Industriens Utredningsinstitut
THE INDUSTRIAL INSTITUTE FOR ECONOMIC AND SOCIAL RESEARCH

A list of Working Papers on the last pages

No. 434, 1995

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by
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June 1995

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International Migration and Economic Growth: A Theoretical Analysis*

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ABSTRACT

We use a two-country version of the quality ladders endogenous growth model and show that free international migration raises world growth if it is driven by imbalances in labor supplies. International migration may, however, lower growth if it is induced by policy changes in one country. We also find that, other things being equal, workers want to migrate to less populated countries, to countries that subsidize R&D less, to countries with lower tariffs on imported goods, and to countries with wealthier consumers. Neither structural or public policy differences generate any differences in growth rates across countries when tariffs are set at non-prohibitively high levels.

*This project has been financially supported by a grant from HSFR, (the Swedish Council for Research in Humanities and Social Sciences).

1. Introduction

Real wage differences across countries are often very large and create strong incentives for international migration. For example, a typical Polish worker who migrates to work in Germany but spends his income in Poland can raise his real wage by a factor of 10.[1] With the former communist countries no longer preventing workers from emigrating, the European Union today must deal with a potential flood of immigrants. The same holds true for the United States, which is the desired destination for a large number of workers in Mexico and elsewhere.

Many concerns have been raised about the economic consequences of migration. While the static welfare effects of free labor mobility are today well understood, little theoretical work has been done on the implications of immigration for growing economies.[2] Furthermore, most of what has been done utilizes growth models of the Solow vintage, with an exogenous given rate of technological change.[3] This literature ignores the possible effects of immigration on innovation and technological change. Thanks to recent developments in the endogenous growth literature, we are now in a better position to explore how immigration influences firm behavior, technological change and economic growth.

In this paper we use an endogenous growth model developed by Segerstrom, Anant and Dinopoulos (1990), and Grossman and Helpman (1991a) to study the implications of immigration for growing economies. In this "quality ladders" model, economic growth is driven by the R&D decisions of profit maximizing firms, which compete in races over time to develop new higher quality products. According to Scherer (1980), 59% of firm R&D expenditure is, in fact, aimed at improving existing products. By focusing on the dramatic improvements over time in the quality of many goods and services, the quality ladders model provides a simple but appealing explanation for economic growth.

To explore immigration issues, we develop a two-country version of the quality

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[1]See e.g. Layard *et al* (1992).

[2]See Borjas (1994) for a recent survey.

[3]See Braun (1993), Dolado, Goria and Ichino (1993) and chapter 9 in Barro and Sala-i-Martin (1995).

ladders model.[4] In our model, free trade between the two countries implies factor price equalization and, as a result, no economic incentives for international migration. To generate migration incentives, we assume that there are trade barriers between the two countries. These trade barriers lead to international wage differences and incentives for labor migration when there are structural or policy differences between the two countries.

This model has an important steady state equilibrium growth property: structural and/or public policy differences between the two countries do not generate *any* differences in economic growth rates. To understand why, it is important to keep in mind that we restrict attention to tariff rates that are not prohibitively high in either country. Under these circumstances, even when the tariff rates differ between the two countries, they are still connected by trade in goods. This means that when any firm in the world innovates, consumers in both countries buy the new higher quality product. Since consumers in both countries benefit from any innovation, both countries must grow at the same rate. Public policy and/or structural differences generate differences in utility *levels* across countries but not differences in utility *growth rates*.

This property of our model may help explain why empirical research on cross-country differences have met with limited success. Levine and Renelt (1992), for example, find that most of the statistically significant parameter estimates in cross country growth regressions are fragile, that is, cannot withstand slight alterations in the list of explanatory variables. Our results on trade and growth may also help to explain Lucas′ (1988) observation that the rich (and highly trade dependent) countries′ growth rates are generally stable and similar while the poor (and less trade dependent) countries′ growth rates are generally unstable and differ much between them.

The absence of growth differences simplifies our analysis because it implies that

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[4]Labor migration has also been studied using one-country endogenous growth models. For example, Rivera-Batiz (1994) treats immigration as an increase in the population of a single isolated country, using the Romer (1990) endogenous growth model. Although this approach has the advantage of simplicity, there are some drawbacks. One drawback is that the incentives for immigration cannot be analyzed. Using our two-country model, we are able to study how international public policy differences can give rise to migration incentives. Another drawback is that real world countries are typically connected by trade in goods (even if this trade is not free). As we show, this has important implications for how immigration affects economic growth in the two countries.

migration incentives are completely determined by international differences in worker utility levels (at any point in time). We explore in this paper four reasons why utility levels might be different for similar workers in the two countries: differences in population sizes, R&D subsidy rates, tariff rates and ownership shares of world assets. For each of these four cases, by comparing restricted and free migration regimes, we can assess the effects of free labor mobility across countries.

If the Home country has a larger population of workers than the Foreign country, two considerations are important for the migration incentives. On the one hand, a larger population of Home consumers means higher profits for Home firms, increased demand for Home R&D workers and upward pressure on the Home relative wage. On the other hand, the larger supply of Home labor directly depresses the Home relative wage. Which of these two considerations dominates depends on how sensitive R&D investment is to the reward for innovating. If R&D investment is infinitely sensitive - as in Grossman and Helpman (1991a,b) where a linear R&D technology is assumed - then the first consideration dominates and workers want to migrate to the more populated Home country. Workers will then migrate until no workers remain in the foreign country implying that the model is basically unstable with such a technology. If R&D investment is not very sensitive to the reward for innovating (i.e. if sufficiently decreasing returns to R&D effort are assumed), then the second consideration dominates and workers migrate to the less populated, higher wage, Foreign country until populations sizes are equalized. Recent empirical work by Kortum (1993) suggests that R&D is subject to significant decreasing returns and thus we focus on the second case (where workers want to migrate to the higher wage countries).

When workers do migrate to higher wage, less populated countries, not only are population sizes equalized but R&D effort levels as well. Given our decreasing returns to R&D assumption, economic growth is faster when R&D effort is more balanced in the two countries. Thus migration that results in more balanced R&D investment in the two countries also leads to faster economic growth.

If the Home country subsidizes R&D more than the Foreign country, two considerations are again important in determining migration incentives. On the one hand, to finance the higher R&D subsidies taxes must be higher in the Home country. This gives workers a reason to migrate to the "lower tax" Foreign country. On the other hand, a higher Home R&D subsidy makes R&D investments for firms more profitable, increasing the demand for labor and raising the Home relative wage. This gives workers a reason to migrate to the "higher wage" Home country. With our assumed parameter values, the first consideration dominates, and workers want to migrate to the "low tax, low wage" Foreign country. Furthermore, the increase in Home wages allows Foreign firms to charge higher prices (since prices are pinned down by international competition) and this stimulates Foreign R&D effort even more than Home R&D. Allowing for migration to the "low tax" Foreign country *lowers* the growth rate since differences in R&D effort levels increase with labor flows to the foreign country.

If the Home country imposes higher tariffs on imports than the Foreign country, we find that workers want to migrate to the "freer trade" Foreign country. These incentives arise mainly because prices of goods are lower on average in the less protectionist Foreign country. A unilateral increase in the Home tariff rate leads to higher profits for Home innovators and faster economic growth. Still, workers want to move to the Foreign country so that they can "free ride" on the Home country's efforts to promote economic growth. The tariff makes the Home country more R&D intensive than the Foreign and as workers leave the Home country, this tends to equalize R&D efforts between the two countries and therefore raise growth. But, we find that so many workers leave that, in the new equilibrium, the Foreign country is much more R&D oriented than the Home country and with decreasing returns to R&D, growth is dampened.

Finally, we consider what happens when the Home country has a larger ownership share of world assets than the Foreign country. With wealthier Home consumers and trade barriers between countries, R&D investments are more profitable in the "richer" Home country. The increased demand for Home R&D labor drives up the Home relative wage and as a result, workers want to migrate to the richer Home country. Such migration makes the two countries' R&D efforts even more imbalanced and given the decreasing returns to R&D, leads to lower economic growth. The basic mechanism at work here is the same as before: international labor migration lowers growth when it enhances differences in R&D effort levels.

The rest of the paper is organized as follows: The two-country model of trade and growth is described in section 2. Results are presented in section 3 and section 4 offers some concluding comments.

2 The Model

A. Some General Comments.

We will analyze a quality ladders growth model with two structurally similar countries that use tariffs to restrict trade and adopt similar if not exactly identical public policies. Our review of how the basic quality ladders model works will be brief so as to provide more space for describing how we extend this model. For more details concerning the basic model, see Grossman and Helpman (1991a,b) and Segerstrom (1995).

In this model of the world economy, there is a continuum of industries with individual industries indexed by $\omega \in [0,1]$. In each industry, firms are distinguished by the quality j of the products they produce. Higher values of j denote higher quality and j is restricted to take on integer values. At time $t=0$, the state-of-the-art quality product in each industry is $j=0$, that is, some firm in each industry knows how to produce a $j=0$ quality product and no firm knows how to produce any higher quality product. To learn how to produce higher quality products, firms in each industry engage in R&D races. In general, when the state-of-the-art quality in an industry is j, the next winner of a R&D race becomes the sole producer of a $j+1$ quality product. Since firms are Bertrand price-setters, each R&D race winner is able to price lower quality competitors out of business and take over the world market in its industry. Thus, over time, product quality improves as innovations push each industry up its quality ladder.

In each of the two countries, Home and Foreign (top index h and f, respectively), labor is the only input in both production and research. In both countries, one unit of labor is required to produce one unit of output, regardless of quality. The labor endowments in the two countries, L^h and L^f, respectively, are constant over time. The labor markets in each country are perfectly competitive and firms are free to hire as many workers as they desire to engage in either production or research. We treat the wage rate in the Foreign country as the numeraire and let w denote the relative wage of Home country workers.

Free trade does not prevail between the two countries. Instead, each country imposes an ad valorem tariff, τ^h and τ^f, respectively, on imports in those industries where there are domestic firms to protect. In industries where no domestic firm would benefit from tariff protection (on the margin), no tariff on imports is imposed. Thus, although countries use tariffs to restrict imports these tariffs are not applied across-the-board in all industries. Motivated by the literature on the political economy of protectionism, we restrict attention to tariffs that individual domestic firms would find beneficial to lobby for.[5]

B. Consumers' Behavior

All consumers live forever, have identical preferences and maximize discounted utility

$$U \equiv \int_0^\infty e^{-\rho t} \log u(t) dt, \qquad (1)$$

where ρ is the subjective discount rate and log *u(t)* is each consumer's static utility at time t. This static utility is given by

$$\log u(t) \equiv \int_0^1 \log[\sum_j \lambda^j d(j,t,\omega)] d\omega. \qquad (2)$$

where d(j,t,ω) denotes the quantity consumed of a product of quality *j* produced in industry ω at time *t*, and λ>1 represents the extent to which higher quality products improve on lower quality products.

At each point in time t, each consumer allocates expenditure E to maximize log u(t) given the prevailing market prices. Solving this optimal control problem yields a unit elastic demand function

$$d = E/p \qquad (3)$$

where d is quantity demanded and p is the market price for the product in each industry with the lowest quality adjusted price. The quantity demanded for all other products is zero. Given this static demand behavior, each consumer chooses the path of expenditure over time to maximize (1) subject to the usual intertemporal budget constraint. Solving this optimal control problem yields

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[5]For example, Trefler (1993) finds that the degree of protection is greater when protection is more valuable to private interests.

$$(4) \qquad \frac{dE(t)}{dt}/E(t) = r(t)-\rho$$

that is, a constant expenditure path is optimal if and only if the market interest rate equals ρ. We will restrict attention to steady state properties of the model. Then ρ is the equilibrium interest rate throughout time and consumer expenditure is constant over time. Let E^h and E^f denote aggregate steady state consumer expenditures in the Home and Foreign countries, respectively.

C. Firm Behavior

C.1 Targeting and the Product Market

Since one unit of labor produces one unit of output regardless of quality, and the Foreign wage rate has been normalized to equal one, every Foreign firm has a constant marginal cost equal to one and every Home firm has a constant marginal cost equal to w. When a non-leader firm innovates, it becomes the single quality leader in its industry. To determine the profits of the quality leader there are eight possible cases to consider, since there are two markets (Home and Foreign), two types of leaders (Home and Foreign) and two types of previous leaders (Home and Foreign). We will refer to the previous quality leader as the follower firm in the rest of the paper.

Consider first the profits earned by a Home leader selling to Home consumers and competing against a Home follower. With the follower charging a price of w, the lowest price such that losses are avoided, the new quality leader earns instantaneous profits

$$(5) \qquad \pi(p) = \begin{cases} (p-w)E^h/p, & p \le \lambda w \\ 0, & p > \lambda w \end{cases}$$

where p is the quality leader's price. These profits are maximized by choosing $p=\lambda w$. Therefore, this quality leader earns as a reward for its innovative activity the profit flow $\pi=(1-1/\lambda)E^h$, and none of the other firms in the industry can do any better than break even by selling nothing at all to Home consumers.

Consider next the case of a Home leader selling to Home consumers and competing against a *Foreign* follower. In this case, the leader is in a position to benefit from a Home tariff τ^h on imports because its closest competitor is a Foreign firm. The lowest price that the Foreign follower can charge in the Home market without losing money is $1+\tau^h$. In this case the leader maximizes profits by setting the limit price $p=\lambda(1+\tau^h)$. Then all the Home consumers buy from the Home leader and its profit flow is $\pi=[\lambda(1+\tau^h)-w]E^h/\lambda(1+\tau^h)$. Letting $\delta^h \equiv 1/(1+\tau^h)$, this simplifies to $\pi=(1-w\delta^h/\lambda)E^h$. Using similar calculations we can derive prices and profits earned in the other six cases. All eight cases are summarized in Table 1.

Table 1. Location of leader firm, follower firm and consumers, and the corresponding price and profit flows.

Case	Leader's location	Follower's location	Consumer's location	Price	Profits
1	Home	Home	Home	λw	$(1-\frac{1}{\lambda})E^h$
2	Home	Foreign	Home	λ/δ^h	$(1-\frac{\delta^h}{\lambda}w)E^h$
3	Home	Home	Foreign	λw	$(1-\frac{1}{\lambda})E^f$
4	Home	Foreign	Foreign	λ	$(1-\frac{w}{\lambda})E^f$
5	Foreign	Home	Home	λw	$(1-\frac{1}{\lambda w})E^h$
6	Foreign	Foreign	Home	λ	$(1-\frac{1}{\lambda})E^h$
7	Foreign	Home	Foreign	$w\lambda/\delta^f$	$(1-\frac{\delta^f}{\lambda w})E^f$
8	Foreign	Foreign	Foreign	λ	$(1-\frac{1}{\lambda})E^f$

In case 7, $\delta^f \equiv 1/(1+\tau^f)$. Note that a higher tariff only affects profits in cases 2 and 7. In both of these cases, a higher tariff τ (or lower δ) leads to higher profits for the protected domestic producer. We will assume that both governments concede and impose tariffs on imports in those industries where domestic firms benefit from tariff protection.

Furthermore, firms anticipate future tariff protection and target their current R&D efforts accordingly.

Based on Table 1, we may determine the most profitable R&D targeting behavior. Any quality leader earns profits from selling to both Home and Foreign consumers. A Home leader competing against a Home follower earns world wide profits equal to the sum of profits in cases 1 and 3 (in Table 1). A Home leader competing against a Foreign follower earns world-wide profits equal to the sum of profits in cases 2 and 4. Comparing these world-wide profits, we find that a Home leader prefers to compete against a Foreign follower if $(1-\delta^h w/\lambda)E^h+(1-w/\lambda)E^f>(1-1/\lambda)E^h+(1-1/\lambda)E^f$. Likewise, by comparing the added profits of cases 6 and 8 with cases 5 and 7, we find that a Foreign leader prefers to compete against a Home follower if $(1-1/\lambda w)E^h + (1-\delta^f/\lambda w)E^f > (1-1/\lambda)E^h+(1-1/\lambda)E^f$. Both these equations hold if and only if

$$\frac{E^h+E^f}{\delta^h E^h+E^f} > w > \frac{E^h+\delta^f E^f}{E^h+E^f}. \tag{6}$$

Given that $\delta^h<1$ and $\delta^f<1$, w=1 satisfies equation (6). Thus when factor price equalization holds (w=1), Home leaders prefer to compete against Foreign followers and Foreign leaders prefer to compete against Home followers. It follows that Home firms find it more profitable to innovate in industries with a Foreign leader and Foreign firms find it more profitable to innovate in industries with a Home leader. Essentially, Home (Foreign) leaders want to compete against Foreign (Home) followers so as to reap the benefits of trade barriers. And by means of international R&D targeting, they can guarantee the desired outcome.

In this paper we focus in on the effects of trade between two countries that are very similar. Workers in the two countries have the same productivity, innovations are of the same size, and consumers have the same preferences. The two countries only differ in their tariff rates on imports, their R&D subsidy rates, their endowments of labor and their ownership shares of world assets. Furthermore, we only consider the effects of small differences. Under these circumstances, we should expect *approximate* factor price equalization to occur and accordingly, in this paper, we restrict attention to steady state equilibria which satisfy (6) and result in international R&D targeting.[6]

C.2 R&D Efforts by Firms.

The returns to engaging in R&D are independently distributed across industries and over time. In industry ω at time t, let ℓ_i denote firm i's employment of R&D labor and let $\ell^r \equiv \sum_i \ell_i$ denote the industry-wide R&D employment. Firm i's instantaneous probability of winning the R&D race and becoming the next quality leader is assumed to equal $\ell_i/(a+b\ell^r)$, where $a>0$ and $b\geq 0$ are R&D technology parameters. Individual R&D firms behave competitively and treat ℓ^r as given, not influenced by their choice of ℓ_i [as in Dixit (1988)].

This R&D formulation with b=0 is used in Grossman and Helpman (1991a,b) and corresponds to assuming constant returns to R&D. By allowing for b>0, we consider a broader range of possibilities. With b>0, each firm's instantaneous probability of success is a decreasing function of industry-level R&D effort. One way to interpret this property is that when firms do more R&D, R&D duplication becomes more likely and success in the R&D laboratory becomes less likely to translate into profits in the relevant product market. Individual R&D firms can be hurt when other firms do more R&D if it becomes less likely that they will be rewarded for R&D success. It is this instantaneous probability of being rewarded in the relevant product market that we are ultimately concerned with. The instantaneous probability that some firm will be rewarded for R&D success is $\ell^r/(a+b\ell^r)$. Since this is a strictly concave function, b>0 corresponds to assuming decreasing returns to R&D at the industry level.

With international R&D targeting, R&D is only undertaken by Home firms in industries with a Foreign leader and R&D is only undertaken by Foreign firms in industries with a Home leader. Thus we can distinguish between Home and Foreign R&D races, based on which firms choose to participate. Let υ^h and υ^f denote the expected discounted rewards for winning Home and Foreign R&D races, respectively. Likewise, let s^h and s^f denote R&D subsidy by the Home and Foreign governments, respectively. Then, in Home R&D races, each firm i chooses its R&D employment ℓ_i^h to

[6] Judging from our simulations, this restriction on the wage does not seem particularly strong. In all simulations, including those discussed in the section "robustness", the equilibrium wage rate was well within the boundaries specified in equation (6).

maximize instantaneous profits $\upsilon^h \ell_i^h/(a+b\ell^h)-w(1-s^h)\ell_i^h$, where $\ell^h \equiv \sum_i \ell_i^h$ is the industry-wide employment of labor in a Home R&D race. And in Foreign R&D races, each firm i chooses its R&D employment ℓ_i^f to maximize instantaneous profits $\upsilon^f \ell_i^f/(a+b\ell^f)-(1-s^f)\ell_i^f$, where $\ell^f \equiv \sum_i \ell_i^f$ is the industry-wide employment of labor in a Foreign R&D race.

For a steady state equilibrium, the relative wage must adjust so that in the Home country $\upsilon^h=w(a+b\ell^h)(1-s^h)$, and applying the same reasoning to the Foreign R&D firm's maximization problem yields $\upsilon^f=(a+b\ell^f)(1-s^f)$.[7] We can now see the advantage of allowing for diminishing returns to R&D (b>0). When b>0, we obtain a positive relationship between the reward for winning a R&D race (υ) and how much R&D is done (ℓ). Slightly higher rewards lead to slightly more R&D. When b=0, R&D behavior becomes infinitely sensitive to the size of the reward. For example, starting from $\upsilon^h=wa(1-s^h)$, the slightest increase in υ^h leads firms to want to choose $\ell^h=+\infty$ and the slightest decrease in υ^h leads firms to want to choose $\ell^h=0$. In the interest of obtaining reasonable results, we focus mainly on the properties of the model when b is greater than zero.

We will now determine the equilibrium rewards for winning R&D races. From equation (4), in any steady state equilibrium, the market interest rate must equal ρ. Not only must we discount profits using ρ, but we must also consider that every quality leader is eventually driven out of business by further innovation in the other country. For a Home leader, this occurs with instantaneous probability $\ell^f/(a+b\ell^f)$ and for a Foreign leader, this occurs with instantaneous probability $\ell^h/(a+b\ell^h)$. Thus we obtain as equilibrium R&D conditions:

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[7]Solving the Home R&D firm's maximization problem, we find that $\ell_i^h=0$ is profit-maximizing when $\upsilon^h < w(a+b\ell^h)(1-s^h)$ and $\ell_i^h=+\infty$ is profit-maximizing when $\upsilon^h > w(a+b\ell^h)(1-s^h)$. In the former case, the lack of demand for R&D workers implies eventual excess supply of labor in the Home country (with R&D only being undertaken in the Foreign country, the number of Home leaders is going to gradually shrink over time, implying reduced demand for Home production workers). In the latter case, given a finite labor endowment L^h, there must be excess demand for labor in the Home country. Thus neither case represents a steady state equilibrium possibility.

(7) $$v^h = \frac{(1-\delta^h w/\lambda)E^h + (1-w/\lambda)E^f}{\rho + \ell^f/(a+b\ell^f)} = w(a+b\ell^h)(1-s^h)$$

and

(8) $$v^f = \frac{(1-\delta^f/(\lambda w))E^f + (1-1/(\lambda w))\ E^h}{\rho + \ell^h/(a+b\ell^h)} = (a+b\ell^f)(1-s^f).$$

These two equations capture the idea that, in equilibrium, Home leaders are eventually driven out of business by Foreign innovation, and, Foreign leaders are eventually driven out of business by Home innovation.

Because of international R&D targeting, each industry ω alternates over time between having a Home leader and having a Foreign leader. Thus, at any given time, a fraction α of industries have Home leaders and a fraction $1-\alpha$ of industries have Foreign leaders. In any steady state equilibrium where α is constant over time, the flow out of the "α-industry" state must be exactly balanced by the flow into the "α-industry" state, that is, $\alpha\ell^f/(a+b\ell^f)=(1-\alpha)\ell^h/(a+b\ell^h)$. Solving for α yields:

(9) $$\alpha \equiv \frac{\ell^h(a+b\ell^f)}{\ell^h(a+b\ell^f)+\ell^f(a+b\ell^h)}.$$

D Labor Markets

In the Home country, the proportion α of industries have Home quality leaders. Each Home leader employs $E^h\delta^h/\lambda$ workers for domestic production and E^f/λ workers for export production. In each of the remaining $1-\alpha$ industries, Home firms only do R&D and employ ℓ^h workers per industry. Thus, full employment of Home labor L^h implies that $L^h = \alpha\ (E^h\delta^h/\lambda + E^f/\lambda) + (1-\alpha)\ell^h$. Substituting in for α using (9), we obtain the Home labor market condition

(10) $$L^h = \frac{\ell^h(a+b\ell^f)(E^h\delta^h + E^f)/\lambda + \ell^f(a+b\ell^h)\ell^h}{\ell^h(a+b\ell^f)+\ell^f(a+b\ell^h)}.$$

In the Foreign country, the proportion $1-\alpha$ of industries have Foreign quality leaders. Each Foreign leader employs $E^f\delta^f/\lambda w$ workers for domestic production and $E^h/\lambda w$ workers for export production. In each of the remaining α industries, Foreign firms only do R&D and employ ℓ^f workers per industry. Thus, full employment of Foreign labor L^f implies that $L^f=\alpha\ell^f+(1-\alpha)(E^f\delta^f/\lambda w+E^h/\lambda w)$. Substituting in for α using (9), we obtain the Foreign labor market condition

(11) $$L^f = \frac{\ell^h(a+b\ell^f)\ell^f + \ell^f(a+b\ell^h)(E^f\delta^f + E^h)/\lambda w}{\ell^h(a+b\ell^f)+\ell^f(a+b\ell^h)}.$$

E. Expenditures

To close the model, we need to determine consumer expenditures in each country. In the Home country, steady state consumer expenditure E^h must equal wage income plus interest income on assets owned minus taxes paid to finance the Home R&D subsidy. The value of all assets owned in the world economy A^w equals the stock market value of all leader firms in the world economy, i.e. $A^w=\alpha\upsilon^h+(1-\alpha)\upsilon^f$. Substituting for α using (9) and for υ^h and υ^f using (7) and (8) respectively, we obtain

(12) $$A^w = \frac{(a+b\ell^h)(a+b\ell^f)[w\ell^h(1-s^h)+\ell^f(1-s^f)]}{\ell^h(a+b\ell^f)+\ell^f(a+b\ell^h)}.$$

Let ϕ denote the share of world assets owned by Home country consumers. Then $\rho\phi A^w$ is Home interest income and $\rho(1-\phi)A^w$ is Foreign interest income. To determine the amounts of Home taxes that need to be raised to finance the Home R&D subsidies, we note that $\ell^h(1-\alpha)$ workers do R&D in the Home country. These workers are paid $w\ell^h(1-\alpha)$ and the government pays the fraction s^h of this wage bill. Thus the Home government must raise $s^hw\ell^h(1-\alpha)$ in taxes to finance the R&D subsidy. Putting this all together, Home consumer expenditure $E^h=wL^h+\rho\phi A^w-s^hw\ell^h(1-\alpha)$ becomes:

(13) $$E^h = wL^h + \frac{\rho\phi(a+b\ell^h)(a+b\ell^f)[w\ell^h(1-s^h)+\ell^f(1-s^f)] - ws^h\ell^h\ell^f(a+b\ell^h)}{\ell^h(a+b\ell^f)+\ell^f(a+b\ell^h)}.$$

In the Foreign country, $\ell^f\alpha$ workers do R&D, are paid $\ell^f\alpha$ and the Foreign government pays the fraction s^f of this wage bill. Thus, the Foreign government must raise $s^f\ell^f\alpha$ in taxes to finance the R&D subsidy. Since Foreign consumer expenditures must also equal wage income plus interest income on assets owned minus taxes paid to finance the Foreign R&D subsidy, we obtain:

(14) $$E^f = L^f + \frac{\rho(1-\phi)(a+b\ell^h)(a+b\ell^f)[w\ell^h(1-s^h)+\ell^f(1-s^f)] - s^f\ell^f\ell^h(a+b\ell^f)}{\ell^h(a+b\ell^f)+\ell^f(a+b\ell^h)}.$$

We have now completed the presentation of the two-country endogenous growth model and it is useful at this stage to sum it up. We have derived six equations; a Home and a Foreign R&D condition (Equations (7) and (8)), a Home and Foreign labor condition (Equations (10) and (11)) and a Home and Foreign expenditure condition (Equations (13) and (14)). Thus we have six equations but only five unknowns (E^h, E^f, ℓ^h, ℓ^f and w). However, since the model is a general equilibrium model, Walras Law applies, and if five of the six equations are satisfied, the sixth equation must also be satisfied. Thus we can solve the model for a steady state equilibrium by solving a system of five equations in five unknowns.

3. Results

3.a Symmetric Steady State Equilibria

We begin our analysis of this model by considering the special case where both countries are exactly symmetric ($L^h=L^f\equiv L$, $s^h=s^f\equiv s$, $\delta^h=\delta^f\equiv\delta$ and $\phi=1/2$). Then there is an enormous simplification because we can solve for a steady state equilibrium with factor price equalization (w=1) and symmetric equilibrium behavior ($\ell^h=\ell^f\equiv\ell$ and $E^h=E^f\equiv E$). Substituting the symmetry conditions into (10) and (11) yields a single labor market condition:

(15) $$L=\frac{\ell}{2}+\frac{E(1+\delta)}{2\lambda}.$$

Equation (15) states that, in each country, all the workers must either be employed in the R&D sector or in the production sector. Substituting the symmetry conditions into (7) and (8) yields a single R&D condition

(16) $$(2-\frac{\delta}{\lambda}-\frac{1}{\lambda})E=(1-s)[\rho(a+b\ell)+\ell].$$

Equation (16) states that when consumer expenditures E increases, it is profitable for firms to devote more resources ℓ to R&D.

Equations (15) and (16) are illustrated graphically in Figure 1. As illustrated, the R&D condition is an upward sloping straight line and the labor market condition is a downward sloping straight line. By comparing the E-intercepts, it is easy to see that there exists a unique interior symmetric steady state equilibrium (ℓ^*,E^*) provided that each country's labor force L is sufficiently large, that is, provided we assume

A1 $2L>\rho a/(\lambda-1)$

and, of course, restrict attention to nonnegative tariffs and R&D subsidies ($0<\delta\leq 1$, $0\leq s<1$). Like Grossman and Helpman (1991a, p. 49), we will assume that assumption A1 holds, as it is needed to guarantee that growth occurs when the two countries freely trade goods and do not subsidize R&D.

The comparative steady state properties of this symmetric steady state equilibrium are easily determined by considering how the labor market and R&D conditions in Figure 2 shift in response to parameter changes. We will consider the effects of increasing population size, R&D subsidies and tariffs.

A Population Increase

An increase in each country's population of workers L causes the labor market condition to shift to the right, resulting in higher equilibrium R&D employment ℓ^* and higher equilibrium consumer expenditures E^*. Having a larger population of wage earners in each country increases wage income, and in turn consumer expenditure, increasing the profits earned by innovative firms. At the same time, having a larger population of workers means that firms can devote more resources to production. Both considerations complement each other and imply that an increase in population size results in faster growth. Kremer (1993) has found empirical support for this common property of endogenous growth models.

A R&D Subsidy Increase

An increase in each country's R&D subsidy s causes the R&D condition to shift to the right, resulting in a higher equilibrium R&D employment ℓ^* and lower equilibrium consumer expenditure E^*. Thus R&D subsidies have the expected effect of stimulating R&D investments (and economic growth) at the expense of current consumption.

A Tariff Increase

An increase in each country's tariff rate on imports τ decreases $\delta \equiv 1/(1+\tau)$ and causes both the R&D and labor market conditions to shift to the right. The steady state effect of a higher common tariff rate on imports is illustrated in Figure 2 by the movement from point A to point B. Although the effect on equilibrium consumer expenditure E^* is ambiguous, a higher common tariff increases equilibrium R&D employment ℓ^* and thus results in faster economic growth, provided, of course, that $0<\tau<\lambda-1$. If the common tariff rate is sufficiently high, then quality leaders will not necessarily export their products and the previously derived profit expressions need to be recalculated.[8]

Although this result that tariffs are growth-enhancing may come as a surprise, it is a natural implication of our quality ladders framework. The only firms that benefit from moderate tariff protection in our model are quality ladder firms. To take an example, in

[8]Segerstrom, Anant and Dinopoulos (1990) analyzed the growth effects of prohibitively high tariffs designed to protect firms in dying industries from international competition. They found that increasing the proportion of industries receiving prohibitively high tariff protection lowers growth. Thus our conclusion that higher common tariffs stimulate growth is only valid for non-prohibitively high tariff rates.

an industry with a Home leader and a Foreign follower, an increase in the Foreign tariff does not help the Foreign follower since the Home leader just lowers it's price enough to offset the tariff increase (and, in doing so, prices the Foreign follower out of business). Thus only quality leaders get tariff protection in our analysis. Higher tariffs on imports allow quality leaders to charge higher prices to domestic consumers and these higher prices serve two purposes. First, they generate higher profits for quality leaders and result in higher rewards for R&D success. Second, higher prices lead consumers to buy less, consequently less is produced in equilibrium, and production labor is freed up to do more R&D. Both considerations work together to generate a positive relationship between tariffs and growth.[9]

Rivera-Batiz and Romer (1991b) have also studied the relationship between common tariff rates and growth using a two-country model. They found a U-shaped relationship between tariffs and growth, that is, increasing the common tariff initially lead to slower growth but eventually lead to faster growth. In their model, firms do R&D in order to discover new horizontally differentiated products. Because all firms are in some sense symmetric, all firms benefit to the same extent from tariff protection in their model. In contrast, firms do not benefit equally from tariff protection in our model because different firms sell different quality products.

3.b Welfare Analysis

To evaluate the welfare effects of alternative tariff and R&D subsidy policies, we calculate consumer welfare (discounted consumer utility) starting from time t=0 in each of the two countries. Remember that all consumers are assumed to have identical preferences. Consider first the utility of a Home consumer with steady state expenditure e^h. At any point in time, this consumer only buys the highest quality product in each industry, and from (3), this consumer's static demand function is given by $d(j,t,\omega)=e^h/p^h(j,t,\omega)$. This consumer buys from a Home leader charging the price λ/δ^h in α industries and from a Foreign leader charging the price λw in $1-\alpha$ industries. Before we substitute this information into (2) we note that, in this equation,

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[9]Of course, we make no claim that tariffs are good for economic welfare. In our model, R&D subsidies are preferable to tariffs as instruments for promiting economic growth since tariffs create price distortions between domestically produced and imported products.

$_0\int^1 \log\lambda^j/d\omega = tI \log\lambda$ where I is the steady state industry-wide instantaneous probability of R&D success. [See Grossman and Helpman (1991a, p. 50)]. With international R&D targeting, there is an additional complication because R&D intensities differ across industries. In α industries, the instantaneous probability of R&D success is $\ell^f/(a+b\ell^f)$ and in $1-\alpha$ industries, the instantaneous probability of R&D success is $\ell^h/(a+b\ell^h)$. Thus, $_0\int^1 \log\lambda^j/d\omega = t\log(\lambda)[\alpha\ell^f/(a+b\ell^f) + (1-\alpha)\ell^h/(a+b\ell^h)]$. Substituting all the above information into (2) yields the Home consumer's instantaneous utility

$$\log\, u^h(t) = \frac{2\ell^h\ell^f \log(\lambda)t + \ell^h(a+b\ell^f)\log(e^h\delta^h/\lambda) + \ell^f(a+b\ell^h)\log(e^h/\lambda w)}{\ell^h(a+b\ell^f)+\ell^f(a+b\ell^h)}. \tag{17}$$

For a Foreign consumer with steady state expenditure e^f, the situation is slightly different. This consumer buys from a Home leader charging the price λ in α industries and from a Foreign leader charging the price $w\lambda/\delta^f$ in $1-\alpha$ industries. Substituting this information into (2), along with the redefined integral, yields the Foreign consumer's instantaneous utility:

$$\log\, u^f(t) = \frac{2\ell^h\ell^f \log(\lambda)t + \ell^h(a+b\ell^f)\log(e^f/\lambda) + \ell^f(a+b\ell^h)\log(e^f\delta^f)/\lambda w}{\ell^h(a+b\ell^f)+\ell^f(a+b\ell^h)}. \tag{18}$$

Comparing (17) and (18), we see that the time derivatives of $\log u^h(t)$ and $\log u^f(t)$ are identical. This means that both countries must experience *identical growth rates* in consumer utility. Since this conclusion applies even when $\ell^h \neq \ell^f$, it does not hinge on both countries adopting identical tariff and R&D subsidy policies. Both countries experience identical steady state equilibrium growth rates even when they adopt different tariff and R&D subsidy policies.

To understand the intuition behind this result, we must remember that even when the tariff rates differ across the two countries, given that these tariffs are not large enough to eliminate imports in any industry, both countries are still connected by trade. This means that when any firm in the world innovates, consumers in both countries buy the new higher quality product. Since consumers in both countries benefit from any innovation, both countries must grow at the same rate. Differences in tariffs and/or R&D subsidies cause international differences in utility *levels*, not utility *growth* rates. Thus the distinction between growth and level effects that is emphasized in the exogenous growth theory literature is also important when analyzing endogenous growth models.

This interesting property of our model helps explain why empirical research on cross-country growth differences has met with limited success. Levine and Renelt (1992) stress the general lack of theoretical foundation in the empirical growth literature and their sensitivity analysis aptly shows that the empirical results are typically fragile. In particular, the empirical literature has found no differences in growth across countries as individual countries have changed policy or experienced factor endowments changes. Our results suggest that such growth differences should not appear across trading countries and that country involvement in international trade should be of a crucial importance in the empirical studies.

To evaluate overall consumer welfare in each of the two countries, we set $e^h=E^h$ and $e^f=E^f$. Substituting (17) and (18) into (1) then yields

$$W^h \equiv \rho U^h = \frac{2\ell^f\ell^h \log(\lambda)/\rho + \ell^h(a+b\ell^f)\log(E^h\delta^h/\lambda) + \ell^f(a+b\ell^h)\log(E^h/\lambda w)}{\ell^h(a+b\ell^f)+\ell^f(a+b\ell^h)} \tag{19}$$

and

$$W^f \equiv \rho U^f = \frac{2\ell^h\ell^f \log(\lambda)/\rho + \ell^h(a+b\ell^f)\log(E^f/\lambda) + \ell^f(a+b\ell^h)\log(E^f\delta^f/\lambda w)}{\ell^h(a+b\ell^f)+\ell^f(a+b\ell^h)} \tag{20}$$

where W^h and W^f denote Home and Foreign welfare levels, respectively.

Besides measuring overall welfare in the two countries, we are also interested in the incentives workers have to migrate. To determine these incentives, we first calculate their expenditures. In the Home country, total income before taxes equals $wL^h+\rho\phi A^w$ and total taxes equal $ws^h\ell^h(1-\alpha)$. We will assume that taxes are spread evenly across all income earners (wage as well as interest income). Then a Home worker with one unit of labor pays taxes $[ws^h\ell^h(1-\alpha)/L^h]/[wL^h/(wL^h+\rho\phi A^w)]$. Since this worker earns before tax income of w, (after tax) steady state consumer expenditure for this Home worker is $e^{hw}\equiv w[1-(ws^h\ell^h(1-\alpha))/(wL^h+\rho\phi A^w)]$. Using similar calculations, a Foreign worker with one unit of labor has (after tax) steady state consumer expenditure $e^{fw}\equiv 1-(s^f\ell^f\alpha)/(L^f+\rho(1-\phi)A^w)$.

Given that consumer utility grows at the same rate in the two countries, if there is any incentive for international migration in a steady state equilibrium, it must be present at time t=0. Thus, to determine migration incentives, we will compare the static utilities at t=0 of similar workers in the two countries. Substituting the expenditure expressions into (17) and (18) and evaluating at t=0, we obtain static utility levels (in anti-log form) u^{hw} and u^{fw} for workers in the two countries.

3.c Asymmetric Steady State Equilibria

Having analyzed the properties of the model when both countries are exactly symmetric, we are now ready to analyze how international differences generate incnetives for international migration. When the two countries adopt different tariff or R&D subsidy policies, in general, factor price equalization does not hold ($w \neq 1$) and steady state equilibrium behavior is not symmetric ($\ell^h \neq \ell^f$ and $E^h \neq E^f$). Using Walras law, we can ignore (14) and solve for a steady state equilibrium by solving the system of five equations ((7), (8), (10), (11) and (13)) in five unknowns (E^h,E^f, ℓ^h, ℓ^f and w). This system of non-linear equations is not analytically tractable and thus we will use computer simulations to shed light on the model's properties.

The main reason why our model is complicated is that we allow for differences across countries. In previous work on the relationship between trade barriers and economic growth by Rivera-Batiz and Romer (1991a,b), it is assumed that both trading countries are identical in every respect. Two country endogenous growth models become considerably more complicated when either structural or public policy differences lead to cross country differences in the endogenous variables. Such differences, more specifically in relative utilities, are, however, necessary for migration to be an interesting issue.

In our computer simulations, we used as benchmark parameter values $\lambda=1.3$, $\rho=.05$, $L^h=L^f=1$, $b=5$, $s^h=s^f=0$, $a=1.84$, $\delta^h=\delta^f=.95$ and $\phi=.5$. The economic interpretation of these parameter choices is as follows: $\lambda=1.3$ means that each innovation represents a 30% improvement, that is, consumers are willing to pay 30% more for each new higher quality product. Given (4), $\rho=.05$ implies that the steady state market interest rate is 5%. $L^h=L^f=1$ represents a convenient normalization of the labor endowments in the two countries. To interpret the diminishing returns to R&D effort parameter b, first note that the industry-wide instantaneous probability of R&D success is $I=\ell^r/(a+b\ell^r)$. This implies that the time duration of a R&D race is exponentially distributed and that the expected duration is $1/I=(a+b\ell^r)/\ell^r$. Letting ℓ^r approach $+\infty$, we obtain that b=5 years is the shortest possible expected duration for an R&D race. This value of b can also be interpreted as placing an upper bound on the world economy's GNP growth rate G, which satisfies $(1+G)^{1/I}=\lambda$. Substituting $\lambda=1.3$ and $1/I=5$, b=5 implies that the economy's maximum GNP growth rate is 5.4% (G=.054). $s^h=s^f=0$ of course means that neither country subsidizes R&D. Given the benchmark parameter values $\lambda=1.3$, $\rho=.05$, $L^h=L^f=1$, b=5 and $s^h=s^f=0$, a=1.84 implies a 2.5% equilibrium GNP growth rate when free trade prevails $(\delta^h=\delta^f=1)$. This is verified by solving (15) and (16) for the steady state equilibrium R&D employment ℓ^r and then substituting into the above GNP growth equation. Finally, $\delta^h=\delta^f=.95$ means that each country protects domestic leader firms by imposing 5% tariffs on imports, and $\phi=.5$ means that both countries have equal asset ownerships.

With these parameter values, we obtain the benchmark solution given in column 2 in Table 2. Lines 1 and 2 show, for each endogenous variable, the absolute value and the percentage change from the benchmark solution when no international labor migration occurs. Lines 3 and 4 show the absolute value and the percentage change from the benchmark solution under free international labor migration. In all simulations $e^{fw}=1.00000$. The growth rate g is defined as $2\log(\lambda)\ell^h\ell^f/(\ell^h(a+b\ell^f)+\ell^f(a+b\ell^h))$, the Home price index, $HPI=\alpha\lambda/\delta^h+(1-\alpha)\lambda w$, and the Foreign price index, $FPI=\alpha\lambda+(1-\alpha)\lambda w/\delta^f$. The correctness of the results reported in Table 2 can be directly verified by plugging these solution values back into equations (7), (8), (10), (11), (13) and (14).

Effects of Labor Force Size Differences Across Countries.

We first want to investigate what happens when the two countries initially only differ with respect to labor force size and the countries are opened up for international migration. This simulation is of particular interest to us since the free labor mobility eliminates the only difference between the two countries. In the remaining simulations, international policy differences make the post-migration equilibria asymmetric.

In column 4 of Table 2 is presented the steady state solution when L^h is 1.01 rather than 1.0 and L^f is .99 rather than 1.0. With these endowments the Home country is more labor-abundant than the Foreign country. In addition, the larger Home labor supply

Table 2 The results of the benchmark solution and the policy experiments.

Dependent variables	Benchmark solution.	Migration regime	L^h=1.01 L^f=.99	s^h=.01	δ^h=.94	ϕ=.6
w Home Wage	1	Restr. migration	.99923	1.00149	1.00211	1.00035
		% change	-.077	+.149	+.211	+.035
		Free migration	1	1.00158	1.00397	1.00015
		% change	±0.0	+.158	+.397	+.015
ϱ^h Home R&D	.36295	Restr. migration	.37061	.36423	.36742	.36310
		% change	+2.11	+.353	+1.23	+.041
		Free migration	.36295	.36337	.34953	.36508
		% change	±0.0	+.012	-3.697	+.006
ϱ^f Foreign R&D	.36295	Restr. migration	.35543	.36512	.36557	.36280
		% change	-2.072	+.598	+.722	-.041
		Free migration	.36295	.36599	.38399	.36083
		% change	±0.0	+.838	+5.80	-.585
E^h Home expendi-tures	1.09137	Restr. migration	1.10057	1.09086	1.09401	1.11001
		% change	+.843	-.047	+.242	+1.70
		Free migration	1.09137	1.08982	1.07238	1.11240
		% change	±0.0	-.142	-1.74	+1.93
E^f Foreign expendi-tures	1.09137	Restr. migration	1.08135	1.09119	1.09191	1.07311
		% change	-.918	-.016	+.049	-1.67
		Free migration	1.09137	1.09234	1.11563	1.07050
		% change	±0.0	+.089	+2.22	-1.91
g Growth rate	2.6055%	Restr. migration	2.6052	2.61174	2.6182	2.60551
		% change	-.0003	+.00624	+.013	+2E-7
		Free migration	2.6055	2.61173	2.6163	2.60548
		% change	±0.0	+.00623	+.011	-.00003
W^h Home welfare	.32052	Restr. migration	.32897	.32057	.31911	.33728
		% change	+2.64	+.016	-.440	+ 5.23
		Free migration	.32052	.31960	.29855	.33946
		% change	±0.0	-.287	-6.865	5.909
W^f Foreign welfare	.32052	Restr.migration	.31189	.32085	.32255	.30348
		% change	-2.692	+.103	+.633	-5.32
		Free migration	.32052	..32182	.34204	.30121
		% change	±0.0	.406	+6.714	-6.025
u^{hw} Home worker utility	.74975	Restr. migration	.74926	.74907	.74655	.74988
		% change	-.065	-.091	-.427	+.017
		Free migration	.74975	.74912	.74778	.74975
		% change	±0.0	-.084	-.263	±0.0
u^{fw} Foreign worker utility	.74975	Restr. migration	.75024	.74918	.74899	.74963
		% change	+.065	-.076	-.101	-.016
		Free migration	.74975	.74912	.74778	.74975
		% change	±0.0	-.084	-.026	±0.0
e^{hw} Home worker expendit.	1	Restr. migration	.99923	.99982	1.00211	1.00035
		% change	-.077	-.018	+.211	+.035
		Free migration	I	.99991	1.00397	1.00015
		% change	±0.0	-.009	+.397	+.015
HPI Home price level	1.33421	Restr. migration	1.33407	1.33516	1.34291	1.33445
		% change	-.010	+.071	+.652	+.018
		Free migration	1.33421	1.33518	1.34315	1.33441
		% change	±0.0	+.073	+.670	+.015
FPI Foreign price level	1.33421	Restr. migration	1.33333	1.33525	1.33561	1.33444
		% change	-.066	+.078	+.105	+.017
		Free migration	1.33421	1.33536	1.33779	1.33421
		% change	±0.0	+.086	+.268	± 0

implies higher Home expenditure E^h and correspondingly lower Foreign expenditure E^f, since there are now more wage earners in the Home country and fewer wage earners in the Foreign country. Not surprisingly, in the new steady state equilibrium, these direct effects dominate other considerations, resulting in a .84% increase in E^h, a .92% decrease in E^f and a .077% decrease in w. Since there are positive tariff barriers, Home leader profits are influenced more by changes in Home expenditure than changes in Foreign expenditure. The increase in E^h and the roughly corresponding decrease in E^f increases Home leader profits and Home R&D (ℓ^h increases by 2.110%) while having the reverse effect in the Foreign country (ℓ^f decreases by 2.072%). To summarize, it is more profitable to do R&D in the more populated (and as a result lower wage) Home country.

What are the incentives for migration when the labor supplies differ? Since u^{hw}=.74926 is less than u^{fw}=.75024, workers want to migrate to the less labor-abundant Foreign country. There are two reasons why workers find the Foreign country more attractive: higher wages and lower prices. Wages are higher in the Foreign country for the usual reason that labor is relatively scarce. Prices are lower in the Foreign country because they are pinned down by international competition; Foreign leaders compete against lower cost (lower wage) Home followers and are forced to charge relatively lower prices, whereas Home leaders compete against higher cost (higher wage) Foreign followers and are able to charge relatively higher prices.

What happens when workers freely migrate to the higher wage, less populated Foreign country? First, wages are equalized as workers keep on migrating until no international differences in labor endowments exist. Second, the migration slightly increases economic growth in both countries (g increases from 2.6052% to 2.6055%) since it leads to a more balanced R&D effort in the two countries. Third, host (Foreign) country workers are hurt by the immigration (u^{fw} decreases from .75024 to .74975). Thus host country workers are justified in opposing population-induced immigration (even though they benefit from the slightly higher growth rate).

Effects of Unilateral R&D Subsidies

In column 5 of Table 2, the steady state effects of a 1% increase in the Home R&D subsidy (from s^h=0 to s^h=.01) holding s^f fixed at 0, are reported. A higher Home R&D subsidy has two direct effects. First, the higher subsidy reduces the cost of engaging in R&D for Home firms. Second, Home consumer expenditure falls since taxes must increase to finance the R&D subsidy. Since only a small fraction of the Home economy (the R&D sector) is being subsidized, the first effect dominates and Home R&D is stimulated by the Home R&D subsidy (ℓ^h increases by .353% whereas E^h decreases by only .047%).

What is particularly interesting about the results in column 5 of Table 2 is that the higher Home R&D subsidy increases Foreign R&D even more than Home R&D (ℓ^f increases by .598%). What is going on is that the higher Home R&D subsidy increases the demand for Home R&D workers. This puts upward pressure on the Home relative wage (w increases by .149%). Although this increase in w seems small, it has a magnified effect on profits earned by quality leaders in both countries. In the Home country, the higher wage means higher production costs for Home leaders which cannot be passed on to consumers through higher prices because the prices Home leaders charge are pinned down by international competition. In the Foreign country, the higher Home wage enables Foreign leaders to charge higher prices while having no effect on their production costs. Thus the higher Home wage decreases Home profits significantly while increasing Foreign profits significantly and the Home R&D subsidy stimulates Foreign R&D even more than Home R&D.

Although the Home R&D subsidy increases growth (by .006%) and Home welfare (by .016%), the big beneficiaries are Foreign consumers (W^f increases by .103%). Foreign consumers benefit from the higher growth rate that a Home R&D subsidy causes without having to pay the taxes to finance it. Since $u^{hw}<u^{fw}$ workers have incentives to migrate to the Foreign "low tax" country as a result of a higher Home R&D subsidy. The Foreign country "free rides" on the Home country's effort to promote growth.

What happens when workers freely migrate to the "low tax" Foreign country? R&D subsidy-induced migration has a negligible effect on economic growth (g falls from 2.611743% to 2.611733%). Home workers gain (u^{hw} rises from .74907 to .74912) and Foreign workers lose (u^{fw} falls from .74918 to .74912) as a result of the R&D subsidy-induced migration. Thus workers want to migrate to countries that subsidize R&D less and host (Foreign) country workers are justified in opposing R&D subsidy-induced immigration.

Effects of Unilateral Tariff Increases

In the section on symmetric equilibria, we showed that a bilateral increase in tariffs leads to faster economic growth. Now we want to see the implications of the Home country unilaterally increasing its tariff rate τ^h. We thus let $\delta^h \equiv 1/(1+\tau^h)$ drop from .95 to .94 while holding δ^f fixed at .95. This corresponds to an approximately 1% increase in the Home tariff rate. The results are presented in column 6 of Table 2.

A higher Home tariff has two direct effects. First, the higher tariff increases the demand for Home R&D workers since it increases the profits of protected Home firms. Second, the higher tariff decreases the demand for Home production workers since consumers buy less in response to the higher prices protected firms charge. Thus, firms want to do more R&D and labor is freed up for more R&D. It is quite natural that the dominant effect of a higher Home tariff is to increase Home industry-level R&D employment ℓ^h (by 1.23%).

If the only effect of a higher Home tariff was to increase Home R&D, then over time, the number of Foreign leaders would decline. Since most workers are employed in production in both countries, this decline in the number of Foreign leaders depresses demand for workers in the Foreign country. Thus the wage of Foreign workers must fall to clear the Foreign labor market, which in turn stimulates Foreign R&D effort. From Table 2, we see that a higher Home tariff increases the Home relative wage by .211% and increases Foreign R&D employment ℓ^f by .722%.

These steady state equilibrium effects have interesting implications for international labor migration. Since $u^{hw}<u^{fw}$ workers have incentives to migrate to the Foreign "freer trade" country as a result of higher Home tariffs. Essentially consumers in both countries benefit from the higher world growth rate that higher Home tariffs cause (g rises by .013%) but Foreign consumers benefit more because they pay lower average prices for products (the Home price index rises by .652% whereas the Foreign price index rises by only .078%). The increase in overall Foreign welfare (by .633%) and decrease in overall Home welfare (by .440%) indicate that the Foreign country "free rides" on the Home country's effort to promote growth through higher tariffs. Naturally, workers' welfare is affected similarly, i.e. in favor of the Foreign country.

We may ask how growth is affected if the incentives for labor migration materialize into international labor flows. Lines 3 and 4 in each entry give the answers. We noted that under country specific labor endowments the tariff increase raised growth by .013%. If we allow labor to migrate, growth increases *less*, by .011%. The intuition is the following: The tariff increase makes both countries more R&D oriented but the Home country more so than the Foreign. Home workers have incentives to emigrate to the less R&D intensive Foreign country. With decreasing returns to R&D, this would raise growth further but emigration continues to such an extent that the Foreign country becomes more R&D intensive and growth falls as the differences between the R&D levels increase (ℓ^h=.34953 is significantly less than ℓ^f=.38399 with free labor mobility).

The reallocation of labor from the Home to the Foreign country equalizes workers utility levels and consequently welfare levels. Home workers gain (u^{hw} rises from .74655 to .74778) and Foreign workers lose (u^{fw} falls from .74899 to .74778) as a result of tariff-induced migration. The effect of this migration on growth is small (g falls from 2.6182% to 2.6163%). To summarize, workers want to migrate to countries with lower tariffs on imports (other things being equal) and host (Foreign) country workers are justified in opposing tariff-induced immigration.

Effects of Wealth Differences Across Countries.

In column 7 of Table 2, the steady state effects of an increase in the Home asset ownership share ϕ from .5 to .6 are reported. This increase makes the Home country richer than the Foreign country. With ϕ=.6, Home consumers own 1/5 of the Foreign leader firms in addition to owning all of the Home leader firms.

From (13) and (14), an increase in ϕ directly increases Home expenditure E^h decreases Foreign expenditure E^f. Not surprisingly, these direct effects dominate and in the new steady state equilibrium, E^h increases by 1.70% while E^f decreases by 1.67%. Since there are positive tariff barriers, Home leader profits are influenced more by changes in Home expenditure than changes in Foreign expenditure. Thus the increase in ϕ increases Home leader profits and Home R&D (ℓ^h increases by .041%) while having the reverse effect in the Foreign country (ℓ^f decreases by .041%). It is more profitable to do R&D in the "richer" Home country.

Due to the increased demand for Home R&D workers, Home workers get paid higher wages (w increases by .035%). Not surprisingly, u^{hw}>u^{fw} and workers have an incentive to migrate to the "richer" Home country where they get paid higher wages.

When migration does occur, there is a negligible decrease in both economic growth (g falls from 2.60551% to 2.60548%) and the Home wage (w falls from 1.00035 to 1.00015). The decrease in the Home wage is the natural result of the immigration-induced increased supply of Home workers. Since R&D is subject to decreasing returns, economic growth is faster when R&D effort is more balanced in the two countries. Migration reduces economic growth essentially because it leads to an imbalance; Home firms doing significantly more R&D than Foreign firms. Home workers lose (u^{hw} falls from .74988 to .74975) and Foreign workers gain (u^{fw} rises from .74963 to .74975) as a result of labor migration to the "richer" Home country. Thus host country workers are justified in opposing wealth-induced immigration as well.

Robustness

To see how sensitive the qualitative results reported in Table 2 are to our choice of benchmark parameters, we reran all our policy experiments with high and low values of b, ρ, λ, and L. In particular b= 1 or 10, ρ=.01 or .1, λ=1.1 or 2, and L=.5 or 2.

The most surprising result that we found is that a permanent increase in the Home labor supply does not necessarily lower the steady state equilibrium Home wage. We found that when b is relatively low (the decreasing returns to R&D are slight or nonexistent), an increase in the Home labor supply (and corresponding decrease in the Foreign labor supply) raises the Home wage and gives workers further incentive to migrate to the more populated Home country (all the other results turned out to be robust). The intuition behind this property of the model is as follows: The migration of workers to the Home country directly increases Home labor supply but it also increases Home labor demand since higher Home consumer expenditure makes Home R&D more attractive. When b is low, R&D effort is very sensitive to the size of the reward. It turns out that it is so sensitive that an increase in labor supply causes an even bigger increase in labor demand and the wage w must rise to clear the Home market.

We can formally prove this result when b=0. First substituting b=0, $s^h=s^f=0$, $\delta^h=\delta^f=0$ and $\phi=.5$ into (13) and (14), then totally differentiating with respect to L^h (letting $dL^f=-dL^h$) and finally evaluating at the symmetric equilibrium yields:

(21)
$$\frac{dE^h}{dL^h}=1+\left(L^h+\frac{a\rho}{4}\right)\frac{dw}{dL^h}$$

and

(22) $$\frac{dE^f}{dL^h} = -1 + \frac{a\rho}{4}\frac{dw}{dL^h}.$$

Following the same procedure, total differentiation of (10) and (11) yields (after appropriate substitution using (21) and (22))

(23) $$\frac{d\ell^f}{dL^h} = \frac{1-\delta}{\lambda} - (1+\frac{\delta}{\lambda})L^h\frac{dw}{dL^h} - (2+\frac{\delta}{\lambda}+\frac{1}{\lambda})\frac{a\rho}{4}\frac{dw}{dL^h}$$

and

(24) $$\frac{d\ell^h}{dL^h} = -\frac{d\ell^f}{dL^h}.$$

Now suppose $dw/dL^h \leq 0$. Then (23) and (24) imply that an increase in L^h increases ℓ^f and correspondingly decreases ℓ^h. The total labor employed in the Home R&D sector $\ell^h\ell^f/(\ell^h+\ell^f)$ is not affected by an increase in L^h on the margin. But the fraction of industries with a Home leader $\ell^h/(\ell^h+\ell^f)$ decreases, and from (21) and (22), the employment of labor by each Home leader $(E^h\delta+E^f)/\lambda$ also decreases. Thus total Home labor employment must decrease as L^h increases. But when L^h increases, to clear the Home labor market, the wage w must adjust so that employment increases. Contradiction. It must be that $dw/dL^h>0$. Q.E.D.

We have just shown that when b=0, as is assumed in Grossman and Helpman (1991), immigration increases the wages of workers in a country. More generally, our simulation result indicate that when b is relatively low, immigration has a positive wage effect and when b is relatively high, as is the case with our choice of benchmark parameters, immigration has a negative wage effect. Recent empirical evidence suggests that a negative wage effect is more likely. Altonji and Card (1991) find that a 1% increase in a country's labor force due to immigration lowers wages by 1.2%. Also Borjas, Freeman and Katz (1992) find that between 1980 and 1988, relative incomes of low-skilled Americans fell by 2.5% due to immigration.

Allowing for free migration at low values of b, i.e. at low degrees of decreasing returns to R&D, tend to yield unreasonable results as changes in tariffs, subsidies and wealth distribution occur. In the subsequent sensitivity assessment, we therefore rule out the case b=1 as being obviously unrealistic.[10]

We now ask if the growth effects of international migration are robust. That tariff induced migration lowers growth is a robust result withstanding all our alternative parameter values. In the benchmark case, subsidy induced international migration also lowers the growth rate, but two exceptions occur: as b=10 and λ=2 the growth rate rises. In these two cases migration takes place to the less R&D intensive Home country such that the rates of R&D tend to equalize across the two countries. With a high degree of decreasing returns to R&D or if the rate of quality improvements is high, the Home wage is up to an extent that workers are attracted to the Home country. In all other cases, the migrants leave the Home country tending to increase the R&D difference between the Home and Foreign country, thus lowering growth as in the benchmark case.

When the Home tariff is increased by 1%, the only qualitative result in Table 2 that is not robust under restricted migration is the decrease in Home welfare W^h. When ρ=.01 the unilateral tariff increase raises Home welfare. At this parameter value, the market bias toward underinvestment in R&D is sufficiently strong so that the positive effect of higher growth more than offsets the negative effect of higher prices for Home consumers.

Our results concerning the overall welfare effects of a Home R&D subsidy are quite sensitive to whether there is a market bias toward over- or underinvestment in R&D. With our benchmark parameters, there is a market bias toward underinvestment in R&D and the optimal R&D subsidy in both countries is approximately 22%. But in roughly 50% of the experiments with different parameter values, a R&D tax was optimal. Our result that workers have a slight incentive to migrate to the Foreign "low tax" country not surprisingly is not robust since such migration would also mean leaving the higher wage country.

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[10]Segerstrom (1995) shows that when b=0 in the basic (one-country) quality ladders growth model, R&D subsidies have extreme steady state effects and there always exists a second steady state equilibrium involving zero economic growth. These findings represent another reason why we need to assume that R&D is subject to sufficiently decreasing returns (b is sufficiently large).

4. Concluding Remarks

In this paper, we have studied a two-country quality ladders model with international trade barriers. Unlike in the previous literature, we have focused mainly on the properties of the model when the two countries are not identical. One of our most interesting findings is that, irrespective of economic structure or public policies adopted, countries that trade with each other grow at the same rate and only autarky gives a country a distinct growth rate. Lucas (1988) observed that the developed countries′ growth rates are very similar over time and across countries while growth rates differ widely in semi-developed and under-developed countries. Our theoretical model suggests that this growth structure of the world may be explained by international trade relations. Empirically, we should find that the rich countries′ intensive trade with each other should lead to similar growth rates in the rich part of the world. In the poor countries, trade dependence is generally lower and consequently growth rates differ more.[11] This trade and growth linkage should be accounted for in the empirical cross country studies and could potentially explain a great deal of the fragility of the regression results pointed out by Levine and Renelt (1992).

By allowing for differences between countries, we have also been able to study the incentives for international migration. We find that, other things being equal, workers want to migrate to less populated countries, countries that subsidize R&D less, countries with lower tariffs on imported goods, and countries with wealthier consumers. We find that migration is growth enhancing when it is driven by imbalances in factor supplies but can be growth-retarding when migration is driven by public policy differences. Domestic workers are clearly justified in opposing immigration when it is growth-retarding.

Our model should be viewed as a first attempt at understanding the long-run implications of international migration. As such, it is natural that we have made some strong assumptions and it is worth exploring in future research how sensitive our conclusions are to these assumptions. One strong (and obviously unrealistic) assumption is that there is only one type of workers who can, at no cost of education, switch from

[11] Strictly speaking, our model predicts that some trade gives identical growth rates between two countries and only full autarky may give a country a distinct growth rate. In interpreting such a theoretical result for empirical applications, one should expect to find that the stronger is the trade dependence the more difficult it is to deviate from the trading partners′ growth rates. This interpretation of our results gives scope for other growth effects than those captured in our model.

the assembly line to the research lab. Our results might have been different had we made a distinction between skilled and unskilled workers. One should in general expect the consequences of immigration of high-skilled workers to differ from those of immigration of low-skilled workers. Another strong assumption, carried over from the basic Grossman-Helpman (1991a) model, is that proliferation of product information is perfect and immediate, implying that industry leader firms do not undertake any R&D. And we have restricted attention to tariff rates that are never prohibitively high. It is not uncommon for real-world trade barriers to be prohibitively high and benefit technologically backward firms.

Keeping these limitations in mind, can our results be of some guidance to governments facing a "migration problem"? Our model points to the conclusion that free international migration will stimulate growth to the extent that it is a reaction to labor force differences across the countries. If migration is the result of policy differences or wealth differences across the countries the growth effects are much more uncertain. Consequently, allowing for migration across the borders of similar countries in the North or in the South is more likely to stimulate growth than opening up for migration between the North and the South. Our migration results rest, though, on the existence of (non-prohibitive) tariffs and empirically free international migration has normally been preceded by free trade, like in the case of the creation of the European union.

Our result that growth does not differ across trading countries is not very encouraging for governments of small open economies. To these governments, the size of the domestic economy is so small that it mainly has to take the growth rate as exogenously given in the world market. Only large country governments have the ability to stimulate world growth through R&D subsidies and even in this case, we find strong incentives for large countries to "free-ride" on the growth-stimulating R&D subsidies of other large countries.

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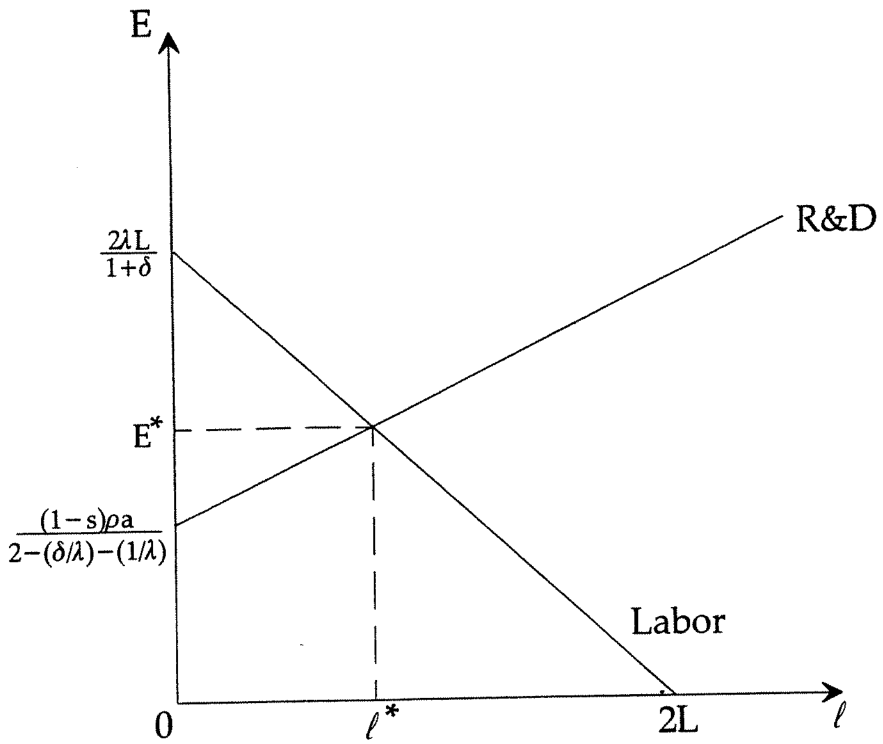

Figure 1 The Symmetric Steady State Equilibrium

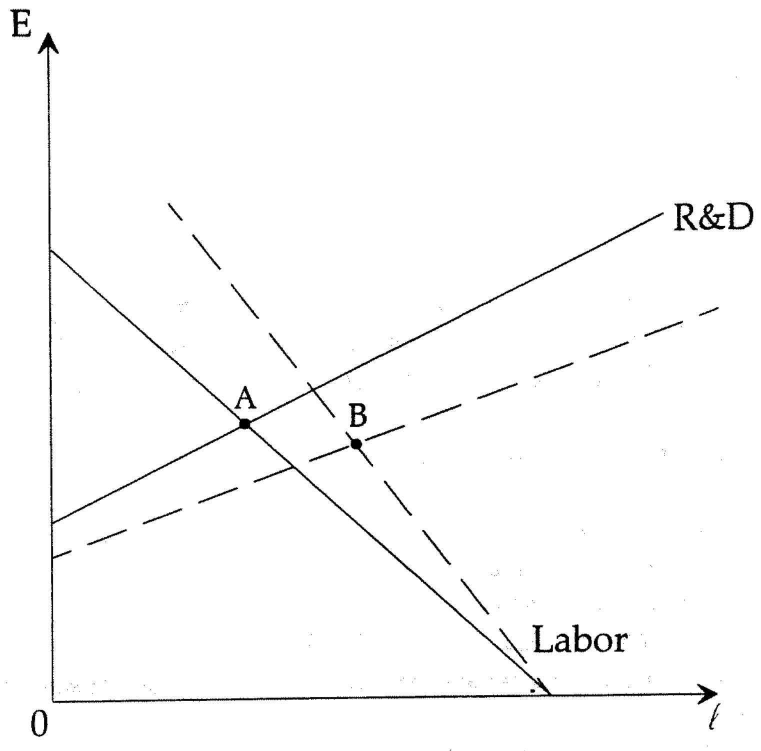

Figure 2 A Higher Common Tariff