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AND GROWTH

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ABSTRACT

In this paper, we examine one channel through which the trade regime might affect growth in the long run. We model endogenous technological progress that results from profit maximizing investments by far-sighted entrepreneurs. Productivity in the research lab depends upon the "stock of knowledge capital", a variable reflecting the state of scientific, engineering and industrial know-how in the local economy. We argue that local knowledge capital is likely to vary positively with the extent of contact between domestic agents and their counterparts in the international research and business communities, and that the number of such contacts increases with the level of commercial exchange. We derive the implications of this for the relationship between trade and growth.

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Most economists believe that openness to international exchange contributes to a country's dynamic performance. Yet the mechanisms by which trade may promote long-run growth have rarely been articulated. The familiar sources of gains from trade, which include specialization according to comparative advantage and the realization of economies scale, suggest that an open economy will enjoy higher levels of income and consumption than an otherwise similar, closed economy. But they do not necessarily imply that the open economy will grow faster. In other words, the traditional literature identifies level effects, but no rate effects.

In this paper we investigate one channel through which the trade regime potentially can influence growth in the long run. We model endogenous technological progress that results from the profit maximizing behavior of far-sighted entrepreneurs. These entrepreneurs invest in research and development in order to capture monopoly rents from innovative products. The productivity of their employees in the research lab depends on the general state of scientific, engineering, and industrial know-how in the country. We argue that this level of know-how -- which we shall refer to as the "stock of knowledge capital" -- will be related to the number of contacts that local agents have with their counterparts in the international research and business communities. The number of contacts most probably increases with the extent of commercial exchange.

Our argument hinges on the public good characteristics of many forms of knowledge. Knowledge is non-rival; that is, the same idea can be used in different applications and in different locations at the same time. In many cases it is also non-excludable; that is, the originators of an idea may have difficulty extracting compensation from all agents that make use of it. These

characteristics imply that spillover benefits may be created in the process of innovation. Several recent papers (e.g., Romer, 1990, Aghion and Howitt, 1990, and Grossman and Helpman, 1990b) have shown how these spillovers may sustain long-run growth in an economy with no exogenous technological progress and constant returns to scale in production. These papers have focused on spillovers within the local research community of a closed economy, or those that extend automatically to all researchers in the world economy. Here, we explore the implications for dynamic performance of the plausible hypothesis that international trade in tangible commodities facilitates the exchange of intangible ideas.

In the next section we describe our model of endogenous innovation and growth. Then in Section II, we show how changes in the degree of openness (as measured by the level of trade protection or trade promotion) affect the long-run rate of growth, the transition to the steady state, and the level of social welfare.

I. New Products in a Small Economy

Our model is based on Grossman and Helpman (1991). Related treatments may be found in Grossman and Helpman (1990a) and Romer (1990). We consider a small country endowed with a single primary factor, called labor. Households in this economy consume two final products, Y and Z, but the country specializes in the production of Y.¹ Perfectly competitive firms manufacture this good using labor and a set of non-traded, horizontally differentiated, intermediate products. Total factor productivity in final production increases

¹This assumption could be justified in a two-factor setting by cross country differences in relative factor endowments. Here we simply assume that, for reasons outside the model, the domestic economy is not competitive in the production of good Z at the given international prices.

with the number of available differentiated inputs. New varieties become available once they have been developed in the industrial research lab.

The production function for good Y takes the form

$$(1) \quad Y = \Lambda_Y L_Y^{1-\beta} \left[\int_0^n x(\omega)^a d\omega \right]^{\beta/a}, \quad 0 < a, \beta < 1,$$

where Λ_Y is a constant, L_Y and $x(\omega)$ denote the inputs of labor and intermediates of type ω , respectively, to final production, and $n(t)$ represents the number of varieties available on the market at time t . We take the relative international price of good Y in terms of the import good Z to be exogenous to the small country, and (without loss of generality) equal to one.

Each unit of any intermediate is produced with one unit of labor. Therefore, its marginal production cost is equal to the wage rate, w . The intermediates are manufactured by a set (continuum) of monopolistic competitors, each one of whom holds the patent to a countable number of varieties. The patents are, of course, the outgrowth of prior investments in R&D. It is well known that with a constant elasticity of substitution between varieties, each monopolist sets a price that is a constant mark-up over its marginal costs. This gives

$$(2) \quad p_Y = w/a.$$

With all available intermediates entering symmetrically into the production function, and all bearing the same price, each one is demanded to the same extent $x = x(\omega)$ at any moment in time. Using this fact, (1) can be simplified to

$$(3) \quad Y = A_Y L_Y^{1-\beta} X^\beta n^{\beta(1-a)/a},$$

where $X \equiv nx$ is the aggregate quantity of intermediates used, and also the amount of labor embodied in these intermediates. If the intersectoral allocation of labor remains constant, as it will in a steady state, then Y grows at the rate $g\beta(1-a)/a$, where $g \equiv \dot{n}/n$ is the rate at which new varieties of intermediates are being introduced to the economy.

We assume that an entrepreneur can invent a measure dn of new varieties of intermediate goods per unit time by applying $(a/K)dn$ units of labor per unit time to research. The parameter a is constant, while K represents the economy's instantaneous stock of knowledge capital. Knowledge capital accumulates in two ways. First, in the course of local product development efforts, researchers make discoveries that have wider applicability. They are unable to appropriate the benefits from these discoveries beyond what they earn from the patents on their new products. That is, we assume (as in Grossman and Helpman, 1991) the existence of a spillover benefit from each domestic research project to the stock of knowledge capital in the research community at large.

Beyond this is the new feature that we emphasize here. We assume that when residents of the small country interact with agents in the outside world, they gain access to a body of accumulated wisdom there, as well as to some of the new discoveries that are being made on an ongoing basis. The foreign contribution to the local knowledge capital stock increases with the number of commercial interactions between domestic and foreign agents. While knowledge can be acquired from the international community through channels that have nothing to do with business relations, it seems reasonable to suppose that the extent of the spillovers between two countries will increase with the volume

of their bilateral trade.

In view of these alternative sources for the accumulation of knowledge capital, let $K(t) = F[n(t), T(t)]$, where $T(t)$ represents the cumulative volume of trade (exports plus imports) up to time t . As before, $n(t)$ is the number of available varieties, which also reflects the cumulative amount of domestic research that has taken place. We take $F(\cdot)$ to be increasing in both arguments and homogeneous of degree one. The latter assumption allows us to define the "intensive" function $\varphi(\cdot) \equiv F[1, T(t)/n(t)]$, such that

$$(4) \quad K = n\varphi(T/n), \quad \varphi' > 0.$$

Entrepreneurs enter freely into R&D. The cost of developing a new product at a moment in time is aw/K . The benefit is v , the value of a patent. Free entry implies $v = aw/K$. The patent yields an infinite stream of profits $\pi(t)$ from sales of $x(t) = X(t)/n(t)$ units at the price given in (2). The value of a patent at every moment is such that the dividend rate on this asset, π/v , plus the rate of capital gain, \dot{v}/v , provides a "normal" rate of return. This "no-arbitrage" condition implies

$$(5) \quad (1-a)X\varphi/aa + \dot{w}/w - \dot{K}/K = r,$$

where r is the instantaneous rate of interest on a consumption loan.

The representative household maximizes an intertemporal utility function of the form

$$(6) \quad U_t = \int_t^{\infty} e^{-\rho(\tau-t)} \log u[c_Y(\tau), c_Z(\tau)] d\tau,$$

where $c_i(\tau)$ is the consumption of final good i at time τ . Here $u(\cdot)$ represents instantaneous utility, which we assume to be non-decreasing, strictly quasi-concave, and homogeneous of degree one in its arguments. The household equates the marginal rate of substitution between the two final goods to the relative domestic price, $p \equiv p_Z/p_Y$, at every moment in time. With international relative prices fixed at unity, we have $p = 1 + z$, where z is the ad valorem rate of an import tariff (subsidy if negative) applied to good Z . Each household obeys an intertemporal budget constraint. But in the aggregate, expenditure must equal national income plus tariff revenue, under the assumption that the country cannot borrow or lend internationally. Dynamic optimization requires that spending, E , evolve according to

$$(6) \quad \dot{E}/E = r - \rho.$$

The model is closed with the labor market clearing condition,

$$(7) \quad ag/\varphi + X + L_Y = L,$$

where L is the constant and inelastic supply of labor. The three terms on the left-hand side of (7) represent employment in R&D, intermediate production, and final production, respectively. Cost minimization in the production of good Y makes L_Y/X a function of p_X/w , which, by the pricing relationship (2), remains constant through time. It follows that L_Y is proportional to X , and the resource constraint can be written as

$$(8) \quad ag/\varphi + b_L X = L,$$

for a constant $b_L > 1$.

Let us suppose now, for the moment, that $\varphi(T/n)$ tends to a finite, long-run value, $\bar{\varphi}$. Then the small economy approaches a steady state. We depict this steady state in Figure 1. In the figure, the line RR represents the resource constraint (8), drawn for the particular value of $\bar{\varphi}$ that applies in the long run. The line $\Pi\Pi$ depicts the steady-state no-arbitrage condition, also drawn for $\varphi = \bar{\varphi}$. The equation for this line can be derived as follows. From (6), $r = \dot{E}/E + \rho$. The aggregate budget constraint limits the growth of spending to the rate of growth of final output, or $\dot{E}/E = g\beta(1-a)/a$. Wages grow at this same rate, because total factor productivity in the final goods sector rises at this rate, unit production costs are constant (equal to the given international price) and relative input prices are constant as well (see (2)). Finally, when φ approaches a constant, the rate of growth of knowledge capital converges on g . Therefore, in the steady state, (5) reduces to

$$(9) \quad (1-a)\bar{\varphi}/a = g + \rho.$$

II. Trade, Openness and Growth

In the steady state, consumption of each good grows at the same rate as final output. Therefore, the volume of trade grows at this rate, or $\dot{T}/T = g\beta(1-a)/a$. It follows that T/n will either shrink to zero, grow without bound, or tend to a constant in the long run, depending upon whether a is larger than, smaller than, or equal to $\beta(1-a)$. We consider each of these possibilities in turn.

If $a > \beta(1-a)$, the relative importance of international trade spillovers as a source for the accumulation of domestic knowledge capital declines over time. In the long run, cumulative trade experience makes a negligible

contribution to K in comparison with the contribution made by cumulative local research. The degree of openness cannot alter this inevitability, and so the trade regime has no effect on the long-run growth rate. Growth in the long run is determined entirely by the available resources and by parameters describing tastes and technologies (see Grossman and Helpman, 1991, for the details). Trade policy will, however, influence the economy along the transition path to the steady state. Policies that serve to expand the level of trade (i.e., an import subsidy or an export subsidy) promote contacts between local and foreign residents. Policies that contract trade, such as tariffs and export taxes, reduce the number of contacts. The former type of policy accelerates the rate of knowledge accumulation and growth, while the latter type retards learning and growth.

In the event that $a < \beta(1-a)$, the ratio of trade volume to the number of varieties tends to infinity. There are two possibilities in this case. First, φ may converge to a finite limit. This would occur, for example, if $F(\cdot)$ had a CES form, with an elasticity of substitution between information from domestic and foreign sources in excess of one. Then the long-run dynamic equilibrium is the same as for an economy that does not learn from abroad, except that the limiting value for φ as T/n approaches infinity enters into equations (8) and (9) in place of an arbitrary constant. In contrast to the case where T/n tends to zero, here the knowledge gained from trade contacts continues to drive growth in the long run. However, a marginal increase in the amount of trade (as might be effected, for example, by policy intervention) does not change the steady-state rate of innovation or growth. The full potential for trade contacts to contribute to the local knowledge stock will eventually be realized, regardless of whether policy stimulates or depresses the volume of trade. As in the previous case, a country that is

more open to trade (i.e., has lower trade barriers) will converge more rapidly to the steady state, all else equal.

A different type of long-run dynamics result when $a < \beta(1-a)$ and $\varphi(\cdot)$ has no bound. Then productivity in the research lab also increases without bound. This causes the rates of growth of productivity and instantaneous utility to become unbounded. Since the household maximization problem is not well defined when utility is unbounded, we shall not pursue this case any further.

The final case to consider is an interesting one, even though it represents a "razor's edge" in the present formulation. This case arises when $a = \beta(1-a)$. Then both the volume of trade and the number of varieties grow at the rate g in the long-run equilibrium. The ratio of the two approaches an endogenously determined, finite value. We can use Figure 1 to investigate how trade policy affects the long-run growth rate in this case.

Suppose first that φ were to increase exogenously. This would cause both RR and III to shift to the right, as illustrated by the dotted lines. Equations (8) and (9) imply that the horizontal shift of the III line (at a given X) is larger than that of the RR line. From this we conclude that g must rise and X must fall. A reduction in φ has the opposite effects on intermediate production and the long-run rate of technological progress.

Now consider the effect of an opening of the economy, as represented by a reduction in the tariff rate, z . The homotheticity of preferences implies that consumption of good Z at given relative prices is proportional to national income, Y. Factor proportions in the final good sectors remain constant (because $w/p_X = a$), so Y is proportional to employment of intermediates, X, with a factor of proportionality that grows at rate g when $a = \beta(1-a)$. Therefore, the ratio of the cumulative trade volume to the number

of varieties is proportional to X/g .² A reduction in the tariff rate causes consumers to substitute c_Z for c_Y , given national income, but X and thus Y conceivably could fall. It seems at first glance that T/n could move in either direction. But in fact, the long-run ratio of the cumulative trade volume to the number of varieties must rise. For, suppose not. Then φ would decline. We have seen above that a decline in φ causes X/g to rise. But T/n cannot fall if both X/g rises and the relative price of imports falls.³

Now the long-run effects of the reduction in the size of the barrier to trade are immediate. The ratio of the cumulative volume of trade to the number of varieties increases. This causes $\varphi = K/n$ to rise, which acts like a boost to productivity in the research lab. Technological progress accelerates, and the economy grows more quickly.

What is the implication of this speeding of growth for social welfare? In Grossman and Helpman (1991) we have shown that, if φ is taken to be exogenous, an economy such as this one converges immediately to a balanced growth path along which the rate of growth is slower than is optimal. We refer to Figure 2. In the figure we have drawn an indifference curve through the equilibrium point E . This indifference curve can be derived from the preferences in (6). Higher X means more output and more consumption early on, but slower growth and therefore less consumption further in the future. Our earlier result implies that an indifference curve cuts the RR line as shown.⁴

²Trade volume is the sum of exports and imports. This equals twice imports, with balanced trade and an international relative price of unity.

³We calculate that $T/n = 2A_Y[(1-\beta)/a\beta]^{1-\beta} X \sigma_Z(z)/g[1+z-z\sigma_Z(z)]$, where $\sigma_Z(z)$ is the share of spending devoted to the import good Z . This ratio is increasing in X and non-increasing in z , and it falls with z whenever some substitution is possible between the two consumption goods.

⁴In Grossman and Helpman (1991) we studied a model similar to the one here, except that there were no knowledge spillovers from international trade, and

The lowering of the trade barrier has two effects on the dynamic allocation, as we have seen. The RR line rotates out and the III curve rotates down. From the diagram, we see that each of these shifts raises social welfare. Intuitively, the opening of trade alleviates two dynamic distortions. First, it encourages contact with foreign businessmen and markets, thereby generating spillover benefits for the local economy. Second, it raises the incentive for local R&D. This activity also generates a positive externality, and so is under compensated in a tariff-ridden (or free trade) equilibrium. There are two further distortions in this economy, which do not appear in the diagram. A static consumption distortion results from protection, as usual. Instantaneous utility rises when the tariff is lowered for this familiar reason. A second static distortion arises from the non-competitive pricing of intermediate goods. Due to this, the labor intensity of final production is too high. However, the tariff neither exacerbates nor alleviates this inefficiency, since it does not affect relative input prices as determined by (2). We conclude that any reduction in the level of a tariff barrier raises welfare in this economy, and that it is in fact optimal to subsidize imports (or exports) at some appropriate level.⁵

III. Concluding Remark

Previous authors writing on trade and endogenous growth (including

the small economy produced both final goods. There we showed that an indifference curve cuts the resource constraint as in Figure 2, in the event that the small country follows a policy of free trade. If the small country there were to specialize in the production of only one final good (as here), a tariff would have no effect on resource allocation. Therefore, our earlier result implies that an indifference curve cuts RR as drawn for exogenous φ and any initial $z > 0$.

⁵Our welfare analysis has been based on a comparison of steady states. It follows, however, from our discussion of the existing externalities that the same conclusions apply when the entire equilibrium trajectory is taken into account.

ourselves) have typically assumed that when knowledge enters the public domain, it becomes readily and immediately available to researchers and entrepreneurs worldwide. In other words, international spillovers were taken to be automatic and instantaneous, in symmetry with the treatment of local spillovers. But all this literature ignores the mechanisms by which these spillovers take place. Here we have explored the possibility that commodity traders serve as a conduit for information flows. Our approach has been both too simple and too extreme. It assumed that all commercial interactions, regardless of the type of commodities involved and the conditions under which they take place, are equally valuable in generating additions to the stock of knowledge capital. And it ignored all but one vehicle for the exchange of ideas. In future work we plan to investigate in more detail the mechanisms and incentives that exist for the international transfer of science and technology.

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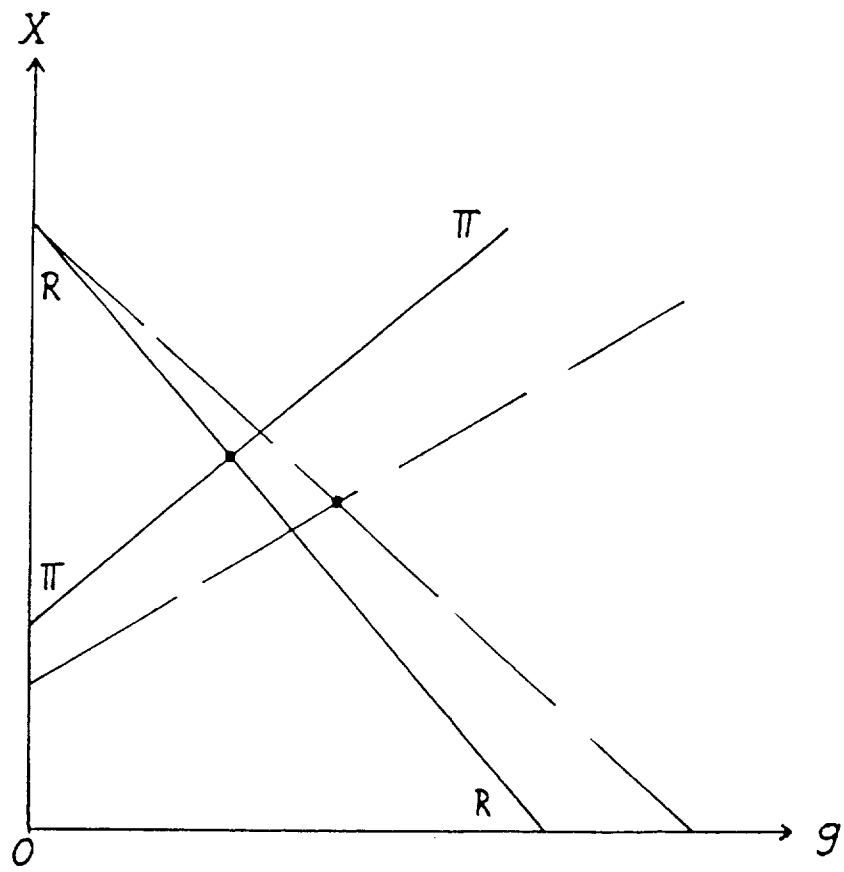


Figure 1

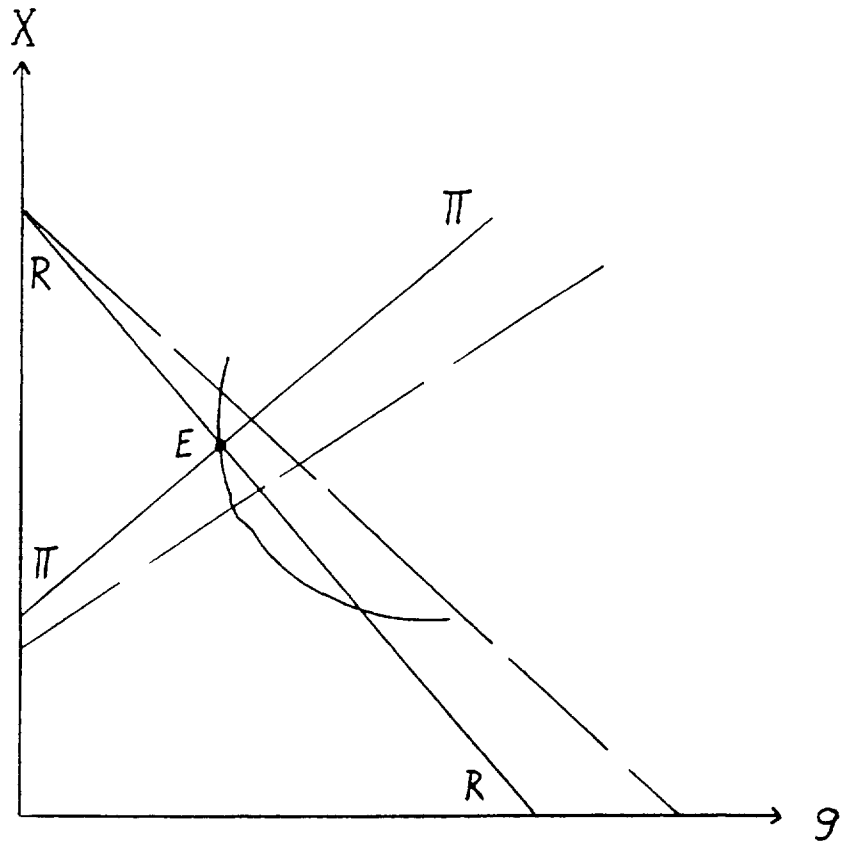


Figure 2