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International Taxation and Endogenous Growth

Lucas (1988) posed the *problem of economic development* as the problem of accounting for *"… the observed pattern, across countries and across time, in levels and rates of growth of per capita income …"*. Assuming symmetry in preferences and technology across countries, the growth literature has been successful in explaining income *level* differences in terms of asymmetry in initial factor endowments (as a transitory short run phenomenon in exogenous growth models and as a sustainable long run phenomenon in endogenous growth models). The explanation of growth *rate* differences is a much harder challenge—especially in exogenous growth models, where the natural growth rate is an unalterable given. In the context of recent models of endogenous growth, one explanation that has been widely explored lies in differences in national (especially tax) policies.[1] Such asymmetry can generate differential effects on the private agents' incentives to invest in growth-enhancing activities and hence the rates of productivity growth in different countries.[2]

With the increasing global integration of the world economy, factor mobility opens a room for cross-border spillovers of policy effects, with policy changes in one country exerting an impact on resource allocation and growth in another country through changes in factor price differentials. In this chapter, we examine whether the tax-driven diversity in income growth rates can be preserved when (a) factors of production are freely mobile across national borders, and (b) the factor incomes earned in the foreign country are potentially subject to double taxation by both the home and foreign governments and are thus affected by both domestic and foreign tax policies. In particular, is international income taxation a growth-diverging force? How do factor mobility and cross country tax structures interact to determine growth differentials?

15.1 Tax-Driven Divergence in a Closed Economy

Consider the closed economy endogenous growth model of Chapter 13. Suppose now that there is a fiscal authority that levies flat rate taxes on labor income (τ_{wt}) and capital income (τ_{rt}). We allow for tax-deductibility of depreciation expenses for physical capital ($\tau_{rt}\delta_k K_t$) and, possibly, human capital ($\phi\tau_{wt}\delta_h e_t N_t h_t$, with $\phi = 1$ if deductible and $\phi = 0$ otherwise) as well. If depreciation of human capital is tax-deductible and if income taxation is comprehensive and uniform so that the tax rates on labor and capital incomes are equal, the tax treatment of the two forms of capital becomes symmetric. As usual, in order to focus on the distortionary effects of taxation, we assume that the tax proceeds are rebated in a lump-sum fashion to the households. The consumer budget constraint, the counterpart of (13.2), is given by

$$\begin{aligned} & N_t c_t + [K_{t+1} - (1-\delta_k)K_t] - [B_{t+1} - (1+r_t)B_t] - T_t \\ & \Omega_{wt} w_t (1-e_t) N_t h_t + \phi\tau_{wt}\delta_h w_t N_t h_t + \Omega_{rt} r_{kt} K_t + \tau_{rt}\delta_k K \end{aligned} \quad (15.1)$$

where T_t is the lump-sum rebate, and the tax wedges are defined as $\Omega_{rt} = 1-\tau_{rt}$ and $\Omega_{wt} = 1-\tau_{wt}$.

The optimization problem facing the household is to choose $\{c_t, e_t, K_{t+1}, h_{t+1}, B_{t+1}\}_{t=0}^{\infty}$ to maximize utility (12.1) subject to the human capital accumulation equation (13.1) and the budget constraint (15.1), given $\{w_t, r_t, \tau_{wt}, \tau_{rt}\}_{t=0}^{\infty}$.

Following similar steps in Appendix A of Chapter 13, we can derive the following steady state equation in the time allocated to education (e).

$$1+g_h)^{1-F}(1+g_N)\left\{1+(\left(\frac{1-e}{e}\right)\left(\frac{g_h+*_h}{1+g_h}\right)\left[1+N*_h\left(\frac{J_w}{S_w}\right)\left(\frac{}{1}\right.\right.\right. \qquad (15.2)$$

$$where \quad g_h = Be^{(-*}{}_h .$$

Given the solution for e from (15.2), the ratio of the stocks of physical capital to human capital $\tilde{k}$ (= K/Nh) can be solved from

$$(1+g_h)^F = \$\left\{1+S_r\left[(1-")A\left(\frac{\tilde{k}}{1-e}\right)^{-"} -*_k\right]\right\}. \qquad (15.3)$$

Direct inspection of (15.2) reveals that the intertemporal (capital) tax wedge (Ω_r) has no effect on the allocation of time between work and education, hence growth rates, in the steady state. The source of this neutrality lies in the fact that, in our model, there are no other time-consuming activities (such as leisure) and physical capital is not required for the production of human capital.

In the absence of depreciation allowance for human capital ($\phi = 0$), the intratemporal (labor) tax wedge (Ω_w) will have no effect on long run time allocation (hence, growth rate) either. This can be understood from Boskin's (1975) argument that increase in the *constant* tax rate on labor income along the balanced growth path will reduce both the returns (in terms of future wage earnings) and costs (in terms of forgone earnings) of investment in human capital equally at the margin.[3] When depreciation of human capital is tax-deductible ($\phi = 1$), however, the reduction in returns in terms of future wage earnings due to the wage tax are exactly offset by this allowance. Thus, since only the costs in terms of income forgone are reduced, the labor income tax is no longer neutral.

In reality, tax-deductibility of depreciation of human capital does not exist in the exact form as modelled here, but can be viewed as mimicking the effects of two common provisions of taxation: tax progressivity and subsidized health care.[4] This is proxied by $0 < \phi < 1$ in our model. On the other hand, our simplified setup has abstracted from modelling other time-consuming activities such as leisure or child-rearing (a driving force behind population growth), and the use of physical capital as an input in the production of human capital. Adding these features to our model will strengthen the effects of the labor income tax on the growth rate of human capital (and population) and introduce a channel through which the capital income tax may affect the growth rate as well.

In our model, countries with similar preferences and technology but different labor income tax rates will have different long run growth rates. Differences in capital income tax rates, however, will not lead to divergence in growth rates.

15.2 Tax Divergence in an Open Economy: Capital Mobility

We now integrate our economy into the world capital market. We continue to assume that tax rates are different across countries. If the residence principle of international taxation is adopted universally, then (as shown in Chapter 14) the pre-tax marginal products of physical capital will be equalized across countries. The after-tax marginal products will differ, however, if the capital income tax rates vary across countries. The interest-equalization arbitrage-based relation $(1-\tau_{rD})r = (1-\tau_{rA}-\tau^*_{rN})r^*$ can be viewed as an additional condition (relative to the autarky case) in the set of world equilibrium conditions. Since the other equilibrium conditions remain the same as in the closed economy, the analogue of the time equation (15.2) indicates that the steady state growth rate of human capital also remains unchanged. This implies that countries with different (the same) labor income tax rates will grow at different (the same) rates [Implication 1].

If net capital flows are non-zero in the long run, the size of this flow can, in principle, be determined from the arbitrage-based condition. However, in the steady state, these flows should grow at the same rate as the outputs in both the home country and the rest of the world. Thus, if they exhibit identical (exogenous) rates of growth of population (as we have been assuming so far), they must also have the same growth rates in human capital (or consumption). But, this contradicts Implication 1, implying that either the steady state is non-existent or capital flows are zero.

Suppose, then, that net capital flows are zero in the steady state. In the absence of barriers to capital flows, the arbitrage-based condition will continue to hold even when no capital flows exist in equilibrium. From (15.3), we can write

$$\left(\frac{1+g_y}{1+g_y^*}\right)^{F} = \frac{1+(1-J_{rD})(r_k-*_k)}{1+(1-J^*_{rA}-J_{rN})(r_k-*_k)}\,. \tag{15.4}$$

As explained in Chapter 14, the residence principle implies that $\tau_{rN} = 0$ and $\tau^*_{rA} = \tau^*_{rD}$. This implies that g_y and g^*_y are different (equal) as long as $\tau_{rD} \neq (=)\ \tau^*_{rD}$, thus ruling out zero capital flow as a steady state equilibrium phenomenon from Implication 1 (unless the two countries have strong similarities across the two tax bases). As a result, a steady state will not exist, in general, in the presence of tax differences. In other words, capital mobility will drive countries off the world steady state growth path.[5]

To restore the possibility of a steady state, we introduce an additional source of growth which, similar to human capital, involves time-consuming activities: endogenous population growth.

Given the close connection between population growth and economic growth in the development process and as a broadening of the definition of the *problem of development*, we shall devote equal emphasis to accounting for the observed diversity in the growth of (per capita and aggregate) income as well as population. When population growth is determined exogenously, taxes can only affect income growth through the growth engine (say, human capital), with indistinguishable effects on the growth of per capita income and aggregate income. Endogenizing population growth will introduce a new channel through which taxes can affect per capita income growth and aggregate income growth differently.

For the above reasons, we think that it is important to examine the interaction between taxation and (population and income) growth in the presence of factor mobility. To accomplish this, we need to extend the model in three dimensions: preferences for the quantity and quality of children, the time constraint, and the law of motion of population.

Consider the home country as a dynastic family with N_t identical members in each period ($t = 0,1,2,\ldots$) and two engines of growth (human capital and population). The typical household cares about his/her own consumption c_t and the other family members N_t. His/her preferences are given by:

$$\sum_{t=0}^{\infty} \$^{t} N_t^{>} \left(\frac{c_t^{1-F}}{1-F} \right) \qquad (15.5)$$

where $\xi \in (0,1)$ an altruism parameter.[6] As long as $\xi > 0$, altruism is reflected not only in preference for `quantity' but also `quality' of children (viz., consumption per capita, or standard of living)—since, with positive ξ, there is weight given to quantity, but the weight on the consumption term is magnified as well. Observe that if $\xi > 1-\sigma$, then there will be a relative bias in preference towards quantity; whereas if $\xi < 1-\sigma$, the bias will be in the opposite direction. When $\xi = 1-\sigma$, the representative agent is said to be `fairly altruistic' in the sense that he cares only about the size of the total pie ($N_t c_t$) to be shared among all family members, but is indifferent to the exact sharing arrangement.

In each period t, there are N_t members in the representative family (given N_0 at $t=0$). As before, each household member is endowed with one unit of non-leisure time in each period t. But instead of splitting it between work and education, he/she can now divide the unit time among three time-consuming activities: work (n_t for number of work hours), learning in schools (e_t for education), and child-rearing (v_t for vitality). The child-rearing activity gives rise to population growth:

$$N_{t+1} = D(v_t^{\alpha})N_t + (1-\delta_N)N_t, \qquad (15.6)$$

where $D > 0$ and $\alpha \in (0,1]$ are the fertility efficiency coefficient and productivity parameter respectively. One can think of N_{t+1}/N_t as one plus the number of children per family (when the number of parents is normalized to unity). Since the child-rearing cost (v) is increasing with the number of children, Dv^{α} can be thought of as the inverse function of this cost-quantity relation. This completes the description of the new elements of the model.

The Role of Capital Mobility in Growth Rate Convergence

As in Chapter 12, under free capital mobility, the law of diminishing returns implies that capital will move from capital-rich (low marginal product of capital, henceforth, MPK) countries to capital-poor (high MPK) countries. Over time, such cross-border capital flows will equalize the MPKs (pre-tax or post-tax, depending on the international tax principle) prevailing in all countries. In the long run, an empirically relevant steady state world equilibrium will involve positive net capital flows from some countries to some other countries.

Without further restrictions, two other situations are possible in the long-run: (a) all capital in the world resides in one single country; and (b) no cross-border capital flows (i.e., back to autarky). Both are unrealistic cases. We make sufficient assumptions to eliminate them even as theoretical possibilities. Case (a) will not occur if the MPK becomes infinitely high when the capital remaining in any capital-exporting country gets sufficiently small (i.e., the Inada conditions can rule out this corner solution). Case (b) will not occur as long as the countries are heterogeneous in some fundamentals. (If they were homogeneous in all respects, capital flows would not have taken place in the first place.) Since we want to investigate the role of taxes on growth, we shall assume that asymmetry in capital income tax rates is the factor that first induced cross-border capital flows. Suppose further that these countries were travelling along their steady state growth paths initially. Should these taxes remain different, the driving force that initiated capital movement to begin with will be reactivated if the countries revert to their long-run autarky growth paths. As such, (b) can also be ruled out. The only empirically interesting case that remains is the one that involves non-zero flows. In that case, we should expect the direction of capital flows to be from low after-tax MPK countries to high after-tax MPK countries.

Let us now try to understand how capital mobility may affect the convergence in long term growth rates across countries. In the world steady state equilibrium, the non-zero net capital flow of each country must be growing at the same rate as its total income. But since the capital inflow of one country is equal to the capital outflow of another country, the steady state (balanced growth) restriction forces the total income growth rates to be uniform across countries in the long run, i.e.,

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

To prove this, suppose without loss of generality that capital flows from the rest of the world to the home country (since, in our full certainty model, equilibrium capital flows will be unidirectional.) Consider the resource constraint facing the home country with all the growing variables detrended by dividing the whole equation through by $N_t h_t$:

$$+g_N)(1+g_h)](K^H+K^{H*}) = F(K,n) - (1-J_{rN})rK^{*H}\Big(.$$

The steady state growth rate of per capita GDP, g_y, is equal to g_h, so that the steady state growth rate of GDP is $g_Y = (1+g_N)(1+g_h)-1$; and similarly for the rest of the world. We can rewrite the last term as:

$$- (1-J_{rN})rK^{*H}\left(\frac{N^*h^*}{Nh}\right)\left(\frac{(1+g_N^*)(1+g_h^*)}{(1+g_N)(1+g_h)}\right)^t$$

where $N \equiv N_t/(1+g_N)^t$ and $h \equiv h_t/(1+g_h)^t$ are the detrended steady state levels of population and human capital respectively in the home country, and similarly in the rest of the world. Note that this term is time-varying unless $(1+g_N)(1+g_h) = (1+g_N^*)(1+g_h^*)$, implying equality of the growth rates of (total) GDP g_Y^i in the two countries along the steady state growth path.

We can decompose the *total* income growth rates into the *per capita* income growth rates and *population* growth rates: $(1+g_Y) = (1+g_N)(1+g_y)$. Together with the total growth equalization result, this decomposition implies that $(1+g_N)(1+g_y) = (1+g_N^*)(1+g_y^*)$. Two empirical implications follow:

(a) *Long-term rates of growth of population and per capita incomes should be negatively correlated across countries*;[7] and

(b) *Total income growth rates should exhibit less variation than per capita income growth rates across countries*.

Some empirical support for these and other related implications is provided by Razin and Yuen (1995d).

The Role of International Capital Taxation in Growth Rate Convergence

When capital is mobile, the choice of international tax principle and tax rates levied on capital incomes earned by residents and non-residents at home and abroad will affect the after-tax rates of return on capital and, indirectly, the rates of growth of per capita consumption and population (g_c and g_N) across countries through the intertemporal conditions:

$$(1+g_N)^{1->}(1+g_c)^{F} = 1 + (1-J_{rD})(r_k-*_k), \textit{ and}$$
$$(1+g_N^*)^{1->}(1+g_c^*)^{F} = 1 + (1-J_{rD}^*)(r_k^*-*_k).$$

Along the steady state growth path, $g_c = g_y$ and $g_c^* = g_y^*$ and, as we have just shown,

$(1+g_N)/(1+g_N^*) = (1+g_y^*)/(1+g_y)$. The arbitrage-based condition implies that $(1-\tau^*_{rD})(r^*_k-\delta_k) = (1-\tau^*_{rA}-\tau_{rN})(r_k-\delta_k)$. Substituting these conditions into the above equations, and dividing on equation by the other, we get

$$\left(\frac{1+g_y}{1+g_y^*}\right)^{\xi-(1-\sigma)} = \frac{1+(1-\tau_{rD})(r_k-\delta_k)}{1+(1-\tau^*_{rA}-\tau_{rN})(r_k-\delta_k)}\,. \tag{15.7}$$

This equation shows how the relative (per capita) income growth rates in the two countries depend on their capital tax rates and relative bias in preference towards quantity versus quality of children (ξ versus $1-\sigma$).

Recall that, under perfect capital mobility, the no-arbitrage restrictions will force the after-tax rates of return on capital ($\bar{r}$'s) to be equalized across countries under the source principle. Equation (15.7) therefore implies convergence in both the per capita and total income growth rates if the *source* principle prevails (when $\tau^*_{rA} = 0$ and $\tau_{rN} = \tau_{rD}$). Under the alternative *residence* principle (when $\tau_{rN} = 0$), since the after-tax interest rates are not equalized by capital mobility, asymmetry in $\bar{r}$'s (due to the asymmetry between τ_{rD} and τ^*_{rD}) implies, in turn, asymmetry in growth rates.

Equation (15.7) also indicates that under residence-based taxation, when $\xi \neq 1-\sigma$, asymmetric tax rates may have differential effects on the growth of per capita income and population. In particular, when people are more biased towards quality than quantity ($\xi < 1-\sigma$), the country with a higher capital tax rate will exhibit faster growth in per capita income and slower growth in population. The reverse is true when people are more biased towards quantity than quality ($\xi > 1-\sigma$).[8] Other things equal, the country with a higher capital tax rate will have less incentive to invest in physical capital and more to invest in child quality if $\xi < 1-\sigma$ or in child quantity if $\xi > 1-\sigma$. We summarize these results as follows.

Under capital mobility and international capital income taxation:

(1) When both countries adopt the source principle, they will exhibit identical rates of growth of per capita income and population if $\xi \neq 1-\sigma$ irrespective of international tax differences;

(2) When both countries adopt the residence principle, they will exhibit different rates of growth of per capita income and population in general. In particular, $g_y \gtreqless g_y^*$ and $g_N \lesseqgtr g_N^*$ as $\tau_{rD} \lesseqgtr \tau_{rD}^*$ if $\xi > 1-\sigma$, $g_y \lesseqgtr g_y^*$ and $g_N \gtreqless g_N^*$ as $\tau R_D \lesseqgtr \tau_{rD}^*$ if $\xi < 1-\sigma$. [9]

While asymmetry in tax rates can induce differential growth rates when both countries adopt the residence principle, we note that the adoption of asymmetric international tax principles by different countries can also generate disparity in growth rates. Note also from equation (15.7) that, in cases intermediate between the source and residence principles (i.e., without complete exemption from taxes on foreign-source capital income to be paid to the domestic and/or foreign governments), the relative magnitudes of the tax wedges (with respect τ_{rD}, τ_{rA}, and τ_{rN}) matter. In those cases, it will also be important to distinguish between the differential growth effects of the credit system that we have been assuming here and the alternative deduction system.

15.3 Tax Divergence in an Open Economy: Labor Mobility

Let us now turn to the other extreme case where labor is freely mobile but capital is not. Under perfect labor mobility, the absence of arbitrage opportunities ensures the equalization of after-tax marginal products of labor (MPH or wage rates) for any worker who can choose to work in either country. In particular, $(1-\tau_{wDt})MPH_t = (1-\tau^*_{wAt})(1-\tau_{wNt})MPH^*_t$, implying that $MPK^*_t = {}_t MPK_t$. The fundamental relative growth equation (15.7) can be rewritten as:

$$-(1-F) = \frac{1+(1-J_{rD})(r_k-*_k)}{1+(1-J^*_{rD})(7r_k-*_k)}, \quad where\ 7 = \left(\frac{1-J_{wA}-}{1-J_v} \right) \tag{15.8}$$

Note that $\tau_{wD} = \tau_{wA}$ and $\tau_{wN} = 0$ (implying $= 1$) under the residence principle of wage taxation, and $\tau_{wD} = \tau_{wN}$ and $\tau_{wA} = 0$ (implying $\gtreqless 1$ as $\tau_{wD} \gtreqless \tau^*_{wD}$) under the source principle. The proposition below should be transparent.[10]

Under labor mobility and international labor income taxation:

(3) **When both countries adopt the source principle, they will exhibit different rates of growth of per capita income and population in general. In particular, $g_y \gtreqless g^*_y$ and $g_N \lesseqgtr g^*_N$ as $(1-\tau_{rD})^{1-\alpha}(1-\tau_{wD})^{\alpha} \gtreqless (1-\tau^*_{rD})^{1-\alpha}(1-\tau^*_{wD})^{\alpha}$ if $\xi > 1-\sigma$, $g_y \lesseqgtr g^*_y$ and $g_N \gtreqless g^*_N$ as $(1-\tau_{rD})^{1-\alpha}(1-\tau_{wD})^{\alpha} \gtreqless (1-\tau^*_{rD})^{1-\alpha}(1-\tau^*_{wD})^{\alpha}$ if $\xi < 1-\sigma$.**

(4) **When both countries adopt the residence principle, they will exhibit different rates of growth of per capita income and population in general. In particular, $g_y \gtreqless g^*_y$ and $g_N \lesseqgtr g^*_N$ as $\tau_{rD} \lesseqgtr \tau^*_{rD}$ if $\xi > 1-\sigma$, $g_y \lesseqgtr g^*_y$ and $g_N \gtreqless g^*_N$ as $\tau_{rD} \lesseqgtr \tau^*_{rD}$ if $\xi < 1-\sigma$.**

Contrary to what we find in the capital mobility case, (3) shows that the source principle is not necessarily growth-equalizing. Although the post-tax MPHs are equalized under territorial taxation, the post-tax MPKs are not unless the weighted tax wedges $(1-\tau_{rD})^{1-\alpha}(1-\tau_{wD})^{\alpha}$ are uniform across countries. So, in contrast to (1), wage tax asymmetry matters here as much as interest tax asymmetry. Like (2), though, (4) implies that asymmetry in capital tax rates can be a source of growth disparity under worldwide taxation. As before, we can show that asymmetry in the international income tax principle can also be another source of growth rate differences.

In Chapter 14, we have seen how labor mobility combined with knowledge spillovers (the Lucas-externality) can bring about convergence in income levels in the absence of tax differences. When tax rates do differ across countries, however, the resulting differences in growth rates (as shown in (3) and (4) above) imply that level convergence can no longer be achieved. We can therefore view cross-country tax asymmetry as both a growth-diverging and level-diverging force.

15.4 Summary

Let us first summarize the answers to the several questions posed in the introduction, and then make some concluding remarks.

(a) Is factor mobility a growth-equalizing force?

Yes, for *aggregate* income growth rates; but not necessarily, for *per capita* income growth rates.

(b) Are capital mobility and labor mobility perfect substitutes as growth-equalizing forces?

Yes, in the absence of international tax differences.

(c) Can tax-driven diversity in growth rates be preserved under factor mobility and international income taxation?

Yes, (i) under residence-based taxation with either capital or labor mobility; (ii) under source-based taxation if labor is mobile; (iii) if different countries adopt different international tax principles; and (iv) if different international tax principles are applied to capital incomes and labor incomes separately.

(d) Are the growth effects of taxes symmetric under capital mobility and labor mobility?

Yes, under the residence principle. No, under the source principle, or when different countries follow different international tax principles.

In a nutshell, we have identified two sources of disparity in income and population growth rates across countries. They are: (a) asymmetry in factor income tax rates, and (b) asymmetry in international income tax principles, as adopted by different countries or applied to different factors of production. We have also shown how the growth effects of capital mobility and labor mobility can differ under these two cases and how they are related to the relative bias in preferences towards quantity and quality of children. Although these differences can easily be eliminated if enough symmetry is assumed between the two factors (e.g., uniform taxation of incomes from both factors), we believe that the asymmetries examined here are very real. In fact, the unequal barriers to the cross-border movements of the two factors can be another real source of asymmetry that is nonetheless ignored in our analysis.

Appendix A: Derivation of the Tax-Growth Relation in the Closed Economy

In this appendix, we derive equations (15.2) and (15.3) in the text. The consumer's first order conditions with respect to c_t, e_t, K_{t+1}, and h_{t+1} are given by:

$$c_t^{-F} = \mu_t \, , \tag{A.1}$$

$$\mu_{h_t} (B e_t^{(-1} = \mu_t S_{wt} w_t N_t \, , \tag{A.2}$$

$$\mu_t = \$ \mu_{t+1} [1 + S_{r_{t+1}} (r_{t+1} - *_k)] \, , \tag{A.3}$$

$$[\mu_{h_{t+1}} [B e_{t+1}^{(} + (1 - *_h)] + \mu_{t+1} w_{t+1} N_{t+1} [S_{w_{t+1}} (1 - e_{t+1}) + NJ \tag{A.4}$$

The Lagrange multipliers (μ for `mu'ltipliers) at time t associated with the consumer budget constraint and the law of motion of human capital are denoted by μ_t, and μ_{ht} respectively. Assuming that the capital income tax rate τ_{rt} applies uniformly to both financial and physical capital, the arbitrage condition implies that $r_t = r_{kt} - \delta_k$. The firm's first order conditions are

$$w_t = (1 - ,) A \left(\frac{K_t}{H_t} \right)^{,} , \text{ and} \tag{A.5}$$

$$r_t = , A \left(\frac{K_t}{H_t} \right)^{, -1} . \tag{A.6}$$

The equilibrium conditions in the labor and capital markets are

$$N_t h_t = H_t^d , \text{ and} \tag{A.7}$$

$$K_t = K_t^d . \quad \textbf{(A.8)}$$

Substituting (13.1) and (A.5) into (A.2), we get,

$$\frac{(\mu_{h_t}[h_{t+1}/h_t-(1-*_h)]}{e_t} = \frac{"\mu_t S_{w_t} Y_t}{1-e_t}. \qquad \textbf{(A.9)}$$

Along the balanced growth path, time allocations and tax rates are constant, i.e., $e_t = e_{t+1}$, $\Omega_t = \Omega_{t+1}$, $\Omega_{wt} = \Omega_{wt+1}$, and $\Omega_{rt} = \Omega_{rt+1}$, and human capital and consumption will grow at the same constant rate g_h and output at the rate $(1+g_N)(1+g_h)-1$ respectively, so that (A.1) and (A.9) imply that

$$\frac{\mu_{h_{t+1}}}{\mu_{h_t}} = \frac{\mu_{t+1}Y_{t+1}}{\mu_t Y_t} = (1+g_N)(1+g_h)^{1-F}. \qquad \textbf{(A.10)}$$

Multiplying (A.4) throughout by h_{t+1} and dividing the resulting expression by $\mu_{ht+1}h_{t+2}$, we get

$$\frac{\mu_{h_t}h_{t+1}}{\$\mu_{h_{t+1}}h_{t+2}} = 1+\left(\frac{\mu_{t+1}Y_{t+1}}{\mu_{h_{t+1}}h_{t+2}}\right)"\left[S_w+N*_h J_w\left(\frac{1}{1-e}\right)\right],$$
$$where \quad \frac{\mu_{t+1}Y_{t+1}}{\mu_{h_{t+1}}h_{t+2}} = \left(\frac{(}{"S_w}\right)\left(\frac{1-e}{e}\right)\left(\frac{g_h+*_h}{1+g_h}\right). \qquad \textbf{(A.11)}$$

Combined with (A.10), this yields equation (15.2) in the text.

Equation (15.3) can be derived by combining (A.1) and (A.3) and imposing the steady state restrictions.

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Problems

1. Consider the closed economy model of Section 15.1 with an additional time-consuming activity, leisure (L_t). The time constraint is specified as: $L_t + n_t + e_t = 1$. The utility function is rewritten as:

$$U = \sum_{t=0}^{\infty} \$^t N_t \left(\frac{(c_t^{0} L_t^{1-0})^{1-F} - 1}{1-F} \right) .$$

Assume for simplicity that $\phi = 0$ and $\delta_h = 1$. Analyze the effects of capital and labor income taxes on the steady state growth rate of income.

2. Consider the closed economy model of Section 15.1 with an additional time-consuming activity, child-rearing (v_t), which gives rise to endogenous population growth. The time constraint is specified as: $v_t + n_t + e_t = 1$. The utility function is given by (15.5), and the law of motion of population by (15.6). Assume for simplicity that $\phi = 0$, $\delta_k = \delta_h = \delta_N = 1$, and $\tau_r = 0$. Analyze the effects of labor income tax on the investment in physical capital, human capital (child quality), and population (child quantity), and the steady state growth rate of income.

3. Consider the capital mobility model with endogenous population in Section 15.2. Explain how the effects of international capital income taxation on cross-country growth rates will change if the home country adopts the source principle while the rest of the world adopts the residence principle.

4. Consider the labor mobility model in Section 15.3. Explain how the effects of international labor income taxation on cross-country growth rates will change if the home country adopts the source principle while the rest of the world adopts the residence principle.

5. Suppose capital and labor are both internationally mobile. Examine how the effects of international capital and labor income taxation on cross-country growth rates will change if the source principle is applied to the taxation of labor income and the residence principle to the taxation of capital income in both countries.

Endnotes

1. Two other explanations include (a) multiple steady states—economies with different initial endowments can evolve along the same equilibrium growth path, but in different directions, thus converging to different long-run positions (see, e.g., Becker, Murphy, and Tamura (1990) and Azariadis and Drazen (1990)), and (b) multiple equilibria—economies with the same initial endowment can follow different equilibrium growth paths and converge to different long-run positions (see, e.g., Benhabib and Perli (1993) and Xie (1993)).

2. See, e.g., Rebelo (1991) and Jones and Manuelli (1990) for a qualitative analysis; Easterly and Rebelo (1995) for an empirical examination; and King and Rebelo (1990), Lucas (1990), and Stokey and Rebelo (1995) for a quantitative assessment, of the effects of tax changes on long run growth rates in models with capital formation (human and physical) as the source of growth.

3. This argument applies to substitution effect between education and work. The potential income effect of taxes is absent in this case due to the homotheticity of preferences.

4. The progressivity of income tax implies that the tax rate which could have been applied to forgone income is smaller than the tax rate which is actually applied to the increase in future labor earnings due to human capital investment. Subsidized health care in the form of tax-deductibility of medical expenses is equivalent to the depreciation allowance for human capital associated with health.

5. Another way to see this is to observe that, with zero capital flows, the number of unknowns falls short of the number of equilibrium conditions.

6. See Razin and Ben-Zion (1975) for similar setup. Note that, as in Becker and Barro (1988), the altruism parameter ξ dictates the extent to which the marginal utility of children diminishes as the number of children is increased. Note that σ does not only reflect the elasticity of substitution in consumption, but also the preference weight attached to child quality (relative to quantity). We thus restrict σ to be less than unity to ensure that children command positive marginal utility, which implies a different restriction on its value for the existence of steady state than that specified in Section 13.1. The utility function from previous chapters is altered by dropping the `$-$ 1' from the numerator in order to ensure that, under endogenous population growth, consumption will grow at the same rate as human capital in the steady state. The objective function (1) can also be interpreted as a social welfare function. In terms of the utilitarian approach, it is a Millian (average utility) social welfare criterion when $\xi = 0$. When $\xi = 1$, it becomes a Benthamite (sum of utilities) criterion. See Razin and Yuen (1995a) for details.

7. This implication means that, in a small vs large economy world, the small economy may `disappear' relative to the large economy in terms of population, but its aggregate income will still grow at the same rate as the latter's in the limit. This need not be true, though, if capital is not mobile across these two economies or if they do not have current account imbalances in the long run.

8. The tax rate τ_{rD}, rather than the after-tax MPK, matters here because the cross-country MPKs will be equalized under the residence principle anyway.

9. We require tax symmetry across countries $\tau_{rD} = \tau^*_{rD}$, so $(1+g_N)(1+g_y) = (1+g^*_N)(1+g^*_y)$, for the existence of world steady state growth, if $\xi = 1-\sigma$. This condition is not required, however, in (1) when $\xi = 1-\sigma$.

10. We require $\Omega = \Omega^*$ in case (1) and $\tau_{rD} = \tau^*_{rD}$ in case (2), so $(1+g_N)(1+g_y) = (1+g^*_N)(1+g^*_y)$, for the existence of balanced growth, if $\xi = 1-\sigma$.