TRADE, DEVELOPMENT AND CONVERGING GROWTH RATES

Dynamic Gains From Trade Reconsidered*

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ABSTRACT: Within an endogenous growth framework, we examine dynamic gains from trade for *parametrically distinct* countries. In the absence of international spillovers or factor mobility, previous endogenous growth models generally imply that trade in goods must amplify differences in (1) factor endowments, (2) rates of technical change and (3) economic growth. Even the dynamic HOS model suggests that trade intensifies differences in endogenous factor endowments. In contrast, we present a model where trade in goods alone is sufficient to reduce differences in rates of growth, technological change and factor endowments between leader and laggard economies. The key to the reduction in the gap in growth rates is that both human capital and technological change are not just endogenous, but that their respective costs of accumulation interact. Since skilled and unskilled labor is endogenous, we can also derive implications for cross-country relative wage movements.

Key Words: Trade, Convergence, Dynamic Gains, Uneven Growth. (*JEL F43, 031*)

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I. Introduction

The purpose of this paper is to analyze how international trade affects factor endowments, technical change, and growth, in parametrically distinct economies. The Heckscher Ohlin model, enriched to account for endogenous factor accumulation, predicts that trade amplifies initial differences in factor endowments and comparative advantage.[1] In the absence of capital mobility or international knowledge spillovers, endogenous growth models carry even more discouraging implications for laggard economies. In this case, trade between parametrically distinct economies reinforces the position of the technological leader, intensifies the initial pattern of comparative advantage and increases the disparities in factor endowments to further uneven growth. The implication of divergence between leader and laggard economies in open economy models can certainly be prevented by assuming international spillovers or factor mobility.[2] The contribution of this paper is to prove that trade in final goods alone suffices to narrow the technology gap, and that spillovers or factor mobility are not necessary conditions for conditional convergence within an endogenous growth structure.

We also show that the uneven growth results in the previous literature depend on the assumption that *either* technology *or* factor endowments are endogenous. For example, in models of endogenous technological change (e.g. Romer 1990), a key determinant of the growth rate is human capital, whose stock is assumed exogenous. As countries open up to international trade, the returns to skilled labor change while their stock do not. Hence trade tends to reinforce rather than alter the existing pattern of comparative advantage as the leader country generally enjoys dynamic gains, while the laggard economy experiences comparatively minute gains, if not losses. Feenstra (1996) shows that the leader's growth rate may only be slowed in the special case where demand for the R&D intensive good is inelastic.[3] In contrast, our model begins with the premise that both endowments and technology are endogenous, and that their respective costs and benefits of accumulation interact. We

[1] This is shown in Stiglitz (1970) and Findlay and Kierzkowski (1983) for physical and human capital accumulation, respectively.

[2] Feenstra (1996) provides an overview of models and conditions that imply either convergence or uneven growth due to international trade.

[3] In this special case the autarchy equilibrium does not exist.

show that it is this interaction that generates the trade induced dynamic gains that serve to narrow technology and growth gaps.

Our approach is complementary to previous models of endogenous technological change that focus on private incentives to invest in research (Grossman and Helpman 1991), or on serendipitous learning (Young 1991). Here, we specify that private incentives induce agents to invest in skills by entering an education sector to be instructed by skilled labor. The by-product of the education process is non-rival technology, whose absorption into production requires skilled workers with knowledge of the specific vintage. When high and low Tech sectors differ in skill-intensity and technological sophistication, technological change generates strong skill-biased labor demand that exerts upward pressure on the relative wage. This change in the relative returns alters not only the cost and benefit of investment in human capital, but also the allocation of skilled labor between inventing and absorbing technology.

The model endogenously determines the relative demand, supply and wage of skilled workers, their allocation between the research and production, and the rates of technological change and growth. We label the country which possesses an endogenously larger supply of unskilled labor, and a comparative advantage in the Low Tech good the *laggard*. A change in the terms of trade alters the costs and benefits of both, human capital investment and invention/absorption of technology. After opening up to the world's goods market, the laggard experiences an initial static contraction of its skill-intensive, technologically progressive High Tech sector. This lowers the relative wage of skilled workers and frees resources to expand research and education. The resulting dynamic increase in the supply of skilled workers and the rate of domestic innovation allows the laggard to reduce the gaps in technology, factor endowments and growth rates.

Since the model features skilled and unskilled workers, the structure also provides implications for trade induced relative wage movements across countries. High relative wages and scarcity of skilled labor are often mentioned as major impediments to economic growth in laggard countries. Both features of the laggard are generated endogenously in our model under autarky. Free trade is shown to narrow the relative wage gap across countries, with rising wages in the advanced country and falling relative wages in the laggard.[4]

Previous models suggest similar dynamics. Cartiglia (1992) emphasizes the same resource trade off between output and education, while Grossman and Helpman (1991, ch. 6) feature the trade off between output and research which accelerates growth in the laggard country in our model.[5] The difference in our paper is that we examine the effects when *both* tradeoffs are endogenous and interact. In a model of learning by doing, Young (1991) characterizes one of five possible equilibria as one where a laggard might be capable of closing the technology gap to the leader. For this equilibrium to occur, the initial technology gap must not be too large, and the population size must be several orders of magnitude greater in the laggard. Our results are independent of initial conditions or population size.

While the empirical literature on trade and growth is diverse, it does not seem to support uneven growth results. The initial comprehensive study by Levine and Renelt (1992) found no direct effect of trade policy on growth, but their positive correlation between trade and investment suggested that the effects of trade liberalizations could operate through enhanced resource accumulation. Subsequent work with large samples of 30 to 95 developing countries (Dollar 1992 and Edwards 1992, 1993) show that trade liberalizations improved growth performance. Harrison (1995) surveys the literature and introduces robust evidence that greater openness is associated with higher growth. Focusing solely on OECD countries, Ben-David (1993) finds that the timing of trade liberalizations has been strongly linked with trade and income convergence in the EEC.

II. The Two Sector Economy

This section outlines the model, which extends the two sector closed economy in Eicher (1996) to the three sector open economy. The joint production in the education sector is also essentially equivalent to the one assumed by Fershtman, Murphy and Weiss (1996). Consider an

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[4] This trend is confirmed by Davis (1992) who examines cross-country relative wage patterns.

[5] Investment in human capital is exogenous in Grossman and Helpman (1991, ch 6.), but their fifth chapter offers a mechanism to endogenize human capital. Combining the two chapters implies, however, that trade leads to a widening of the difference in human capital endowments.

overlapping generations model with agents who live for two periods. One High Tech and one Low Tech consumption good is manufactured in distinct sectors that differ in technological sophistication and skill-intensity. An education sector produces embodied knowledge (skills) and non-rival knowledge (blueprints) in joint production. In each period t, young agents decide either to accumulate human capital by entering an education sector as students, S_t, or to work in production as unskilled workers, U_t. Students constitute the future stock of skilled workers who choose between employment in the education sector, or in High Tech production. Unskilled workers save and consume when young and (for simplicity) retire when old. To finance human capital investment and consumption, students borrow against their future income at an endogenous interest rate that equates borrowing and saving.

Formally, the education sector employs teachers, P_t, students, S_t, and the cutting edge technological vintage, v_t (the technology invented last period), to produce a new, non-rival technological vintage, v_{t+1}. Young agents and teachers enter the education sector at an exogenously specified student-teacher ratio, γ[6],

$$v_{t+1} - v_t = \mu v_t \min[\gamma P_t, S_t] \qquad \gamma > 1; \quad \mu > 0, \tag{1}$$

where μ is a productivity parameter. We could decompose (1) into two alternative, even simpler, representations $v_{t+1} - v_t = v_t \mu\gamma P_t$, (1a) and $\gamma P_t = S_t$ (1b). The decomposition highlights that the education sector is an amalgam of the standard research sector (1a) in models that follow Romer (1990), and the simplest formulation of the education process (1b), first introduced by Bhagwati and Srinivasan (1977). The direct (tuition) cost per student, z_t, just equals the teacher-student ratio times the teachers' wage, w_t^P/γ, which implies that private incentives to invest in education finance non rival technological change. While the endogenous stock of skilled labor is constant in equilibrium, technology continues to evolve resulting in endogenous increases in the *quality* of the stock of educated workers.

The economy manufactures two consumption goods. The High Tech good utilizes the cutting edge technological vintage, v_t, and unskilled workers, U_t^H, who perform routine tasks. To absorb ever

[6] Alternatively, one could follow Shell (1966) by specifying that a research manager, who maximizes output, imposes γ.

new technologies the High Tech sector also employs skilled labor, E_t, with knowledge of the vintage

$$H_t \;=\; v_t \;\; E_t^{\,r} \;\; U_t^{H\;1-r} \qquad 0 \;<\; r \;<\; 1\,. \tag{2}$$

Once a technology has been absorbed into production, its use requires only unskilled workers. Thus, the Low Tech consumption good, employs only old technology, v_{t-1}, and unskilled labor, U_t^L, to perform the now routine tasks

$$L_t = v_{t-1}\delta\, U_t^L;\;\; \delta > 0, \tag{3}$$

Production of the High and Low Tech goods takes place in perfectly competitive sectors. We choose the price of the High Tech good as the numeraire throughout, so that π_t represents the relative price of the Low Tech good. The factor market equilibrium requires that unskilled workers' wages are equalized across sectors, $w_t^{UL} = w_t^{UH}$, and that the wages of teachers equal their opportunity cost, which is the marginal product in the High Tech sector, $w_t^P = w_t^E$. Equating the marginal products of unskilled in the two sectors yields an expression for the unskilled to skilled worker ratio in the High Tech sector, which can be simplified by using equation (1). To derive the relative wage in the economy we substitute this expression into the relative wage of the High Tech sector to obtain

$$\frac{w_t^E}{w_t^U} \;=\; \frac{r}{1-r}\left(\frac{1+m\,S_{t-1}}{d\;\;p_t\;\left(1-r\right)^{-1}}\right)^{\frac{1}{r}}\,. \tag{4}$$

In partial equilibrium, the relative wage is decreasing in the relative price of the Low Tech good. Nevertheless, the production structure yields a positive, interactive relationship between past human capital investment and today's relative wage (or, between past technological change and today's skilled labor demand). The feature of the model that drives this positive interaction is that the two sectors differ not only in factor intensities but also in technological sophistication. More human capital investment raises not only the future stock of skilled workers, but also finances more technological change that must be absorbed into production. Given the structure of the two sectors, the absorption process is skill intensive and creates skill-biased labor demand that dominates the increase in the supply of skilled workers.

To close the production side, we specify zero population growth, which allows us to normalize the size of each generation to unity. The labor constraints in period t then becomes

$$U_t = U_t^L + U_t^H, \tag{5}$$

$$1 = S_t + U_t, \tag{6}$$

$$S_{t-1} = P_t + E_t. \tag{7}$$

III. Utility Optimization

Individuals share identical tastes, and the preferences of those born at time t can be represented by a two-level utility function. An agent born in period t consumes C_{1t} when young and C_{2t+1} when old. The upper level utility function may written as

$$W^k = \ln C_{1t} + b \ln C_{2t+1}, \qquad b > 0, \tag{8}$$

where $k=U, S$ superscript represents the respective career paths of students and unskilled workers. To minimize notation, we suppress this superscript unless necessary. Within a representative period t, the instantaneous subutility over High and Low tech consumption for young and old can be expressed as

$$\ln C_{it} = a \ln c_{it}^L + \ln c_{it}^H, \qquad a > 0; \; i = 1,2. \tag{9}$$

We now define per capita expenditures in period t, y_{it}^k, as

$$y_{it}^k = p_t c_{it}^L + c_{it}^H \tag{10}$$

Then, from our specification of the subutility in equation (9), demand for the two goods by a consumer in period t satisfies

$$p_t c_{it}^L = a c_{it}^H \tag{11}$$

To determine the stock of students we examine the intertemporal allocation in terms of saving and borrowing. From equations (8)-(11) we derive the indirect utility for each individual born at time t

$$V^k\left[y^k, \; p\right] = (1+a)\left(\ln \; y_{1t}^k + b \ln y_{1t+1}^k\right), \tag{8'}$$

plus a constant term, which reflects the time path of relative prices.

Each unskilled worker receives a wage when young and saves, x_t, for retirement. Each student borrows, b_t, against future income to finance tuition, z_t, and first period consumption. Thus, the respective budget constraints of unskilled and skilled workers are,

$$y_t^U = w_t^U - x_t, \tag{12}$$

$$y^{U}_{t+1} = x_t(1+r_t). \tag{12′}$$

$$y^{S}_{t} = b_t - z_t, \tag{13}$$

$$y^{E}_{t} = w^{E}_{t+1} - b_t(1+r_t). \tag{13′}$$

Substituting the respective constraints in to the objective function (8') yields first order conditions that can be solved for per capita borrowing and saving, respectively

$$x_t = q\, w^{U}_{t}\ , \tag{14}$$

$$b_t = q \left(z_t + \frac{w^{E}_{t+1}}{b(1+r_t)} \right), \tag{15}$$

where $q \equiv b / (1+b)$ 1 denotes the marginal propensity to save. Since skilled workers receive a wage when old, their optimal borrowing is increasing in their future discounted income (w^{E}_{t+1} / b 2$(1+r_t)$). More patience (b increases)3 depresses students' demand for funds, since more consumption is deferred into the future. Higher tuition, z_t, decreases the present period consumption possibility and induces students to transfer income from the future to the present through increased borrowing.

Borrowing and saving are regulated by an endogenous interest rate. The financial market clearing condition requires that total borrowing equals total saving, or $S_t b_t = U_t x_t$. Using this clearing condition and substituting for (14) and (15) yields an interest rate that is contingent on the relative supply of skilled labor.

$$1 + r_t = \frac{w^{E}_{t+1}}{b\left(\frac{U_t}{S_t} w^{U}_{t} - z_t \right)}\ . \tag{16}$$

The market clearing interest rate reflects the simple supply and demand for credit by individuals. The larger the supply of unskilled labor (students), the lower (higher) the interest rate. The higher the discounted return to education (unskilled labor), the greater (lower) the demand for credit and the higher (lower) the interest rate.

To close the model, the determination of the equilibrium interest rate, and thus the stock of students, requires the additional condition that agents must be identical between career paths, or $W^{U} = W^{S}$. Since agents share identical utility functions, and face identical intertemporal rates of transformation we know that $y_t^U = y_t^S$ and $y_{t+1}^U = y_t^E$. We can now equate (12) and (13) and substitute for optimal borrowing and lending from (14) and (15), plug in for the interest rate (16) and use the labor constraint (6) to derive investment in human capital

$$S_t = \frac{q}{\frac{w_t^E}{g w_t^E} + 1} \tag{17}$$

Equation (17) together with equation (1), immediately determines the stock of human capital allocated to the education sector, P_t. The stock of students depends positively on the constant saving rate, θ, because it increases savings and lowers the interest rate. Alternatively, we can write equation (17) as $S_t = q\, w_t^U / \left(w_t^E / g + w_t^U \right)$,[1] which highlights the positive effect of increased lending, $q\, w_t^U$, and the negative impact of an increase in the direct (tuition) and indirect (opportunity) cost of human capital investment $\left(w_t^E / g + w_t^U \right)$. Note that an increase in w_t^E *raises* the tuition expense, and thus effects the stock of students today negatively. That students care about the wage they receive as skilled workers when old, which has been factored into the interest rate (16).

Having obtained the stock of students, we derive the equilibrium interest rate $1 + r_t = w_{t+1}^E / \left(w_t^U + w_t^E / g \right)$, which turns out to simply be the benefit/cost (direct and indirect) ratio of investing in human capital. Higher investment in human capital creates a higher rate of technological change, whose future absorption into production raises the relative wage. As students expect the relative wage to rise tomorrow, their borrowing demand rises, which increases the interest rate. Simply stated, as higher economic growth raises the marginal rate of substitution, it must also raise the marginal rate of transformation.

IV. Autarky Equilibrium

In autarky, domestic supply must equal demand, or $c_{1t}^H + c_{2t}^H = H_t$ and $c_{1t}^L + c_{2t}^L = L_t$. After aggregating per capita consumption as expressed in equation (11) over all individuals, we obtain an expression for the demand price from the inverse relative demand function,

$$p_t = \frac{a \left(c_{2t}^H + c_{1t}^H \right)}{\left(c_{2t}^L + c_{1t}^L \right)} = \frac{a\, H_t}{L_t}, \tag{18}$$

Given equation (18), we can use the factor market clearing condition $w_t^{UL} = w_t^{UH}$ together with the production structure (1)-(4) and the labor constraints (5), (6) to determine the relative price and the relative wage, respectively

$$p_t = \frac{(1+m\mathrm{S}_{t-1})(1-r)}{d}\left(\frac{(1-r+a)(\mathrm{S}_{t-1}-\mathrm{S}_t/g)}{(1-r)(1-\mathrm{S}_t)}\right)^r \tag{19}$$

$$\frac{\mathrm{w}_t^{\mathrm{E}}}{\mathrm{w}_t^{\mathrm{U}}} = \frac{r(1-\mathrm{S}_t)}{(1-r+a)(\mathrm{S}_{t-1}-\mathrm{S}_t/g)} \tag{20}$$

The relative wage in the closed economy deserves a closer look. As discussed above, the partial equilibrium effect of increased past investment in human capital is to *raise* the relative wage. Equation (20) shows, however, that this effect is being reversed once the demand side of the economy is considered. In general equilibrium, higher levels of past human capital investment *depress* the relative wage, as the homothetic demand forces the labor supply effect to dominate the absorption effect. The result is reminiscent of Rosenstein-Rodan (1943), who proposed that lack of demand might restrict development in a dynamic economy with increasing returns. Our model exhibits, however, constant returns to scale in each period, while investment in human capital creates intertemporally increasing returns. The strong intertemporal supply response generated by human capital investment actually results from *two* separate supply effects. First, ceteris paribus, there is a Rybczynski effect, since higher investment in human capital today increases the supply of skilled labor in the next period, which increases the output of the High Tech good and decreases that of the Low Tech good. Second, higher human capital investment today creates higher technological change, which creates Hicks neutral technological change in the next period that is biased to the High Tech sector. Thus, at constant relative prices, higher investment in human capital and higher rates of technological change increases the ratio of the High to Low Tech good. Since the share of consumption expenditures allocated to the High Tech good remains constant, however, the relative price must increase, which then depresses the relative wage.

With the expression for the relative wage in hand, we may now examine the determinants of human capital investment, relative prices and growth in autarchy. Subsequently, propositions I and II serve as a summary discussion of the characteristics of each equation. After substituting for the relative wage in equation (17), investment in human capital can be expressed by the following difference equation that characterizes the general equilibrium,

$$\mathrm{S}_t = \frac{q}{\dfrac{r}{(1-r+a)g}\dfrac{(1-\mathrm{S}_t)}{(\mathrm{S}_{t-1}-\mathrm{S}_t g^{-1})} + 1} . \tag{21}$$

Defining the steady state level of students $\mathrm{S}^* = \mathrm{S}_t = \mathrm{S}_{t-1}$, we can solve equation (21) for the closed form solution of S^* in terms of the parameters of the model

$$\mathrm{S}^* = \frac{q-x}{1-x} , \tag{21'}$$

where $x \equiv r \big/ \big((g-1)(1-r+a)\big)$. To rule out violations of the 2of the labor constraint (6), we require x 3< θ. Thus, $\mathrm{S}_x^* < 0$; or S_q^*, S_g^*, $\mathrm{S}_a^* > 0$, and $\mathrm{S}_r^* < 0.4$ The appendix proves that the system is monotonically stable. We now express the equilibrium relative wage and price as

$$\frac{\mathrm{w}^{\mathrm{E}^*}}{\mathrm{w}^{\mathrm{U}^*}} = xg\,\frac{1-q}{q-x} , \tag{20'}$$

$$p^* = \frac{(1+m\mathrm{S}^*)\ (1-r)}{d}\left(\frac{(1-r+a)\ (1-g^{-1})\mathrm{S}^*}{(1-\mathrm{S}^*)(1-r)}\right)^r , \tag{19'}$$

which we write in terms of the equilibrium stock of students to retain some intuition about how price movements relate to human capital investment.

Finally, by aggregating (12)-(13') we can obtain a closed form expression for the long-run growth rate by logarithmically differentiating total steady state income of the economy, $\mathrm{Y}^*=\mathrm{w}^{\mathrm{U}*}\mathrm{U}^*+\mathrm{w}^{\mathrm{E}*}\mathrm{E}^*$. Defining "^" variables as growth rates, the steady state values of $\hat{\mathrm{U}}^*, \hat{\mathrm{E}}^*, \hat{p}^*$ equal zero, and $\hat{\mathrm{w}}^{\mathrm{E}*} = \hat{\mathrm{w}}^{\mathrm{U}*} = \hat{\mathrm{v}}^*$. Then 5the long-run growth rate, f, is simply

$$f = \hat{\mathrm{Y}}^* = \hat{\mathrm{C}}^* = \hat{\mathrm{v}}^* = m\mathrm{S}^* = \frac{m(q-x)}{1-x} . \tag{22}$$

We are now in a position to examine the determinants of the static comparative advantage, which highlights the counter-balancing influences of the absorption and consumption demand effects in response to changes in human capital investment and the rate of technological change.

Proposition I *An increase in the marginal propensity to save, q, or an increase in the* *student-teacher ratio, g, causes increases in human capital investment, in the rates of technological change and growth. However, the relative wage declines as the relative price of the Low Tech good rises.*

An increase in the saving rate increases the supply of funds and decreases borrowing demand. An increase in the student-teacher ratio lowers the borrowing demand due to a lower direct cost of investment in human capital. Thus an increase in either b 6 or γ creates excess supply in the bond market to lower the interest rate on impact, which renders investment in human capital more attractive. As the stock of student increases, so do the rates of technological change and growth (22). The higher rate of technological change generates Hicks neutral technological change that is biased to the High Tech sector. This increases the relative demand for skilled labor at constant relative prices, consequently the output of the High Tech good tends to expand, which raises π^* (equations (18) and (19′)). With a larger supply of skilled workers, a higher rate of technological change, but also with a higher relative price of the Low Tech good, the relative wage of skilled workers must decline (see equation (20′)). The output and skilled labor supply effects thus dominate the absorption effect in the closed economy. This depresses the wage differential despite the fact that the economy experiences higher rates of technological change and growth.

Proposition II *An increase in consumer preferences for H, or in the share of skilled workers in H results in decreases in the human capital investment, in the rates of technological change and growth. However, the relative wage rises as the relative price of the Low Tech good falls.*

A decrease in α, or an increase in ρ poses two important resource costs to the economy. Ceteris paribus, increased demand for the High Tech good decreases the relative price of the Low Tech good, (18), which leads to a rise in the relative wage as production of the High Tech good expands to satisfy consumer demand. Alternatively, an increase in the share of skilled workers in the High Tech sector raises the relative wage since more skilled workers are required to absorb technology in order to produce the same level of High Tech output. Thus, in both cases the share of skilled labor devoted to the production of the High Tech good increases. This drains skilled workers from the education sector, and increases the direct cost of human capital accumulation. As the number of teachers and students decreases, so do the rates of technological change and growth. The decrease in human capital investment and the rate of technological change leads to a decline in the relative price of the Low Tech good, equation (19′), which then raises the relative wage above its previous equilibrium level, equation (20′).

After having clarified the mechanics that determine the static comparative advantage, we turn to the characteristics that distinguish the leader and laggard countries. One approach with a long tradition in the trade literature is to assume that the leader possesses the higher savings rate.[7] The comparative statics have shown that the static comparative advantage generated *endogenously* by different rates of time preference fits the common description of a leader and laggard quite well. From proposition I we know that the more patient leader is *endogenously* endowed with more human capital and experiences higher rates of technological change and growth as compared to the laggard. Given the assumption of identical, homothetic demand across countries, the autarky relative price of the Low Tech good in the advanced country, π^N, must then exceed that of the laggard, π^S, which implies that the relative wage in the advanced country lies below the relative wage observed in the laggard.

The closed economy analysis exposes, however, one counter-factual implication. While the comparative statics confirm that higher rates of human capital investment and technological change create skill-biased labor demand, the homothetic demand structure limits the return to human capital investment and technological change in the economy and relative wages falls in response to higher rates of technological change. The recent empirical literature has documented that several industrialized countries experienced *rising* relative wages due to higher rates of technological change, which induced skill-biased labor demand (see Eicher 1996 for a discussion).

One extension that would prevent the rise in the relative price of the Low Tech good in response to higher rates of technological change would be to relabel the Low Tech good as 'agriculture' and to assume income inelastic demand for food as in Matsuyama (1992). Engel′s Law would then allow for a continuous decline in the Low Tech good's relative price. Given the objective

[7] A common justification for this assumption that more advanced countries have higher savings rates is that savings rates across countries are positively correlated with the degree of financial development (i.e. Edwards 1995).

of this paper, we explore an alternative approach: we examine how international trade affects the rates of growth, and the relative demand, supply and wage of skilled workers in the leader and laggard economy.

V. The Small Open Economy

Critical to the small country analysis is the perfectly elastic demand on the world market, which immediately implies that the rates of technological change, growth and return to education (the relative wage) are no longer constrained by the autarky demand (prices). Without intending to imply that international spillovers are irrelevant to development, convergence and trade patterns, we examine how trade affects the endogenous variables to foster growth without reliance on international diffusion of knowledge. Thus for the purposes of this paper we assume incomplete specialization and abstract from international diffusion of knowledge, international borrowing and lending, and migration.

Given a world price $\bar{p}$, the relative wage and the number of students can be obtained by substituting for π_t in equations (4) and (17), yielding,[8]

$$\left(\frac{w_t^E}{w_t^U}\right)^j = \frac{r}{1-r}\left(\frac{1+m\,S_{t-1}^j}{d\;\bar{p}\;(1-r)^{-1}}\right)^{\frac{1}{r}}, \tag{23}$$

$$S_t^j = \frac{q^j}{\dfrac{r}{(1-r)\;g}\left(\dfrac{1+m\,S_{t-1}^j}{d\;\bar{p}\;(1-r)^{-1}}\right)^{\frac{1}{r}} + 1}, \tag{24}$$

After imposing the steady state condition $S^j_t = S^j_{t-1} = S^{*j}$ in equations (23) and (24), it can easily be verified that the growth rate of the economy is still $\phi^j = \mu\, S^{*j}$, where S^{*j} is now determined by the difference map in equation (24).[9] For a given a world price, figure 1 characterizes the interaction between technological change and human capital accumulation in the small open economy. The S^jS^j schedule, equation (17), represents the supply of students for each relative wage level and the intuition

[8] where j = n (leader), s (laggard) and w (world) and $q^s < q^w < q^n$.

[9] The transition dynamics and stability conditions for this class of difference maps with more general functional forms have been investigated by Eicher (1996).

to its shape has been discussed above. Much like equation (4), whose intuition has been discussed at length above, the G^jG^j schedule given by equation (23) relates past human capital investment (technological change) to future relative wage movements.

The small open economy results contrast sharply with those observed under autarky. Recall that in the closed economy, higher rates of technological change and human capital investment lead to a *lower* relative wage, due to the increase in the relative price of the Low Tech good. In clear contrast, the small open economy experiences an *increase* in the relative wage in response to higher human capital investment and higher rates of technological change, since increases in the relative supply of the High Tech good may now be exported. This leads to the dominance of the absorption effect, as the skill-biased labor demand is now strong enough to increase the relative wage. In the next section we examine whether trade can serve as an engine for growth, development and convergence. To disentangle the static and dynamic gains (or losses) from trade in the advanced and the laggard countries, we examine either economy as it moves from autarky to free trade.

VI. Trade, Development and Convergence

When we examine how international trade affects the economy, our interest focuses on the question of how trade affects the relative demand, supply and wages of skilled labor. These endogenous variables fully determine the growth rate and the structural transformation of the pattern of production. The new equilibrium stock of human capital under free trade is crucial since it determines the rate of technological change and thus the dynamic comparative advantage. As we shall see, the effect of trade on either country depends on the economy's endogenous factor endowment, its rate of technological change, and its relative wage *before* engaging in free trade. If trade frees skilled workers from the absorption of technology in High Tech production, both the direct cost of education and the resource cost of human capital investment decline with the static fall in the relative wage. Subsequently, increased human capital investment generates a higher rate of technological change to create a dynamic gain. As productivity increases in the High Tech sector accelerate, the share of the High Tech good in production increases again, together with the rate of economic growth.

We show that trade serves as an effective engine of growth in the technologically laggard country. With a rate of time preference that exceeds that of the rest of the world, the laggard generates fewer savings to finance fewer students. This renders the laggard not only unskilled labor abundant under autarky, but also less capable of generating and absorbing technological change. Due to the laggard's static comparative advantage in the Low Tech good, international trade raises the relative price of the Low Tech good and forces a contraction of the High Tech sector. On impact, figure 2 shows how the ensuing excess supply of skilled labor lowers the relative wage (and thus the direct cost of education) in the laggard (A-B). In the long run, the laggard experiences an dynamic gains (B-C), due to the reallocation of skilled labor from production to the education sector, and the simultaneous increase in students and technology. The economy approaches a long run equilibrium, characterized by a higher rate of human capital investment, a higher rate of technological change, but a lower relative wage.

To isolate the static and the dynamic gains, we differentiate equation (23) with respect to the world price

$$\frac{\mathrm{d}\left(\mathrm{w}^{\mathrm{E}^{*}\mathrm{j}} / \mathrm{w}^{\mathrm{U}^{*}\mathrm{j}}\right)}{\mathrm{d}\bar{p}} = \frac{y g \bar{s}}{\bar{p}\left(1+m \mathrm{S}^{*\mathrm{j}}\right)}\left(\bar{p} m \partial \mathrm{S}^{*\mathrm{j}} / \partial \bar{p} - \left(1+m \mathrm{S}^{*\mathrm{j}}\right)\right)$$

$$\text{where } y = \frac{r}{(1-r) g}\left(\frac{1+m \mathrm{S}^{*\mathrm{j}}}{d \bar{p}\ (1-r)^{-1}}\right)^{\frac{1}{r}} . \tag{25}$$

We can sign the expression by implicitly differentiating equation (24), which yields

$$\frac{\bar{p} m \partial \mathrm{S}^{*\mathrm{j}}}{\partial \bar{p}} = \frac{m\ \bar{s}\ y\ q^{\mathrm{j}}}{(1+\ y)^{2}\left(1+\ \dfrac{m\ \bar{s}\ y\ q^{\mathrm{j}}}{(1+\ y)^{2}\ \left(1+\ m\ \mathrm{S}^{*\mathrm{j}}\right)}\right)} . \tag{26}$$

As long as stability is assured, equation (26) must lie between zero and unity, which establishes the familiar Stolper-Samuelson result that the relative wage of skilled workers declines in the relative price of the unskilled labor intensive good.

The two separate effects of world price on the relative wage can be represented by the two terms in brackets in equation (25). As the laggard experiences an increase in the relative price of the Low Tech good, on impact, the relative wage falls in proportion to the stock of human capital from A to B. The contraction of the High Tech sector depresses the demand for skilled labor in production and the relative wage must rise to clear the market for skilled labor. In the long run, however, the laggard experiences the dynamic benefit generated by a structural transformation of the economy, represented by the first term in brackets in equation (25). Not only do skilled workers in production relocate to become teachers, but over time the stock of skilled labor increases, which then also raises the rate of technological change. This constitutes the movement from B to C in figure 2. Note that this version of "industrialization" is based on the explicit modeling of the costs and benefits of investing in human capital and their interaction with the rate of technological change that needs to be absorbed in production. The engine of growth for the technologically laggard country is that international trade allows for the reduction in the absorption cost of technology in the High Tech sector, and for the expansion of education and innovation.

In contrast, free trade diminishes the technological leadership of the advanced economy. With a static comparative advantage in the High Tech good, free trade lowers the advanced country's relative price of the Low Tech good and creates an export market for its High Tech good. These static gains are offset by a dynamic loss as the economy approaches its new long run equilibrium, one characterized by lower investment in human capital, a lower rate of technological change, and a higher relative wage. The dynamic loss can be attributed to the decline in the rate of technological change caused by a dynamic *decrease* in human capital investment. To isolate the static gain and the dynamic loss, we note that trade generates export demand of the High Tech good which increases the demand for skilled labor in the advanced country. Thus the relative wage in the advanced country must rise to clear the market for skilled labor. In the long run, however, higher output of the High Tech good is generated at two important resource costs, represented by the first term in brackets in equation (25). Not only do teachers relocate to become High Tech production, but over time the stock of students declines (due to a higher direct cost of human capital investment), which decreases the rate of technological change.

These long run dynamics beg the question of what degree of cross-country convergence in skill endowments, growth rates and relative wages is implied by the model. Figure 3 summarizes the adjustment process for the advanced country and the laggard. Since the countries share identical production structures, both must share the same $G^W G^W$ schedule after having adjusted to the world price. The SS schedules differ, however, due to the differing saving rates between countries. From (24) it is clear that the country with the higher savings rate must possess a higher rate of technological change. The level of the skill endowment gap narrows and in the long run "conditional" convergence within the endogenous growth structure occurs. Conditional convergence was introduced By Barro (1991) and Mankiw et al. (1992) in recognition of the fact that parametrically different countries cannot be expected to converge to identical steady state position. When countries differ parametrically (i.e. in their savings rate), the term describes the process of convergence to distinct stationery states, in contrast to constant or even diverging steady states. Hence convergence is “conditional” on controlling for parametric differences such as savings rates.

VII. Conclusion

In the absence of international diffusion of knowledge or factor mobility, previous models of endogenous growth necessarily imply that trade either reinforces the position of the leading nation, or leaves the laggard country with few alternatives but to rely on international knowledge spillovers for development. These conclusions have stood in sharp contrast to the empirical evidence, which documents a trend towards conditional convergence, and that trade and openness do serve as an engine for growth, factor accumulation, and a narrowing of the technology gap. This paper suggests that if *both* technological change and human capital accumulation are endogenous, and if incentives to invest in education interact with the rate of technological change, trade does narrow the differential in factor endowments and rates of growth and technological change.

Our model exposes the interaction between human capital and the rate of technological change as the driving force behind convergence. Opening to trade generates a dynamic gain to the laggard country, whose contraction of the skill-intensive High Tech sector frees skilled labor, which lowers the relative wage and the direct cost of education. The dynamic increase in its research and education effort then allows the laggard to narrow the technology gap and increase its human capital endowment.

It is important to note that this paper does not intend to suggest that spillovers, or private incentives to innovate, or learning on the job, may not have a significant impact on the development and convergence process. Rather, the objective was to qualify the strong implications of the HOS model and the recent endogenous growth models that endogenous factor accumulation and trade in goods highly likely to lead to divergence between the leader and the laggard, as long as we rule out international spillovers. We also do not rule out that active policy on the part of a planner may influence development.

Allowing for international migration presents another appealing extension, which may provide new insights as to why both skilled and unskilled labor seeks to migrate from poor to rich countries. Trade in goods does not substitute for trade in factors in our model, as the advanced country's higher autarky rate of growth and technological progress creates incentives for migration towards the advanced country. The model suggests an intriguing relation between brain drain and migration since the advanced country gains by increasing its stock of skilled workers, not only to increase the output of its High Tech sector, but also to increase its education and research effort.

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Appendix

I. Local Behavior Around The Fixed Point S* In Autarky.

The first order difference equation which governs the dynamics of the system is given by (21) whose asymptotic stability is assured as long as $\left| dS_t / dS_{t-1} \right| < 1$. Equations (25) and (20') imply that $y^{*} = x(1-q)/(q-x)$. Implicit differentiation of (21) yields

$$\left.\frac{dS_t}{dS_{t-1}}\right|_{S^*} = \frac{y^{*}q}{(-1/g)S^{*}\left((1+y^{*})^{2} + y^{*}q\left(\left((g-1)S^{*}\right)^{-1}(1-S^{*})\right)^{-1}\right)} \; . \qquad \text{(A1)}$$

which proves that the system approaches the equilibrium monotonically. From (A1) we find

$$\left(\frac{(1 + y^{*})^{2} \; S^{*}}{q\,x} - 1\right)(g - 1) + (S^{*-1} - 1) > 0. \qquad \text{(A2)}$$

As γ and $1/S^*$ exceed unity, it suffices to show that the very left term in (A2) is positive. Given the definition of y^* that term can be rearranged to $q + x(1-q)/(1-x) > qx$, which must always hold since we required that θ > x [7] to assure U^* and S^* to be non negative. Stability is assured if (A1) can be shown to be smaller than 1. By the same procedure that proved stability, tedious calculations show that this condition is also assured for θ > x .

8**FIGURE 1**

Equilibrium in a Small Open Economy

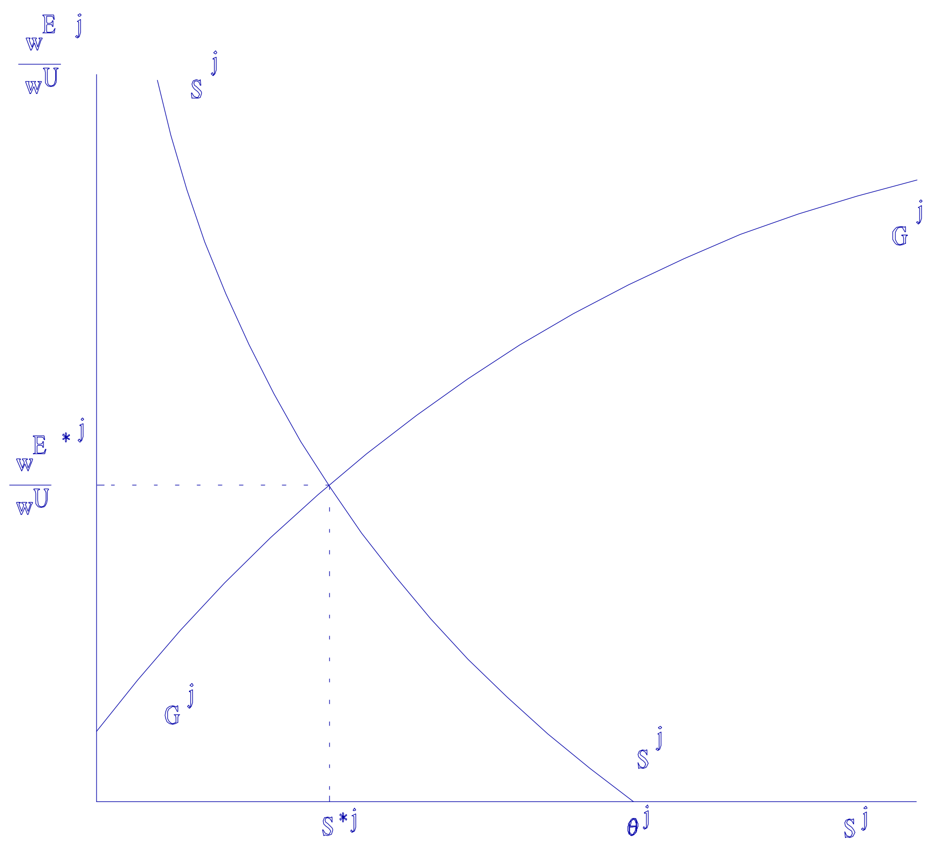


FIGURE 2

Trade Liberalization in a Laggard Country

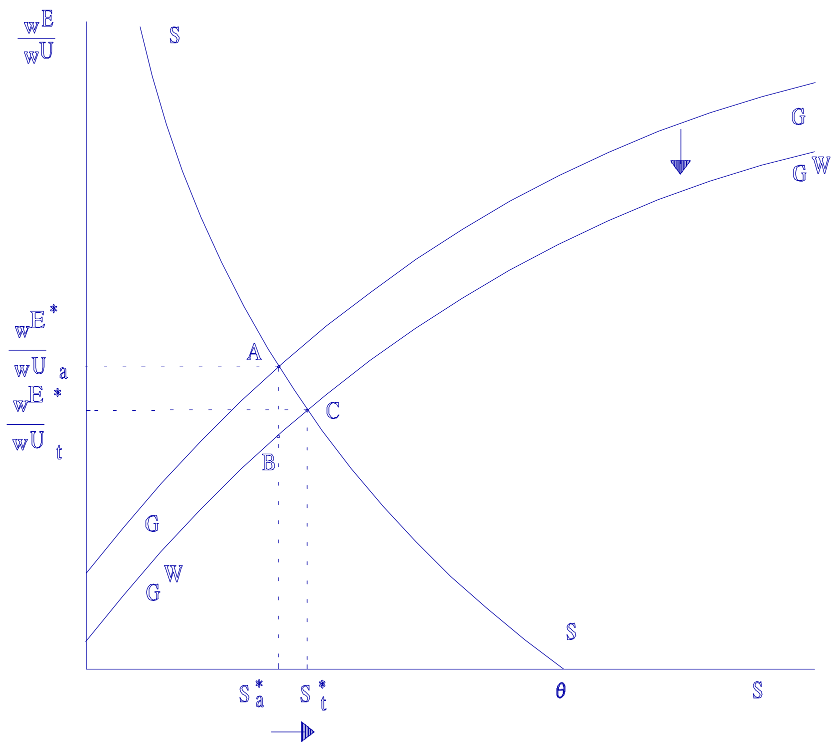
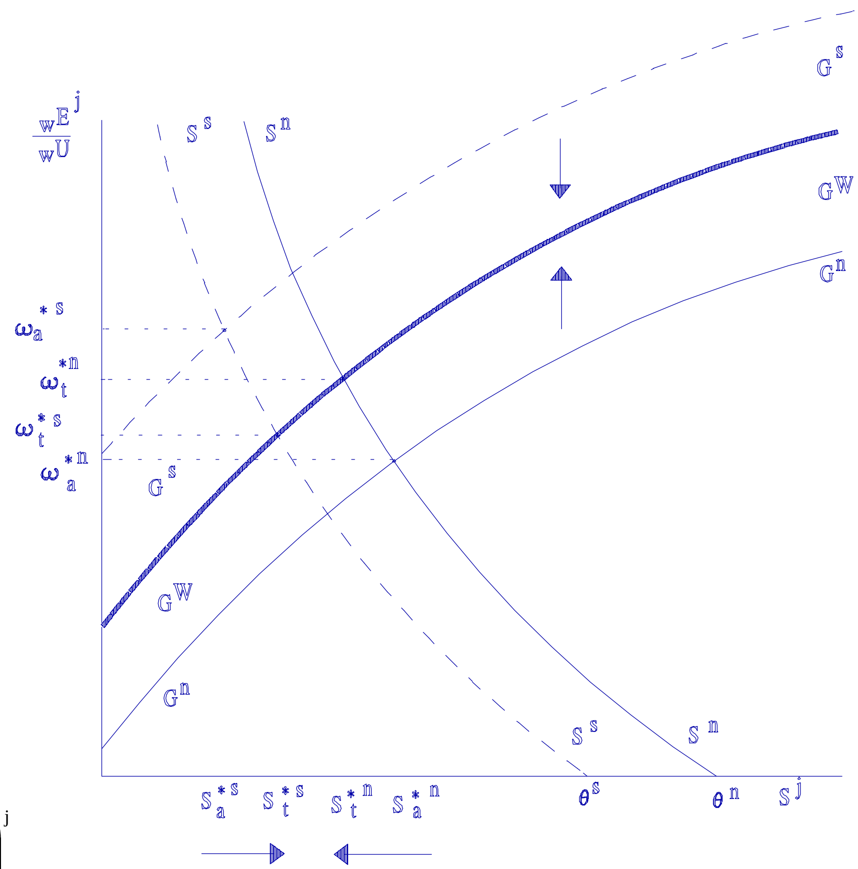


FIGURE 3

Trade Liberalization in the Leader and Laggard Countries

Conditional Convergence to a World Growth Rate



$$w_t^j = \left(\frac{w_t^E}{w_t^U}\right)^j$$