OPTIMAL INTERNATIONAL TAXATION AND GROWTH RATE CONVERGENCE: TAX COMPETITION VS. COORDINATION *

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ABSTRACT

Optimal international taxation and its implications for convergence in long run income growth rates are analyzed in the context of an endogenously growing world economy with perfect capital mobility. Under tax competition, (i) the residence principle will maximize national welfare; (ii) the optimal long run tax rate on capital incomes from various sources will be zero in all countries; and (iii) long term per capita income growth rates will be equalized across countries. Under tax coordination, (i) becomes irrelevant while (ii) and (iii) will continue to hold. In other words, optimal tax policies are growth-equalizing with and without international policy coordination.

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I. Introduction

Accounting for the observed diversity in levels and rates of growth of per capita incomes across countries))as posed by Lucas (1988) as the *problem of economic development*))has occupied a large part of the recent growth literature. Investigating cross-country data, Baumol (1986) argues that there has been convergence in long run productivity levels among developed countries since 1870. Using a much more extensive dataset, however, Baumol and Wolff (1988) conclude that although levels of income across high-income countries seem to have converged, mid-income countries exhibit only moderate convergence and low-income countries divergence. Indeed, Ben-David (1994) finds that the group of wealthy countries is characterized by "upward convergence", where the poor members catch up with the richer members in the group; the group of extremely poor countries exhibits "downward convergence", where the richer members dwindle down to join the poor members in the group. One of the reasons for the divergence lies in adoption of different national tax policies by different countries. This tax-driven growth divergence hypothesis has been extensively examined both theoretically (see, e.g., Rebelo (1992) and Razin and Yuen (1996)) and empirically (see, e.g., Easterly and Rebelo (1993)).

On the other hand, the issue of optimal taxation has occupied a large part of the public finance literature. It draws heavily on the classic work of Diamond and Mirrlees (1971), who establish the remarkable aggregate production efficiency theorem))the backbone of this literature until today. This theorem has been applied repeatedly to the theory of international taxation, and helped to develop a ranking between the major international tax (residence vs. source) principles. (See Razin and Sadka (1991a).) Somewhat parallelly, addressing the issue of capital income taxation for a growing economy, Judd (1995) and Chamley (1996) show that it is not efficient to tax capital income in the steady state when capital has essentially a perfect elastic supply. Chamley (1996) shows, in addition, that it is efficient to tax capital income quite heavily during the transition to the steady state while the supply of capital is inelastic. Both lines of the optimal tax literature have not been linked, however, to the issue of international growth convergence. The purpose of our paper is to provide such a missing link.

We extend the analysis of optimal taxation to endogenously growing economies. Comparison is made between an international tax competition regime and an international tax coordination regime, focusing on the superiority of the residence vs. the source principle and on the long run tax rates on different sources of capital incomes. The implications of the two optimal tax regimes for growth rate convergence across countries with different initial per capita incomes are explored. Two growth engines are involved in our convergence analysis: human capital and population. This model with bi-engines of growth is important for accounting for long-run differences in total and per capita income growth rates across countries. (See, e.g., Razin and Yuen, 1996, 1997a, 1997b.)[1, 2]

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[1] 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. 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).

[2] Other than its empirical relevance, another motivation for introducing endogenous population is technical. As shown in Frenkel, Razin, and Yuen (1996, Chapter 15), in the presence of tax asymmetry, steady state growth will generally not exist in the world economy when population grows exogenously. On the one hand, the balanced growth restriction requires that *gross* income growth rates be equalized in the long run across countries connected by capital mobility. On the other hand, the marginal condition for intertemporal consumption (see equation (8) below) allows for cross-country variation in *per capita* income growth rates in response to differences in national tax rates. To reconcile these two possibilities, we cannot allow population growth to be arbitrarily and exogenously determined. We emphasize here, though, that none of the results in this paper hinges on this endogenous population feature. It is assumed merely to guarantee logical consistency in our analysis.

The paper is organized as follows. Section II lays out the analytical growth framework, and Section III the tax framework. Our 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 growth rate convergence. Section V extends the analysis in Section IV to international tax policy coordination. Section VI concludes. All the technical derivations and proofs of the main propositions are relegated to the Appendix.

II. The Analytical Framework

Let us begin with a brief description of the basic features of our model, adapted from Razin and Yuen (1996). We use the simple representative household framework with two kinds of capital goods in each country: human capital 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 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 thus potentially subject to double taxation by more than one national tax authorities. As in the real world, tax policies are assumed to be uncoordinated internationally (although tax coordination will be examined briefly as well). We also assume that population growth is endogenously determined through altruistic motives, which are constrained by the time costs of raising children.

Similar to Razin and Yuen (1996), our simplifying perfect foresight model is based on the Uzawa (1965)-Razin (1972)-Lucas (1988,1990)-type human capital growth framework augmented with endogenous population and international mobility of physical capital. Population, human capital, and physical capital are the (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 multi-country dynastic world, where each country i (i = 1,2,...,M) is populated by N_t^i identical agents at each date t. Following the growth-based endogenous fertility analysis of Razin and Ben-Zion (1975) and Becker and Barro (1988), we assume that the representative agent cares about his/her own consumption (c_t^i) as well as the population at large (N_t^i). For simiplicity, preferences of the dynastic head of the representative family in country i are assumed

$$\sum_{t=0}^{\infty} b^t \left(N_t^i \right)^x \left[\frac{(c_t^i)^{1-s}}{1-s} \right],$$

to be isoelastic:

where β is the subjective discount factor, ξ an altruism parameter, and σ the inverse of the intertemporal elasticity of substitution in consuption.[3]

To avoid the vintage capital problem, we suppose 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

[3] As long as ξ > 0, altruism is reflected not only in preference for 'quantity', but also quality (as measured by their living standard in terms of consumption per capita), of children) since, with positive ξ, there is weight given to quantity, but the weight on the consumption term is also magnified. Observe that, if ξ > 1−σ, then there will be a relative bias in preference towards quantity; whereas, if ξ < 1−σ, then the bias will be in the opposite direction. See Razin and Yuen (1995) for the Millian (average utilitarianism) and Benthamite (classical utilitarianism) interpretations

from date t−1, at each date t ≥ 1 (given S_0/N_0 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.[4] We denote the stock of physical capital invested abroad in country j by S_t^j, and that at home by S_t^i (i,j = 1,2,...,M and j ≠ i), then $S_t \equiv S_t^i + \sum_{j\neq i} S_t^j$ is the total savings accumulated from time t−1. Concerning the unit endowment of time, a fraction n_t is allocated to producing final output, e_t (e for education) to accumulating human capital (say, through schooling), and $1-n_t-e_t \equiv v_t$ (v for vitality) to rearing children.

In every period t, $\Pi(v_t)N_t$ people are born and $\delta_N N_t$ people pass away. In the absence of

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

cross-border migration, the size of population in the following period is given by,

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.[5]

New knowledge and skills are 'produced' with existing human capital h_t and schooling time e_t. $\delta_h h_t$ disappears at each date t through death, obsolescence, illness, or memory loss. The human capital of each agent thus evolves according to:

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of this function and their implications for the tradeoff between population growth and income growth.

[4] Perfect substitutability between physical and financial capital implies that there is no nontrivial distinction between foreign direct investment and foreign portfolio investment, especially given our assumption that production technology is common across countries. 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. See Gordon and Jun (1993) for an empirical examination, and Razin, Sadka, and Yuen (1998) for a theoretical examination, of these issues.

[5] A more correct interpretation of v_t 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 through an increasing and convex function _(.). We can then think of $\Pi(.)$ as an inverse function of_(.). For convenience, we shall continue to label v_t as child-rearing time.

$$h^i_{t+1} \ = \ H(e^i_t)\,h^i_t \ + \ (1-d_h)\,h^i_t$$

where the human capital production function H(.) is increasing and concave in the educational input, with H(0) = 0, and δ_h is the rate of depreciation of human capital.

There is one single malleable consumption good produced with physical capital K^i_t and effective labor $H^i_t \equiv n^i_t N^i_t h^i_t$ via a standard constant returns to scale production function F(.), satisfying the Inada conditions. 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., $K^i_t = S^{ii}_t + \sum_{j\neq i} S^{ji}_t$. Since capital can flow in either direction, GNP^i_t equals GDP^i_t plus net capital income from abroad, i.e., $F(K^i_t,H^i_t) + \sum_{j\neq i}(r^j_t S^{ij}_t - r^i_t S^{ji}_t)$ where r^i_t is the rate of return on capital in country i. Part of this income G^i_t 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 consumption $N^i_t c^i_t$ or accumulation of

$$N^i_t c^i_t \ + \ S^i_{t+1} \ - (1-d_k)S^i_t \ + \ G^i_t \ = \ F(K^i_t, H^i_t) \ + \ \sum_{jnei}(r^j_t S^{ij}_t \ - \ r^i_t S^{ji}_t),$$

physical capital $I^i_t = S^i_{t+1} - (1-\delta_k)S^i_t$. Country i's resource constraint can therefore be written as:

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 all M countries to get the total

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

world resource constraint:

where $C_t = \sum_{i=1}^{M} N_t^i c_t^i$, $S_t = \sum_{i=1}^{M} S_t^i$, $G_t = \sum_{i=1}^{M} G_t^i$, and $Y_t = \sum_{i=1}^{M} F(K_t^i, H_t^i)$.

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) among the M 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 initial endowment of human capital h_0^i and physical capital S_0^i owned by the 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 among the M countries—mutually beneficial.

III. World Equilibrium with International Taxation

Suppose each national government can levy four kinds of taxes (on labor income, domestic residents' domestic-source and foreign-source capital incomes, and non-residents' capital income) and issue one-period debt to finance its exogenous streams of spending and transfers in

$$G_t^i + T_t^i - [B_{t+1}^i - (1 + r_{Bt}^i) B_t^i]$$
$$= \tau_{wt}^i w_t^i H_t^i + (r_t^i - \delta_k)(\tau_{rDt}^i S_t^{ii} + \tau_{rNt}^i \sum_{j \neq i} S_t^{ji}) + \sum_{j \neq i} (\tau_{rFt}^i - \alpha_t^i \tau_{rNt}^j)(r_t^j - \delta_k) S_t^{ij},$$

each period. We can write the time-t fiscal budget constraint in country i as:

where T_t^i = lump-sum transfer payments,

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

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

τ_{rFt}^i = tax rate on the domestic residents' foreign-source net capital income $\sum_{j \neq i}(r_t^j - \delta_k) S_t^{ij}$,

τ^i_{rNt} = tax rate on the non-residents' net capital income $\sum_{j\neq i}(r^i_t - \delta_k)S^{ji}_t$,

a^i_t = domestic credit rate on the non-resident taxes paid by the domestic residents to the foreign government $\sum_{j\neq i}\tau^j_{rNt}(r^j_t - \delta_k)S^{ij}_t$,

B^i_t = public debt issued at time t−1 and maturing at time t, and

r^i_{Bt} = interest rate on the debt B^i_t.

The tax and credit rates τ^i_{wt}, τ^i_{rDt}, τ^i_{rFt}, τ^i_{rNt}, and a^i_t are linear, but not necessarily time-invariant.[6] To facilitate our discussion below, we denote the effective tax rate on foreign investment paid by investors from country i to both the i and j governments by $\tau^i_{rEt} = \tau^i_{rFt} + (1-a^i_t)\tau^j_{rNt}$. For simplicity, the tax paid to the i[th] government $(\tau^i_{rFt} - a^i_t\tau^j_{rNt})$ is assumed to be non-negative.[7]

We suppose that each country acts as a small open economy, taking the pre-tax rates of return on capital in the foreign countries as given. As in the real world, tax policies are assumed to be uncoordinated internationally, so each government has to take the tax policies of the other governments as given while designing its own policies. We shall first discuss the private agents' optimization problems and the world equilibrium, and leave the analysis of the optimal policy choices of the M national governments to the next section.

In our world economy, the household-producer runs a representative firm in his own country, renting capital K^i_t at the given rental rate r^i_t from the domestic capital market and hiring labor H^i_t from the domestic labor market at the going wage rate w^i_t to produce output $F(K^i_t, H^i_t)$.

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6 In present value terms, the government budget constraint (6) can be expressed as:

$$\sum_{t=0}^{\infty} d^i_t \Big\{ \tau^i_{wt} w^i_t H^i_t + (r^i_t - \delta_k)(\tau^i_{rDt} S^{ii}_t + \tau^i_{rNt} \textstyle\sum_{j\neq i} S^{ji}_t) + \sum_{j\neq i}(\tau^i_{rFt} - a^i_t \tau^j_{rNt})(r^j_t - \delta_k) S^{ij}_t - (G^i_t + T^i_t) \Big\} = B^i_0,$$

where $d^i_t \equiv \prod^t_{s=0}(1+r^i_{Bs})^{-1}$ with r^i_{Bt} equal to $(1-\tau^i_{rDt})(r^i_t - \delta_k)+\delta_k$ by no-arbitrage.

7 Here, we assume the more popular *credit* system. Under the alternative *deduction* system, non-resident taxes on capital income paid by the home residents to the foreign governments are deducted from their foreign-source capital income tax base in the home country. This can be represented by a multiplicative specification of double taxation $(1-\tau^i_{rFt})\sum_{j\neq i}(1-\tau^j_{rNt})(r^j_t - \delta_k)$ on foreign-source capital incomes. The reader can easily verify that all the qualitative results in this paper apply to the deduction system as well.

(Firms are therefore purely production units. As explained below, investment decisions are carried out at the household level.) $r_t^i K_t^i$ is paid out as rental cost, and $w_t^i H_t^i$ as labor cost. By the linear homogeneity of F(.) in K and H and the familiar profit-maximizing conditions, profit of the firm ($\equiv F(K_t^i, H_t^i) - r_t^i K_t^i - w_t^i H_t^i$) 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, $[(1-\tau_{rDt}^i)(r_t^i-\delta_k)+\delta_k]S_t^{ii}/N_t^i$ of domestic-source after-tax capital income, $\sum_{j\neq i}[(1-\tau_{rEt}^i)\bullet(r_t^j-\delta_k)+\delta_k]S_t^{ij}/N_t^i$ of after-tax foreign-source capital income, gets back $(1-\delta_k)S_t^i/N_t^i$ of undepreciated capital from various 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 whatever remains in the form of physical capital $[S_{t+1}^i-(1-\delta_k)S_t^i]/N_t^i$ and government bonds $[B_{t+1}^i-(1+r_{Bt}^i)B_t^i]/N_t^i$. Division of the latter into investment at home S^{ii}/N^i and investment abroad $\sum_{j\neq i}S^{ij}/N^i$ is as explained in the previous section. Thus, the family budget constraint is:

$$N_t^i c_t^i + S_{t+1}^i + B_{t+1}^i = (1-\tau_{wt}^i)w_t^i H_t^i + [(1-\tau_{rDt}^i)(r_t^i-\delta_k)+\delta_k]S_t^{ii} + \sum_{j\neq i}[(1-\tau_{rEt}^i)(r_t^j-\delta_k)+\delta_k]S_t^{ij} + (1-\delta_k)S_t^i + (1+r_{Bt}^i)B_t^i + T_t^i.$$

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' income, equation (4) has to be revised as follows:

$$N_t^i c_t^i + S_{t+1}^i - (1-\delta_k) S_t^i + G_t^i$$
$$= F(K_t^i, H_t^i) + \sum_{j \neq i} [(1-\tau_{rNt}^j)(r_t^j - \delta_k) + \delta_k] S_t^{ij} - [(1-\tau_{rNt}^i)(r_t^i - \delta_k) + \delta_k] \sum_{j \neq i} S_t^{ji} .$$

This modification does not affect the world resource constraint (5), 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 world equilibrium. A *world taxed equilibrium* is a sequence of prices $\{w_t^i, r_t^i\}_{t=0}$ and allocations $\{c_t^i, n_t^i, e_t^i, S_{t+1}^i, S_{t+1}^{ij}, h_{t+1}^i, N_{t+1}^i\}_{t=0}$ (i =1,2,...,M; j ≠ i) such that given the policy paths $\{G_t^i, T_t^i, B_t^i, \tau_{wt}^i, \tau_{rDt}^i, \tau_{rNt}^i, \tau_{rNt}^j, \tau_{rFt}^i, a_t^i\}_{t=0}$ satisfying the government budget constraint,

(i) $\{K_t^{di}, H_t^{di}\}$ maximize the firm's profits $F(K_t^{di}, H_t^{di}) - r_t^i K_t^{di} - w_t^i H_t^{di}$, given $\{w_t^i, r_t^i\}$;

(ii) $\{c_t^i, n_t^i, e_t^i, S_{t+1}^i, S_{t+1}^{ij}, h_{t+1}^i, N_{t+1}^i\}$ maximize the dynastic head's utility (1) subject to the family budget constraint (7), the population growth equation (2), and the human capital accumulation equation (3), given $\{w_t^i, r_t^i, r_t^j\}$, S_0^i, h_0^i and N_0^i; and

(iii) The labor markets ($H_t^{di} = H_t^i \equiv n_t^i N_t^i h_t^i$), capital markets ($K_t^{di} = S_t^i + \sum_{j \neq i} S_t^{ji}$), bond markets ($B_t^{di} = B_t^i$), 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.

The set of first order conditions describing the optimizing behavior of the households and firms are laid out in the Appendix. Here, we shall focus only on a condition that is crucial in determining the tax-growth relation between any two countries (say, A and B) linked by capital mobility, viz., the intertemporal conditions governing the choice of investment at home and abroad (see equations (C4) and (C5) in the Appendix):

$$\left(\frac{1+g^A_{Nt}}{1+g^B_{Nt}}\right)^{1-x}\left(\frac{1+g^A_{ct}}{1+g^B_{ct}}\right)^{s} = \frac{1+(1-t^A_{rDt})(F^A_{kt}-d_k)}{1+[1-t^B_{rFt}-(1-a^B_t)t^A_{rNt}](F^A_{kt}-d_k)} \text{ for all } t > 0,$$

where g_x denotes the growth rate of any variable x (x = N,c here). Along the *balanced* growth path, per capita consumption in each country (c^i) will grow at the same rate as its per capita output ($y^i = Y^i/N^i$), i.e., $g_{c^i} = g_{y^i}$.[8] Moreover, as we show elsewhere (Razin and Yuen (1996)), aggregate output in the two countries will also grow at the same rate, i.e., $g_{Y^A} = g_{Y^B}$.[9] Imposing these steady state restrictions while noting that $1+g_Y = (1+g_N)(1+g_y)$, we can rewrite the above

$$\left(\frac{1+g^A_{y}}{1+g^B_{y}}\right)^{x-(1-s)} = \frac{1+(1-t^A_{rD})(F^A_{k}-d_k)}{1+[1-t^B_{rF}-(1-a^B)t^A_{rN}](F^A_{k}-d_k)}.$$

equation as:

Equation (8)' suggests that whether long term income growth rates converge across countries depends on the tax rates, which depend in turn on the choice of international tax principle (i.e., how foreign-source capital incomes are taxed by the home and foreign governments individually), and the relative preference bias towards the 'quality' and 'quantity' of children. We

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[8] Since we are interested in looking at steady state growth rates, we have 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, as we assume earlier, are consistent with steady state growth. The fiscal budget equation implies, furthermore, that the distortionary tax and credit rates $\{\tau^i_{wt}, \tau^i_{rDt}, \tau^i_{rNt}, \tau^i_{rFt}, \alpha^i_t\}$ be constant and $\{G^i_t, T^i_t, B^i_t\}$ be growing at the same rate as GDP^i starting from some finite date.

[9] This is due to the balanced growth restriction that the net capital flows between the two countries must grow at the same rate as their respective GDPs. It implies, *inter alia*, that countries with lower population growth will enjoy faster growth in their per capita incomes. See Razin and Yuen (1997) for supportive evidence on this and other related empirical implications. In a multi-country world, it is possible for aggregate output growth to diverge across blocs of countries that are not interconnected by capital mobility (i.e., when net capital flows exist only among countries within each bloc, but not across blocs). But within each bloc (where capital mobility is effectively at work), this total income growth equalization result will still apply, and it is around this scenario that our analysis is built.

consider two polar principles with a wide application, viz., the *source* (of income) or *territorial* principle and the *residence* (of taxpayer) or *worldwide* principle.[10] When both countries adopt the source principle, $\tau^i_F = a^i = 0$ or $\tau^i_F = a^i \tau^j_N$ and $\tau^i_N = \tau^i_D$ (implying $\tau^i_E = \tau^j_D$, $i = A,B$ and $j = B,A$) so that $g^A_y = g^B_y$ for $\xi \neq 1-\sigma$. When they both adopt the residence principle, $\tau^i_N = 0$ and $\tau^i_F = \tau^i_D$ (a^i irrelevant, implying $\tau^i_E = \tau^i_D$) so that $g^A_y > (<) \; g^B_y$ as $\tau^A_D < (>) \; \tau^B_D$ for $\xi > 1-\sigma$ and $g^A_y < (>) \; g^B_y$ as $\tau^A_D < (>) \; \tau^B_D$ for $\xi < 1-\sigma$.[11] In other words, the source principle is growth-equalizing while the residence principle is generally growth-diverging. These tax-growth relations have been shown and elaborated in greater details by Razin and Yuen (1996) in a slightly different framework. We review them briefly here so as to facilitate our discussion below regarding the

[10] In terms of Mintz and Tulkens' (1996) taxonomy of alternative systems of foreign income taxation, the two polar systems are the *pure* residence-based and *pure* source-based systems. According to the residence principle, residents are taxed on their worldwide income uniformly, regardless of the source of income (domestic or foreign), while non-residents 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 non-residents are taxed equally as residents on income originating in the country. 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.

[11] Recall that there are two engines of output 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. Suppose, initially, 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' 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 lower under a higher tax rate.

implications of optimal international taxation for growth rate convergence.

IV. Tax Competition: Optimal International Taxation without Policy Coordination

We now turn to an analysis of the role of capital mobility for the design of national-welfare-maximizing policies. Under tax competition, each government will make its policy choice once-and-for-all at date zero, taking the policy choices of the other $M-1$ governments as given. The policy rules are then announced and strictly adhered to. We assume a full commitment technology which prevents these 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' decision rules will form constraints to the governments' optimization problems.

The optimal non-cooperative 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 (i.e., national welfare) subject to the individual agent's first order conditions and constraints, the economy-wide resource constraint, and the policy choices of the other $M-1$ governments. We set up the problem formally and prove the following propositions in the Appendix. Our first proposition concerns the choice of nationally efficient international tax principle.

Proposition 1: Optimality of the Residence Principle and Investment Efficiency

(a) *The residence principle maximizes national welfare; and*

(b) *Investment is efficiently allocated across the world along the optimal growth path (i.e., production efficiency).*[12]

[12] In fact, this result applies to any factor input that is internationally mobile (i.e., it holds also for the labor

These results are straightforward extensions of fairly standard results in simple two-period worlds (see, e.g., Razin and Sadka, 1991a). Note that non-residents are not taxed when the residence principle is adopted, so that the distinction between the credit and deduction systems becomes irrelevant. As a corollary, we show formally in the Appendix that the deduction system is just as optimal as the credit system.

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. This implies, however, diversity in their intertemporal marginal rates of substitution in consumption, hence inefficiency in the international allocation of world savings. From equation (8), it also implies growth rate divergence unless $\tau^A_D = \tau^B_D$. In order to see whether long run growth rates will diverge under tax competition, let us now turn to determine the optimal capital income tax rates under the residence principle (with equal treatment of domestic-source and foreign-source capital income, i.e., $\tau^i_t = \tau^i_{Dt} = \tau^i_{Ft}$).

Proposition 2: Optimal Long Run Capital Income Taxation under Tax Competition[13]

If there exists a stable world balanced growth path, then the optimal tax on capital income will be zero as the economies converge to this path.

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income tax if labor is the mobile factor) .

[13] As in a closed economy, we can also show the following. In the initial period, the optimal tax on initial capital is maximal except when either the marginal excess tax burdens or initial savings ($S_0 = B_0$) are zero. Along the transition path, if lump-sum transfers per capita are either zero or turn out to be proportional to consumption in equilibrium, then the optimal policy will be to tax capital at the maximum rate for a finite number of periods and leave capital untaxed thereafter. See Chamley (1986) for a proof in a continuous time setup, and Yuen (1991) in discrete time.

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. As a result, capital income taxes have to be zeroed out along the balanced growth path. This result was first proved in the neoclassical growth model by Chamley (1986) and Judd (1985), and later reaffirmed in several versions of endogenous growth models by Lucas (1990), Yuen (1991), and Jones, Manuelli and Rossi (1993,1997). Note that it applies to all countries, and can therefore be regarded as a further extension of Chamley-Judd, in conjunction with Proposition 1, to an endogenously growing open economy with capital mobility.[14]

Since the capital income tax rates are eliminated in all countries under tax competition in the long run, the rates of return on capital (both before and after taxes) will be equalized across countries. As a result, they will all enjoy the same income growth rates. In other words, tax competition implies growth rate convergence.

Efficient Taxation under an Inefficient International Tax Principle

The above results are derived by assuming that the governments are free to choose whatever tax principles and tax rates that they find welfare-maximizing and that these policies can easily be implemented. Due to the problem of the under-reporting of foreign-source income, however, the pure residence principle is difficult to enforce in practice. For this reason, countries in the real world also resort to source-based taxation. It is therefore interesting to examine what

[14] As Jones, Manuelli, and Rossi (1997) and Milesi-Ferretti and Roubini (1996) show, since human and physical capital are alternative means of transferring consumption from the present to the future, the labor income taxes will create similar intertemporal distortions and should similarly be abolished in the long run. We do not examine the optimal tax on human capital here as the issue of growth rate convergence (the main issue we address in this paper) does not hinge on the level of such tax.

policies will be optimal if the countries somehow have to adopt the inefficient source principle.

Proposition 3: Optimal Capital Income Taxation under the Source Principle
If all countries are restricted to adopt the source principle, then taxation on capital income from both domestic and foreign sources will be abolished completely.

Under free capital mobility and without coordination among the M 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 tax-driven capital flight possibility will therefore force both governments to abstain entirely from taxing non-residents' 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 pure 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—here, 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.[15] Note that, unlike Proposition 2 (which is purely a long-run result), these arguments apply to the entire dynamic growth path and not merely the steady state.

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 1–3 imply the following.

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

Corollary: Convergence in Long Run Growth Rates under Tax Competition

Optimal uncoordinated tax policies are growth-equalizing in the long-run.[16]

[16] In fact, equation (8) also suggests that, under the source principle, aggregate consumption growth will be equalized across countries at all times (and not just in the long run)) i.e., $(1+g^{i}_{N_t})(1+g^{i}_{c_t}) = (1+g^{j}_{N_t})(1+g^{j}_{c_t})$ for all $t > 0$) if $\xi = 1-\sigma$.

V. Optimal International Taxation with Policy Coordination

In face of the growing integration of the world economy in general and the European Union in particular, globalization of policy making is undoubtedly of practical interest. Under international coordination, the M governments will jointly choose prices, allocations, and tax rates so as to maximize global welfare (i.e., weighted sum of national welfare across countries) subject to all the first order conditions, constraints, and market clearing conditions in all M countries under the world taxed equilibrium. We show in the Appendix that marginal productivities of capital will be equalized across countries (i.e., production/investment efficiency) along the entire dynamic growth path. This would require either total elimination of all capital taxes or identical tax rates on capital incomes across countries. The former is not feasible if taxes on labor incomes alone (plus the initial government assets, if any) in each country are not sufficient to finance the government expenditures. The latter then implies that it is immaterial which international income tax principle (source or residence, or some mixture) these countries will choose to adopt under coordination.

Although it is infeasible to fully abolish all capital taxes at all times, it may be optimal to do it some of the time. Along the long run balanced growth path, in particular, Proposition 2 will carry over. (This Chamley-like result is shown in the Appendix as Proposition 4.) From equation (8)', it is obvious that the abolition of capital income taxes along the balanced growth path implies growth rate convergence under the cooperative equilibrium as well.

Corollary: Convergence in Long Run Growth Rates under Tax Coordination

Optimal coordinated tax policies are also growth-equalizing in the long run.

VI. Conclusion

The objective of our paper has been to examine the implications of capital mobility and international taxation for convergence/divergence in long term growth rates when capital tax rates are optimally chosen by the national governments either in isolation or in cooperation with one another. Our main finding is that optimal tax policies are growth-equalizing in the long run under both tax competition and tax coordination.

In this paper, we focus only on the long run. But as we noted in passing, the dynamic patterns of such policies would generally involve levying fairly high tax rates and accumulating budget surpluses at the beginning and declining tax rates over time. In practice, we do not see such policy adopted because, as Yuen (1991) points out, the dynastic and possibly time inconsistent nature plus the implementation costs of this time-varying tax scheme make it almost impracticable. The more practical time-invariant tax policies he considers can probably be non-growth-equalizing under tax competition))when the residence principle is efficient))if optimal tax rates turn out to be country-specific (due to, say, different government revenue requirements and initial debts outstanding). But since the source principle is growth-equalizing even when tax rates are different across countries, tax coordination in the restrictive sense of mutually agreeing to taxing capital incomes only at source will continue to induce growth rate convergence.

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APPENDIX

A.I First Order Conditions in the Global Taxed Equilibrium

In the global taxed equilibrium, equations (2), (3), (7), and (4)' will hold together with the following first order conditions for the consumer's problem with respect to c^i_t, n^i_t, e^i_t, S^i_{t+1}, S^j_{t+1}, B^i_{t+1}, h^i_{t+1}, and N^i_{t+1} respectively:

$$(N^i_t)^{x-1}(c^i_t)^{-s} = m^i_t,$$

$$m^i_t(1-t^i_{wt})w^i_t h^i_t = m^i_{Nt}\Pi^i_{vt},$$

$$m^i_{ht}G^i_{et}h^i_t = m^i_{Nt}\Pi^i_{vt}N^i_t,$$

$$m^i_t = b\,m^i_{t+1}[1+(1-t^i_{rDt+1})(r^i_{t+1}-d_k)],$$

$$m^i_t = b\,m^i_{t+1}\{1+[1-t^i_{rFt+1}-(1-a^i_{t+1})t^j_{rNt+1}](r^j_{t+1}-d_k)\},$$

$$m^i_t = b\,m^i_{t+1}(1+r^i_{Bt+1}),$$

$$m^i_{ht} = b\{ m^i_{ht+1}[G(e^i_{t+1}) + (1-d_h)] + m^i_{t+1}(1-t^i_{wt+1}) w^i_{t+1} n^i_{t+1} N^i_{t+1} \},$$

$$m^i_{Nt} = b\Big\{ m^i_{Nt+1}[\Pi(v^i_{t+1}) + (1-d_N)] + m^i_{t+1}[(1-t^i_{wt+1}) w^i_{t+1} n^i_{t+1} h^i_{t+1} - c^i_{t+1}] + \left(\frac{x}{1-s}\right)(N^i_{t+1})^{x-1}(c^i_{t+1})^{1-s} \Big\},$$

where μ^i_t, μ^i_{Nt}, and μ^i_{ht} are the time-t Lagrange multipliers associated with the consumer's budget constraint (7) and the laws of motion of human capital and population (2) and (3) respectively. The factor prices are given by the usual marginal productivity conditions from the firm's profit-maximization problem, i.e., $w^i_t = F^i_{Ht}$ and $r^i_t = F^i_{kt}$.

Observe that (C4), (C5), and (C6) imply the no-arbitrage condition that after-tax returns

$$(1-t^i_{rDt})(r^i_t - d_k) = [1 - t^i_{rFt} - (1-a^i_t)t^j_{rNt}](r^j_t - d_k) \equiv \bar{r}^i_t = r^i_{Bt}.$$

on capital be equalized across locations of investment for any investor, i.e.,
For sure, after-tax rates of return on capital need not also be equalized across investors in different countries. This rate-of-return arbitrage condition (A1) may also fail in the case of corner solutions, where all of the capital moves from a high-tax country to a low-tax country. These extreme (but empirically irrelevant) possibilities are nonetheless ruled out by the Inada conditions we have assumed for the production technology. In particular, since the rate of return (or marginal product) of capital will become infinitely high when capital flees the high-tax country, 100% capital flight will not occur. We can therefore safely invoke this rate-of-return equalization condition to prove some of the propositions below.

A.II National Efficiency

The optimal tax problem facing the country i government is to choose a sequence of prices $\{w^i_t, r^i_t\}_{t=0}$ (including the shadow prices $\{\mu^i_t, \mu^i_{ht}, \mu^i_{Nt}\}_{t=0}$), allocations $\{c^i_t, n^i_t, e^i_t, S^{ji}_t, S^{ii}_{t+1}, S^{ij}_{t+1}, h^i_{t+1}, N^i_{t+1}\}_{t=0}$, and tax rates and bond issues $\{\tau^i_{rDt}, \tau^i_{rFt}, \tau^i_{rNt}, a^i_t, B^i_{t+1}\}_{t=0}$ to maximize the utility of its representative citizen (national welfare) subject to the agent's first order conditions (C1)–(C8) and constraints (2), (3), and (7) plus the economy-wide resource constraint (4)', given the initial conditions (S^i_0, h^i_0, N^i_0, B^i_0), exogenous spending streams $\{G^i_t, T^i_t\}_{t=0}$, the policy paths chosen by the foreign government $\{G^j_t, T^j_t, B^j_t, \tau^j_{rDt}, \tau^j_{rFt}, \tau^j_{rNt}\}_{t=0}$, and the pre-tax rates of return on capital $\{r_t^j\}_{t=0}^{\infty}$ in the foreign country.[17, 18]

Following Lucas and Stokey (1983) and Yuen (1991), we can eliminate some of the constraints by substitution. In particular, we can combine (C2) and (C3) and substitute the result

$$m^i_{ht} \;=\; b\, m^i_{ht+1}\,[G(e^i_{t+1}) + G^i_{et+1}\, n^i_{t+1} + (1 - d_h)].$$

into (C7) to get

$$m^i_{Nt} \;=\; b\left\{ m^i_{Nt+1}\,[\,\Pi(v^i_{t+1}) + \Pi^i_{vt+1}\, n^i_{t+1} + (1 - d_N)] + \left(\frac{x}{1-s} - 1\right)(N^i_{t+1})^{x-1}(c^i_{t+1})^{1-s}\right\}.$$

Similarly, plug (C1) and (C2) into (C8) to obtain
Applying (C4) and (C5) to (7) recursively and using (C2) and (C3), we can derive the following

$$\sum_{t=0}^{\infty} b^t\,[(N^i_t)^x (c^i_t)^{-s}(c^i_t - T^i_t / N^i_t) \;-\; m^i_{ht} H^i_{et}\, n^i_t h^i_t] \;=\; (N^i_0)^{x-1}(c^i_0)^{-s}(1 + \bar{r}^i_0) S^i_0,$$

present value implementability constraint:
where $\bar{r}^i_0$ is the after-tax net rate of return on domestic capital in country i. Finally, we can

$$N^i_t c^i_t \;+\; S^i_{t+1} \;-\; (1 - d_k) S^i_t \;+\; G^i_t = F(K^i_t, H^i_t)$$
$$+\;\sum_{j\neq i}\left\{[(1 - t^j_{rNt})(r^j_t - d_k) + d_k]\, S^{ij}_t \;-\; [(1 - t^i_{rNt})(1 - t^j_{rDt})(r^j_t - d_k)/(1 - t^j_{rEt}) + d_k]\, S^{ji}_t\right\}.$$

employ the no-arbitrage condition (A1) to rewrite (4)' as

The country i government's problem can now be reduced to one of maximizing (1) subject to (2), (3), (4)'', (7)', (C7)', and (C8)' by choice of allocations $\{c^i_t, n^i_t, e^i_t, S^{ji}_t, S^i_{t+1}, S^{ij}_{t+1}, h^i_{t+1}, N^i_{t+1}\}_{t=0}^{\infty}$, the tax rate $\{\tau^i_{rNt}\}_{t=0}^{\infty}$, and *pseudo* state variables $\{\mu^i_{ht}, \mu^i_{Nt}\}_{t=0}^{\infty}$, given the tax rates $\{\tau^j_{rDt}, \tau^j_{rEt}, \tau^j_{rNt}\}_{t=0}^{\infty}$, and interest rates $\{r^j_t\}_{t=0}^{\infty}$, in the rest of the world (i.e., for j ≠ i). After solving for the optimal values of these variables, the optimal tax rates can be backed out as follows: τ^i_{wt} from (C2), τ^i_{rDt} from (C4), and τ^i_{rEt} from (C5).[19] In principle, given τ^j_{rNt}, many different combinations

[17] We subsume the upper bounds on the capital tax rates here for simplicity. See Chamley (1986) and Yuen (1991) for a discussion of the importance of these constraints in solving the dynamic Ramsey tax problem.

[18] 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 $K^i_t = S^{ii}_t + \sum_{j\neq i} S^{ji}_t$ is, so knowing S^{ii}_t and S^{ji}_t is equivalent to knowing K^i_t and S^{ji}_t.

[19] As in Lucas and Stokey (1983), the optimal tax solution obtained indirectly by choosing allocations (the

of τ^i_{Ft} and a ^{i} can yield the same τ^i_{Et}. The corollary following Proposition 1 below shows, however, that there exists a unique optimal combination of the two rates, while Proposition 1 shows how the optimal tax on non-residents (τ^i_{Nt}) is determined.

The first order conditions of this maximization problem are excessively complicated. In order to obtain the qualitative results reported in the paper, however, it suffices to consider a

$$f^i_{kt} \;=\; b\, f^i_{kt+1}\,[1+(F^i_{kt+1}-d_k)],$$

$$f^i_{kt} \;=\; b\, f^i_{kt+1}\,[1+(1-t^j_{rNt+1})(r^j_{t+1}-d_k)],\ and$$

$$F^i_{kt}-d_k \;=\; \left(\frac{(1-t^i_{rNt})(1-t^j_{rDt})}{1-t^j_{rEt}}\right)(r^j_t-d_k),$$

subset of first order conditions concerning the choice of S^i_{t+1}, $S^i_{jt+1,}$ and S^i_j only:
where ϕ^i_{kt} is the multiplier associated with the resource constraint (4)".

Proof of Proposition 1: Optimality of the Residence Principle and Investment Efficiency

(a) Equation (A4) together with the no-arbitrage condition (A1) imply that $F^i_{kt}-\delta_k = (1-\tau^i_{Nt})(r^i-\delta_k)$. Matching this with the profit-maximizing condition (i.e., $r^i = F^i_{kt}$) yields $\tau^i_{Nt} = 0$ for all $t \geq 0$, i.e., the *residence* principle.

(b) Equations (A2) and (A3) imply that $F^i_{kt} - \delta_k = (1 - \tau^j_{Nt})(r^j - \delta_k)$. Since the result in (a) holds true for both countries ($\tau^j_{Nt} = 0$), this condition together with the profit-maximizing condition (i.e., $r^j = F^j_{kt}$) imply efficient allocation of investment (or production efficiency) across the world, i.e., $F^i_{kt} = F^j_{kt}$ for all $t \geq 0$ and $i \neq j$.

Proof of Corollary: Optimality of the Deduction System

The first order condition with respect to τ^i_{Nt} implies that $\tau^j_{Ft} = a^j$, implying in turn that $1-\tau^j_{Et} = (1-\tau^j_{Ft})(1-\tau^i_{Nt})$ for all j = 1, 2, ..., M. With the credit rate set equal to the tax rate on foreign-source income, there is no essential difference between the credit system and the deduction system. In fact, the redundancy of the distinction between the two systems can also be inferred from the optimality of the pure residence principle obtained under Proposition 1.

Proof of Proposition 2: Optimal Capital Income Taxation under Tax Competition

Along the balanced growth path, both the private and social marginal utilities of consumption will fall at the same rate (i.e., $\mu^i_{t+1}/\mu^i = \phi^i_{kt+1}/\phi^i_{kt}$). Pairing up the intertemporal conditions (C4) and (A2), we get $\tau^i_D = 0$ in the steady state. Applying this result to the no-arbitrage condition (A1)

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so-called primal approach) should be identical to that obtained directly by choosing tax rates. Here, the primal problem is complicated by the inclusion of *pseudo* state variables. But the back-of-the-envelope method of calculating optimal tax rates from these state variables and allocations that we have just described suggests that the same logic applies to our analysis as well. Our problem is entirely different in nature from the possibility of obtaining different solutions when countries play Nash in tax rates as they play Nash in government expenditure levels.

and invoking Proposition 1, we have $\tau^{i}_{F} = 0$ as well. In other words, it is optimal to eliminate all capital taxes in the steady state.

Proof of Proposition 3: Optimal Capital Income Taxation under the Source Principle
When both countries adopt the source principle (which is not national-welfare-maximizing according to Proposition 1), $\tau^{i}_{Ft} = a^{i} = 0$ and $\tau^{i}_{Nt} = \tau^{i}_{Dt} \equiv \tau^{i}_{t}$ so that $\tau^{i}_{Et} = \tau^{j}_{Nt}$. Substituting these conditions into (A4) and (A1), we have $F^{i}_{kt} - \delta_k = (1-\tau^{j}_{Dt})(r^{j}_{t} - \delta_k) = (1-\tau^{i}_{Nt})(r^{i}_{t} - \delta_k)$. The marginal productivity condition (i.e., $r^{i}_{t} = F^{i}_{kt}$) then implies that $\tau^{i}_{t} = 0$ for all $t \geq 0$.

A.III Global Efficiency

If the governments of the M countries cooperate in choosing their tax policies so as to maximize global efficiency, the (reduced) problem becomes one of maximizing global welfare

$$\sum_{i=1}^{M} \sum_{t=0}^{\infty} b^{t}\, l^{i}_{t} (N^{i}_{t})^{x} \left[\frac{(c^{i}_{t})^{1-s}}{1-s} \right],$$

(i.e., the weighted sum of national welfare
(where λ^{i}_{t} is the relative weight attached to country i in period t and $\sum_{i=1}^{M} \lambda^{i}_{t} = 1$ for all t) subject to the equilibrium conditions in all countries (i.e., (2^i), (3^i), (4^i)'', (7^i)', ($C8^i$)' for i = 1,2,...,M and the world resource constraint (5)) by choice of allocations $\{c^{i}_{t}, n^{i}_{t}, e^{i}_{t}, S^{i}_{jt}, S^{i}_{it+1}, S^{i}_{jt+1}, h^{i}_{t+1}, N^{i}_{t+1}\}_{t=0}^{\infty}$ and *pseudo* state variables $\{\mu^{i}_{ht}, \mu^{i}_{Nt}\}_{t=0}^{\infty}$. The first order conditions for this problem

$$f_{kt} = b f_{kt+1} [F^{i}_{kt+1} + (1-d_k)].$$

with respect to S^{i}_{it+1} is:

$$f_{kt} = b f_{kt+1} [F^{j}_{kt+1} + (1-d_k)].$$

and that with respect to S^{i}_{jt+1} is:
Due to symmetry, the first order conditions with respect to S^{j}_{jt+1} and S^{j}_{it+1} are given by similar equations with the superscripts i and j interchanged. Obviously, (A5) and (A6) together imply equalization of pre-tax rates of returns ($F^{i}_{k} = F^{j}_{k}$), hence production efficiency, over time.
Proof of Proposition 4: Optimal Capital Income Taxation under Tax Coordination
Along the balanced growth path, ϕ_{kt} will grow at the same rate as μ^{i}_{t}. Thus, direct comparison of (A5) with (C4) and (A6) with (C5) yields $\tau^{i}_{D} = 0$ and $\tau^{i}_{E} = 0$ (or $\tau^{i}_{F} + \tau^{j}_{N} = a^{i}\tau^{j}_{N}$, i.e., the domestic tax credit fully offsets the total tax levied on foreign-source incomes by both the domestic and foreign governments) respectively.

Proof of Proposition 5: Optimality of Capital Control under the Source Principle

Under capital control, after-tax net returns on capital need not be equalized across locations of investment for any given investor, i.e., $\underline{r}^i \neq \underline{r}^j$. In this case, the implementability constraint will

$$\sum_{t=0}^{\infty} b^t \left\{ (N_t^i)^x (c_t^i)^{-s} \, [c_t^i - T_t^i / N_t^i + \sum_{jnei} (\bar{r}_t^i - \bar{r}_t^j) S_t^{ij}] \; - \; m_{ht}^i H_{et}^i n_t^i h_t^i \right\} \; = \; (N_0^i)^{x-1} (c_0^i)^{-s} (1 + \bar{r}_0^i) S_0^i .$$

have to be rewritten as:

$$f_{kt}^i \;=\; b\, f_{kt+1}^i [1 + (1 - t_{rNt+1}^j)(r_{t+1}^j - d_k)] \;+\; b\, \Phi^i m_{ct+1}^i \sum_{jnei} (\bar{r}_{t+1}^i - \bar{r}_{t+1}^j).$$

As a result, the first order condition with respect to S^{ij}_{t+1} becomes

We shall try to prove the proposition by contradiction. Suppose there does not exist capital control so that $\underline{r}^i = \underline{r}^j$, then (A2) and (A3)' imply that