Free Trade, Growth, and Convergence

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Can trade liberalization have a permanent affect on output levels, and more important, does it have an impact on steady-state growth rates? The model emphasizes the role that knowledge spillovers emanating from heightened trade can have on income convergence and growth rates during transition and over the long run. Among the results of the model, unilateral liberalization by one country reduces the income gap between the liberalizing country and other, wealthier countries. From the long-run growth perspective, unilateral (and multilateral) liberalization generates a positive impact on the steady-state growth of all the trading countries.

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1. Introduction

There has been much discussion in recent years concerning the presumed advantages and disadvantages of enacting trade agreements designed to permit freer trade among countries. NAFTA and the Uruguay Round of GATT have been two of the main focal points of these discussions. At the core of these debates are the related questions of whether movement toward free trade will (1) foster a reduction in the disparity of incomes among countries and (2) lead to more rapid growth for all parties concerned, or for just a subset of the signatories.

With regard to the first question, it is not at all obvious why free trade should foster income convergence. From the international trade literature, the factor price equalization theorem (Samuelson, 1948; Helpman and Krugman, 1985) implies that if a number of limiting restrictions are met, then free trade in goods should lead to commodity price equalization and to a subsequent equalization of factor prices. However, as Ben-David (1996), Rassekh and Thompson (1996), and Slaughter (1997) point out, factor price equalization need not be synonymous with an equalization of per capita incomes. From the traditional growth literature, the Solow (1956) model, and the Cass (1965) and Koopmans (1965) modifications, imply that differences in initial capital-labor endowments will be eliminated over time and that this in turn leads to a convergence in per capita incomes. But the Solow-Cass-Koopmans model focuses on a closed economy so that convergence occurs without the need for trade.

While the traditional trade and growth literature does not yield an unequivocal theoretical link between movement toward free trade and income convergence among countries, the empirical evidence suggests that there does indeed exist such a link. Studies by Ben-David (1993, 1994, 1996) show that the elimination of trade barriers and increases in the volume of trade lead to a marked reduction in the income gaps that had existed between trading countries. Hence, one of the objectives of this article is to develop an open-economy model that addresses the trade-convergence link.

With regard to the second question posed above, although a reduction in income disparity may be a desired result for some, it does not allay the concern of others that the income convergence may come at the expense of wealthier countries. To this end, the model also addresses the long-run growth implications of trade liberalization by endogenizing the steady-state impact of tariff reductions. The emphasis here is on developing as simple a model as possible to facilitate an analysis of levels in addition to just growth rates, and of transitional period in addition to just steady states.

While most of the existing growth literature focuses on only two countries, or trading blocks, the model developed below—while deliberately rudimentary for the reasons outlined above—is a multicountry model that lends itself to analyses of trade agreements by subsets of countries. Unilateral trade liberalization—or multilateral liberalization, for that matter—is shown to lead to terms of trade dynamics that increase trade with some partners and reduce it with other partners during the transition and subsequent steady state. This trade-varying behavior ultimately affects in different ways both the output levels and the growth rates of the individual countries. Hence, an analysis that accounts for the price and trade dynamics makes it possible to determine the circumstances under which a fast-growing country is in the process of catching up to the leaders or in the process of pulling away from the laggards. It also makes it possible to gauge the impact of unilateral, bilateral, or multilateral trade liberalization programs on the long-run growth rates of countries, whether those countries are directly or indirectly related to the particular liberalization programs.

The general equilibrium model presented here is based on the premises that (1) knowledge may be characterized as a nonrivalrous public good that in many cases is nonexcludable and (2) trade flows facilitate the diffusion of knowledge among countries. The nonrival aspect implies that ideas may be used concurrently in different places and on different production processes. Nonexcludability implies that an idea has public-good characteristics that limit the ability of its originators to receive compensation for its creation.

Heightened trade will, in general, lead to greater diffusion and faster knowledge growth and hence, to faster per capita output growth. Even though the liberalizing country's tariff reductions also affect relative prices that lead to reductions in trade between other pairs of countries, we show that the overall outcome of tariff elimination, even when it is being carried out by a single country, nevertheless leads to a faster steady-state growth for all trading countries. This growth effect is greater the more countries enact tariff-reduction policies.

While all countries experience faster steady-state growth as a result of unilateral tariff reductions, the level effect for the liberalizing country is not negligible, enabling it to converge with, or even to leapfrog over, other countries during the transition to the new steady state. Since all countries with similar levels of technology grow at the same rate in

steady state (in the absence of any additional changes in commercial policy), the relative improvement of one country vis-à-vis the other countries will persist in the long-run.

At this juncture, it is important to clarify the boundaries of this article and to specify its limitations. First, the framework developed here is obviously not the only way to characterize international trade's impact on economic growth. In order to focus on the impact of knowledge spillovers, some of the more traditional explanations (such as economies of scale and comparative advantage, as well as sectoral delineations of economies that include R&D sectors) have been omitted. Second, this article does not attempt to explain why countries levy tariffs in the first place or why they continue to impede trade when this may inhibit growth. Trade barriers may exist as a result of uncertainty regarding the possible level and growth implications of liberalization. Alternatively, political economy considerations, which may differ across countries depending on the distribution of influence of various groups or factions, can lead to varying degrees of protection. In any event, this article is not about why trade barriers exist but about what may happen to output when they are removed.

The outline of the article is as follows. The next section provides some background and discusses related studies. Section 3 provides a theoretical framework that details the contribution of trade toward the diffusion of knowledge, while Section 4 describes the model's solution. The impact of tariff reductions on output levels and growth rates in the short and long runs is highlighted by means of numerical simulations in Section 5. Among other things, these simulations make it possible to examine what occurs during the transition between one steady state and another as a result of changes in tariff policies. Section 6 concludes.

2. Background and Motivation

The past decade has been witness to a growing number of studies aimed at explaining the impact of international trade on economic growth. The main catalyst for the resurgence of this topic has been the emergence of growth models that endogenize the growth process. These models facilitate analyses of the growth effects of a host of policy instruments.

This resurgence notwithstanding, the relationship between trade and growth has been studied at least as early as Adam Smith. More recently, in the aftermath of World War II, economic policies were affected by two major (and contradictory) strands of influence. On the one hand, American policy makers exerted tremendous pressure on European countries to liberalize trade by making economic support via the Marshall Plan contingent on trade reform. On the other hand, import substitution policies, particularly for developing countries, received a boost from early work by Prebisch (1950), Singer (1950), Myrdal (1957), and others. Specifically, this work was interpreted as implying that the impact of terms of trade will be negative for developing countries that primarily produce goods with low income elasticities and that infant industries need increased protection in order to become viable. The latter view received support from several important international lending institutions, which in turn led many poor countries to adopt more protectionist policies.

Over time, however, these protectionist views were challenged by increasing evidence that more outward-oriented economies seemed to be growing faster than countries that re-

stricted trade. This observation received a variety of possible explanations by, among others, Kindleberger (1962), Caves (1965), Corden (1971), and Johnson (1971), who placed an emphasis on, respectively, the existence of a trade sector as a leading, balancing, or lagging sector; exports as a "vent for surplus"; "factor-weight" effects; and factor price and factor utilization ratios. More recent studies, which include Romer (1990), Grossman and Helpman (1991a), Rivera-Batiz and Romer (1991), Young (1991), Baldwin (1992), and Feenstra (1996), emphasize various other aspects of the growth process and how international trade may affect them.

But as Rodrik (1992) asks, if the positive link between trade and growth is so obvious, then why has it taken so long for the countries of the world to embrace free trade? Part of the answer lies in the fact that this positive relationship has not been particularly obvious. According to Olson (1982), the political and economic reorganizations that occurred following World War II led to the dissolution of many of the distributional coalitions that had previous existed. These developments were important aspects of the recovery process that culminated in, among other things, an eventual opening of markets. It is interesting to note that, while the postwar period has been characterized by movement toward freer trade, most countries experienced either growth slowdowns or no noticeable growth improvements.[1]

For example, Ben-David and Papell (1998) study the behavior of GDP for seventy-four countries from 1950 through 1990 and show that fifty-four of the countries exhibit a break in their growth path during this period. Of these fifty-four countries, forty-six experienced significant slowdowns following their breaks. Only eight countries out of the entire sample exhibited significant increases in their rates of growth. From the trade perspective, however, Ben-David and Papell (1997) find that the majority of countries in the postwar period exhibited increases in the volume of their trade. The evidence of heightened trade on the one hand, combined with growth slowdowns on the other, appears to indicate that the relationship between trade and growth, to the extent that one exists, is a negative one (see also Fieleke, 1994).

We claim that this is not the only way to interpret the empirical evidence, however. The postwar period is, by definition, a period following a major upheaval. Standard growth theory tells us that in the aftermath of a negative shock as great as World War II, countries should be expected to exhibit growth rates that initially exceed their steady-state rates. Eventually, as countries return to their original growth paths, their growth rates should fall back to the original steady-state values. Hence, the fact that growth rates have fallen during the past several decades could very well be due to the return of countries to their long-run growth paths. However, in light of the extensive trade liberalization that has occurred since the war, one might ask whether the postwar steady-state paths are the same as the prewar paths or are they new paths characterized by faster growth?

Ben-David and Papell (1995) examine twelve decades of annual GDP data for fifteen OECD countries. Each of these countries was found to have experienced a significant break in their real per capita GDP between 1870 and 1989. In all but one of the cases, the break was characterized by a sharp drop in levels followed by substantially faster growth.[2] For the majority of the countries, the break occurred during World War II.[3] While the standard neoclassical model predicts that the countries should have returned to their earlier steady-state paths after an interim transition period, Ben-David and Papell show instead

that each of the countries in the sample rebounded to a new path that transcended its old one. Not only were output levels higher along the new path, but average growth rates for the period *after* the old paths were surpassed were found to be two and a half times higher than the *pre*break steady-state growth rates.[4]

An interesting case in point is that of the founding members of the European Economic Community (EEC). The removal of trade barriers between these countries led to substantial increases in trade, with the average ratio of exports to GDP in five of the six original member countries (Belgium, France, Germany, Italy, and the Netherlands) during postwar years exceeding the average ratio for these countries in the seven decades preceding World War II by a factor of 2.11.[5] Although the increased openness of the postwar period is accompanied by higher growth rates, it would be presumptuous to attribute all of the faster growth following World War II to increased trade. Nevertheless, it is still useful to compare results between the relatively free trade years prior to World War I (1870–1913) and the years following the postwar slowdown (1973–1989). The average export-output ratio across the five countries for the post-slowdown period exceeds the pre–World War I ratio by a factor of 2.83. Likewise, the five-country average growth rate of per capita real GDP for the post-slowdown period is also higher, exceeding the pre–World War I rate by a factor of 1.63. Not only did the EEC countries grow faster, the degree of income disparity among them declined significantly as well.[6] How might trade have played a role in the heightened growth and the income convergence that occurred?

The notion that the dissemination of ideas is essential to the growth process would seem to be fairly intuitive. Hence, any mechanism that might advance the flow of knowledge from one country to the next should provide a positive, or at least a nonnegative, spur to the development of countries. Parente and Prescott (1994) show how differences in barriers to technology adoption can account for the large income gaps across countries, while Rosenberg (1980) provides evidence that the increasing number of ideas has been an important factor in rising modern standards of living.[7]

What spurs the diffusion of these ideas? The primary assumption of this article, which follows the intuition of Dollar, Wolff, and Baumol (1988), Grossman and Helpman (1991a, 1991b, 1995), and others is that trade between countries acts a a conduit for the dissemination of knowledge.[8] Therefore, to the extent that this is true, the erection of barriers to trade inhibits the transmission of ideas and prevents countries from attaining levels of wealth that might otherwise be possible. Coe, Helpman, and Hoffmaister (1997) show that R&D spillovers from industrial countries to developing countries are substantial and that the extent of openness by LCD's to developed countries significantly impacts the extent of these spillovers, which in turn positively affect growth in total factor productivity. Harberger (1984) also provides evidence that the existence of impediments to trade limits the growth of poor countries. Their removal, in the instances that this has occurred, has corresponded to heightened growth. This finding is corroborated and strengthened by empirical evidence presented in Sachs and Warner (1995) that compares growth rates of open and closed economies and finds that former exhibit consistently higher growth.[9]

Nevertheless, as Lucas (1988) points out, the removal of trade barriers may be nothing more than a series of level effects disguised as growth effects. Indeed, level effects may be far from inconsequential and may even lead a country to leapfrog over initially wealthier

countries.[10] The theoretical framework developed here shows that movement toward free trade (or alternatively, movement toward protectionism) produces growth effects as well as level effects. So, while the model shows how unilateral or multilateral trade liberalization may lead to convergence by some—and divergence from others—all countries will be shown to experience long-term benefits in the form of faster steady-state growth as a result of trade reforms initiated by even one country.

3. The Model

> It is plausible to suppose that the foreign contribution to the local knowledge stock increases with the number of commercial transactions between domestic and foreign agents. That is, we may assume that international trade in tangible commodities facilitates the exchange of tangible ideas. . . .It seems reasonable to assume therefore that the extent of the spillovers between any two countries increases with the volume of their international trade (Grossman and Helpman, 1991a, pp. 166–167).

Intuition of this kind—namely, that international trade acts as a conduit as well as an impetus for the flow of knowledge across international borders—provides the underlying basis for the model to be developed here. Specifically, the goal of this section is to construct an open-economy version of the neoclassical growth model that includes knowledge as a factor of production. When all countries are identical, with the exception of initial endowments, their behavior over time is similar to the predicted behavior of countries in the Solow-Cass-Koopmans model—namely, convergence to identical long-run growth paths. The model developed in this article departs from the usual neoclassical conclusions with regard to the impact of trade policy and the relative openness of countries. Here, the extent of openness not only affects output levels but also has an impact on steady-state growth rates.

The model that we propose follows Romer (1990) by focusing on the importance of knowledge accumulation in the production of output. Physical capital is assumed here to be constant and is normalized to equal unity.[11] Like Romer, we assume that growth in per capita output is due to the accumulation of knowledge. However, in contrast with his model, we make no distinction between firm specific knowledge and the aggregate stock of knowledge that an economy possesses.

Consider a world with J countries, each of which produces a distinct good, with good i being the output of country i. Let $L_i(t)$ be the population size in country i at time t, n_i be country i's population growth rate, and $c_{ij}(t)$ be the per capita quantity of good j consumed in country i at time t. Assuming that each agent in country i is identical, the aggregate preferences of the agents in country i are given by

$$\int_0^\infty e^{-(\rho-n_i)t} L_i(0) \sum_{j=1}^J \alpha_{ij} \ln c_{ij}(t) dt, \tag{1}$$

where $\sum_{j=1}^J \alpha_{ij} = 1$, and the discount rate ρ is common across all J countries. In what follows, we normalize the initial population level in each country to one and, in order to

avoid additional notation, assume that population size and labor force are equal. Note that the form of the utility function implies that country i will trade with each of the remaining $J - 1$ countries at every point in time. Since the same is true of all other countries, there will exist bilateral trade between every pair of countries.

Good i is produced using labor and knowledge. Assuming that the production function is linear homogeneous in labor, this relationship may be written in per capita terms as

$$y_i(t) = A H_i(t)^{\varepsilon_i}, \tag{2}$$

where $y_i(t)$ is per capita output, $H_i(t)$ is the aggregate stock of knowledge in country i at time t, and $0 < \varepsilon_i$. Note that as was the case with population growth rates n_i, we permit the production parameter ε_i to differ across countries, although there is no requirement that this be the case. While the existence of such differences in ε implies that countries' per capita incomes will grow at different rates in the steady state, as we show below, their steady-state rates of knowledge accumulation nevertheless will be the same.

Per capita income in country i is the sum of per capita output plus per capita government tariff revenue. This income is then used to finance the consumption of both domestic and foreign goods. Let good 1 be the numeraire good, $p_i(t)$ be the time t price of good i, and τ_{ij} be country i's tariff on imports from country j ($\tau_{ii} = 0$ by definition). Tariffs are set exogenously and are assumed to be constant over time. Hence, country i's budget constraint is

$$\sum_{j=1}^{J} \frac{p_j(t) \cdot (1 + \tau_{ij})}{p_i(t)} c_{ij}(t) = A H_i(t)^{\varepsilon_i} + g_i(t), \tag{3}$$

where

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

represents government revenues from the imposition of import tariffs which are transferred back to agents lump sum.

As in Lucas (1988), per capita growth in the steady state is obtained by positing that the technology of knowledge accumulation for country i is constant returns to scale in the level of knowledge of country i. It is assumed further here that this technology is also constant returns to scale in the level of knowledge of all other countries. Moreover, the impact of country j's knowledge on country i's rate of knowledge accumulation depends on (1) the degree of country i's access to country j's knowledge and (2) country i's ability to absorb and utilize the accessible part of country j's knowledge.

As the quotation at the beginning of the section suggests, the share of country j's knowledge to which country i has access (and therefore is the source of any potential knowledge spillovers), what we denote as $v_{ij}(t)$, is likely to be an increasing function of the volume of trade between the two countries. In line with what Grossman and Helpman (1991b) propose, $v_{ij}(t)$ is modeled as the ratio of country i's total trade with country j (that is,

bilateral imports plus bilateral exports) divided by country i's aggregate output, or

$$v_{ij}(t) = \frac{\dfrac{p_j(t)}{p_i(t)}L_i(t)c_{ij}(t) + L_j(t)c_{ji}(t)}{L_i(t)y_i(t)}, \quad i \neq j, \tag{5}$$

where recall that $c_{ij}(t)$ represents country i's real per capita consumption of country j's good, $p_i(t)$ is the price of good i, and $L_i(t)$ is the size of the population in country i, each at time t.

Next, define a_{ij} (where $0 \leq a_{ij} \leq 1$) as a constant representing the share of country j's accessible knowledge that can actually be utilized (or absorbed) by country i as part of its own knowledge.[12] One can view a_{ij} as capturing Abramovitz's (1986) notion of "social capability" that determines the potential of a country to utilize existing technologies. Given these definitions, the accumulation of knowledge in country i may be written as

$$\dot{H}_i(t) = \phi \left[\sum_{j \neq i} a_{ij} v_{ij}(t) H_j(t) \right] + (\phi - \delta_H) H_i(t), \tag{6}$$

where ϕ and δ_H represent the common productivity parameter and rate of depreciation of the knowledge stock (in terms of obsolescence or otherwise), and it is assumed that $\phi \geq \delta_H > 0$.[13]

Note that in the absence of trade (or with no capacity to absorb others' knowledge), domestic knowledge grows at the exogenous rate $\phi - \delta_H$. In such a case, the model reverts to a simple exogenous growth model that is essentially a modified version of the Solow model. Should it also be the case that $\phi = \delta_H$, then there would be no per capita growth in autarky.

As far as the impact of tariffs on growth is concerned, recall (from equation (5)) that tariffs do not directly affect the rate of knowledge accumulation. However, as is shown below, they do have a direct effect on consumption through their impact on market clearing prices. This, in turn, has an effect on the v_{ij}'s and therefore on $\dot{H}_i$.[14]

4. Solution

Following Lucas (1988), suppose that the population in each country $j = 1, \ldots, J$ is sufficiently large so that its private agents are atomistic. Hence, the first-order conditions for consumption and the budget constraint for country i imply that

$$c_{ii} = \alpha_{ii}(y_i + g_i) \tag{7}$$

and

$$c_{ij} = \alpha_{ij} \frac{p_i}{p_j(1 + \tau_{ij})}(y_i + g_i). \tag{8}$$

Substituting equation (8) into the expression for g_i in equation (4), and then substituting

the resulting expression into equations (7) and (8) produces the closed-form expressions

$$c_{ii} = \alpha_{ii} Q_i y_i \tag{9}$$

and

$$c_{ij} = \alpha_{ij} \frac{p_i}{p_j(1 + \tau_{ij})} Q_i y_i, \tag{10}$$

where

$$Q_i = \frac{\prod_{j \neq i}(1 + \tau_{ij})}{1 + \sum_{j \neq i} \tau_{ij}(1 - \alpha_{ij}) + \sum_{j \neq i, k} \sum_{k \neq i, j} \tau_{ij} \tau_{ik}(1 - \alpha_{ij} - \alpha_{ik}) + \cdots + \left(1 - \sum_{j \neq i} \alpha_{ij}\right) \prod_{j \neq i} \tau_{ij}}.$$

Recalling that good 1 is the numeraire, the prices of goods $2, \ldots, J$ are found by substituting equations (9) and (10) for each (i, j) into $J - 1$ of the following market clearing conditions

$$c_{ii} + \sum_{j \neq i} \frac{L_j}{L_i} c_{ji} = y_i. \tag{11}$$

Solving this system implies that

$$p_i = \pi_i \frac{L_1 y_1}{L_i y_i} \qquad i = 2, \ldots, J, \tag{12}$$

where π_i is a function of $\hat{\alpha}_{ij} = \dfrac{\alpha_{ij} Q_i}{1 + \tau_{ij}}$ for all i and j $(i \neq j)$. For example, if $J = 2$, then $\pi_1 = 1$ (trivially) and $\pi_2 = \hat{\alpha}_{12}/\hat{\alpha}_{21}$. More interestingly, if $J = 3$, then again $\pi_1 = 1$, while

$$\pi_2 = \frac{\hat{\alpha}_{12}(\hat{\alpha}_{31} + \hat{\alpha}_{32}) + \hat{\alpha}_{13}\hat{\alpha}_{32}}{\hat{\alpha}_{21}(\hat{\alpha}_{31} + \hat{\alpha}_{32}) + \hat{\alpha}_{23}\hat{\alpha}_{31}} \tag{13}$$

and

$$\pi_3 = \frac{\hat{\alpha}_{13}(\hat{\alpha}_{21} + \hat{\alpha}_{23}) + \hat{\alpha}_{12}\hat{\alpha}_{23}}{\hat{\alpha}_{21}(\hat{\alpha}_{31} + \hat{\alpha}_{32}) + \hat{\alpha}_{23}\hat{\alpha}_{31}}. \tag{14}$$

Unilateral and/or multilateral trade liberalization influences prices through the affected $\hat{\alpha}$'s, and the resultant price dynamics lead to subsequent changes in trade behavior, which, in turn, lead to corresponding increases and decreases, as the case may be, in the extent of trade of the individual countries. Hence, the eventual impact on steady-state growth is not readily apparent—although, as is shown below, it is positive. (Section 5 below provides some examples of these dynamics during the transitional period as well as on the eventual steady state.)

Country i's measure of openness toward country j, v_{ij}, is found by substituting into equation (5) the expressions for c_{ij} and c_{ji} from equation (10) and p_i and p_j from equation (12). Doing so yields

$$v_{ij} = \hat{\alpha}_{ij} + \hat{\alpha}_{ji}\frac{\pi_j}{\pi_i} \tag{15}$$

for all $i \neq j$. Given its significance in what follows, note that each v_{ij} equals a constant that is a function of, among other things, the entire set of tariff rates, $\{\tau_{ij}\}_{i\neq j}$.

Finally, although there is no requirement that *bilateral* trade be balanced between any two countries i and j, the market clearing conditions (11), national budget constraint (3), and the government budget constraint (4) jointly imply (in the absence of international capital flows) that each country maintains multilateral trade balance at every point in time. In other words,

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

Turning to the dynamic behavior of country i, the specification of equation (6) implies that this is governed by the system of all J versions of equation (6). Writing this system in vector notation, it follows that

$$\dot{\mathbf{H}}(t) = \mathbf{\Phi} \cdot \mathbf{H}(t), \tag{16}$$

where $\mathbf{H}(t) = (H_1(t), \ldots, H_j(t))'$ and

$$\mathbf{\Phi} = \begin{bmatrix} \phi - \delta_H & \phi a_{12}v_{12} & \cdots & \phi a_{1J}v_{1J} \\ \phi a_{21}v_{21} & \phi - \delta_H & \cdots & \phi a_{2J}v_{2J} \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & \ddots & \cdot \\ \cdot & \cdot & & \cdot \\ \phi a_{J1}v_{J1} & \phi a_{J2}v_{J2} & \cdots & \phi - \delta_H \end{bmatrix}.$$

Since $\mathbf{\Phi}$ is a matrix of constants (recall equation (15)), the solution to equation (16) may be written as

$$\mathbf{H}(t) = \sum_{j=1}^{J} \xi_j e^{\mu_j t}\mathbf{x}_j, \tag{17}$$

where $\mu_1, \ldots, \mu_J$ are the eigenvalues of $\mathbf{\Phi}$, $\mathbf{x}_1, \ldots, \mathbf{x}_j$ are the associated eigenvectors with $\mathbf{x}_i = (x_{1i}, \ldots, x_{Ji})'$, and $\xi_1, \ldots, \xi_J$ are constants determined by the initial conditions, $H_1(0), \ldots, H_J(0)$, and the eigenvectors.

Let μ_1 be the largest eigenvalue of $\mathbf{\Phi}$. As long as at least one $a_{ij} > 0$ for each i and because all goods are traded (that is, $v_{ij} > 0$), it follows that $\mu_1 > \phi - \delta_H \geq 0$ and $\mathbf{x}_1 \gg 0$.[15] Since the steady state is, by definition, an equilibrium in which endogenous variables (here in per capita terms) grow at constant rates, equation (17) implies that in each country i the

steady-state level of knowledge, H_i^*, must grow at the common rate $\gamma_H^* = \mu_1$ (where the asterisk denotes steady-state values). Furthermore, by the definition of $\mathbf{x}_1$, it follows that in the steady state the *relative* levels of knowledge, H_j^*/H_i^*, are given by x_{j1}/x_{i1}, which are also constant. Note that μ_1 is increasing in every v_{ij} since the more open country i is toward country j, the faster it, and hence every other country that trades with country i, grows. Since the utility function guarantees that all countries trade with each other, then even if country i becomes more open only toward country j, *all* countries grow faster in the steady state. Of course, in such a case, country i also experiences positive level effects relative to its trade partners.

These results, together with those from above, imply that the steady-state behavior of each country may be characterized by the following relationships:

$$\gamma_{c_{ii}}^* = \gamma_{y_i}^* = \varepsilon_i \gamma_H^*; \qquad \gamma_{c_{ij}}^* = n_j - n_i + \varepsilon_j \gamma_H^*, \tag{18}$$

where γ_x^* denotes the steady-state rate of growth of any variable x. Therefore, the rate of knowledge accumulation is identical for each country, while the growth rate of per capita output and consumption may vary if the production parameters (ε_i's) and/or the population growth rates (n_i's) differ. To the extent that these parameters are the same, so too will be the steady-state growth rates of per capita output and consumption in each country.

To better highlight the short- and long-run effects that changes in tariff policy may have on the initiating country, as well as on its trade partners, the focus now shifts to a number of simulations of the model. These facilitate a clearer understanding of the impact of the liberalization process on output levels and growth rates by detailing the changes that take place during the transition from one steady state to the next.

5. Simulations

The focus in this section is on a three-country world since this permits an analysis of (among other things) the effects of unilateral trade liberalization on the part of the country with the middle level of income on both its wealthier and poorer trade partners. Within such a scenario, can the liberalizing country catch-up with or even surpass the per capita income level of the wealthier country? Would the long-run growth effects of such a policy be different if it were instituted instead (or as well) by the wealthy country or the poor country? The following simulations show that various conclusions are possible.

5.1. Simulation 1: Different Initial H (Baseline Case)

The first simulation, which also serves as our baseline case, assumes that all three countries are identical save for their initial levels of knowledge. For simplicity, A, $L_i(0)$, $i = 1, 2, 3$, and a_{ij}, $i, j = 1, 2, 3, i \neq j$, are set at unity, while $\mathbf{H}(0) = (1, 2, 3)'$, $\phi = 0.1$, $\delta_H = 0.05$, $\rho = 0.04$, $n_i = 0.02$, $\varepsilon_i = 0.3$, $\alpha_{ii} = 0.6$, and $\alpha_{ij} = 0.2$, where $i, j = 1, 2, 3$ and $i \neq j$. Hence, country 1 is initially the poorest country, and country 3 is initially the wealthiest country. Also, consumers in each country give most weight to the utility derived from consuming their own good while giving less, but equal, weight to the utility derived from

consuming the two imported goods. Tariffs are set at the rate of 75 percent by each country i on both partners' imported goods. This relatively high rate is not mandatory and is primarily used for illustrative purposes in order to yield clearer distinctions in the graphs that follow. The qualitative behavior described below works for lower tariffs as well.

Given these baseline parameters, these three countries converge to identical per capita output levels and growth rates (of 3.05 percent annually) in the steady state. The outcome of this simulation, with respect to levels and growth rates, is similar to that of the standard neoclassical model when countries differ only by their initial endowments. In that model, as is the case here, if countries begin from different starting points or alternatively, if a country experiences a shock to its inputs, countries eventually return to their original steady-state path.[16]

5.2. Simulation 2: Different Initial H and a Reduction in a Single Tariff, τ_{23}

Consider once again the baseline economies of Simulation 1. Suppose that starting in period 15, country 2 (the initially middle-income country) unilaterally begins to reduce its tariffs on imports from country 3 (the initially wealthy country) at the rate of 15 percentage points per period. Hence, this tariff is completely eliminated by period 20. Suppose that no other tariff reductions occur.

Panels A to E of Figure 1 include the fourteen periods prior to the tariff reduction, the five periods of tariff reduction, and thirty-one postliberalization periods. The unilateral tariff reduction sets in motion a series of relative price changes and subsequent movements in the bilateral shares of output being traded by the three countries. These combined changes affect the growth path of the individual countries, in terms of their relative income levels and their steady-state growth rates.

The decrease in τ_{23} implies that there is a reduction in the gross of tax price of good 3 in country 2, $p_3(1 + \tau_{23})/p_2$, which, in turn, increases c_{23}, the imports, by 2 from 3. Import substitution in country 2 then leads to a reduction in c_{21}. The increase in demand for good 3 increases its price p_3 (see panel A) and therefore improves country 3's terms of trade. This in turn increases c_{31} and c_{32}. The increase in p_3 also affects country 1's imports from country 3, leading to a decrease in c_{13}. To determine the effect on c_{12}, note first that the increased exports from 2 to 3 and the increased imports by 2 from 3 coupled with the increase in the relative price of the imports unambiguously increases v_{23}. Next, note that by equation (6) this increase causes an increase in the knowledge stock of country 2. Equation (2) then implies that the supply of good 2 rises, which, in turn, decreases its price (see panel A). The resultant decline in p_2 increases c_{12}.[17] As panel B indicates, four of the six v_{ij}'s rise while two others fall. However, as the discussion of long-run results below shows, the decreases are more than offset by increases in the remaining v_{ij}'s, and a reduction in τ_{23} leads to an increase in the steady-state growth rate that is common to all three countries.

Panel C shows that the main beneficiary in the short run is country 2, the liberalizing country, whose income overtakes that of country 3 to become the wealthiest country. This result is seen more clearly in panel D, which shows the income gap between country 3 and the other countries, and in panel E, which displays each country's growth rate. The
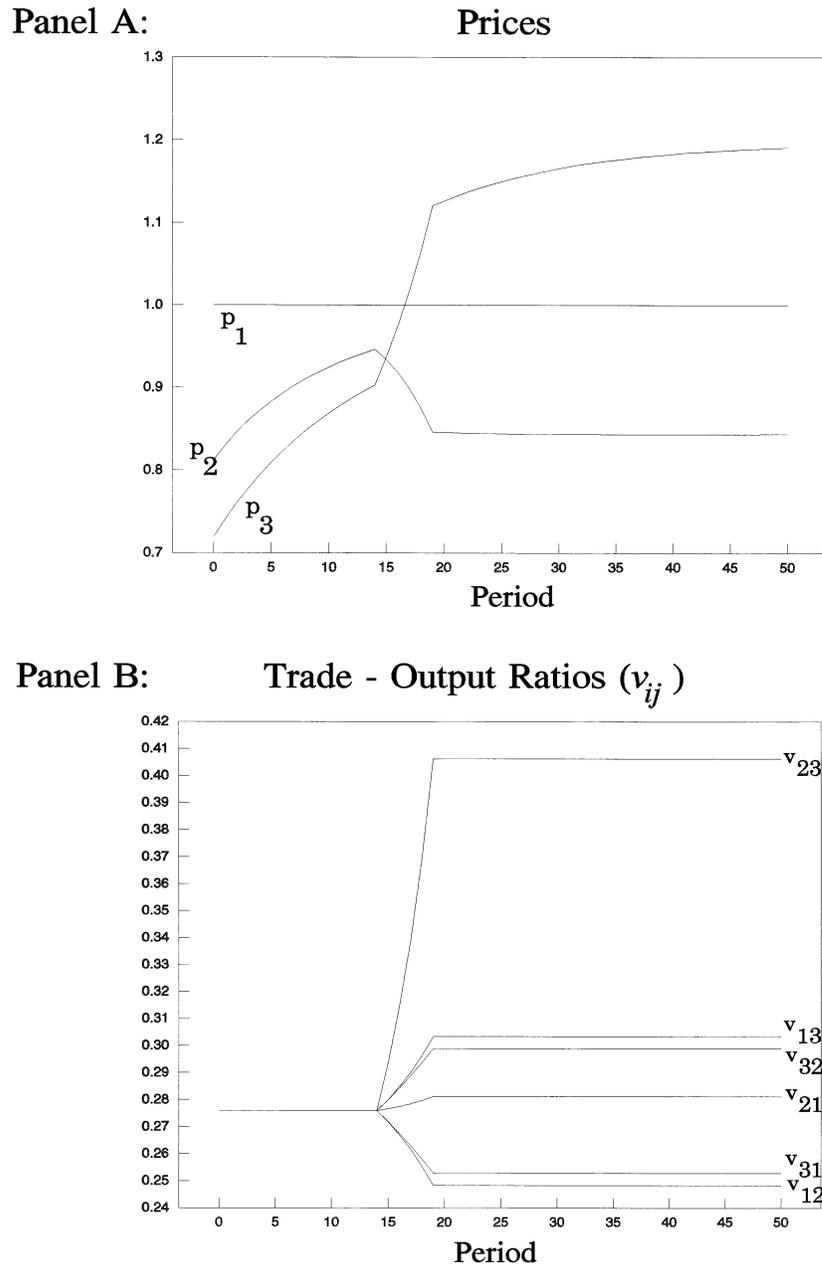
Panel A: Prices

Panel B: Trade - Output Ratios (v_{ij})

Figure 1. Unilateral tariff reductions by Country 2 on imports from Country 3 (1 = poor country, 2 = middle income country, 3 = rich country). Continued following two pages.
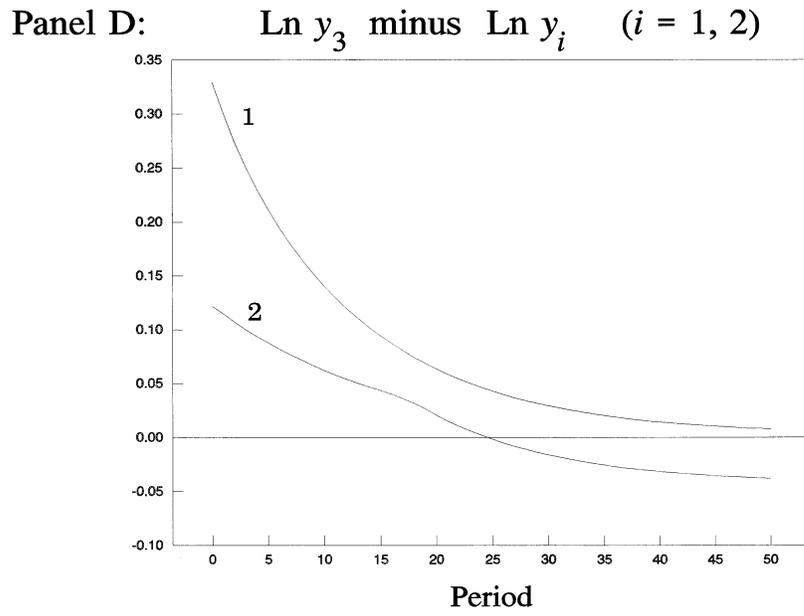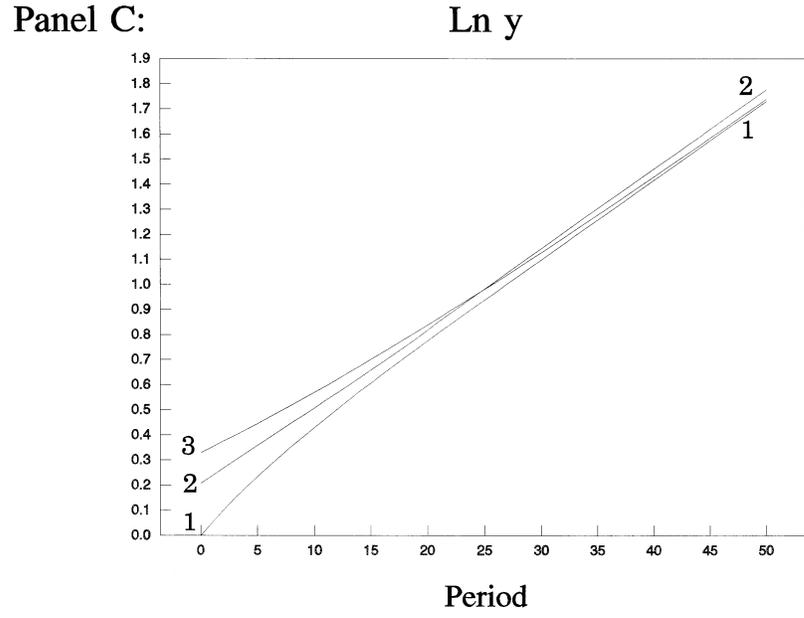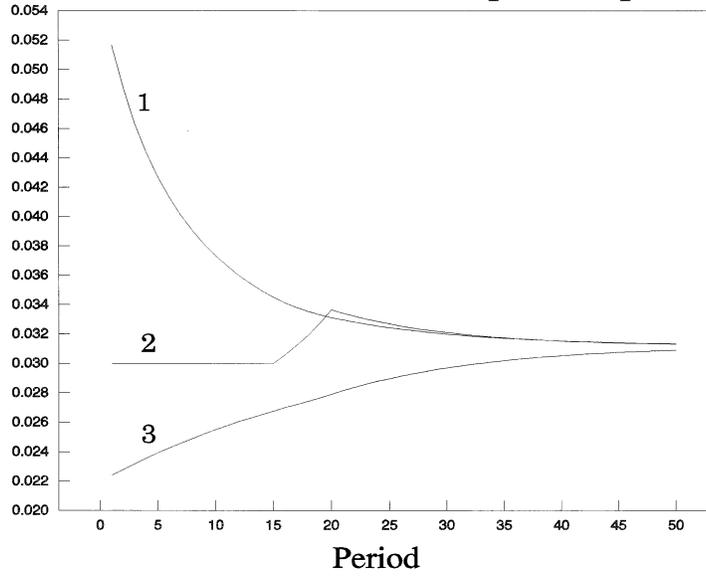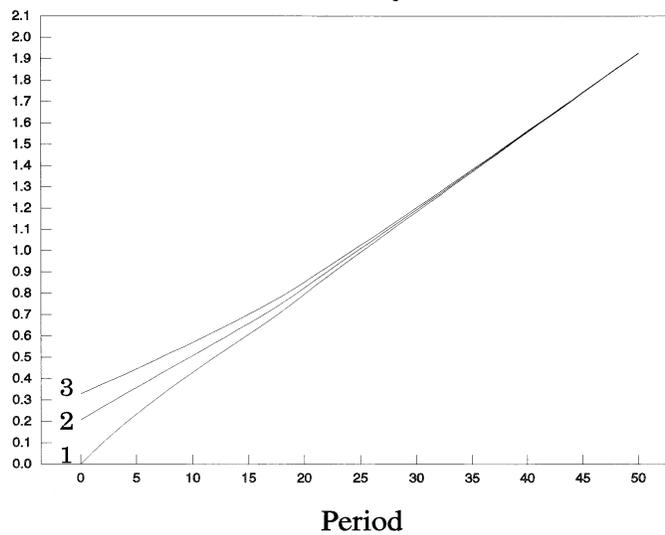
Panel C: Ln y

Panel D: Ln y_3 minus Ln y_i (i = 1, 2)

Figure 1. Continued. Unilateral tariff reductions by Country 2 on imports from Country 3 (1 = poor country, 2 = middle income country, 3 = rich country).

Panel E: Growth Rates of Per Capita Output

Period

Movement to Free Trade by All Countries
Panel F: Ln y

Period

Figure 1. Continued. Unilateral tariff reductions by Country 2 on imports from Country 3 (1 = poor country, 2 = middle income country, 3 = rich country).

initial income gap between countries 3 and 2 is eventually eliminated and then is reversed as country 2 surpasses country 3. While there is eventual income convergence between countries 1 and 3, the gap between them and country 2 continues to exist in the steady state since all countries grow at the same rate in the long run.

As a result of the unilateral liberalization by country 2 on imports from country 3, the steady-state growth rate for each country rises from 3.04 percent found in Simulation 1 to 3.17 percent. Because of the similarity in preferences, it turns out not to matter which country embarks on trade reform. Growth rates rise to 3.17 percent independently of country choice. Naturally, the level effects would differ.

If one country decides to eliminate tariffs on *both* of its imports, then long-run growth rates rise to 3.26 percent. Note that while the choice of liberalizing country is immaterial as far as growth is concerned, this is not the case when the issue is output levels. If any pair of countries moves to completely free trade, then the income levels of the two will converge— with an income gap persisting between the two countries that fully eliminate tariffs and the one that does not—and steady-state growth rates will rise to 3.49 percent. If all three countries remove all tariffs, then the steady-state growth rate increases to 3.73 percent, and all three income levels converge along the new, steeper, growth path (see panel F).

5.3. *Simulation 3: Liberalization Among Developed Countries*

Suppose that new "worldwide" trade agreements mandate that all tariffs must be reduced by a third. At the same time, suppose further that the two wealthier countries sign a free-trade agreement stipulating that they must remove all barriers to trade with one another within five years. In other words, while countries 2 and 3 completely eliminate their tariffs on trade with each other, they partially reduce their tariffs on trade with country 1, as does 1 on trade with 2 and 3. This example is not particularly different from the agreement that led the European Economic Community to initiate a formal timetable for the complete removal of all remaining tariffs between 1959 and 1968 and from the subsequent Kennedy Round Agreements within the GATT framework that led to across-the-board *partial* tariff reductions beginning in 1968. Finally, suppose that in each country greater weight is given to the utility of consumption of the import of the wealthier trade partner, letting the α_{ii}'s equal 0.6 as before and the α_{ij}'s equal 0.267 and 0.133 for the more developed and the less developed partners, respectively.

The effects of these policies are depicted in Figure 2, which shows that the top two countries converge to similar paths while maintaining a gap with the poorer country. Thus, while tariff reductions boost trade (panel A) and all countries move to faster steady-state growth of 3.51 percent (as indicated in panel B), an income gap with the less developed country continues to exist (panels C and D). This lack of convergence, or catch-up, by the poor country is consistent with the empirical evidence in Baumol (1986), Quah (1993), and Ben-David (1995).

The presence of both income convergence and faster growth among the wealthier countries in the simulation appears to describe the major postwar liberalization experiences fairly well. Continuing with the example of the original EEC countries, a trade barrier index that is a composite measure of tariffs and quotas for the EEC between 1950 and 1968

Panel A:

Trade - Output Ratios (v_{ij})

Panel B:
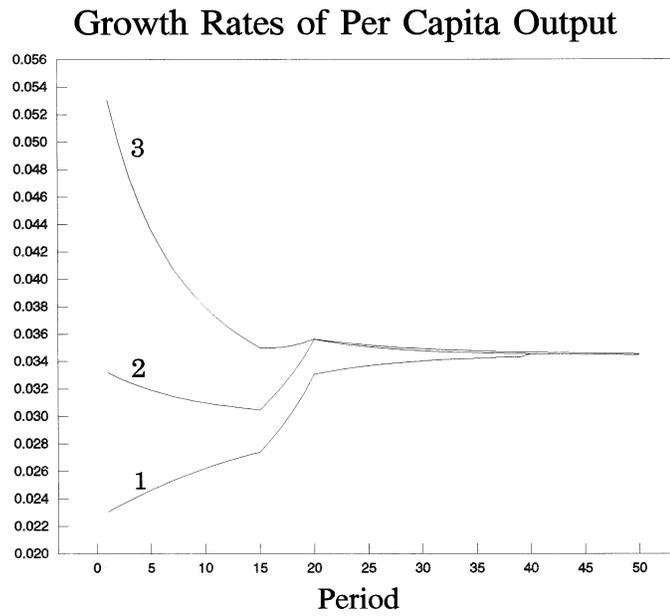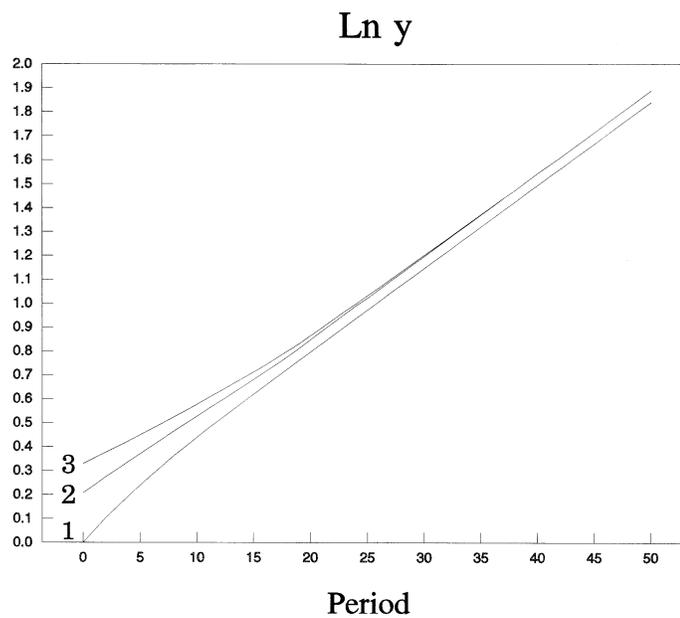
Growth Rates of Per Capita Output
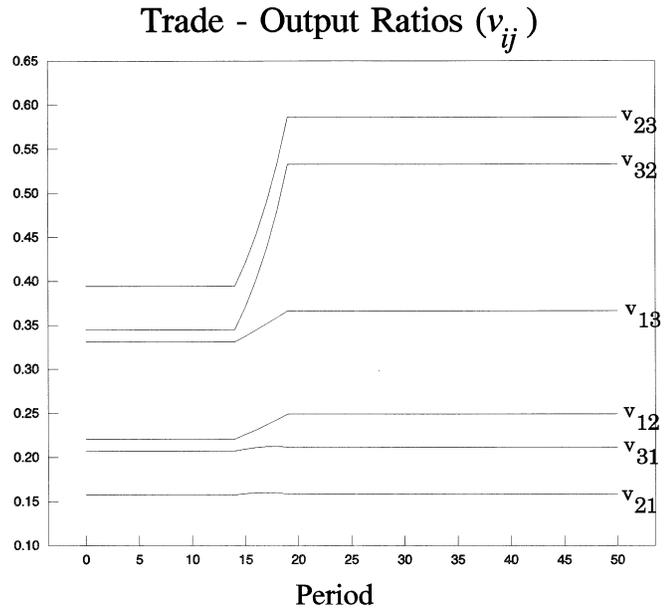
Figure 2. Free trade only among the developed countries (1 = poor country, 2 = middle income country, 3 = rich country). Continued on following page.

Panel C:

Ln y
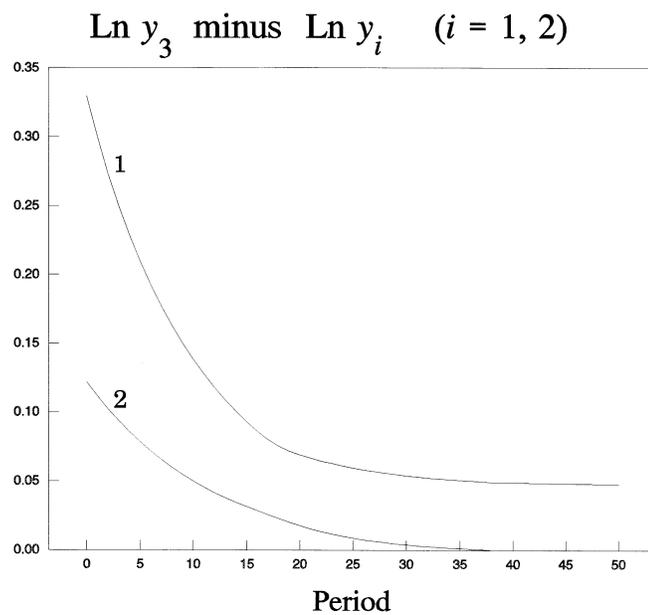

Period

Panel D:

Ln y_3 minus Ln y_i (i = 1, 2)

Period

Figure 2. Continued. Free trade only among the developed countries (1 = poor country, 2 = middle income country, 3 = rich country).

is constructed in Ben-David (1994) and plotted at the bottom of panel A in Figure 3.[18] Although the Community was officially created in the late 1950s, member countries began to liberalize trade in varying degrees beginning in the late 1940s. The removal of trade barriers manifested itself in an increasing ratio of total intra-EEC trade to total EEC output, depicted as v_{EEC} in panel A. As is evident in panel B, in the years between 1870 and World War II, the standard deviations of the EEC countries' log real per capita incomes had been relatively constant. However, with the elimination of trade impediments following the war, this measure of income disparity among the countries (labeled σ_{EEC} in panel A) began to fall.[19]

As the liberalization process tapered off in the late 1960s, so too did the fall in σ_{EEC} and the rise in v_{EEC} (Ben-David, 1993, 1994). Note that the convergence process does not end immediately with the formal end of the EEC's liberalization period. This is consistent with the simulated convergence process (in panels C and D of Figure 2), which does not immediately end following the complete elimination of tariffs.

What happened to the long-run growth path of the countries as they liberalized trade and did the trade-related convergence come at the expense of slower growth by the initially wealthy countries of the Community? In the case of Belgium (panel A of Figure 4), for example, the country grew at a fairly steady pace from 1870 until the outbreak of World War I over four decades later.[20] The ratio of the country's exports to GDP was also quite stable throughout this period.

World War I coincided with a sharp drop in levels that was followed by a return to the prewar long-run growth path—just as predicted by the Solow model. The trade-output ratio continued to remain stable as the country returned to its earlier path. World War II also coincided with a sharp drop in levels, but its aftermath was quite different. As Belgium began to liberalize its trade, its trade-output ratio rose steadily, and the country not only returned to its earlier growth path, it eclipsed it by a sizeable margin.[21] When the 1970s slowdown came, the country was already far above its earlier path—not only in terms of levels but also in terms of real per capita growth rates.

Panel B shows that France underwent a similar evolution. World War I represented a temporary shift from the long run path, while World War II was followed by movement to a new and steeper path that was accompanied by higher trade-output ratios. As predicted by the model (and represented by countries 2 and 3 in Figure 2, panel C), each one of the EEC countries moved to a new and steeper growth path following World War II. And, as noted earlier in Section 2, average trade-output ratios and growth rates for the EEC countries *after* the onset of the slowdowns in the 1970s were over 50 percent higher than the respective averages prior to the outbreak of WWI.

Hence, the trade-related convergence exhibited by the countries was not a catchup that came at the expense of the initially better-off countries but rather a catchup that was part of a movement by each of the countries to higher and faster growth paths. Note that the long-run plots of each country's total export to GDP ratios—which indicate a clear difference in the extent of postwar trade compared to prewar trade—are similar to the behavior of v_{23} and v_{32} in panel A of Figure 2.

Ben-David (1993, 1994) shows how this type of trade liberalization scenario was repeated between the United States and Canada as well as between the EEC and EFTA (European

Panel A: **EEC Trade Liberalization:**
                              Trade Volumes and Income Convergence
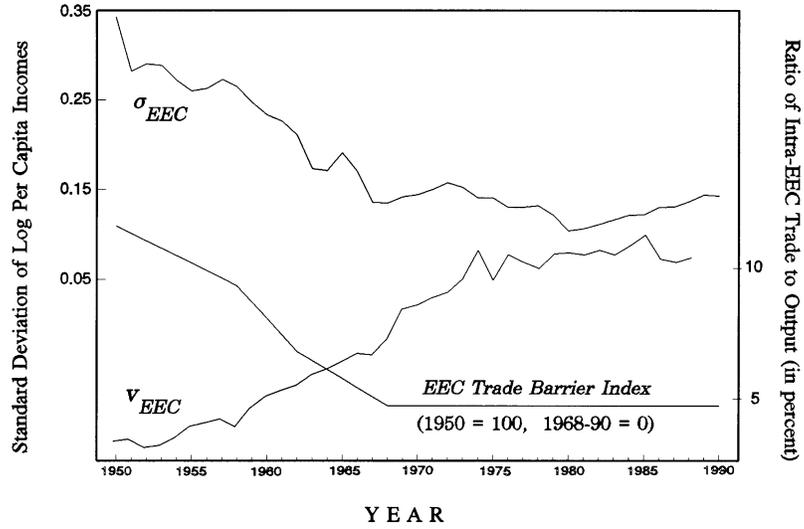
Panel B: **Long-Run Income Disparity Among Future EEC Founders**
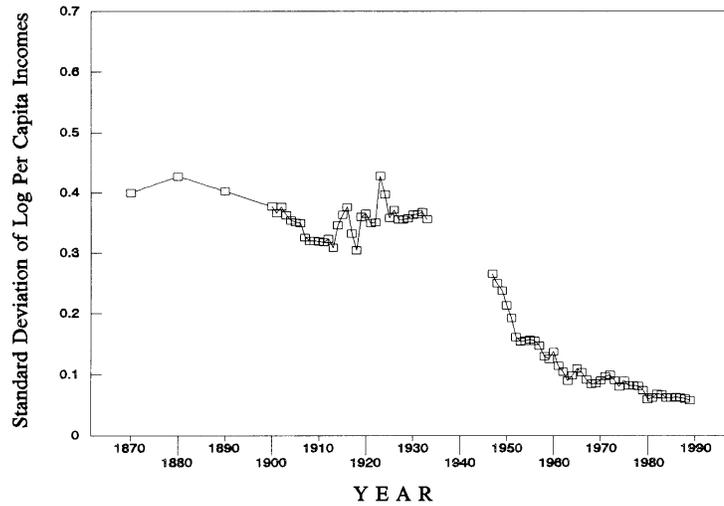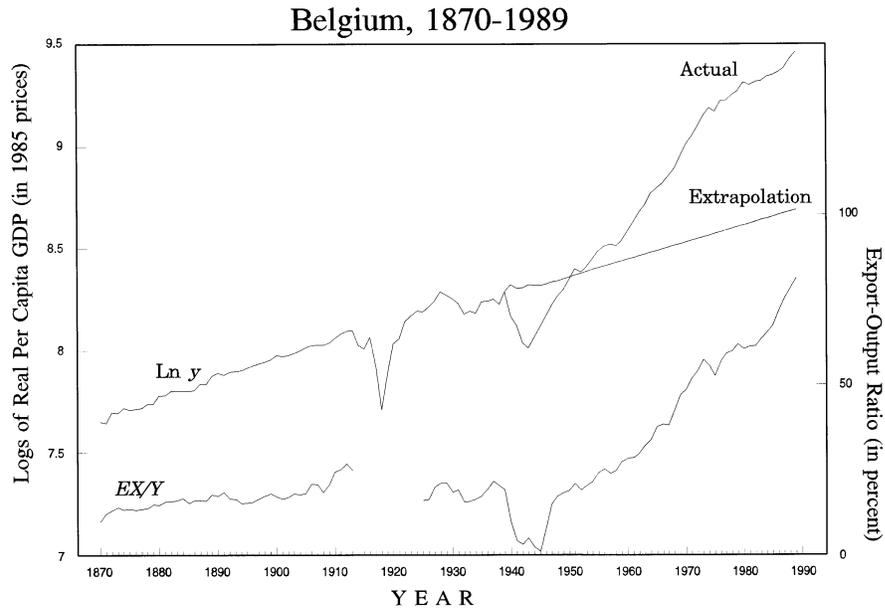   **(Belgium, France, Italy, Germany, and the Netherlands)**

Figure 3. EEC trade liberalization and income disparity.
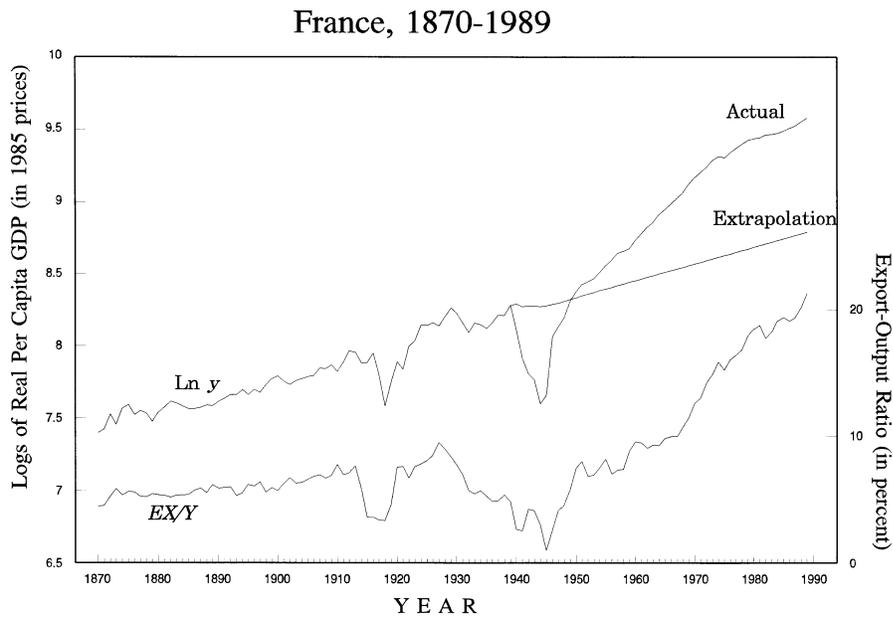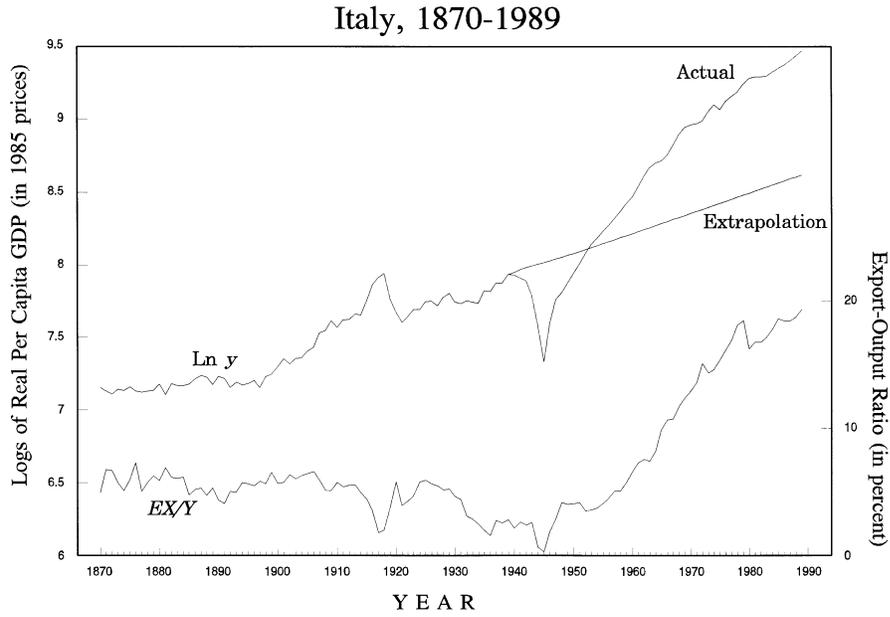
Panel A:

Belgium, 1870-1989

Panel B:

France, 1870-1989

Figure 4. Comparisons of 1940 to 1989 growth paths with 1870 to 1939 paths. Continued on following two pages.
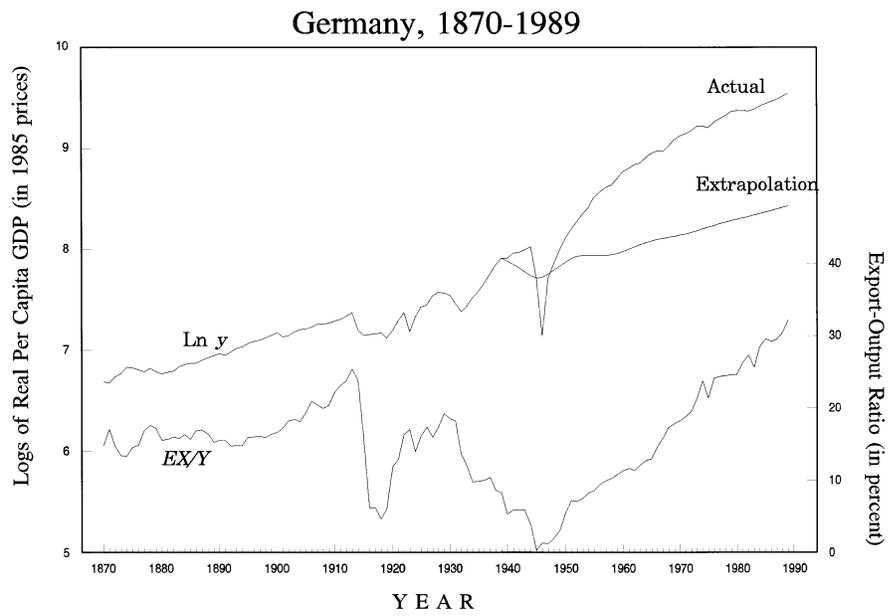
Panel C:

Italy, 1870-1989

Panel D:

Germany, 1870-1989

Figure 4. Continued. Comparisons of 1940 to 1989 growth paths with 1870 to 1939 paths.

Panel E:

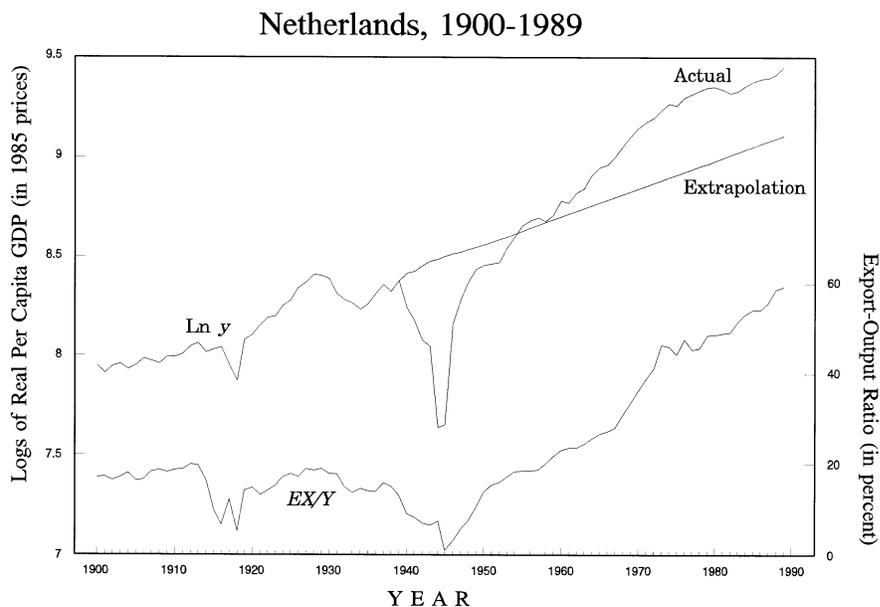## Netherlands, 1900-1989

Figure 4. Continued. Comparisons of 1940 to 1989 growth paths with 1870 to 1939 paths.

Free Trade Association). In each case, these episodes culminated in increased trade and significant income convergence by the liberalizing countries. As in the EEC case, the countries moved to higher and steeper growth paths.

6. Conclusion

This article focuses on the impact of international trade on income convergence and economic growth. While the traditional trade literature addresses the impact of trade on equalization of factor prices, it does not necessarily imply that incomes should converge as well. On the other hand, the Solow-Cass-Koopmans growth model predicts income convergence, but this occurs within autarky. In addition, both frameworks are silent on the possible steady-state impact of trade liberalization. The theoretical framework developed here provides a simple model that bridges these gaps while illustrating the impact of tariff reductions not only on the steady-state outcomes but on transitional behavior as well—and not only on the growth effects but on the changes in the individual output levels of countries. While the model is purposefully simple so as to enable such an analysis, it goes beyond the common two-country models to permit examinations of unilateral and multilateral policy changes on the countries enacting the changes, as well as on the remaining countries.

   The more open an economy, the greater the competitive pressures on it, and the greater

the need for it to incorporate foreign knowledge into its production processes to be able to compete with foreign firms. This provides the basis for our assumption that trade flows between countries facilitate the diffusion of knowledge and spur the growth process. Like the Solow-Cass-Koopmans model, the theoretical framework presented here predicts that countries with similar technological parameters exhibit similar per capita growth in the long run. In this model however, steady-state growth rates depend on the rate of knowledge accumulation, which in turn is a function of the stocks of knowledge worldwide. Each country accesses foreign knowledge by conducting trade with other countries. The extent of this trade dictates the extent of the knowledge spillovers that will ensue and, hence, the rate of output growth. Countries with identical tariff structures converge to the same steady-state growth path and to similar per capita outputs in the long run.

Unilateral trade liberalization (in the form of tariff reductions) leads to terms of trade dynamics that result in changes in the extent of trade between countries—with some bilateral trade rising and other bilateral trade falling. The output of countries is affected in two ways. First, there is a level effect captured by the liberalizing country that may enable it to catch up with and possibly leapfrog over initially wealthier countries. Second, and most important, there is a positive growth effect that affects all countries in the long run. If wealthy countries (in per capita terms) are also the countries with the greatest stocks of knowledge, then the elimination of tariffs on these countries' trade will have the greatest growth effects.

Empirical evidence appears to corroborate the model's predictions. Specifically, the increasing tendency toward trade liberalization during the postwar period has led to a significant convergence in income levels within the EEC, between the United States and Canada and between the EEC and EFTA. The faster growth (by the poorer countries in each group) that caused the convergence in levels did not come about at the expense of their wealthier trade partners. In fact, each of these liberalizing countries moved to growth paths that were higher during the postwar period than during the period 1870 and the start of World War II.

Finally, while trade liberalization and income convergence characterize many of the world's wealthier countries, this is not an apt characterization of what has occurred with the poorer countries. These countries tend to surround themselves with greater walls of protection that also, in the context of the model presented here, act as a buffer that limits knowledge spillovers to them. Hence, the income gap between these countries and the developed world continues to exist and, to the extend that this model is correct, will continue to exist until the barriers start to come down.

Acknowledgments

Notes

1. These slowdowns are examined in, among others, Griliches (1980), Bruno (1984), and Baumol, Blackman, and Wolff (1989).

2. The other country, Switzerland, experienced a positive increase in GDP levels.

3. World War I and the Great Depression were the primary break periods for the remaining countries.

4. These findings stand in contrast with those of Jones (1995), who states that growth rates of OECD countries have exhibited "little or no persistent increase" following World War II.

5. The periods of comparison here are 1870 to 1939 and 1950 to 1989 using data from Maddison (1991). The sixth original member of the EEC, Luxembourg, is not included in Maddison's data set.

6. See Ben-David (1993, 1994).

7. Eaton and Kortum (1994) show that the number of patents registered abroad—as an indicator of the development of ideas—affects the international diffusion of technology.

8. Marin (1995) provides empirical evidence showing that Austria's relatively fast growth during the postwar period "has been induced by knowledge spillovers from its trading partners," particularly Germany.

9. It also appears to be consistent with evidence in Balassa (1977), Michaely (1977), Harrison (1991), and others.

10. See, for example, Brezis, Krugman, and Tsiddon (1993) and Goodfriend and McDermott (1994).

11. In a separate study (Ben-David and Loewy, 1997), we allow for the accumulation of both physical capital and knowledge and examine the conditions for existence and stability in the model. We find that the addition of physical capital leads to no substantive qualitative differences as far as steady-state outcomes are concerned. The inclusion of physical capital does, however, considerably constrain the examination of transitional dynamics. This, in turn, makes its inclusion less useful for the analysis conducted below.

12. The assumption that the a_{ij}'s are constants is made for simplification purposes only and is not meant to imply that this is the only way to model this issue. For example, a more plausible specification might be to assume that a_{ij} is an increasing bounded function of the associated relative knowledge stocks H_j/H_i when $H_j > H_i$ and zero if $H_j < H_i$. However, formulations such as this complicate the model considerably and so come at the expense of providing an analysis of level and growth changes along the transition between steady states.

13. In contrast to our approach, Lucas (1993) assumes that the level of knowledge in other countries affects knowledge accumulation in country i through the average level of knowledge worldwide. In his specification, complete openness is assumed.

14. To the extent that a reduction in tariffs leads to an increase in growth rates, it follows that ad valorem subsidies funded by a lump-sum tax lead to even faster growth. However, if the lump-sum tax is replaced by the more common proportional income tax, then the growth outcome is less clear since the issue converts to an optimal income tax/trade subsidy problem that is beyond the scope of this article.

15. Since Φ is a nonnegative matrix, it is interesting to note that the resulting dynamics of our model are quite similar to those in von Neumann (1945). We thank an anonymous referee for pointing out this parallel to us.

16. To the extent that the a_{ij}'s differ from country to country—for example, if the ability of each country to absorb knowledge spillovers is not the same—then the countries will converge to different, but parallel, growth paths.

17. This pattern of results is by no means unique to this example. Similar results obtain whenever there is a unilateral decrease in a single tariff.

18. Although 1968 marked the end of the formal period of trade liberalization among the six founding members of the Community, some additional trade impediments, both informal and formal (most notably regarding trade in agricultural goods), continued to exist.

19. Data for standard deviations in panel A comes from Summers and Heston (1995), while the data for construction of the v's comes from the International Monetary Fund *International Financial Statistics* and *Direction of Trade* data. Data used in panel B comes from Maddison (1991).

20. Data from Maddison (1991).

21. The extrapolations in these figures were done using standard augmented-Dickey-Fuller tests. Since the sole purpose of these extrapolations is to facilitate clearer visual inspections of the postwar and prewar differences, the regression results are not reported here so has not to diffuse the main focus of this article. However, these results are available from the authors on request. For a more comprehensive analysis of long-run growth rates, see Ben-David and Papell (1995b).

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