discourage both the child-rearing and schooling activities, while a time-invariant flat rate tax on labor income will have neutral effect on the allocation of time between work and schooling. Equation (9) shows how a higher tax on domestic-source capital income will induce people to substitute human capital formation for physical capital accumulation, whereas higher future wage taxes will lead to a substitution between the two forms of investment in the reverse direction. Unlike the case with physical capital, the depreciation of human capital is not commonly tax-deductible. This implies that an increase in the comprehensive income taxes (with uniform rates on both capital and labor incomes) will discriminate against human capital investment in favor of physical capital investment.[16] Equation (10) indicates that a higher tax on domestic-source capital income

[16] See Nerlove, et al. (1992).

or a higher tax levied either by the home or foreign government on the foreign-source capital income will induce the domestic people to invest abroad, but will attract capital from abroad if these taxes are lower. In addition to producing substitution effects at the various choice margins, these taxes also create negative wealth effects on consumption in all time periods. Evidently, the presence of these tax distortions implies that the world equilibrium allocation is not Pareto optimal.

Since we are interested in looking at steady state growth rates, it is important to impose some restrictions on preferences, technology, and the policy paths to guarantee the existence of a world taxed equilibrium balanced growth path. It is well-known that CRRA preferences and CRS technology are consistent with steady state growth. The fiscal budget equation implies, furthermore, that the distortionary tax rates $\{\tau^i_{wt}, \tau^i_{rDt}, \tau^i_{rNt}, \tau^i_{rPt}\}$ be constant and $\{G^i_t, T^i_t\}$ be growing at the same rate as GDP^i_t starting from some finite date. Under such restrictions, we can show that if both countries pick the same tax rates (zero rates being one special case), there will not be any incentive for capital to flow from one country to another except along the transition path. However, in the absence of adjustment costs, the period involving nonzero net capital flows will be extremely short, lasting for as long as it takes for physical capital to move across the national borders to equate the marginal productivities of capital (before and after taxes), hence the capital-effective labor ratio, in both places. From then on, both countries will move along their own (actually identical) transition paths individually, heading towards their (again identical) steady state growth paths, as if they were closed economies. No cross-border capital movement will occur in the case where the ratios of initial endowments of physical capital to total human capital $S^i_0/N^i_0h^i_0$ are the same in both countries (because then the two countries become identical in all respects). So what capital mobility does is to shorten the transition path for the capital-importing country, and lengthen the transition path for the capital-exporting country (unless they begin from an over-accumulation of physical capital situation, and have to unload capital along the transition path). Under our assumptions, cross-country differences in taxes therefore remain the key factor in explaining the direction of capital flows and growth rate differentials across countries. Below, we show the roles of capital mobility and international taxation in determining the long-run growth rate differential between the two countries.

Proposition 1: Capital Mobility and Long-Run Growth

If the steady state growth path exists with nonzero net capital flows, then the growth rates of (total, not per capita) GDP must be equal across countries.

Proof: Suppose not. In particular, suppose the GDP in country B is growing at a different rate than that in country A, and there is a net capital flow from B to A. For there to exist a balanced growth path in country B, the capital flowing out of B must be growing at the same rate as GDP^B. On the other hand, the same capital flowing into country A must also be growing at the same rate as GDP^A for A to be growing along the balanced growth path. The inequality of the GDP growth rates in A and B, however, precludes this double equality of the growth rate of net capital flow, hence the co-existence of balanced growth in both countries.[17]

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[17]More formally, consider the resource constraint facing country A with all the growing variables detrended by dividing the whole equation through by $N_t^A h_t^A$:

$$c^A + [(1+g_N^A)(1+g_h^A) - (1-\delta_k)]S^A + G^A = F(k_y^A, n^A) - [(1-\tau_{rN}^A)(r^A-\delta_k) + \delta_k]S^{BA}\left(\frac{N_t^B h_t^B}{N_t^A h_t^A}\right)$$

where the detrended variables are denoted by the same symbol without a time subscript, g_N^A and g_h^A are the steady state growth rates of population and human capital respectively in country A, $k_y^A \equiv K_{y,t}^A/N_t^A h_t^A$, and $S^{BA} \equiv S_t^{BA}/N_t^B h_t^B$. (The term involving S^{AB} is missing here because we assume capital flows from B to A net.) It turns out that the steady state growth rate of per capita GDP g_y^i is equal to g_h^i, so that the steady state growth rate of GDP is $g_Y^i = (1+g_N^i)(1+g_h^i)-1$. We can rewrite the last term as:

$$- [(1-\tau_{rN})(r^A-\delta_k) + \delta_k]S^{BA}\left(\frac{N^B h^B}{N^A h^A}\right)\left(\frac{(1+g_N^B)(1+g_h^B)}{(1+g_N^A)(1+g_h^A)}\right)^t$$

where $N^i \equiv N_t^i/(1+g_N^i)^t$ and $h \equiv h_t^i/(1+g_h^i)^t$ are the normalized steady state levels of population and human capital respectively in country i. Note that this term involves time t unless $(1+g_N^A)(1+g_h^A) = (1+g_N^B)(1+g_h^B)$, implying equality of the growth rates of GDP g_Y^i in A and B along the steady state growth path.

At first glance, this stringent restriction, together with the implied unidirectional flow of physical capital, may make it sound highly implausible. The unilateral net capital flow may seem to imply that all capital in the world will reside in only one country. This is certainly not true along the transition path, or else intertemporal external balance will be violated. (Recall that Proposition 1 is a steady state result. Capital flows in the reverse direction along the adjustment path will be required to maintain current/capital account balance intertemporally.) This cannot be true along the balanced growth path either, given the Inada conditions.

This steady state restriction implies that the diversity in the long-run per capita income growth rates must go hand in hand with the diversity in population growth rates. In particular, it implies the stylized fact that countries with lower population growth will enjoy faster growth in their per capita incomes.[18] Given the existence of capital market imperfections in the real world and the fact that countries are hit by shocks of various kinds from time to time, we should not expect this result to hold exactly. It suggests nonetheless that the cross-country variation in *total* income growth rates, averaged over long periods of time, should be smaller than that in *per capita* income growth rates. Using 1965-87 data for the 120 countries (excluding those with missing data) listed in Tables 1 and 26 of the 1989 World Development Report, we find that the coefficient of variation in the total growth rates [= 0.58 for $g_Y \equiv \ln((1+g_N)(1+g_y))$, and 1.28 for $g_Y \equiv (1+g_N)(1+g_y)-1$] indeed falls short of that in the per capita growth rates [= 1.35].

[18]Strictly speaking, what the data show is a negative correlation between population growth rates and the levels of per capita GDP. The correlation between the population growth rates and per capita income growth rates is more a question of demographic transition, and varies with the stage of development the countries are in. [See Ehrlich and Lui (1991) for a theory of the demographic transition linking longevity, fertility, and economic growth.] Actually, the negative correlation referred to in the text is observed only in the more advanced phase of development. This is not surprising because, as many people argue, *growth* models are not truly *development* models in the sense that they explain how DCs grow far better than how LDCs develop into DCs.

Proposition 1 indicates that, in the presence of free capital mobility, differences in tax policies can only affect long-term per capita income growth rates if they also affect the long-term population growth rates. Under some more specific assumptions, we can show the direct relation between taxes and these two growth rates under different international tax principles.

Proposition 2: International Taxation and Long-Run Growth

Suppose utility is isoelastic $U(c) = c^{1-\sigma}/(1-\sigma)$ and altruism is a constant elasticity function $a(N) = N^{\xi}$ with $\sigma > 0$ and $\xi \leq 1$, then

(a) $g_c^A = g_c^B$ *and* $g_N^A = g_N^B$ *if* $\xi \neq 1-\sigma$, *and* $(1+g_{Nt}^A)(1+g_{ct}^A) = (1+g_{Nt}^B)(1+g_{ct}^B)$ *for all* $t > 0$ *if* $\xi = 1-\sigma$, *irrespective of tax differences, when both countries adopt the source principle; and*

(b) $g_c^A \gtreqless g_c^B$ *and* $g_N^A \lesseqgtr g_N^B$ *as* $\tau_{rD}^A \lesseqgtr \tau_{rD}^B$ *if* $\xi > 1-\sigma$, $g_c^A \lesseqgtr g_c^B$ *and* $g_N^A \gtreqless g_N^B$ *as* $\tau_{rD}^A \lesseqgtr \tau_{rD}^B$ *if* $\xi < 1-\sigma$, *and* $(1+g_{Nt}^A)(1+g_{ct}^A) \gtreqless (1+g_{Nt}^B)(1+g_{ct}^B)$ *as* $\tau_{rD}^A \lesseqgtr \tau_{rD}^B$ *along the transition path, but* $\tau_{rD}^A = \tau_{rD}^B$ *so* $(1+g_N^A)(1+g_c^A) = (1+g_N^B)(1+g_c^B)$ *is required for the existence of balanced growth, if* $\xi = 1-\sigma$, *when both countries adopt the residence principle,*

where ξ is the constant elasticity parameter in the altruism function, σ is the inverse of the intertemporal elasticity of substitution in consumption, and g_c^i and g_N^i are the steady state growth rates of per capita consumption and population in country i respectively.

Proof: Applying the above functional forms for U(.) and a(.) to the intertemporal choice equation (10) for both countries, we have

$$\left(\frac{1+g_{Nt}^A}{1+g_{ct}^A}\right)^{1-\xi}\left(\frac{1+g_{Nt}^B}{1+g_{ct}^B}\right)^{\sigma} = \frac{1+(1-\tau_{rDt}^A)(F_{kt}^A-\delta_k)}{1+(1-\tau_{rPt}^B)(1-\tau_{rNt}^A)(F_{kt}^A-\delta_k)} \text{ for all } t>0.$$

We can simplify this expression further by noting that $\tau_{rPt}^i = 0$ and $\tau_{rNt}^i = \tau_{rDt}^i$ under the source principle, and $\tau_{rNt}^i = 0$ and $\tau_{rPt}^i = \tau_{rDt}^i$ under the residence principle. When considering the steady state growth path, we need only drop the time subscripts and impose the restriction $(1+g_N^A)(1+g_c^A) = (1+g_N^B)(1+g_c^B)$ from Proposition 1. The results should be transparent once we impose the parameter restriction for the various cases stated in the proposition.

To understand and interpret this proposition, recall that there is two engines of growth in our model: human capital and population. *Per capita* consumption growth is actually driven by the former engine, and *total* consumption growth by both. In fact, the rate of growth of per capita consumption and that of per capita income will both turn out to equal that of human capital along the balanced growth path. Now, suppose everything is the same in the two countries. All of a sudden, the home government decides unilaterally to raise the tax on domestic-source capital income permanently. This policy change is announced and fully understood by residents of both countries. As a consequence, investment in physical capital at home becomes less attractive. The question is whether the domestic agent will substitute into investment in (a) physical capital abroad, or (b) human capital (quality of children) at home, or (c) fertility (quantity of children) at home. The answer hinges on which international tax principle is adopted by both countries, and how much the agent cares about his own consumption (reflected by $1-\sigma$) relative to that of the total population (reflected by ξ). Under the residence principle, type (a) investment will be subject to the same residents's tax at home. The agent will therefore opt for type (b) investment if he is more selfish ($1-\sigma$ large relative to ξ), and type (c) investment if he is more altruistic (ξ large relative to $1-\sigma$). When he is 'justly altruistic' ($\xi = 1-\sigma$), the family can be viewed as one single person so that transferring consumption from one family member to another will not change the utility of any family member. In this case, they are indifferent between substituting into type (b) and type (c) investment, because all they care about is growth in total consumption. Under the source principle, type (a) investment will be undertaken to exploit the arbitrage opportunities created by different tax treatments of capital income in the two countries. The result is an equalization of the after-tax rates of return on capital across locations of investment. Although the equality in the rates of growth of per capita consumption and population preceding the tax change will be preserved, they will both be smaller under a higher tax rate.

IV. Tax Competition: Ramsey Equilibrium without Policy Coordination

We turn now to the design of national-welfare-maximizing policies. Under tax competition, each government will make its policy choice once-and-for-all at date zero. The policy rules are then announced and strictly adhered to. We assume a full commitment technology which prevents the two governments from deviating from their announced policies at a later date. This helps us dodge the problem of time consistency by eliminating the possibility of capital levy (and default on debt). Being functions of the announced policy rules, the private agents's decision rules will form constraints to the governments's optimization problems.

The Ramsey tax problem facing the country i government is to choose a time path of prices, allocations and tax rates to maximize the utility of its representative citizen subject to the individual agent's first order conditions and constraints plus the economy-wide resource constraint outlined in the previous section. Following Lucas and Stokey (1983) and Yuen (1991), we can substitute out some of the constraints and restate the problem as choosing a time path of allocations $\{c^i_t, n^i_t, e^i_t, \eta^i_t, S^{ji}_t, S^{ii}_{t+1}, S^{ij}_{t+1}, h^i_{t+1}, N^i_{t+1}\}^\infty_{t=0}$ and *pseudo* state variables $\{\mu^i_{ht}, \mu^i_{Nt}\}^\infty_{t=0}$—Lagrange multipliers ($\mu$ for 'mu'ltiplier) associated with h^i_{t+1} and N^i_{t+1} in the individual optimization problems—to solve the maximization problem below, given S^i_0, h^i_0 and N^i_0 and the policy paths chosen by the foreign government $\{G^j_t, T^j_t, \tau^j_{rDt}, \tau^j_{rFt}, \tau^j_{rNt}\}^\infty_{t=0}$ and the pre-tax rates of return on capital $\{r^j_t\}^\infty_{t=0}$ in the foreign country.[19, 20]

[19] We subsume the upper bounds on the capital tax rates here for simplicity. They are nonetheless required in proving Proposition 4 below. See Chamley (1986) for a discussion of the importance of these constraints in solving the dynamic Ramsey tax problem.

[20] Although it may sound weird, the capital flowing from country j to country i S^{ji}_t is truly a choice variable for the country i government in the sense that $K^i_t = S^{ii}_t + S^{ji}_t$ is, so knowing S^{ii}_t and S^{ji}_t is equivalent to knowing K^i_t and S^{ji}_t.

$$Max \quad \sum_{t=0}^{\infty} \beta^t a(N_t^i) U(c_t^i)$$

$$s.t. \begin{cases} \sum_{t=0}^{\infty} \beta^t \left\{ a(N_t^i) U_{ct}^i (c_t^i - T_t^i / N_t^i) + \mu_{ht}^i G((1-\eta_t^i) S_t^{ii}, e_t^i h_t^i) - \mu_{Nt}^i \Pi_{nt}^i (n_t^i + e_t^i) N_t^i \right\} = U_{c0}^i S_0^i, \\ \mu_{ht}^i = \beta \left\{ \mu_{ht+1}^i G_{Et+1}^i (n_{t+1}^i + e_{t+1}^i) + (1-\delta_k) \right\}, \\ \mu_{Nt}^i = \beta \left\{ \mu_{Nt+1}^i [\Pi_{nt+1}^i + \Pi(1 - n_{t+1}^i - e_{t+1}^i) + (1-\delta_N)] - \mu_{ht+1}^i G_{kt+1}^i (1-\eta_{t+1}^i) S_{t+1}^{ii} / (N_{t+1}^i)^2 \right. \\ \quad \left. + [a'(N_{t+1}^i) U(c_{t+1}^i) - a(N_{t+1}^i) U_{ct+1}^i c_{t+1}^i / N_{t+1}^i] \right\}, \\ h_{t+1}^i = G((1-\eta_t^i) S_t^{ii}, e_t^i h_t^i) + (1-\delta_k) h_t^i, \\ N_t^i c_t^i + (S_{t+1}^{ii} + S_{t+1}^{ij}) + G_t^i = F(\eta_t^i S_t^{ii} + S_t^{ji}, N_t^i n_t^i h_t^i) + (1-\delta_k)(S_t^{ii} + S_t^{ij}) \\ \quad + [(1-\tau_{rNt}^j)(r_t^j - \delta_k) + \delta_k] S_t^{ij} - [(1-\tau_{rDt}^j)(r_t^j - \delta_k)/(1-\tau_{rFt}^j) + \delta_k] S_t^{ji}. \end{cases}$$

In general, the first order conditions of this maximization problem are excessively complicated and we can get little intuition out of them. In order to obtain the qualitative results reported below, however, it suffices to consider a subset of first order conditions concerning the choice of η_t^i, S_{t+1}^{ii}, S_{t+1}^{ij} and S_t^{ji} only:

$$\phi_{kt}^i = \beta \phi_{kt+1}^i [1 + (F_{kt+1}^i - \delta_k)], \tag{12}$$

$$\phi_{kt}^i = \beta \phi_{kt+1}^i [1 + (1-\tau_{rNt+1}^j)(r_{t+1}^j - \delta_k)], \tag{13}$$

$$F_{kt}^i - \delta_k = \left(\frac{1-\tau_{rDt}^j}{1-\tau_{rFt}^j} \right) (r_t^j - \delta_k) \tag{14}$$

where (12) is derived from the first order conditions with respect to η_t^i and S_{t+1}^{ii}, and ϕ_{kt}^i is the multiplier associated with the resource constraint.

Proposition 3: Ramsey-efficient International Income Tax Principle

(a) The residence principle is Ramsey-efficient; and

(b) Investment is efficiently allocated across the world along the Ramsey path (i.e.,

production efficiency).[21]

Proof: (a) The no-arbitrage condition (10) and (14) imply that $F^i_{kt}-\delta_k = (1-\tau^i_{rNt})(r^i_t-\delta_k)$. Matching this with the profit-maximizing condition yields $\tau^i_{rNt} = 0$ for all $t \geq 0$, i.e., the *residence* principle. (b) (12) and (13) imply that $F^j_{kt}-\delta_k = (1-\tau^j_{rNt})(r^j_t-\delta_k)$. Since the result in (a) holds true for both countries ($\tau^j_{rNt} = 0$), this condition together with the profit-maximizing condition imply efficient allocation of investment (or production efficiency) across the world, i.e., $F^A_{kt} = F^B_{kt}$ for all $t \geq 0$.

Under the residence principle, unless both countries pick the same capital income tax rates, their after-tax rates of return on capital will be different. From equation (10), this means diversity in their intertemporal marginal rates of substitution in consumption, hence inefficiency in the international allocation of world savings. Next, let us turn to the optimal dynamic capital income tax paths under this principle.

Proposition 4: Optimal Capital Income Taxation under Tax Competition

Optimal capital income taxation with $\tau^i_{rt} = \tau^i_{rDt} = \tau^i_{rFt}$ (i.e., equal treatment of domestic-source and foreign-source capital income) under the residence principle:

(a) *Initial period: The optimal tax on initial savings is maximal except when the marginal excess tax burden $\Phi^i = 0$ or initial savings $S^i_0 = 0$;*

(b) *Steady state growth path [Chamley's theorem]: If there exists a stable Ramsey balanced growth path, then the optimal tax on capital income will be zero as the economy converges to this path; and*

(c) *Dynamic path: If preferences are isoelastic in consumption, lump-sum transfers per capita are either zero or turn out to be proportional to consumption in equilibrium, and $\xi = 1-\sigma$, then the optimal policy will be to tax capital at the maximum rate for a finite number of periods and leave capital untaxed thereafter.*

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[21] This result applies to any factor input that is internationally mobile (i.e., it holds also for the labor income tax if labor is the mobile factor.) In fact, the credit-based residence principle is the dominant tax principle for industrialized countries, for individuals as well as corporations. See Frenkel, Razin and Sadka (1991), Table 2.1.

Proof: The structures of the proofs of (a) and (c) follow closely those in a closed economy.[22] As for (b), it can easily be shown that the private and social marginal utilities of consumption (μ_t and ϕ_t) will fall at the same rate along the balanced growth path under isoelastic utility. Pairing up the intertemporal conditions (10) and (12) and invoking Proposition 3, we get $\tau_{rt}^i = \tau_{rDt}^i = \tau_{rFt}^i = 0$ in both countries in the steady state.

This result was first proved in the neoclassical growth model by Chamley (1986), and later reaffirmed in several versions of endogenous growth models by Lucas (1990a), Yuen (1991) and Jones, Manuelli and Rossi (1991). Note that it applies to both countries, and can therefore be regarded as a further extension of Chamley (1986), in conjunction with Proposition 3, to an endogenously growing open economy with capital mobility.

Without characterizing the optimal labor income tax, one may wonder whether Proposition 4 should carry over to human capital. Since both human and physical capital are means to transfer consumption over time, should they be taxed in the same way? To resolve this puzzle, it is important to understand how capital and labor incomes—returns to investment in physical and human capital respectively—are derived. Any physical capital carried forward from the previous period will be inelastically supplied (under no arbitrage) irrespective of the location of investment; this is why taxing old capital is non-distortionary. But the same is not true for human capital. To obtain income from one's human capital, one has to apply his knowledge and skills to work. (In our model, a lazy worker will never be rich, however knowledgeable he is!) Although 'old' human capital (h_t^i) is also in inelastic supply, work effort (n_t^i) is not. An exorbitant tax on labor income will discourage the supply of *effective* labor. So Propositions 4(a) and 4(c) do not hold for human capital. What about

[22]See Yuen (1991), and Chamley (1986) for its continuous time analogue. Note that, in Chamley's original setup, people value leisure. With labor supply being the only alternative use of time in his model, the labor income tax will become essentially a lump-sum tax so the first best will be achievable if leisure is not in the utility function. Dropping leisure from the utility function will not have the same implications in our setup since there is three alternative uses of time: work, schooling, and child-rearing. Making people value leisure will only introduce an additional choice margin which the labor income tax can distort. Except for Proposition 4(c), which requires that consumption and leisure be additively separable, all other qualitative results in this paper will hold all the same.

Proposition 4(b)? This has more to do with the special symmetry (balanced growth) restriction on consumption growth and time allocations. The capital taxes will distort the intertemporal choice, leading to a heavier tax on later consumption than earlier consumption despite their symmetric contribution to utility. But as long as the wage tax is constant, the intratemporal (work-'fertility' and work-schooling) choices will be distorted in the same way across periods, leaving the time allocations unchanged. As a result, capital income taxes have to be zeroed out along the steady state growth path, but the labor income tax does not.

Due to the problem of the under-reporting of foreign-source income, both the source and residence principles coexist in the real world. It is therefore also interesting to examine what policies will be optimal if both countries somehow choose to adopt the Ramsey-inefficient source principle (i.e., optimal choice of tax rates under sub-optimal international tax principle).

Proposition 5: Optimal Capital Income Taxation under the Source Principle
If both countries are restricted to adopt the source principle, then taxation on capital income from both domestic and foreign sources will be abolished completely.

Proof: When both countries adopt the *source* principle (which is not Ramsey-efficient according to Proposition 3), $\tau^i_{rRt} \equiv 0$ and $\tau^i_{rt} = \tau^i_{rDt} = \tau^i_{rNt}$. (14) then becomes $F^i_{kt} - \delta_k = (1-\tau^i_{rt})(r^i_t - \delta_k)$, implying $\tau^i_{rt} = 0$ for all $t \geq 0$ by the marginal productivity conditions.

Under free capital mobility and without coordination between the two fiscal authorities, capital will always flow towards the low-tax country. Tax competition implies that each government will try to lower its capital tax rate in order to prevent capital from leaving the country and/or to attract capital from abroad. Such capital flight possibility generated by tax differences will therefore force both governments to abstain entirely from taxing non-residents's capital income originating from the home country. Since the government levies the same tax rate on the capital incomes of both residents and non-residents under the source principle, even the domestic-source capital income will be tax-exempted. The result is a shift of the entire tax burden to the immobile factor—labor. In cases where labor income is not taxable (say, because the government does not want to discourage human capital investment), we can show that imposing capital control so as to restore the taxation of domestic-source capital income is optimal.[23]

As the source principle is a growth-equalizing force and so is the residence principle when the capital income tax rates are equal across countries, Propositions 2–5 imply the following.

Corollary: Convergence in Growth Rates under Ramsey Equilibrium
Optimal uncoordinated tax policies are growth-equalizing in the long-run.

In face of the growing integration of the world economy in general and the European Community in particular, globalization of policy making is undoubtedly of practical interest. Although this lies outside the scope of our paper, let us just note in passing that, under international coordination, Proposition 4 and the Corollary above will continue to hold whichever tax principle both countries choose to follow. With policy coordination, Chamley's steady state result still applies, but it is no longer necessary for the capital tax to be abolished completely along the whole Ramsey path when both countries adopt the *source* principle because they can then enforce taxes on foreign-source capital incomes.

V. Conclusion

The objective of our paper has been to examine the role of capital mobility and international taxation in explaining the observed diversity of long-term growth rates. Our

[23] The proof can be constructed along similar lines as Razin and Sadka (1991).

major finding is that, under capital mobility, international differences in taxes will not matter for *total* growth differential. Policy differences have a role to play in *per capita* growth differentials, however, when they lead to a divergence in the after-tax rates of return on capital across countries, as when the residence principle is adopted universally. When this is the case, how tax differences affect the growth rates of population and human capital (or per capita consumption or income, for that matter) will depend on the relative preference of the individual household towards these two engines of growth. The other major finding is that optimal tax policies are growth-equalizing in the long-run under both tax competition and tax harmonization, and irrespective of which international income tax principle is adopted. We choose to formulate our model in somewhat more general ways than necessary to show that these results are in fact robust, and to better capture the true aspects of the real world as an analytical benchmark for our calibration and simulation exercises.[24]

Our theoretical results do not give us a clue as to how likely *convergence* in long-term growth rates is. But since they suggest that the source principle is more like a growth-equalizing force, we can turn to the real world for an answer. Casual observations indicate that the residence principle is much more popular among countries. As a plausible solution to the *problem of development*, this is good news. In this paper, we only single out two key factors for analysis. In the context of our model, perhaps population control measures (common in less developed countries) can also make a difference. In a multiple-good world, protectionist policy differences can potentially play no less an important role than budgetary policy differences. Relaxing our simplifying assumptions (such as perfect capital market,

[24]We plan to calibrate our model to, say, the G7 countries over a long period by casting them into a "two-country world" setup: US versus the rest. Assuming that the fundamental (preference and technology) parameters remain the same across global tax and capital mobility regimes, we can simulate the effects of different tax structures and various restrictions on capital flows on cross-country long-term growth rates and welfare in terms of compensating variation in consumption growth. These experiments could help determine the relative importance of fiscal policies versus capital controls for explaining growth differentials.

unanimous adoption of one single international tax principle, and our simple and symmetric tax structure that treats different forms of capital investment as identical) offers some more possible sources of diversity in growth rates.

On the other hand, we have the Chamley-type bang-bang solutions which imply long-run *convergence*. In practice, we do not see such policy adopted because, as Yuen (1991) points out, the time inconsistent and dynastic nature plus the costs of implementing this time-varying tax system make it almost impracticable. The more practical time-invariant optimal policies he considers can probably be non-growth-equalizing if optimal tax rates are country-specific (because of, say, different initial debts outstanding).

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