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**TEACH YOUR CHILDREN WELL:
PLANTING THE SEEDS OF EDUCATION
AND HARVESTING THE BENEFITS OF TRADE***

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ABSTRACT

The dynamic multi-country model developed in this paper focuses on the interaction between education, international trade and economic growth. The model distinguishes between two forms of human capital, knowledge and education. Both are required in production. Knowledge is accumulated in each country, with trade acting as a conduit for its dissemination. Education is embodied in the individuals and regulates the amount of domestic knowledge that they may create, and the amount of foreign knowledge that they may be able to absorb and assimilate. Individuals choose how much time to spend in production and how much in the attainment of education. Education is financed through income taxes and tariffs levied on imports.

The objective is to examine how commercial and education policies may affect the extent of knowledge spillovers across countries, and the extent that these spillovers are captured by a given country. Earlier studies by this author have highlighted a number of empirical regularities of the growth process. The goal here is to develop a theoretical framework that can account for this empirical evidence while providing an indication of how policy changes might affect the future growth paths of nations.

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I. INTRODUCTION

When one considers the impact of increased exposure to international trade, one of the consequences that often comes to mind is that of the heightened competition facing domestic firms – both at home and abroad. Survival and success in the face of the greater competitive pressures presumably requires increased awareness of, and adaptation to, foreign ideas, methods and technologies. Such a link, between the extent of openness and the extent of exposure to foreign knowledge, is a basic premise of this paper.

But being exposed to foreign ideas is one thing. Having the capability to utilize these foreign ideas in a productive manner is quite another story altogether. While successive generations continue to add to our collective stock of knowledge, our ability – both as individuals and as nations – to benefit from this growing stock is wholly dependent on our prior preparations. Hence, we invest both time and resources in the attainment of education – so that we might one day be able to reap the bounties of knowledge (domestic and foreign) that were accumulated by earlier generations. Though the education that each of us receives is not genetically transferable to our descendants, the ideas that we and those around us advance and develop remain documented in one form or another for the benefit of all who follow us.

The model developed here focuses on the importance of both forms of human capital in the growth of nations. The first, knowledge, can be thought of as a stock variable that expands over time. The other form of human capital, education, is a flow variable that continuously needs replenishing as new individuals are born at each point in time. The attainment of education, together with a country's stock of knowledge, is considered here to be a central component in domestic output production and in the further creation of new knowledge.

The next section briefly provides some background and motivation for the model, which is detailed in the section three. Section four provides a two-country example while section five presents the model's policy implications. Section six concludes.

II. MOTIVATION

The relationship between international trade and economic growth has aroused renewed interest in recent years, both from a theoretical perspective – with the emergence of growth models that endogenize the growth process – as well as from an empirical perspective.¹ This paper explores the trade-growth relationship by focusing on the contribution of trade toward the diffusion of knowledge between countries.²

In his discussion of the underlying causes of the large, and persistent, income gaps between nations, Romer (1993) makes a distinction between what he refers to as "object gaps" and "idea gaps". Object gaps, which have received the most attention in mainstream growth and development literature, result from cross-country discrepancies in the accumulation of physical objects (e.g. machines, infrastructure, etc.). Romer argues that the alternative concept of idea gaps, which emphasizes the ability of nations to utilize ideas already being implemented in wealthier countries, is no less important and, in many respects, it represents a more optimistic view of the potential for development by less developed countries.

Following Romer, as well as Grossman and Helpman (1991a) and others, this paper concentrates on the importance of idea gaps, idea flows and the ability of countries to absorb new ideas. While not dismissing the obvious importance of object gaps in the development process, the purpose of this paper is to highlight the role played by the accumulation of ideas, or knowledge, in the growth of per capita output. The assumption being made here is that the relative exposure of one country's products to competition from another's acts as an inducement for the diffusion of ideas between the countries.

¹ See for example: Romer (1990), Jones and Manuelli (1990), Grossman and Helpman (1991a, 1991b), Rivera-Batiz and Romer (1991a, 1991b), Stokey (1991), Young (1991), Backus, Kehoe, and Kehoe (1992), Easterly, King, Levine, and Rebelo (1994), Frankel and Romer (1995), Feenstra (1996), and Connolly (1997).

² Dollar, Wolff, and Baumol (1988) also suggest that trade is a channel for the dissemination of ideas. Grossman and Helpman (1995) provide a formalization of the relationship between technology and trade and provide a review of the related literature.

But while trade may facilitate the spread of ideas, how capable are countries of absorbing them? As noted in the introduction, one important factor influencing the extent of absorption is the level of education in the respective countries (something along the lines of Abramovitz's, 1986, "social capability" notion), which in turn depends upon the amount of time that individuals spend in acquiring education, as well as on the share of output devoted to the production of education.³ In the model developed here, the amount of resources devoted to providing educational services is dependent upon two components: (1) government revenues from income taxes and tariffs, and; (2) the proportion of these revenues that is directed towards the provision of educational services. As will be shown below, countries that allocate relatively little towards education will get what they pay for in terms of productive capacity.

For a given proportion of revenues actually spent on education, there still remains the question of how high tax and tariff rates should be. High income taxes and/or tariffs increase government revenue, but reduce disposable income and limit consumption, which inhibits trade and limits the flow of ideas from abroad. Alternatively, if government revenue is too small, then the level of education will be adversely affected, and that affects knowledge absorption and growth. Hence, the importance of examining the tradeoff between taxes needed to fund education in order to develop more rapidly, and the cost of these taxes in the form of lower disposable income and the subsequent reductions in trade and the dissemination of ideas.

For many years, the primary theoretical framework for describing the process of economic growth was based upon Solow's (1956) neoclassical growth model in its many variations. The model, together with the Cass (1965) and Koopmans (1965) addition of Ramsey-type preferences, provides growth predictions that held up particularly well for a majority of Kaldor's (1961) stylized facts – which had become a sort of standard for measuring the accuracy of growth models.

³ Abramovitz suggests that the propensity for laggard countries (in terms of economic development) to catch up to the lead country increases with their level of backwardness. However, he adds that there exists a "social capability" threshold delineating between those countries that are able to partake in the catch-up process and those that are sufficiently underdeveloped for whom technology transfers are not likely outcomes.

However, one artifact of the exogenous technological changes that drive growth in the standard neoclassical model is also a source of one of the model's major limitations, its inherent inability to account for policy measures that might affect steady state growth. It is this inability that much of the recent endogenous growth literature has attempted to address.

Furthermore, some of the more recent empirical evidence points to a number of additional (to Kaldor) stylized facts of the growth process that growth models need to account for. Some of the issues that are addressed in this paper include the question of why some of the more developed countries exhibit income convergence while at the same time, income gaps continue to persist (and in some cases, even grow) between rich and poor countries? Are these steady state situations, or simply transitional phases? What role might policy play in the continued existence, or possible elimination, of the gap between rich and poor countries?

The model developed here assumes that there is a relationship between trade and technology flows – an intuition that is based upon findings in studies like Helliwell, 1994; Coe and Helpman (1995), Coe, Helpman and Hoffmaister (1997), Keller (1995), Marin (1995), and Eaton and Kortum (1996), who provide evidence of trade-related knowledge spillovers among countries.

The primary focus of earlier models on trade and knowledge dissemination – for example, the work by Rivera-Batiz and Romer, as well as that of Grossman and Helpman – has tended to focus on the link between trade liberalization and output *growth*. Little or no attention is given to the impact on output *levels*, nor to the impact of liberalization by some countries on the growth and level changes of other non-partner countries.

Rather than concentrating on a simple two-country (or two-trading-bloc) world, as most open economy endogenous growth models tend to do, the emphasis here will be on deriving a multi-country model that can yield some insight on how unilateral policy changes – or trade agreements by a subset of countries – can lead to static and dynamic effects for the liberalizing countries, as well as for the non-liberalizing countries who are not partners to the trade agreements. The model is kept as simple as

possible to facilitate not only an analysis of the steady state *growth* effects of policy changes, but also an analysis of the transitional dynamics in *levels*.

III. THE MODEL

The theoretical framework developed here follows Romer (1986) and Lucas (1988) by focusing on the aggregate economy with an emphasis on the contribution of knowledge accumulation in the growth process. As in Romer's model, physical capital is assumed to be constant and, for simplicity, is set at unity.

An advantage of writing down an aggregate model of the type worked out below is the preservation of the conditional convergence feature inherent in the Solow-Cass-Koopmans model. Here too, countries with identical policies and characteristics should exhibit convergence not only to the same steady state growth rate, but also to the same income levels (regardless of initial endowments). The modifications introduced here however, make it possible for different policies to affect not only relative income levels, but steady state growth rates as well – something which is not possible in the traditional growth model.

Assume that there are J countries, with each country i specializing in the production of a distinct good i . To simplify matters, labor and population are assumed to be the same and are denoted by $L_i(t)$ for $t > 0$. As in Lucas (1988), individuals allocate their time between the attainment of education and the production of good i , where $u_i(t)$ designates the proportion of time spent in production of good i ($0 < u_i(t) < 1$).⁴ The domestic level of education per person, $e_i(t)$, the country's stock of knowledge, $H_i(t)$, and $u_i(t)$ combine to produce good i . Thus, aggregate output at every point in time is $Y_i = A(u_i e_i L_i) H_i^\epsilon$ and output per capita, $y_i(t)$, may be written as

⁴ However, in the closed economy Lucas (1988) model, no distinction is made between the attainment of education and the accumulation of knowledge, as is the case here.

$$y_i(t) = Au_i(t)e_i(t)H_i(t)^\varepsilon \quad (1)$$

where A and ε are constant scale and productivity parameters common to all countries. As will be shown below, both $u_i(t)$ and $e_i(t)$ are constant in the steady state. Their relative size, which combines with the growing knowledge stock, $H_i(t)$, determines how much will be produced at any point in time.

The domestic level of education, $e_i(t)$, also plays a role in domestic knowledge accumulation, $\dot{H}_i(t)$. This represents Abramovitz's social capability conjecture noted earlier, which is similar to the Nelson and Phelps (1966) notion that a higher level of human capital in a country better enables it to absorb technology flows.

Domestic knowledge accumulation is also a function of both domestic and foreign knowledge stocks, $H_j(t) \forall j$. Let a_{ij} equal country-specific constant parameters (where $0 \leq a_{ij} \leq 1$) that indicate the importance of each of the individual foreign H_j 's in the accumulation of domestic H_i . In other words, only a fixed proportion a_{ij} of each H_j is relevant for the accumulation of domestic knowledge, hence $\dot{H}_i(t)$ is a function of each $a_{ij}H_j(t) (\forall j \neq i)$.

The variable $v_{ij}(t)$, which indicates the extent of country i 's exposure to competition from goods manufactured with foreign ideas ($0 < v_{ij} < 1 \forall j \neq i$), acts as a spigot regulating the contribution of foreign knowledge in the accumulation of domestic knowledge, *i.e.* $v_{ij}(t)a_{ij}H_j(t) (\forall j \neq i)$ reflects the contribution of each H_j on the accumulation of H_i . It is further assumed that knowledge is non-rivalrous and, to a certain extent, non-excludable. Thus, knowledge accumulation in country i follows

$$\dot{H}_i(t) = e_i(t) \left[H_i(t) + \sum_{j \neq i} v_{ij}(t) a_{ij} H_j(t) \right] \quad (2)$$

where the level of education dictates the flow of knowledge spillovers that the country can assimilate.⁵

⁵ Education enters linearly into both output production and knowledge accumulation only because the addition of an exponent in either case complicates the model considerably.

As noted above, knowledge spillovers between countries in Equation (2) are not complete.⁶ The extent of exposure to foreign ideas, $v_{ij}(t)$ – which determines the magnitude of the knowledge spillovers from abroad – depends on the amount of contact between domestic and foreign producers and consumers. Following Grossman and Helpman (1991b), this measure is reflected in the ratio of bilateral trade to output, *i.e.* $v_{ij}=(IM_{ij}+EX_{ij})/Y_i$, or

$$v_{ij}(t) = \frac{\frac{p_j(t)}{p_i(t)} L_i(t) c_{ij}(t) + L_j(t) c_{ji}(t)}{L_i(t) y_i(t)} \quad , \quad i \neq j \quad , \quad (3)$$

where $c_{ij}(t)$ is country i 's real per capita consumption of country j 's goods and $p_i(t)$ is the relative price of good i at time t (with good 1 designated as the numeraire good).

From the trade and openness measure, we move to education, which is publicly financed. A fixed proportion μ_i of total government revenues, $G_i(t)$ is exogenously allocated towards the provision of educational services while the remainder, $(1-\mu_i)G_i(t)$, is returned to the consumers in a lump sum. To the extent that there exists corruption in the economy, then μ would represent the effective share of taxes that is actually channelled to education.⁷

Denoting $g_i(t)$ as the amount of government expenditures per person and assuming that the government balances its budget, then

$$g_i(t) = \sum_{j \neq i} \frac{p_j(t) \tau_{ij} c_{ij}(t)}{p_i(t)} + b_i y_i(t) \quad (4)$$

where b_i is a fixed rate income tax and the τ_{ij} 's are fixed ad valorem tariffs on imports from each country j .

The per capita level of education in country i ,

⁶ In a related formulation describing the accumulation of human capital in the open economy version of his earlier (1988) model, Lucas (1993) suggests that human capital accumulation is dependent upon the average stock of human capital in the world. In his formulation however, which still makes no distinction between education and knowledge, human capital spillovers are complete – which is not the case here.

⁷ Since the amount of tax revenue not used for education is returned to the consumers in a lump sum, then corruption – which can be viewed as a form of taxation – can be interpreted here as enlarging the proportion of tax revenue that is not being allocated to education.

$$e_i(t) = \psi [1 - u_i(t)] \frac{\mu_i g_i(t)}{y_i(t)} \quad (5)$$

is determined by the amount of time that individuals invest in education as well as the share of the country's output that is devoted to education (ψ is the constant education productivity parameter common to all countries).⁸ Note that if country i is subject to corruption, or other forms of wasted tax receipts, the implication would be a smaller μ_i and a lower level of education.⁹

Individuals in this economy are identical and their preferences are represented by

$$\int_0^{\infty} e^{-\rho t} \sum_{j=1}^J \alpha_{ij} \ln c_{ij}(t) dt \quad (6)$$

where ρ is the discount rate and $0 < \alpha_{ij} < 1$ ensures that all countries will trade with one another ($\sum_{j=1}^J \alpha_{ij} = 1$). Population grows at the rate n while initial levels are normalized and equal unity, *i.e.* $L_i(0) = 1$. Individuals maximize their utility subject to the budget constraint

$$\sum_{j=1}^J \frac{(1 + \tau_{ij}) p_j(t)}{p_i(t)} c_{ij}(t) = (1 - b_i) y_i(t) + (1 - \mu_i) g_i(t) \quad (7)$$

where $\tau_{ii} = 0$. In lieu of international capital movements, market clearing in this model, together with the budget constraint and the assumption of a balanced government budget, imply that each country maintains balanced trade with the rest of the world, *i.e.*

⁸ Rather than have e be a function of $\mu g/y$, as is the case in Equation 5, an alternative formulation could have e be a function of μg alone. However, since g rises over time, the result would be ever-increasing levels of education. And, because e is in the knowledge accumulation equation (2), the result would be explosive growth in H – as opposed to constant steady state growth, which will be shown to be the case here.

⁹ On the issue of insufficient utilization, Olson (1996) argues that the growth solution for developing countries is not one of additional accumulation, but one of less waste of resources that are already available.

$$L_i(t) \sum_{j \neq i} p_j(t) c_{ij}(t) = \sum_{j \neq i} p_i(t) L_j(t) c_{ji}(t) \quad \forall i \quad . \quad (8)$$

Note that there is no imposition that bilateral trade be balanced, only that overall external trade be balanced.

Equation 2 reflects the boost to knowledge growth provided by education and trade-induced knowledge spillovers. It also reflects the tradeoff facing a government. If no taxes are levied, then g_i will be zero and so will e_i which in turn implies that the country will be unable to capture any knowledge spillovers – *i.e.* the economy will not grow. On the other hand, high taxes enable high levels of education, but inhibit consumption – which limits trade, lowers the v_{ij} 's, and suppresses growth. So, while more education places the country in a better position to capture knowledge spillovers, the reduced trade will produce fewer of these spillovers and little improvements to the country's growth rate. Thus, for a given level of μ_i , the government can determine the mix of income taxes and import tariffs that will maximize growth.

As will be shown below, per capita growth rates will be identical in the steady state for each country, though output *levels* may vary. A unilateral change in a country's tax and tariff policies will affect not only its relative income level, it will also have an impact on the steady state growth rates of all the countries.

Dropping the time arguments for notational convenience, the decision variables are c_{ii} , c_{ij} and u_i (for all i and j) which are solved as part of the static allocation problem. The level of knowledge in country i , H_i , is taken as given by each agent and is found by solving the dynamic accumulation problem which yields the growth rates of knowledge and output in the steady state.

Let θ_i be the Lagrangian multiplier for the budget constraint (7). Then, the first-order conditions for this problem are

$$\frac{\alpha_{ii}}{c_{ii}} = \theta_i \quad , \quad (9)$$

$$\frac{\alpha_{ij}}{c_{ij}} = \frac{p_j(1+\tau_{ij})}{p_i} \theta_i \quad \forall \quad j \neq i \quad , \quad (10)$$

and

$$\theta_i \left(\frac{1-\varepsilon}{2-\varepsilon} \right) \left(\frac{1-2u_i}{u_i(1-u_i)} \right) (1-b_i)y_i = 0 \quad . \quad (11)$$

Consumption demands are derived by inserting (9) for θ_i in (10), isolating c_{ij} on the left-hand side and substituting the new equation into the budget constraint (7) to get

$$c_{ii} = \alpha_{ii}[(1-b_i)y_i + (1-\mu_i)g_i] \quad (12)$$

and

$$c_{ij} = \alpha_{ij} \frac{p_i}{p_j(1+\tau_{ij})} [(1-b_i)y_i + (1-\mu_i)g_i] \quad . \quad (13)$$

Closed-form expressions for the consumption demands are obtained by substituting the government's balanced budget constraint (4) for g_i in (12) and (13), yielding

$$c_{ii} = \alpha_{ii} Q_i (1-b_i \mu_i) y_i \quad (14)$$

and

$$c_{ij} = \alpha_{ij} \frac{p_i}{p_j(1+\tau_{ij})} Q_i (1-b_i \mu_i) y_i \quad (15)$$

where Q_i is the constant:

$$Q_i = \frac{\prod_{j \neq i} (1+\tau_{ij})}{1 + \sum_{j \neq i} [1 - (1-\mu_i) \alpha_{ij}] \tau_{ij} + \sum_{j \neq i, k \neq i, j} [1 - (1-\mu_i) (\alpha_{ij} + \alpha_{ik})] \tau_{ij} \tau_{ik} + \dots + [1 - (1-\mu_i) \sum_{j \neq i} \alpha_{ij}] \prod_{j \neq i} \tau_{ij}} \quad .$$

Prices are determined by inserting (14) and (15) for all i and j into $J-1$ of the balanced trade conditions (8), giving

$$p_i = \pi_i \frac{L_1 y_1}{L_i y_i} \quad i = 2, \dots, J \quad (16)$$

where π_i is a function of combinations of the constants $\hat{\alpha}_{ij} = \frac{\alpha_{ij} Q_i}{1 + \tau_{ij}} \quad \forall i, j (i \neq j)$.¹⁰ As is clear from Equation (16), even a unilateral change in one country's tariffs will have subsequent effects on the terms of trade dynamics of the other countries.

Under the assumption that $\varepsilon \neq 1$ and $0 < b_i < 1$, the first order condition, Equation (11) yields the value of $u_i = 1/2$. In other words, agents split their time equally between output production and education.

Shifting the focus now to the dynamic problem, since b_i , τ_{ij} , μ_i , and Q_i are all constants, then – as noted above – c_{ii} grows at the same rate as per capita output, y_i , while c_{ij} grows at the rate of output plus the difference in the growth rates of domestic prices and prices in country j . This implies that v_{ij} is constant and, since g_i grows at the same rate as y_i , then e_i must also be constant. Hence,

$$\gamma_{c_{ii}}^* = \gamma_{y_i}^* = \varepsilon \gamma_{H_i}^* \quad \text{and} \quad \gamma_{c_{ij}}^* = \gamma_{p_i}^* - \gamma_{p_j}^* + \gamma_{y_i}^* \quad , \quad (17)$$

where the (*) represents steady state values.

As is indicated by (17), the determination of $\gamma_{H_i}^*$ nails down all of the other steady state growth rates in this model. To find $\gamma_{H_i}^*$, it is possible to rewrite the system of J differential equations given by (2) in vector notation as

$$\dot{\mathbf{H}} = \Phi \cdot \mathbf{H} \quad (18)$$

where $\mathbf{H} = (H_1, \dots, H_J)'$ and

¹⁰ For example, in the event that there are only two countries, then $\pi_1=1$ and $\pi_2 = \frac{\hat{\alpha}_{12}(\hat{\alpha}_{31} + \hat{\alpha}_{32}) + \hat{\alpha}_{13} \hat{\alpha}_{32}}{\hat{\alpha}_{21}(\hat{\alpha}_{31} + \hat{\alpha}_{32}) + \hat{\alpha}_{23} \hat{\alpha}_{31}}$

and $\pi_3 = \frac{\hat{\alpha}_{13}(\hat{\alpha}_{21} + \hat{\alpha}_{23}) + \hat{\alpha}_{12} \hat{\alpha}_{23}}{\hat{\alpha}_{21}(\hat{\alpha}_{31} + \hat{\alpha}_{32}) + \hat{\alpha}_{23} \hat{\alpha}_{31}}$.

$$\Phi = \begin{bmatrix} e_1 & e_1 v_{12} a_{12} & \dots & e_1 v_{1J} a_{1J} \\ e_2 v_{21} a_{21} & e_2 & \dots & e_2 v_{2J} a_{2J} \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & \ddots & \cdot \\ \cdot & \cdot & & \cdot \\ e_J v_{J1} a_{J1} & e_J v_{J2} a_{J2} & \dots & e_J \end{bmatrix}$$

Since Φ is a matrix of constants, then the solution to Equation (18) is

$$\mathbf{H} = \mathbf{\Omega} \cdot \mathbf{X} \quad (19)$$

where $\mathbf{X} = (\xi_1 \mathbf{e}^{\eta_1 t}, \dots, \xi_J \mathbf{e}^{\eta_J t})'$. The $\{\xi_i\}$ are constants determined by the initial conditions $\{H_i(0)\}$, $\{\eta_i\}$ are the eigenvalues of Φ , and $\mathbf{\Omega}$ is the matrix of associated eigenvectors. Suppose that η_k is the largest eigenvalue. Since all goods are traded, then $v_{ij} > 0$. Therefore, as long as there are some $e_i, a_{ij} > 0$, then $\eta_k > 0$. And, since only the largest growth rate applies in steady state, it follows that H_i grows at the same rate $\gamma_{H_i}^* = \gamma_H^* = \eta_k$ for each country i .

IV. TWO-COUNTRY EXAMPLE

How might a change in one government's policies affect the country's income level vis-à-vis other countries? Can it reduce income gaps that might exist with countries that are wealthier than itself? Aside from such transitional issues, how might a given policy change affect the long-run growth path of the country – and its trade partners?

These questions can be addressed most easily within a two-country setting. Substituting the closed-form value of c_{ij} from Equation (15) into the definition of g_i , which in turn is substituted into Equation (5), then

$$e_i^* = \frac{\psi \mu_i}{2} \left[b_i + \frac{\alpha_{ij} \tau_{ij} (1 - b_i \mu_i)}{1 + \tau_{ij} [1 - \alpha_{ij} (1 - \mu_i)]} \right] \quad (20)$$

In a similar manner, it is possible to show that

$$v_{ij} = \frac{2 \alpha_{ij} (1 - b_i \mu_i)}{1 + \tau_{ij} [1 - \alpha_{ij} (1 - \mu_i)]} \quad (21)$$

From (19), the largest eigenvalue, and hence, the steady state growth rate of H in a two-country world is

where, from (17), $\gamma_{y_1}^* = \gamma_{y_2}^* = \varepsilon \gamma_H^*$. Note that the relative *levels* of output in the steady state,

$$\gamma_{H_1}^* = \gamma_{H_2}^* = \gamma_H^* = \frac{1}{2} \left\{ e_1^* + e_2^* + \left[(e_1^* - e_2^*)^2 + 4e_1^* e_2^* v_{12}^* v_{21}^* a_{12} a_{21} \right]^{0.5} \right\} \quad (22)$$

$$\frac{y_1^*}{y_2^*} = \frac{e_1^*}{e_2^*} \left\{ \frac{e_1^* - e_2^* + \left[(e_1^* - e_2^*)^2 + 4e_1^* e_2^* v_{12}^* v_{21}^* a_{12} a_{21} \right]^{0.5}}{2e_2^* v_{21}^* a_{21}} \right\}, \quad (23)$$

are given by the eigenvector associated with the highest eigenvalue. If both countries are identical as far preference and technology parameters are concerned, and they also adopt identical policies, then $e_1=e_2=e$, $v_{12}=v_{21}=v$, $a_{12}=a_{21}=a$ and both countries will converge to the same long run growth path (as in the Solow model) where

$$\gamma_H^* = e^* (1 + v^* a)$$

and $y_1^* = y_2^*$. Note that policies which increase the level of education, or enhance trade, will lead to faster steady state growth. To the extent that the policies of the countries differ, and hence, their e_i^* 's and v_{ij}^* 's differ, then so will their output levels in the long run, though, as is indicated in (22), both countries will continue to exhibit the same steady state growth rates. A country that pursues policies which increase its e_i^* and v_{ij}^* above those of the other country will ultimately be wealthier in the long run (Equation 23), while concurrently generating faster growth for the other country as well.

To see how changes in the various policy parameters affect steady state growth, the relationship between income taxes (b) and tariffs (τ) for a given μ is depicted in Figure 1. Suppose that both countries have identical policies and that, initially, there is no income tax in either country, *i.e.* $b=0$. If tariffs rates are low, then education will be largely unfunded and almost no knowledge spillovers from trade may be absorbed, hence there will be little growth in the two economies. In this scenario, with no income taxes, the only way to fund education is by raising tariffs. Tariffs set at τ^A will produce the highest steady state growth rate, which is highlighted by point A in the figure. Raising tariffs beyond τ^A comes at a cost however, since the higher the tariffs, the less trade there is, and the less knowledge spillovers are available.

It would be possible to maintain the same growth rate, γ_1^* , by eliminating the tariff altogether and substituting it with the income tax rate, b^B . On the other hand, if income taxes are b^B and the tariff is reduced to just τ^B rather than being eliminated entirely, then the steady state growth rate will rise to γ_2^* . A further increase in b and reduction in τ moves the economies to point C with an even higher growth rate. As the figure illustrates, it is better for the economy to eliminate tariffs entirely, provided that income taxes are sufficiently high to finance the education of the populace. This accords with intuition since income taxes do not distort against trade in the way that tariffs do. The combination of taxes and tariffs which produces the highest steady state growth rate is at point E , where the income tax is \tilde{b} and $\tau=0$. If $b > \tilde{b}$, then the negative effect of higher income taxes on consumption, and hence trade, will more than offset the positive benefits of higher education levels – and growth rates will decline.

If the governments decide to allocate less of their revenues to education, then the growth rate obtained at point E will now require a higher income tax. A comparison of the two cases is provided in Figure 2 where the iso-growth curves for the lower μ are depicted with dotted lines. A reduction in μ shifts these curves upward so that the growth-maximizing \tilde{b} will move from point E to E' .

If the countries differ in their choices of τ and b , then they may grow along different paths, albeit at identical growth rates in the steady state. The iso-income curves in Figure 3 describing the relationship between different combinations of tax policies and the resultant steady state output paths are similar to the iso-growth curves in Figure 1. If, for example, one country were to choose the tax-tariff combination at point B while the other country were to choose the combination at point C – with lower tariff rates and higher income tax rates – then the country choosing the mix at point C will end up on the higher of the two parallel steady state paths.

IV. POLICY IMPLICATIONS

One of the limitations of the two-country example is that it cannot be used to depict how unilateral changes by one country toward a second country may affect a third country – or how a trade agreement

by a subset of countries might impact on the remaining non-partner countries. Hence, the more general multi-country version of the model will be used in this section to evaluate these issues.

As noted above, should the countries choose different sets of policies, then they may grow along different, though parallel, paths. This point will now be expanded upon using an example of a three-country world to illustrate how different policies can affect three otherwise similar countries. Let a_{ij} and the initial values of L_i and H_i equal unity while $n = 0.025$, $\varepsilon = 0.4$, $\rho = 0.1$, $\alpha_{ii} = 0.6$, and $\alpha_{ij} = 0.2$ for $i, j = 1, 2, 3$ and $i \neq j$. To distinguish between the countries, and to add a semblance of realism, suppose that the tariff and tax rates of three imaginary countries – denoted here as one, two and three – resemble those of Zaire, Brazil and the United States. Hence, from Easterly and Rebelo (1993), average income tax rates are $b_1 = 2.6\%$, $b_2 = 4.5\%$, and $b_3 = 10.6\%$, while average tariff rates are $\tau_1 = 10.8\%$, $\tau_2 = 6.2\%$, and $\tau_3 = 1.7\%$. A simplifying assumption being made here is that the countries levy the same tariffs on each of their partners, that is, $\tau_{ij} = \tau_{ik} = \tau_i$.

The proportion of government revenues actually being spent in furthering domestic education is some combination of the fraction of government revenues being allocated toward education spending and the degree of waste, mismanagement and/or corruption that lead to leakage of resources away from their intended targets. For example, ratios of education spending to tax revenues are 0.183, 0.055 and 0.031 for Zaire, Brazil and the U.S.¹¹. On the other hand, Mauro (1995) compiles corruption indices for these countries that are 1.00, 5.75, and 10.00 respectively – where 0 represents the highest degree of corruption and 10 represents the lowest. In the context of this example, a division of the individual corruption indices by 10 could be interpreted as the proportion of allocated money that is actually utilized for its intended purpose. Thus, μ_i is derived by multiplying the ratio of education spending to total revenues by the degree of corruption. Hence, $\mu_1 = 0.02$, $\mu_2 = 0.03$, and $\mu_3 = 0.03$.

Figure 4 provides a simulation of the steady state paths for the three imaginary countries. As is evident from the growth paths in the figure, the countries are growing at the same steady state growth

¹¹ Data source: Easterly and Rebelo (1993).

rates and exhibit neither convergence nor divergence. The persistence of a non-decreasing income gap is consistent with the recent empirical evidence on the lack of convergence between most countries of the world.

The country with the highest per capita output is country 3, the country with the lowest ratio of tariff to income tax rates (τ/b). Conversely, the poorest country has the highest τ/b ratio. One might think of countries 1, 2, and 3 as being on points A, B, and C, respectively, in Figure 3. How closely does this negative relationship between τ/b and y reflect the empirical evidence?

Easterly and Rebelo (1993) find that trade taxes, or tariffs, tend to be higher in poorer countries. Panel A in Figure 5 provides visual evidence of the negative relationship between average trade tax rates from 1970 to 1988 and the log of average real per capita incomes for the same period.¹² The correlation coefficient between the two variables is -0.72.

The relationship between y and the trade tax to income tax ratio is depicted in Panel B. As the model suggests, this ratio tends to be very low for the more developed countries (it is between 0.01 and 0.24 for the G7 countries, for example), and it rises to levels that are considerably higher than 1.00 as per capita incomes decline. Not only do the developing countries tend to have higher τ/b 's, they also exhibit a greater variance in these ratios from country to country.

Furthermore, as Shleifer and Vishny (1993) point out, corruption tends to be more pervasive in countries with the lowest levels of development. This is borne out in Panel C, which illustrates the negative relationship between corruption and real per capita incomes (with a correlation coefficient of -0.69 between the two).¹³ Hence, for a given proportion of tax revenue allocated to education in a

¹² The trade tax data, which comes from Easterly and Rebelo (1993), is the mean of taxes on international trade and transactions over imports and exports. The output data comes from Summers and Heston (1995).

¹³ As noted above, Mauro's (1995) corruption index assigns the number 10 to countries with the least evidence of corruption. To make Figure 7 more visually intuitive, the numbers plotted are: 11 minus Mauro's index numbers. Hence, high levels of corruption are represented by high index numbers in the figure.

country, the actual amount eventually used for that purpose will presumably decline with higher levels of corruption – and education levels could be expected to be adversely affected.

What then, is the relationship between e and y ? The tax and tariff policies used in the numerical example yield the highest level of education in the wealthiest country, and the lowest level of education in the poorest country. This relationship between levels of education and levels of development is also borne out by the empirical evidence. Using educational attainment data from Barro and Lee (1993), Panel D plots the relationship between the average number of years of total education per person and the log of real per capita GDP.¹⁴ A correlation coefficient of 0.85 attests to the positive relationship between the two variables. It would appear that the poorer the country, the less capable it is of engendering technological catch-up since lower levels of education further hamper the ability of poorer countries to reap whatever knowledge spillovers they are exposed to.¹⁵

Thus, not only are developing countries raising the bulk of their revenues from trade taxes – which restrict trade and reduce knowledge spillovers – rather than income taxes, the extent of corruption and waste in these countries also has a negative impact on the education levels that they can provide. As long as the current spread of policies and mismanagement across countries persists, the model predicts that the income gaps between countries will also remain. To the extent that a country's policies change over time, its relative position vis-à-vis the other countries will also be affected. Though not shown here, if the tariff share of total tax revenues in the numerical example is increased even further in the poorer country, or μ_1 is reduced, then the income gap between the countries will increase.

These relationships between income taxes, tariffs and developmental levels are not just a postwar phenomenon. Using pooled cross-section times series regressions on historical data from 1870 through 1988 for 28 countries, Easterly and Rebelo (1993) find a significant positive relationship between real per

¹⁴ The source of the output data is Summers and Heston (1995).

¹⁵ This is consistent with the empirical findings of Eaton and Kortum (1996), who show that while trade relationships enhance the flow of ideas between countries, the education levels within the countries significantly affect the absorption of these ideas.

capita GDP and the income tax share out of total tax revenue. They also find a significant negative relationship between the customs tax share of total tax revenue and real per capita GDP.

Two interesting cases in point are Argentina and Chile, countries that – as De Long (1988) noted – are considered by most accounts to have been among the relatively developed countries during the latter half of the 1800s. In 1895, the ratio of customs tax revenue to income tax revenue was 22.4 in Argentina and 92.0 in Chile.¹⁶ By comparison, this ratio was 2.9 in Denmark, 7.3 in Norway, 17.7 in New Zealand and 2.7 in Sweden. By 1916, these ratios had fallen to approximately 15 for Argentina and 11 for Chile – compared to a reduction to 1 in Denmark, Norway, New Zealand, and Sweden, and a ratio of 2 in the United States. With regard to education, Blomström and Meller (1991) cite substantial discrepancies between the Latin American countries and the Scandinavian countries that favor the latter group.¹⁷ A century later, Argentina and Chile are no longer considered among the world’s most developed countries and the factors noted above were probably among the contributors to their relative change in developmental status.

While the model can account for the empirical evidence of non-convergence among most countries with differing policies, how would things change if countries moved to adopt relatively similar policies? Continuing with the above example, suppose that the middle country signs an agreement with the top country in which (i) both countries eliminate tariffs on trade with one another (*i.e.* $\tau_{23} = \tau_{32} = 0$), and (ii) the middle country adopts income tax rates and tariffs on the bottom country that are equal to those in the top country (*i.e.* $b_2 = b_3 = 10.6\%$ and $\tau_{21} = \tau_{31} = 1.7\%$).

Since such agreements usually entail a transitional period in which the changes are made gradually, the changes in b and τ will be performed in equal amounts in each period of this exercise. If the periods in the simulation represent months, then an agreement establishing a ten year transition (as was

¹⁶ Data source: Easterly and Rebelo (1993)

¹⁷ Among the different comparisons that Blomström and Meller make between the Latin American and Scandinavian countries, they also cite large differences in the degree of openness exhibited in the two regions.

the case with the establishment of the European Economic Community) would imply a formal transition lasting 120 periods in the simulation.

Hence, let the changes in b and τ occur between periods 100 and 220 while the periods following $t = 220$ will reflect the subsequent dynamics as the countries continue to move to their new steady state paths. Before considering the combined price and trade dynamics resulting from the multiple tax and tariff changes, it is useful to consider the effects of each separately. In the case of the increase in income tax b_2 to the level b_3 (in lieu of any changes in tariffs), this would be similar to a vertical move upwards from point B in Figure 3. In other words, one would expect education levels to rise in country 2 as it moves to a higher output path (and possibly even overtakes country 1) as a result of just increasing its b , while all three countries would move to higher steady state growth rates.

The impact of the tariff changes involves a bit more complexity. An example of a unilateral reduction in just one of the tariff rates is depicted in the schematic drawing in Figure 6. Suppose that there is a reduction in the tariff rate imposed by country j on the good produced by country k . This will reduce the gross of tariff price of good k in country j , which in turn will lead to an increase in c_{jk} and to a fall in c_{ji} , or trade diversion, as consumers in country j substitute away from good i towards good k . The increased demand in country j for good k causes the price of k to rise, and country k experiences an improvement in its terms of trade. While the increase in p_k makes good k more expensive in country i – and hence, leads to a reduction in c_{ik} – consumption of both imported goods in country k will rise, *i.e.* c_{kj} and c_{ki} will rise. As is apparent from Equation (2), the increase in v_{jk} leads to heightened knowledge accumulation in country j and to a corresponding increase the supply of good j . The increased supply of j leads to a reduction in its price and to increased consumption of the good by the individuals in country i , hence c_{ij} will increase.

Continuing with the numerical simulation described above, both τ_{23} and τ_{32} are eliminated entirely, while τ_{21} is reduced to the level of τ_{31} and b_2 is increased to the level of b_3 . The combined impact of these

policy changes on the time paths of relative prices is depicted in Panel A of Figure 7 (recall that good 1 is the numeraire good) while the behavior of the trade-output ratios appears in Panel B.

What is the cumulative impact of these policy changes on the steady state growth rate of the countries? That depends on what happens to the education levels and to the trade-output ratios of the countries. If all of these increase, then the implications from Equations (1) and (2) is that growth rates will rise as well. However, while the level of education increases in country 2, it falls slightly in country 3.¹⁸ The changes in the v 's are not uni-directional either, with three of the v 's rising, one v falling, and the two remaining v 's not exhibiting any changes at all. Hence, the cumulative *growth* effect of the policy changes on steady state growth is not immediately apparent.

The output paths of the three countries plotted in Figure 8 reflect the impact of the policy changes. As is evident in the figure, an agreement between the top two countries helps the middle country to catch up and converge with the top country (their new tax and tariff policies, which are now identical lead them to the same – higher – iso-income curves). Note that this convergence coincides with movement to a steeper, *i.e* faster, growth path for *all* three countries (as the countries, as a group, move to a higher iso-growth curve), though a gap still remains – and, in fact, has widened – between the top two countries and the bottom country.

This experiment is similar to that undertaken by the six original EEC countries.¹⁹ By the late sixties, these countries had removed nearly all of the formal obstacles to trade with one another, while coordinating a common external trade policy. Thus, while there are average trade tax rates in Panel A of Figure 5 that exceed 15.0%, average trade tax rates for the Six did not exceed 1.0%. In fact, they did not even exceed 0.1% The ratios of trade tax revenues to income tax revenues were no higher than 0.03

¹⁸ These are not shown here, but are available from the author upon request.

¹⁹ The founding members of the European Economic Community were Belgium, France, Germany, Italy, Luxembourg, and the Netherlands.

for any of the Six, indicating a substantially more growth-beneficial tax mix than that found in the developing countries (see Panel B of Figure 5).

The trade liberalization embarked upon by the EEC countries moved the Six from a situation of protracted *non*-convergence between the late 1800s and the early 1950s to one of significant income convergence (Ben-David, 1993 and 1994) – as in the case of the top two countries in Figure 8. Furthermore, as they liberalized trade, their trade-output ratios grew, and so did their levels of income (Ben-David and Loewy, 1998). Growth rates along their new paths substantially exceeded the pre-liberalization growth rates, even after omitting the high growth period immediately following the Second World War (Ben-David and Papell, 1995; and Ben-David, Lumsdaine and Papell, 1999).²⁰

This three-country simulation illustrates how a trade agreement between two countries can lead to income convergence between the two and to faster steady state growth for all three. A multilateral agreement would produce even higher growth for all, as well as bringing about a reduction – and eventual elimination – of existing income gaps between all 3 countries.²¹

How can education affect trade liberalization's impact on the growth process? Let's return to the 3-country simulation and suppose that, in addition to the movement toward free trade, both liberalizing countries also decide to increase their share of government revenues devoted to education from 0.03 to 0.05. The shift from the free-trade-only growth path to the new higher education growth path is depicted in Figure 9. The growth benefits of such a policy shift are fairly evident.

While not shown here, alternative policies that diminish the effective amount of resources allocated to education will cause a country to fall to a lower growth path. For example, if the poorer country experiences an increase in graft, then it will fall further behind the more developed countries.

²⁰ By comparison, any random choice of six countries would produce a much more disparate combination of tax policies than that found in the Six. As Ben-David (1995) shows, the likelihood of finding income convergence among any such random grouping of six countries will tend to be very low.

²¹ Dinopoulos and Syropoulos (1994) also find that multilateral trade liberalization leads to faster growth than does unilateral liberalization, though liberalization in their model does not produce growth affects for the remaining countries, nor does it yield any predictions regarding relative income levels.

VI. CONCLUSION

This paper focused on the importance of education and international trade in the dissemination of knowledge and its impact on economic growth. The model shows how, in an economy where education is publicly financed, it is preferable that as large a proportion of tax revenues as possible be sourced from taxes on income rather than from taxes on trade. The combination of implementing an income tax combined with zero tariffs is not only beneficial for the growth of all the trading countries, it also serves to enhance the relative income of the country that chooses such a policy.

While the first income tax was imposed in 1799 (in Britain), not all governments have been particularly successful in collecting it. As Blomström and Meller (1991) note in their evaluation of the Latin American countries, the lack of an adequate infrastructure to implement and collect income taxes was no doubt one of the underlying reasons that the tax burden fell more heavily on their external sectors. More than likely, this problem is just as acute, if not more so, in other developing countries today. Thus, while it is clear that a shift of the tax base cannot occur overnight, it is nonetheless important for policy makers to be aware of the consequences of continuing to rely on trade-based taxes.

The creation of the Uganda Revenue Authority in 1991 provides one example of how a developing country might be able to get its tax collection on the right track (*Economist*, 1996). First, all tax collection was brought together into one agency which was initially set up and run by foreigners who were later replaced by Ugandans. Telephone hotlines were installed to enable citizens to report corruption and tax evasion. Roughly 10% of the tax recovered is given back to the callers as an incentive to utilize the hotline. The Authority's employees are given high salaries in an attempt at reducing their temptations to dip into the till as well. As a result, Ugandan tax collection increased several-fold, though approximately one half of Uganda's tax revenues still come from import duties.

When different countries embark on different combinations of policies, it is not surprising that they end up on different growth paths. To the extent that developing countries differ from one another in their policy combinations more than do the more developed countries (see Panel B in Figure 5), or if they alter

and revise their policies often – say with each change of regime – then it should not be too surprising that they may seem to be bouncing from one path to another.²² Hence, developing country growth rates could be expected to exhibit a higher degree of variance than would growth rates in the more developed countries. In fact, if one plots each of the 3,982 available annual growth rates between 1960 and 1992 for each of the 137 countries²³ in the Summers and Heston (1995) dataset – this is done in Figure 10 – then the observations appear to be arrayed in a mean-preserving wedge, with higher growth discrepancies among the poorer countries.

The model presented here provides one way of accounting for the lack of income convergence among countries with differing tax policies, education policies, and degrees of corruption.²⁴ It also provides an explanation for the observed relationship between trade liberalization and income convergence among the more developed countries, as well as the long-term impact of trade reforms on steady state growth and the extent of trade. In this model, the level of education in a country matters if it hopes to capitalize on the available stocks of knowledge worldwide.²⁵ However, concentrating on education alone is insufficient if the country opts for commercial policies that limit its ability to access knowledge spillovers. Alternatively, trade liberalization enhances the diffusion of knowledge. But if this comes at the expense of less funding for educational services, then the capacity of the country to capture these spillovers is diminished.

While this paper has focused on the importance of education in the growth process, similar arguments could also be made for other aspects of infrastructure that facilitate the creation and absorption

²² King and Robson (1993) utilize a model with stochastic depreciation and tax shocks to show how countries with varying tax policies, but otherwise identical economic structures, can display large dispersions in growth rates.

²³ These do not include countries that are primarily oil-exporters.

²⁴ In a related finding, King and Rebelo (1990) use a calibrated two-sector model and show that differences in national public policies can explain the large discrepancies in national growth rates. Frenkel and Razin (1996) also suggest that tax harmonization is an important factor in the convergence of income levels and growth rates.

²⁵ Cohen (1995) finds that, although poorer countries have made large strides in increasing their levels of education, the wealthier countries have nonetheless been able to pull away because of their ability to (1) increase their own education levels, which (2) interacted with their higher knowledge stocks.

of new ideas. Of all these however, probably none is more important than a country investing in the education of its own people.

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Iso-Growth Curves

$$\gamma_1^* < \gamma_2^* < \dots < \gamma_7^*$$

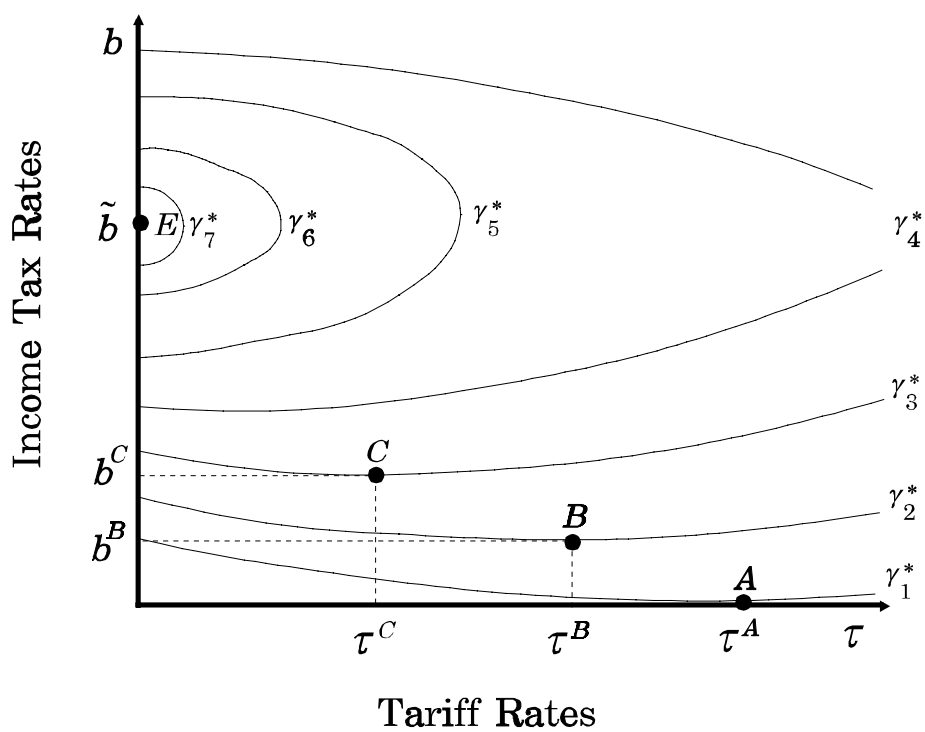


Figure 1

Iso-Growth Curves

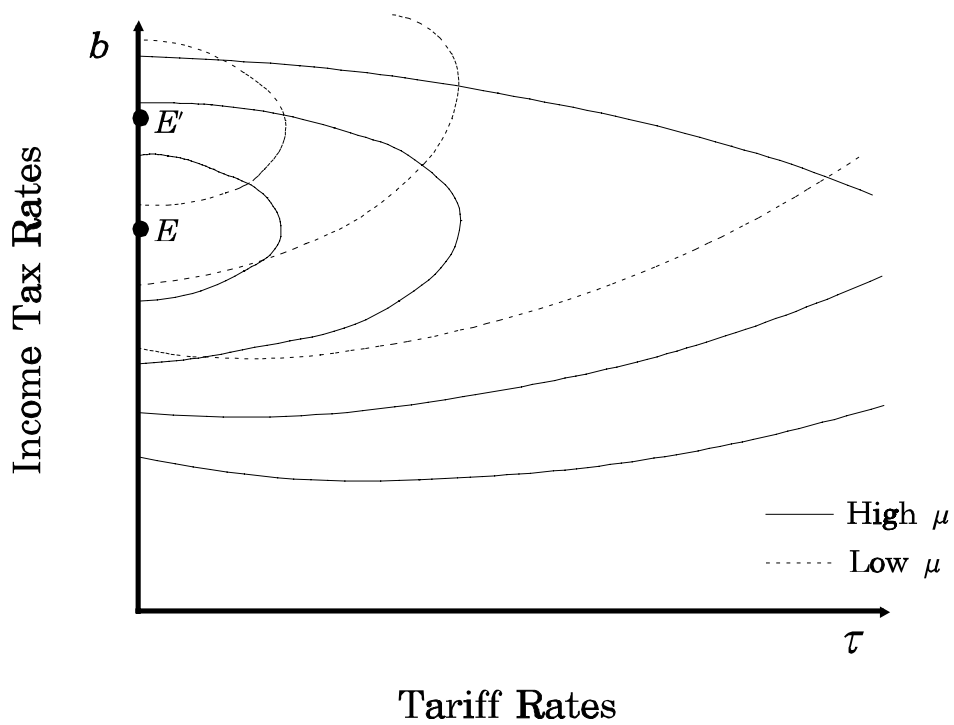


Figure 2

Iso-Income Curves

$$y_1^* < y_2^* < \dots < y_7^*$$

(the y^* s represent steady state paths)

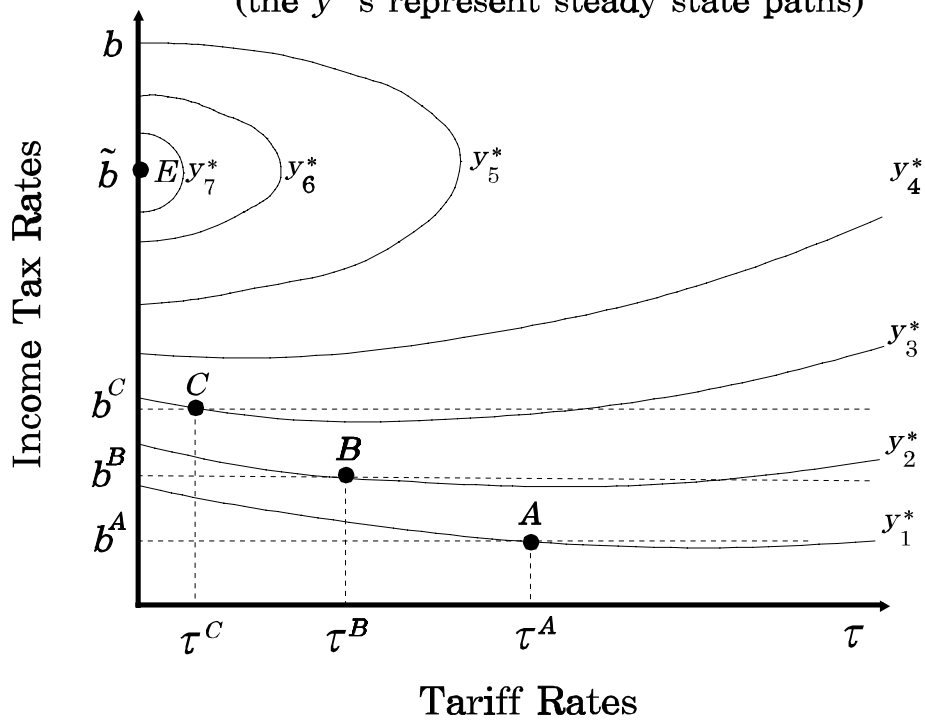


Figure 3

Steady State Growth Paths

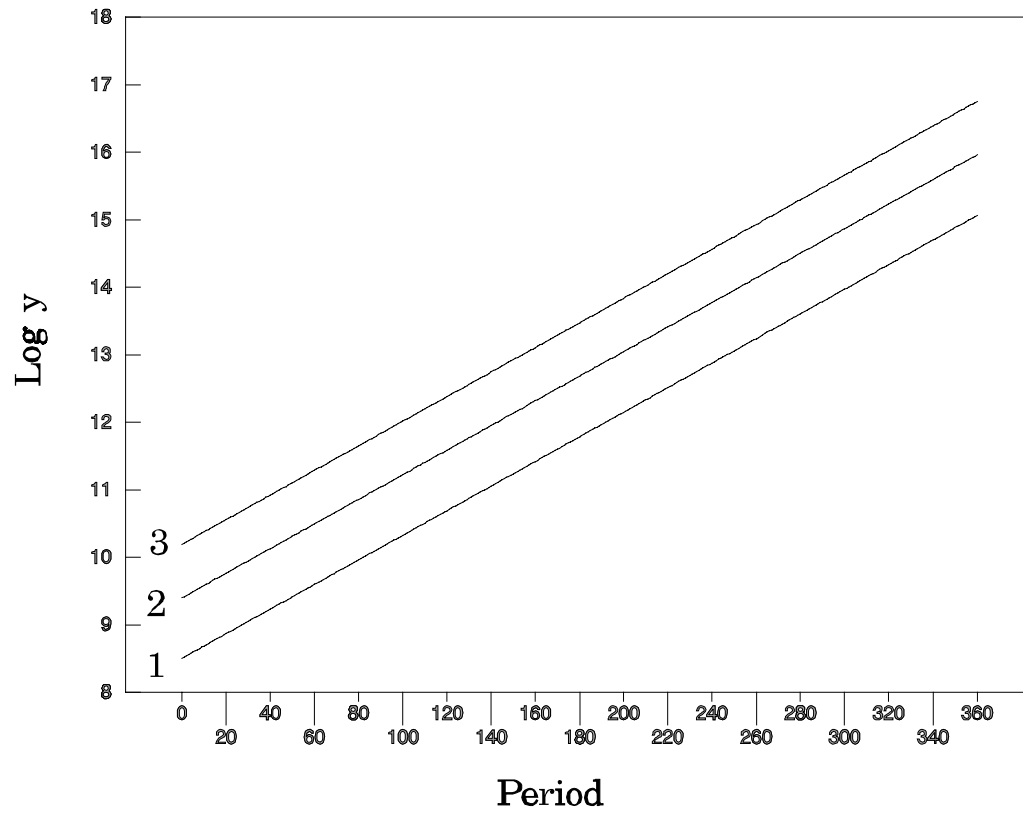
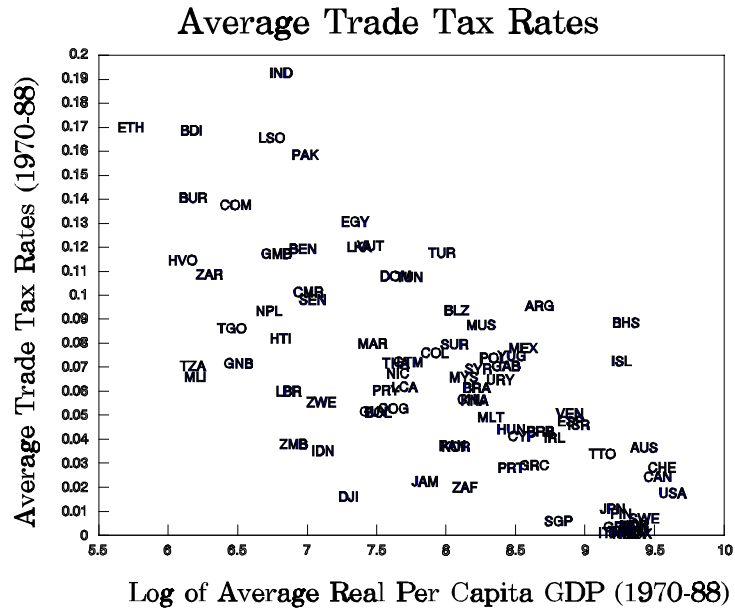
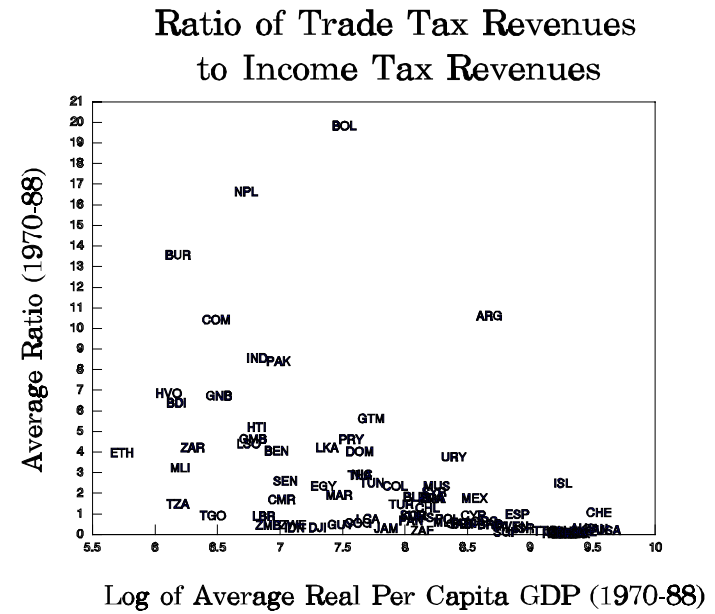


Figure 4

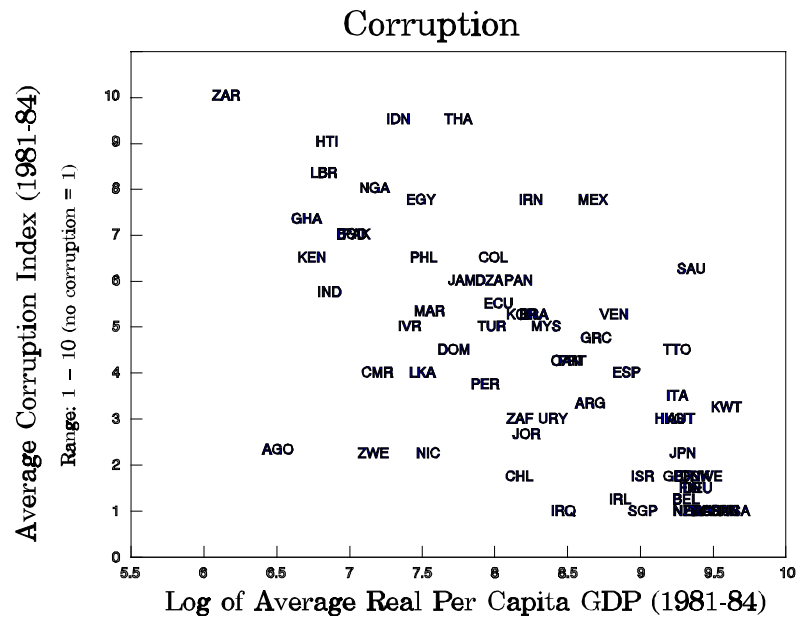
Figure 5



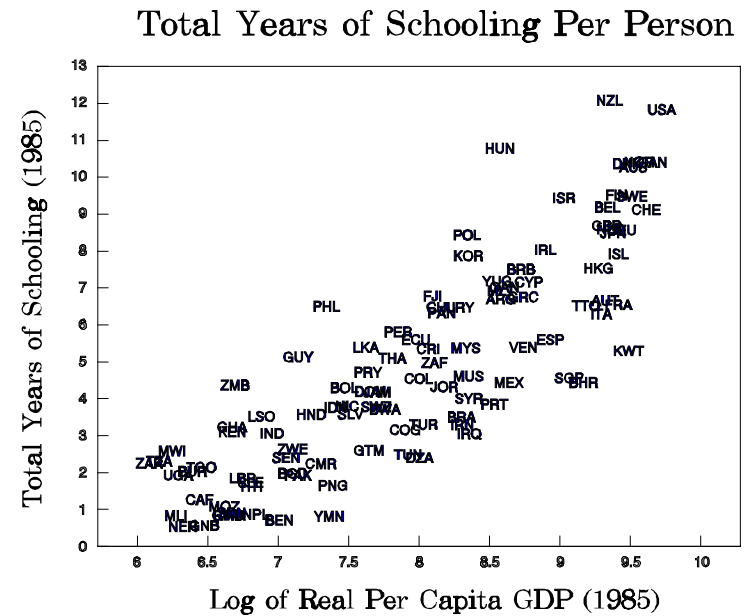
Panel A



Panel B



Panel C



Panel D

THREE COUNTRY EXAMPLE

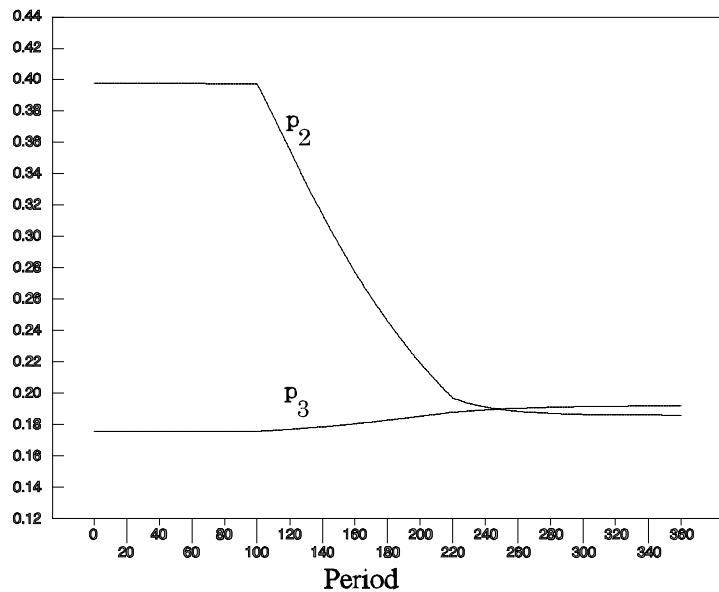
Figure 6: The Impact of a Unilateral Reduction in τ_{jk} on Price and Consumption Levels in Each Country

$$\tau_{jk} \downarrow \Rightarrow \left(\frac{p_k(1+\tau_{jk})}{p_j} \right) \downarrow \Rightarrow \left\{ \begin{array}{l} v_{jk} \uparrow \Rightarrow H_j \uparrow \Rightarrow \text{supply of good } j \text{ increases} \Rightarrow p_j \downarrow \Rightarrow c_{ij} \uparrow \\ c_{jk} \uparrow \Rightarrow \left\{ \begin{array}{l} \text{increased demand in country } j \text{ for good } k \Rightarrow p_k \uparrow \Rightarrow \text{TOT improvement for country } k \Rightarrow \begin{cases} c_{kj} \uparrow \\ c_{ki} \uparrow \end{cases} \\ \text{good } k \text{ becomes more expensive in country } i \Rightarrow c_{ik} \downarrow \end{array} \right. \\ \text{import substitution in country } j \text{ away from good } i \text{ (trade diversion)} \Rightarrow c_{ji} \downarrow \end{array} \right.$$

Figure 7: Combined Impact of: Elimination of τ_{23}, τ_{32} ; Reduction in τ_{21} to Equal τ_{31} ; and Increase in b_2 to Equal b_3

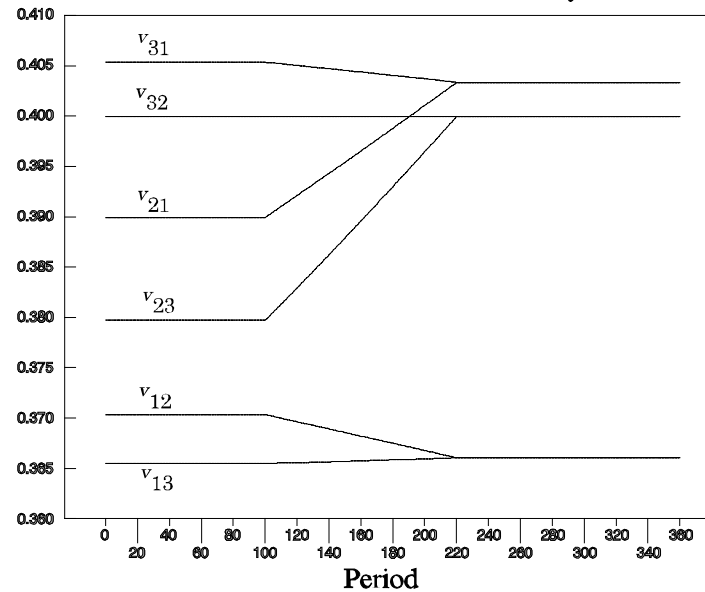
Panel A:

Prices



Panel B:

Trade - Output Ratios (v_{ij})



Countries 2 and 3 Move to Free Trade:
Common External Tariffs,
and Common Income Tax Rates

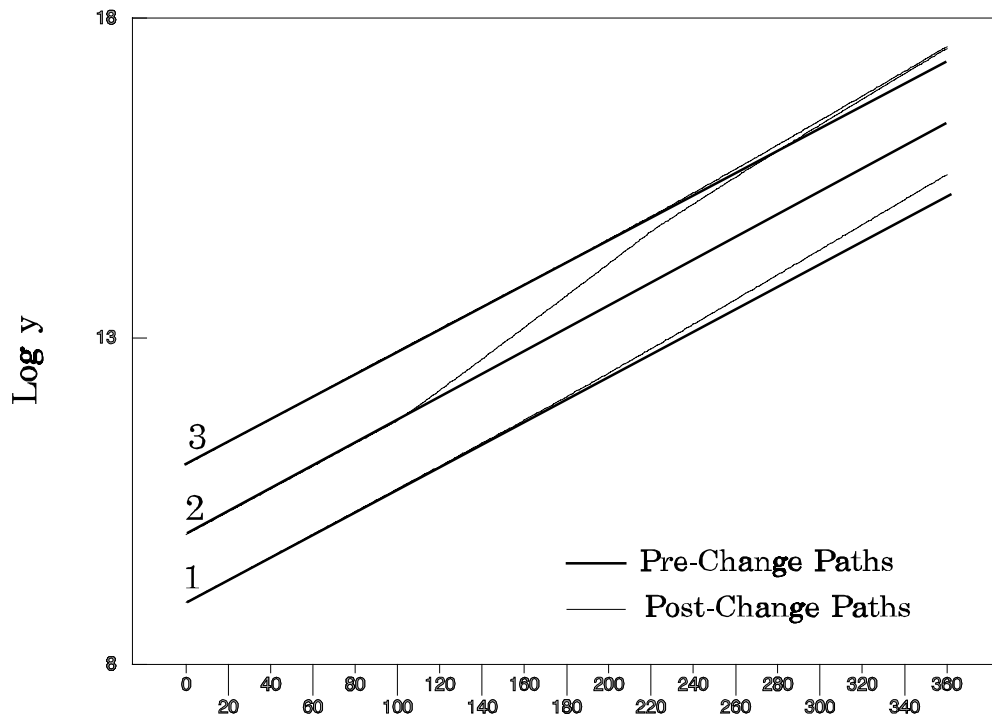


Figure 8

Free Trade Between 2 and 3,
Common Income Taxes and External Tariffs,
And Both Countries Increase Allocation to Education

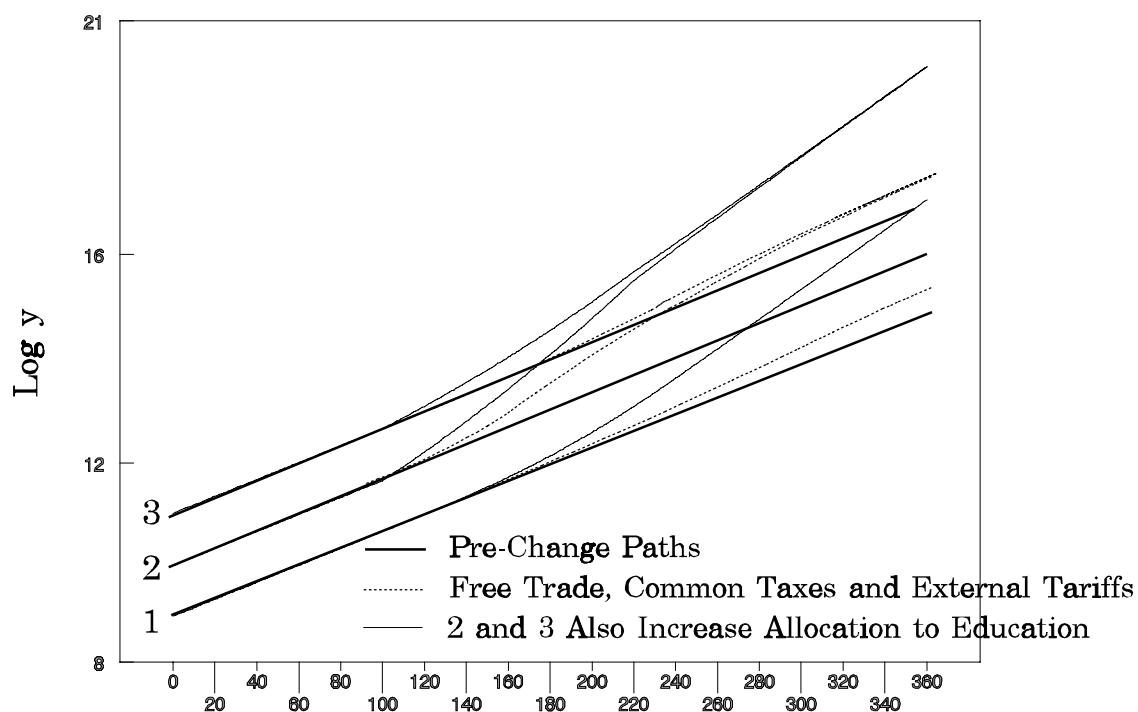


Figure 9

Annual Growth vs. Annual Real Per Capita GDP

137 Countries, 33 Years (3982 observations)

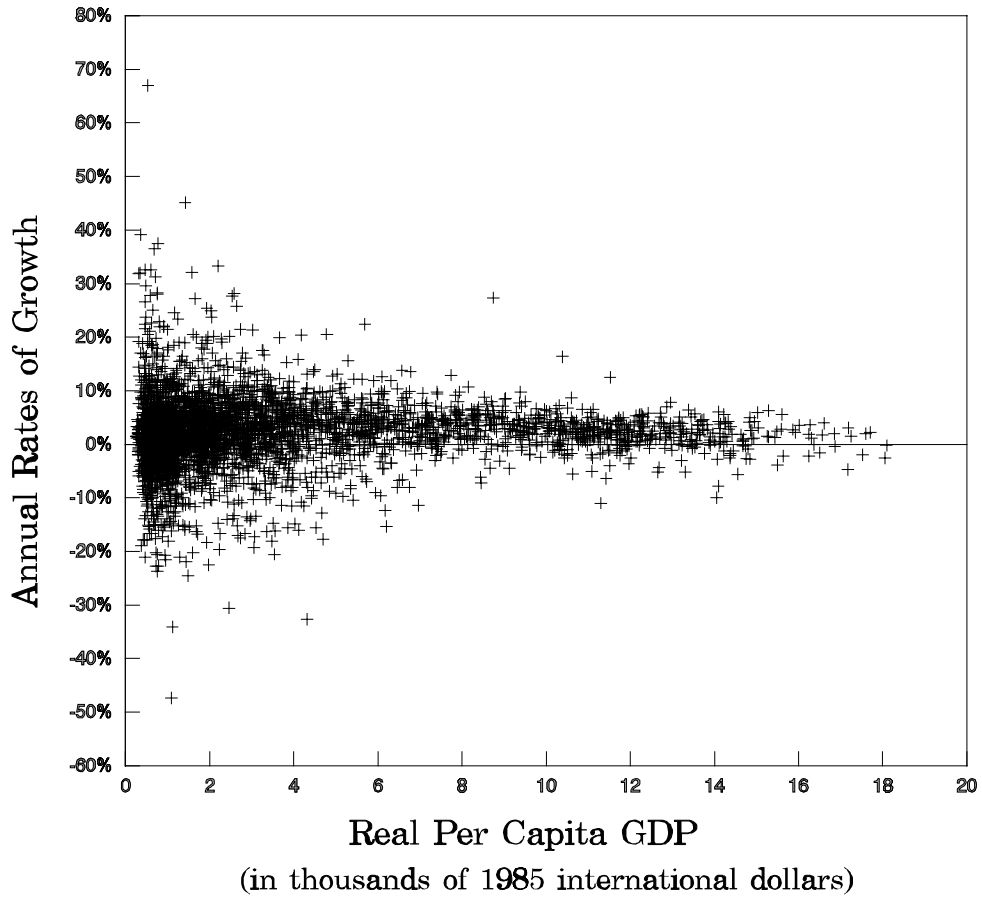


Figure 10