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“Once-off” and Continuing Gains from Trade

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Most economists are familiar with the static or “once-off” welfare gains created by opening an economy to trade. Much less is known about how the resource reallocations necessitated by this move affect long-run growth, and hence whether they provide dynamic or continuing welfare gains in future periods. This paper employs a dynamic Ricardian trade model to provide a decomposition of the gains from trade into “once-off” and continuing categories. In one version of the model, trade is always welfare enhancing; in the other, “once-off” losses may occur alongside dynamic gains. In both versions the magnitude of “once-off” and continuing effects are related to absolute and relative country size, similarity in production structures, rates of time preference, and the productivity of R&D.

1. INTRODUCTION

Most economists are familiar with the static or “once-off” welfare gains created by opening an economy to trade. While the static consumption and production gains from trade are now well understood, much less is known about the gains created when trade enhances economic growth. Recent work within endogenous growth frameworks suggests trade may indeed raise growth rates, but researchers have yet to present a simple decomposition of the gains from trade into “once-off” and continuing categories. In this paper I provide just such a decomposition; moreover, I link the magnitude of these gains to absolute and relative country size, similarity in production structures, the productivity of R&D, and the strength of time preference.

I address these questions within the Ricardian growth model developed in Taylor (1991). The model is created by imbedding the one-factor “Quality Ladders” model of Grossman and Helpman (1991a) within the continuum Ricardian model of Dornbusch, Fischer and Samuelson (1977).¹ Because of the model’s Ricardian features, comparative and absolute advantage play a leading role in determining the size of both “once-off” and continuing gains from trade. Because of the model’s endogenous growth features, access to larger world markets and trade-induced specialization in R&D spurs economic growth.

I use two versions of the basic model to examine the positive and normative consequences of international trade. In the “Footloose R&D” version I show that free trade is always preferred to autarky because trade creates both an immediate and “once-off” level rise in instantaneous utility and an increase in its long-run rate of growth. In the “Traditional Ricardian” version I show that immediate and “once-off” losses may occur, but provide conditions under which there is a strong presumption in favour of overall gains.

Recent work in this area has only considered the welfare consequences of a marginal movement towards autarky from free trade via small tariffs (Grossman and Helpman

1. An important antecedent is also Aghion and Howitt (1992).

(1991*b*)), or examined the dynamic gains from trade within a model with no steady-state growth (Baldwin (1992)).² In contrast I consider the welfare effects of discrete changes in protection (prohibitive versus zero tariffs) in a model where such changes create a trade inspired acceleration of growth.

In addition to these welfare results, I examine the effects of trade in a world where countries differ radically in both technologies and endowments. Most of the recent work in this area examines trade between perfectly symmetric, or at least very similar, countries. For example, Rivera-Batiz and Romer (1991) show that trade between two *perfectly symmetric* economies raises the market size for any one innovation. This market-size effect raises the return to R&D activities, and is responsible for the increase in growth rates brought about by trade.

One of the benefits of adopting a Ricardian approach is its focus on trade-induced specialization. I show that while free trade creates beneficial market size effects, it also forces countries to specialize in R&D. Moreover, this specialization provides an additional, and independent, boost to economic growth.

The paper is organized as follows. In Section 2 I sketch the building blocks of the model and describe some preliminary results. Readers are directed to Grossman and Helpman (1991*a*) and Taylor (1991) for some of these results. In Sections 3 and 4 I characterize the autarky and trading equilibria and then turn to examine the positive implications of trade in Section 5. Section 6 contains the welfare analysis, while Section 7 presents a short conclusion. Detailed calculations are relegated to an Appendix.

2. ASSUMPTIONS AND PRELIMINARY RESULTS

2.1. Consumers

In Taylor (1991) I assume a single primary factor, denoted by L , exists in fixed and inelastic supply. Consumers are endowed with this factor and share identical, time-separable, and homothetic utility functions defined over a continuum of final products indexed by $z \in [0, 1]$. Consumers maximize the expected discounted value of their lifetime utility and can smooth their expenditures over time by investing in the securities offered by the continuum of firms active in innovation. The return to these shares is uncertain, but their risk is idiosyncratic. Therefore, the consumer's intertemporal budget constraint takes the familiar form $dA(t)/dt = r(t)A(t) + w(t) - E(t)$. $r(t)$ is the certain return on consumers' portfolio, $A(t)$ denotes assets, $E(t)$ is expenditure, and each consumer is endowed with 1 unit of labour. I assume lifetime utility is given by:

$$U = \int_0^{\infty} e^{-\rho t} \ln u(t) dt \quad \text{where } \ln u(t) = \int_0^1 b(z) \ln [x(z, t)] dz, \quad (2.1)$$

$$1 = \int_0^1 b(z) dz \quad dB(z) = b(z) dz, \quad B(1) = 1, \quad B(0) = 0. \quad (2.2)$$

$x(z, t)$ is the quantity of good "z" consumed at time t , ρ is the rate of time preference, and $b(z)$ is the continuum counterpart to the many-commodity budget share for good z . Maximizing per-period utility $\ln u(t)$ subject to a period expenditure constraint yields $x(z, t) = b(z)E(t)/p(z, t)$ for $z \in [0, 1]$. Choosing the optimal expenditure path subject to the intertemporal budget constraint yields $[dE(t)/dt]/E(t) = \hat{E} = r(t) - \rho$.

2. One further study of note is Young (1991)

2.2. *Firms*

The economy’s continuum of products is produced by labour power alone, but with methods reflecting the generation of technology currently in use. When generation $j \in (0, 1, 2, \dots)$ technology, $\phi(j, z)$, is applied in industry z , output $x(z, t)$, equals $[1/\phi(j, z)][l(z, t)/a(z)]$. $l(z, t)$ represents labour dedicated to manufacturing in industry z at time t , while $a(z)$ is a time-invariant and industry specific constant. I assume future generations of technology dominate earlier ones; hence $\phi(j + 1, z) \equiv [1 - n(z)]\phi(j, z)$. The “inventive step” between generations $n(z) \in [0, 1)$ is continuous in z , is constant over time, and may vary across industries. Hence innovations bring forth new technologies that lower unit production costs, but the physical characteristics of the goods are unaffected by innovation.

At time $t=0$, patents on generation $j=0$ technologies are already in place, but generations $j>0$ technologies are yet to be discovered.³ Innovators worldwide race to discover the “ $j+1$ st” generation, in each industry z , if generation “ j ” is already in place. When successful, innovators obtain a patent of infinite duration for their discoveries. If innovators in aggregate undertake research at intensity “ i ” in industry z' , then the instantaneous probability of success in z' is approximately $i(z')dt$. One unit of research at intensity “ i ” in industry z , requires $a_I(z)$ units of labour.

When a new innovation arises Bertrand competition between patent holders results in the patent holder of the most advanced technology limit-pricing their nearest competitor out of the market. As a result, instantaneous profits accruing to innovation become $\Pi(z) = n(z)b(z)E(t)$ for $z \in [0, 1]$.⁴ To fund their R&D investments, firms sell equity shares to consumers. The expected rate of return “ $r(z)$ ” earned on shares in any industry must equal the risk-free rate on the portfolio “ $r(t)$ ” since all risk is idiosyncratic. If $V(z)$ is the expected present discounted value of an infinite-life patent in industry z , then free entry into R&D requires $V(z) = wa_I(z)$ when $i(z) > 0$.⁵ Therefore, it can be shown $r(z) = r(t) = \Pi(z)/V(z) - i(z)$ for $z \in [0, 1]$.

3. AUTARKY SOLUTION

In Taylor (1991) I show the steady state is realized immediately and is characterized by:

$$E^A = L + \rho VP, \quad \text{where } VP = A_I \equiv \int_0^1 a_I(z) dz; \tag{3.1}$$

$$i^A(z) = n(z)b(z)[L + \rho A_I]/a_I(z) - \rho, \quad z \in [0, 1]; \tag{3.2}$$

$$g^A = \int_0^1 \{q(z)i^A(z)\} dz > 0; \quad q(z) \equiv -b(z) \ln [1 - n(z)] > 0. \tag{3.3}$$

Autarky expenditures E^A consist of factor and profit income. Since $w = 1$, L gives factor income. Since $V(z) = wa_I(z) = a_I(z)$ for $z \in [0, 1]$, VP is the value of consumer’s portfolio of assets, ρ is the steady-state return on this portfolio, and hence $\rho VP = \rho A_I$ represents

3. Patents on generation-zero technologies are held by a continuum of firms that engage in goods production until displaced by subsequent innovators. The market value of the firms holding these patents represents the initial asset holdings of consumers $A(0)$.

4. See Taylor (1991, p 230) for a derivation.

5. I assume throughout that $i(z) > 0$. Because $b(z)$ is unrestricted, the $n(z)$ schedule must satisfy $n(z) > \rho a_I(z)/[L + \rho A_I]$ for all z . R&D is undertaken as long as the inventive step is large, R&D is very productive, the market size is large, or if consumers’ time preference is small.

the total return on the economy's innovative activities. To facilitate the welfare comparisons made in Section 6, I take as a measure of growth the percentage change in expected utility per period and denote this by " g^A ". With the discovery process Poisson, this growth rate can be written as shown in (3.3).⁶

4. INTERNATIONAL TRADE IN GOODS, KNOWLEDGE AND FINANCIAL CAPITAL

Consider a world with two countries that differ in at most three respects. First, they may differ in population size. Denoting foreign variables with a "*", L^* may exceed or fall short of L . Second, I assume each country has its own $a(z)$ and $a_f(z)$ schedule. Third, I assume each country has a complete set of patents on their own $\phi(j, z)$ technologies at $t=0$. These sets may differ, but the world as a whole has only one most advanced or leading-edge technology $\phi(j, z)$ in each industry z .⁷ I assume home innovators own a fraction μ of these leading-edge technologies, while foreign innovators own the remainder.

To solve for the world equilibrium construct the relative labour productivity schedules in goods, $A(z)$, and research, $RD(z)$:⁸

$$A(z) \equiv a^*(z)/a(z) \quad \text{and} \quad RD(z) = a_f^*(z)/a_f(z) \quad \text{for } z \in [0, 1], \quad (4.1)$$

$A(z)$ and $RD(z)$ are continuous in z by assumption, and $A'(z) < 0$ is obtained by construction. In general the $RD(z)$ schedule may take many possible forms. Rather than consider a taxonomy of cases for $RD(z)$, I adopt a set of specific assumptions yielding two versions of the basic model.

The *Traditional Ricardian version* is characterized by two assumptions: (1) $RD'(z) < 0$ for all $z \in [0, 1]$; and (2), $A(z') > RD(z')$ for all $z' \in [0, 1]$. The first assumption requires a positive but imperfect correlation between comparative advantage in goods and R&D production. The second ensures the home country has what I refer to as a *relative advantage* in goods production.⁹ I refer to this version as "traditional" because the ratio of home to foreign productivities (in both production and R&D) differ across industries, and this is the assumption made by both Ricardo and Dornbusch *et al.* (1977).

The *Footloose R&D version* is characterized by one assumption: $a_f^*(z) = a_f^* = \gamma a_f(z) = \gamma a_f$. Comparative advantage in R&D is absent, but absolute advantage may exist ($\gamma \neq 1$). This version assumes a research lab is a research lab, but overall productivities may differ internationally.¹⁰ I refer to this as the "footloose" version because there is only one relative wage rate consistent with active R&D in both countries—at any other relative wage rate footloose R&D activities will move abroad.

4.1. Trading equilibrium, traditional version

Given these preliminaries in Taylor (1991) I show the steady-state trading equilibrium is characterized by: (1) constant country and world expenditure levels; (2) an unchanging division of labour between research and goods production in both countries; (3) $r(t) =$

6. The derivation follows that in Grossman and Helpman (1991a).

7. This corresponds to our autarky assumption that an industry leader was in place at $t=0$ in all $z \in [0, 1]$.

8. The $\phi(j, z)$ technologies can be employed at home or abroad, therefore a comparison of the "raw" unit labour requirements $a(z)$ and $a^*(z)$ determines the least cost location for any goods production.

9. Define \bar{z} and \bar{z} by $\omega \equiv A(\bar{z}) \equiv RD(\bar{z})$; then the home country has a relative advantage in goods vs. R&D if $\bar{z} > \bar{z}$ for all possible ω .

10. I am grateful to Gene Grossman for suggesting this version of the model.

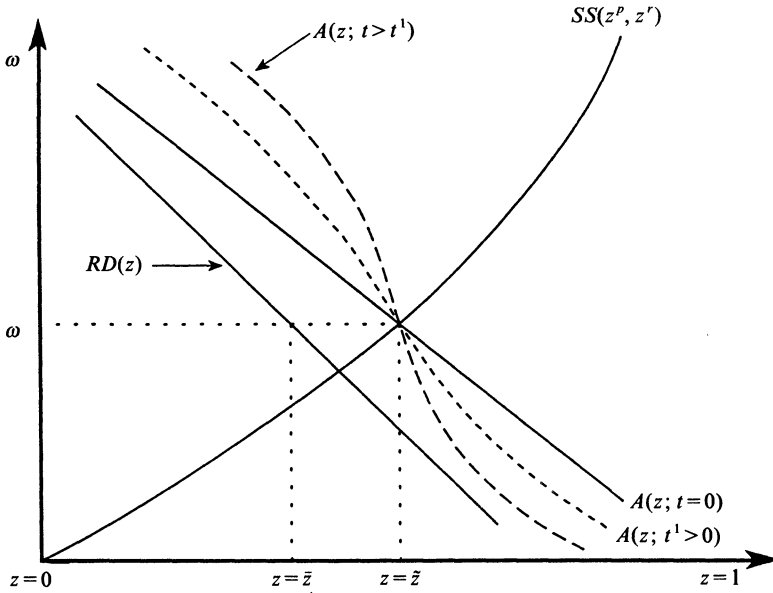


FIGURE 1

$r^*(t) = \rho$; (4) constant relative wages $\omega = w/w^*$; (5) balanced trade in goods, knowledge and capital; and (6) a constant level of growth in expected utility. If we set $w(t) = 1$, and denote trading solutions with a “ T ” when necessary, the steady-state solutions are:¹¹

$$E^T = L + \mu VP^T; \quad E^{*T} = w^*L^* + (1 - \mu)VP^T; \quad (4.2)$$

$$VP^T \equiv \rho[A_I^T + w^*A_I^{*T}] \quad \text{where } A_I^T \equiv \int_0^{\bar{z}} a_I(z)dz \quad \text{and} \quad A_I^{*T} \equiv \int_{\bar{z}}^1 a_I^*(z)dz; \quad (4.3)$$

$$i^T(z) = i(z) = n(z)b(z)[E + E^*]^T/a_I(z) - \rho, \quad z \in [0, \bar{z}]; \quad (4.4)$$

$$i^T(z) = i^*(z) = n(z)b(z)[E + E^*]^T/w^*a_I^*(z) - \rho, \quad z \in [\bar{z}, 1]; \quad (4.5)$$

$$g^T = \int_0^{\bar{z}} \{q(z)i^T(z)\}dz + \int_{\bar{z}}^1 \{q(z)i^T(z)\}dz > 0. \quad (4.6)$$

These solutions are incomplete because they are parameterized by ω and \bar{z} , and implicitly depend on the competitive margin in goods production \tilde{z} . The solution values for these remaining unknowns are found by combining the $A(z)$ and $RD(z)$ schedules with a balance of payments requirement that must hold at all times. In Taylor (1991) I construct the $\omega = SS(z^p, z^r)$ schedule where ω is the terms of trade ensuring balance of payments equilibrium when the home country produces goods $z \in [0, z^p]$, and conducts R&D over $z \in [0, z^r]$. Formally $\omega = SS(z^p, z^r)$ is defined by:

$$\omega = \frac{[L^* + \rho A_I^{*T}]/[L + \rho A_I^T]}{\left[\left[B(\tilde{z}) - \int_{\bar{z}}^{\tilde{z}} n(z)b(z)dz \right] \right] / \left[\left[1 - B(\tilde{z}) + \int_{\bar{z}}^{\tilde{z}} n(z)b(z)dz \right] \right]}. \quad (4.7)$$

As Figure 1 shows, combining the $SS(z^p, z^r)$ schedule in (4.7) with the $A(z)$ and $RD(z)$ schedules determines the initial terms of trade ω and the competitive margins in both

11. To solve for μ recall consumer’s intertemporal budget constraint must be met with equality: hence, $\mu = A(0)/VP^T$ in trade and $A(0) = VP^A$ in autarky.

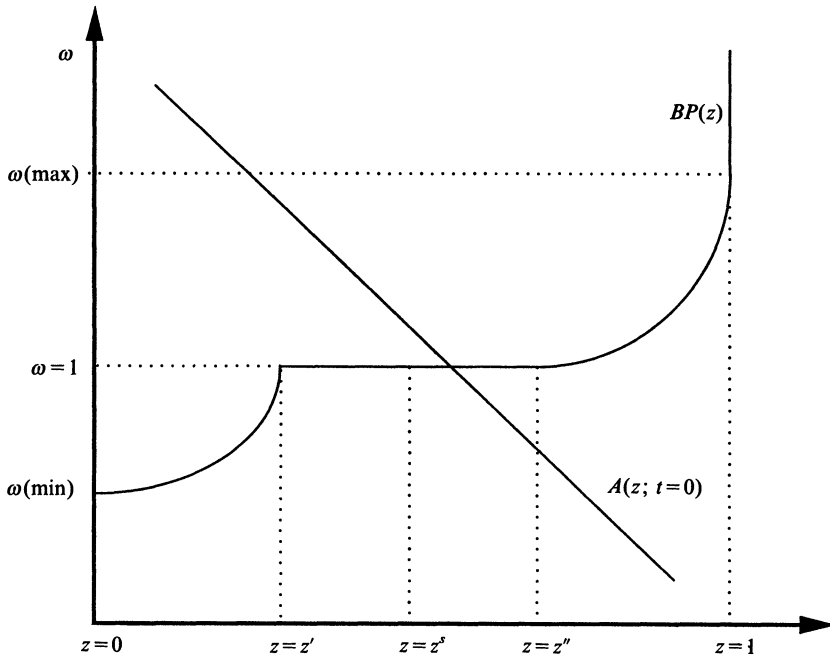


FIGURE 2

goods and R&D.¹² Innovators undertake improvements to the $\phi(j, z)$ components, and incentives lead them to implement these in the least-cost country. As time progresses the original differences in unit labour requirements are amplified.

4.2. Trading equilibrium, Footloose R&D version

To examine the Footloose R&D version the preceding steps need only slight amendment. The $SS(z^p, z')$ schedule and the two productivity schedules are still relevant here, but now we will need to take explicit account of corner solutions. In the Footloose version $RD'(z) = 0$, therefore the world equilibrium can support active R&D in both countries only if $\omega = \gamma$. If $\omega = \gamma$ then $\gamma = A(\bar{z})$ determines the competitive margin in goods \bar{z} , while $\gamma = SS(z^p = \bar{z}, z' = \bar{z})$ determines the home country's share of the world's R&D \bar{z} . If $\omega > \gamma$, all R&D will be conducted R&D abroad: $\bar{z} = 0$. $A(\bar{z}) = SS(z^p = \bar{z}, z' = 0)$ determines the competitive margin in goods \bar{z} , and $A(\bar{z}) = \omega$ sets ω . If $\omega < \gamma$ then all R&D will be conducted at home: $\bar{z} = 1$. $A(\bar{z}) = SS(z^p = \bar{z}, z' = 1)$ again determines \bar{z} , and $A(\bar{z}) = \omega$ sets ω .

As a consequence of these specialization and diversification regions, the graphical representation of the balance of payments schedule must be altered. I denote this new schedule $\omega = BP(z^p)$ and present a typical schedule in Figure 2 assuming $\gamma = 1$.¹³ The schedule starts at $\omega(\min) = SS(\bar{z} = 0, \bar{z} = 1)$ with specialization in both countries. As we move away from a potential equilibrium at $\bar{z} = 0$, the home country undertakes some goods production and home relative wages rise. At $\bar{z} = z'$, relative wages finally reach $\omega = \gamma = 1 = SS(\bar{z} = z', \bar{z} = 0)$ and the foreign country begins to undertake R&D activities. If we

12. $SS(z^p, z')$ is upward sloping as a function of \bar{z} and shifts upward with an increase in \bar{z} .

13. See Section 1 of the Appendix.

continue along $BP(z)$, at $\tilde{z}=z^s$, the home country is conducting just enough R&D to meet the needs of its good producing industries over $z \in [0, z^s]$.

Finally as we move further to the right, the home country becomes a net importer of R&D results. At $\tilde{z}=z''$ we have $\omega = SS(\tilde{z}=z'', \bar{z}=0)$, and the home country ceases R&D activities entirely.

Combining the $BP(z)$ and $A(z)$ schedules sets in motion a dynamic evolution of the world economy much like that depicted in Figure 1. Equations (4.2)–(4.6) also describe the steady-state solutions for the Footloose version when ω , \tilde{z} and \bar{z} are determined as described above and $a_I^*(z) = a_I^* = \gamma a_I$. Autarky and trading equilibria comparisons are straightforward to obtain.

5. AUTARKY VERSUS FREE TRADE

I compare two alternative time paths for the world economy. In the first I assume the home and foreign country are governed by the autarky solutions starting from date $t=0$ onwards. In the second I assume the home country makes a unexpected announcement at $t=0$ that trade will commence immediately.¹⁴ The home and foreign economies move from their autarky solution values to their trading solution values immediately. Because transitional dynamics are absent, a complete welfare analysis is captured by examining welfare along the alternative steady-state growth paths for the home economy. Making use of (4.2)–(4.6) and (3.1)–(3.3) the difference in growth rates can be written:

$$g^T - g^A = [[E + E^*]^T - E^A] \int_0^1 [q(z)n(z)b(z)/a_I(z)] dz + [E + E^*]^T \int_{\bar{z}}^1 [q(z)n(z)b(z)/a_I(z)] [[a_I(z) - w^* a_I^*(z)] / w^* a_I^*(z)] dz. \quad (5.1)$$

Equation (5.1) links the difference in growth rates to both “Market Expansion” effects and “Specialization” gains. Consider the first term in (5.1) and define the “Market Expansion” effects by $ME(\tilde{z}, \bar{z}) \equiv [E + E^*]^T - E^A$. It is straightforward to verify $ME(\tilde{z}, \bar{z}) > 0$ for all $\{\tilde{z}, \bar{z}\}$.¹⁵ For each $z \in [0, 1]$, $ME(\tilde{z}, \bar{z})$ times $[n(z)b(z)]$ captures the increased flow profits in the trading equilibrium. Dividing these incremental profits by $a_I(z)$ gives an exact measure of the resulting increase in R&D in each industry. Equation (5.1) simply translates these increases into their ultimate impact on growth.

The second term in (5.1) captures the “Specialization” gains that arise when trade lowers the cost of conducting R&D, and thereby stimulates R&D effort. The impact of trade-induced specialization in R&D is clear from (5.1) since $[a_I(z) - w^* a_I^*(z)] / w^* a_I^*(z)$ is just the percentage cost reduction achieved when R&D is conducted abroad. Recall that in the Traditional version some R&D is always shifted to the lower-cost foreign country with trade, and over $[\bar{z}, 1]$ we have $[a_I(z) - w^* a_I^*(z)] > 0$. Consequently, growth is enhanced when R&D costs fall with trade.

In the Footloose version similar results apply, but specialization gains only arise when all of home’s R&D is shifted to the foreign country. The all-or-nothing flavour of the Footloose version arises because a research lab is a research lab, and when it is beneficial for one to conduct R&D abroad, it is beneficial for all to conduct R&D abroad. Consequently when $w^* < 1/\gamma$, R&D is cheaper to conduct abroad, $\bar{z}=0$, and $[a_I - w^* a_I^*] > 0$ for

14. $t=0$ is a normalization, choosing any $t=T>0$ will do just as well.

15. See Section 2 of the Appendix.

all z . R&D effort and growth is spurred because the cost of conducting R&D in each and every industry is now lower with trade.

Since the arguments establishing these results for the home country apply with equal force to the foreign, we have shown for both versions.

Proposition 1. *In comparing the steady-state growth paths for autarky and free trade, the time path with free trade has a strictly higher growth rate for both countries. Trade leads to higher growth rates because the increase in market size raises the profitability of conducting R&D (the Market Expansion effect) while simultaneously improving the productivity of those resources engaged in R&D (the Specialization Gains).*

To investigate how the magnitude of the change in growth rates is affected by country characteristics we can differentiate the equilibrium conditions describing the steady state. After some work it is possible to show:¹⁶

Corollary 1.1. *The smaller the relative size of the home country, the greater is the difference in home country growth rates in trade versus autarky.*

Corollary 1.2. *Amplifying the existing differences in comparative or absolute advantage in goods production has no effect on the trade versus autarky growth differential.*

Corollary 1.3. *Increasing one country's absolute advantage in R&D in the Footloose version raises the trade vs autarky growth rate differential for the other country.*

Proposition 1 and its corollaries allow us to conclude, what intuition would lead us to suspect. If trade offers greater profits to innovation because of larger markets, and economic growth derives from the presence of aggregate increasing returns in the R&D sector, then a move to trade should raise economic growth. Since this market expansion effect would be larger for relatively small countries, small countries should exhibit the greatest increase in growth with trade. But the ability to trade goods does more than increase the market for domestic products and R&D. Trade also creates pressures for specialization. Specialization in turn lowers the resource cost of conducting any given amount of R&D, and hence offers an additional, and independent, boost to economic growth.

6. TRADE AND WELFARE

While Proposition 1 and its corollaries are interesting in their own right, they of course beg the question as to whether welfare is higher in the trading equilibrium. Let aggregate welfare in the home country be given by W^i for $i \in \{A = \text{Autarky}, T = \text{Trade}\}$. If we denote the growth rate in expected utility by g^i , then $E_0[\ln [u(t)]] = \ln [u(0)]e^{g^i t} \equiv U^i e^{g^i t}$ and aggregate welfare becomes:

$$W^i = E_0 \left\{ \int_0^\infty \ln [u(t)] e^{-\rho t} dt \right\} \equiv \int_0^\infty U^i e^{(g^i - \rho)t} dt = U^i / [\rho - g^i] > 0. \quad (6.1)$$

16. See Section 3 of the Appendix.

The welfare comparison between free trade and autarky requires finding the sign of $[W^T - W^A]$. By adding and subtracting $U^T/[\rho - g^A]$, it is straightforward to show $W^T > W^A$ if and only if:

$$[U^T/[\rho - g^A]][[g^T - g^A]/[\rho - g^T]] + [U^T - U^A]/[\rho - g^A] > 0. \quad (6.2)$$

The first component of (6.2) captures the growth effects of trade, while the second component captures the level or “once-off” effect. In Section 5 we found $g^T > g^A$, hence the first term in (6.2) is always positive. To examine the level effects more closely rewrite $[U^T - U^A]$ as:¹⁷

$$\begin{aligned} [U^T - U^A] = & \ln \left[\frac{\{L + \mu \rho VP^T\}}{\{L + \rho VP^A\}} \right] + \int_{\bar{z}}^1 b(z) \ln [a(z)/w^* a^*(z)] dz \\ & + [1 - \mu] \int_0^1 b(z) \ln [\phi(j^A, z)/\phi(j^T, z)] dz. \end{aligned} \quad (6.3)$$

Trade affects base period utility in three ways. The first term in (6.3) is negative and reflects the fall in expenditures created when trade destroys the rents earned on some domestic patents, and lowers the rents earned on others. Rents are destroyed because a fraction $(1 - \mu)$ of the $\phi(j^A, z)$ technologies employed at home are dominated by the leading-edge technologies available abroad. With Bertrand competition, the value of holding these patents falls to zero. Hence the rent destruction arising from trade is $(1 - \mu)VP^A$.

But in addition trade may also lower the values of patents on even leading-edge technologies. With trade, innovation is sometimes shifted to more efficient locations but never to less efficient. Consequently, the value of holding even leading-edge patents must sometimes fall because the value of owning a patent varies inversely with the productivity of efforts seeking to displace the incumbent.¹⁸ The magnitude of this valuation effect is $(VP^A - VP^T)$.

The remaining two terms in (6.3) are positive and arise from price reductions brought about by trade. The second component in (6.3) arises because the price of goods over $z \in [\bar{z}, 1]$ falls as production is shifted to the lower cost foreign country. The last component arises since patent holders of foreign leading-edge technologies limit-price out of existence dominated home patents. Hence the rent destruction mentioned above has a corresponding “once-off” benefit of reduced prices for a fraction $(1 - \mu)$ of all industries.

To evaluate the sign of (6.3) it is necessary to make some assumption about the ratio $[\phi(j^A, z)/\phi(j^T, z)]$. The weakest assumption we can make is that leading-edge technologies are only one step ahead of the most advanced technology in the other country. Then, $[\phi(j^A, z)/\phi(j^T, z)] = [1/[1 - n(z)]] > 1$ and it is straightforward to show:¹⁹

Proposition 2. *If both countries conduct R&D in an equilibrium of the Footloose version, both countries are unambiguously better off in the trading equilibrium. Trade creates both “once-off” gains in instantaneous utility and an increase in its growth rate.*

When Proposition 2 holds several other results follow from Corollaries 1.1, 1.2, and 1.3:

Corollary 2.1. *The smaller the relative size of the home country, the greater are the home country’s dynamic gains from trade.*

17. See Section 4 of the Appendix.

18. For example, when $V(z) = a_f(z)$ the marginal product of R&D is $1/a_f(z)$.

19. See Section 5 of the Appendix.

Corollary 2.2. *Amplifying the existing differences in comparative advantage in goods production raises the “once-off” gains from trade, but leaves the dynamic gains unaffected.*

Corollary 2.3. *An increase in the foreign country’s absolute advantage in R&D, raises the home country’s dynamic gains from trade. An increase in the foreign country’s absolute advantage in goods production does not affect either the “once-off” or dynamic gains from trade.*

Proposition 2 follows for two reasons. In autarky domestic patent holders price above marginal cost and hence each product market is distorted. Consequently, if prices fell to marginal cost the loss in profits would be less than the gain in consumer surplus. With the advent of trade, superior foreign innovations drive prices down to the marginal production cost of inferior domestic technologies in a fraction $(1 - \mu)$ of all industries. As a result, domestic residents gain the discounted value of the resulting increase in consumer surplus, but lose the discounted value of profits; i.e. they lose the value of their patents. Because the value of consumer surplus exceeds the value of profits, welfare rises from this rent destruction effect.

In addition to the static effect detailed above, trade also affects the allocation of resources across sectors. In autarky the home economy may be devoting too few or too many resources to R&D, and trade could be welfare reducing if it exacerbated this distortion. When R&D is diversified across countries however, trade is much like growth in the home economy’s labour endowment of L^*/γ . Moreover, it can be shown that at the margin the world’s allocation of this added endowment across manufacturing and R&D is identical to the division the home economy makes for marginal units of labour in autarky. Consequently, regardless of how imperfect the autarky division of labour across activities may be, trade does not exacerbate any existing dynamic distortions.

In the Traditional version similar forces are at work, but at the margin the home and world economy allocate labour across sectors differently. Consequently existing distortions could be worsened by trade. At best we can show that: (1) even if trade creates a level fall in instantaneous utility, there must exist a critical L^*/L ratio where further increases in foreign country size lead to overall gains from trade; (2) instantaneous losses are smaller and dynamic gains larger, if consumer’s rate of time preference is low and R&D very productive; and (3) a balanced increase in L and L^* raises the dynamic gains from trade, while reducing any potential “once-off” losses. While these results are not general welfare statements, they provide a set of conditions relating industry specific attributes to the likelihood of overall gains from trade.

7. CONCLUSIONS

This paper employed a simple model of endogenous growth to examine the relationship between “once-off” and continuing gains from trade. In the Footloose version of the model, trade was shown to raise the welfare of both home and foreign residents. These gains from trade take the form of both immediate “once-off” level effects and dynamic growth effects. Trade can unambiguously raise welfare in this circumstance despite a plethora of second-best considerations because the move to trade does not affect existing distortions. In the Traditional version of the model, less clear cut results were obtained. In this version trade may exacerbate existing distortions in the autarkic economies, but conditions were given for a presumption in favour of overall gains.

Perhaps the most important contribution of the analysis comes from the Ricardian approach and its inherent focus on trade-created specialization. Economists have long known of the benefits arising from specialization in goods production. More recently researchers have described how access to larger markets via free trade may spur R&D and raise economic growth. An important contribution of this paper was to show that access to world markets also creates pressure for specialization in R&D activities; and moreover, that this specialization creates an additional, and independent, boost to economic growth.

APPENDIX

1. Constructing the BP(z^p) schedule

If $\omega < \gamma$, $\bar{z} = 1$ and (4.7) requires:

$$\omega = [L^* / [L + \rho A_T]] \left[B(\bar{z}) + \int_{\bar{z}}^1 b(z)n(z)dz \right] / \left[\int_{\bar{z}}^1 [1 - n(z)]b(z)dz \right]. \tag{A1.1}$$

This segment starts at ω (min) when $z^p = \bar{z} = 0$ and rises as the home country undertakes some goods production. As \bar{z} rises, (A1.1) shows ω must rise as well. Consider $\omega > \gamma$ and hence $\bar{z} = 0$. At $\bar{z} = 0$ (4.7) requires:

$$\omega = [[L^* + \rho A_T^*] / L] \left[\int_0^{\bar{z}} [1 - n(z)]b(z)dz \right] / \left[[1 - B(\bar{z})] + \int_0^{\bar{z}} b(z)n(z)dz \right]. \tag{A1.2}$$

This segment has a maximum at ω (max) when $z^p = \bar{z} = 1$. To construct the factor-price equalization segment we need to solve for the points where the segment begins and ends. Denote these z' and z'' . Then setting $\omega = \gamma$ in (A1.1) implicitly defines z' and setting $\omega = \gamma$ in (A1.2) implicitly defines z'' . Rearranging shows:

$$L^* = \int_{z'}^1 [1 - n(z)]b(z)[E + E^*]dz \quad \text{and} \quad L = \int_0^{z''} [1 - n(z)]b(z)[E + E^*]dz. \tag{A1.3}$$

The self-sufficiency point in R&D is defined by $\gamma = SS(z^p = z^s, z^r = z^s)$. If $A(z^s) = \gamma$, home would be conducting enough R&D to meet the needs of its goods-producing industries.

2. Market expansion effects

Using (4.7) $ME(\bar{z}, \bar{z})$ can be written:

$$ME(\bar{z}, \bar{z}) = [1/D(\bar{z}, \bar{z})] \left[L - \int_0^{\bar{z}} [1 - n(z)]b(z)[L + \rho A_T^*]dz - \int_0^{\bar{z}} [i(z)^T a_T(z)]dz \right] \tag{A2.1}$$

where

$$D(\bar{z}, \bar{z}) \equiv \int_0^{\bar{z}} [1 - n(z)]b(z)dz + \int_0^{\bar{z}} n(z)b(z)dz.$$

If $\bar{z} = \bar{z} = 1$, then the two integrals in (A2.1) represent labour demand in manufacturing and R&D in autarky and would sum to L . Since both \bar{z} and \bar{z} cannot be 1 in trade, (A2.1) must be positive.

3. Corollaries of Proposition 1

Proof of Corollary 1.1. For the traditional version differentiate $\omega \equiv A(\bar{z})$, $\omega \equiv RD(\bar{z})$ and $\omega \equiv SS(\bar{z}, \bar{z})$ to find $d\bar{z}/dL^* < 0$, $d\bar{z}/dL^* < 0$ and $d\omega/dL^* > 0$. Define $h(\bar{z}) \equiv [L + \rho A_T^*]$ and write $ME(\bar{z}, \bar{z}) = h(\bar{z})/D(\bar{z}, \bar{z}) - [L + \rho A_T^*]$. Then $ME_1(\bar{z}, \bar{z}) = -[h(\bar{z})/D^2][1 - n(\bar{z})]b(\bar{z}) < 0$, $ME_2(\bar{z}, \bar{z}) = -[i(z)^T a_T(z)/D] < 0$ and hence $dME(\bar{z}, \bar{z})/dL^* > 0$. To examine the specialization gains note E^A is independent of both \bar{z} and \bar{z} . Therefore, $ME_1(\bar{z}, \bar{z}) < 0$ and $ME_2(\bar{z}, \bar{z}) < 0$ imply $[E + E^*]^T$ increases as \bar{z} and \bar{z} fall. Moreover, $d\omega/dL^* > 0$ implies $dw^*/dL^* < 0$. As a result, inspecting (5.1) shows specialization gains rise with $dL^* > 0$. For the Footloose version assume $\omega < \gamma$; hence $\bar{z} = 1$, and $w^* > 1/\gamma$. Specialization gains are zero, and $ME(\bar{z}, \bar{z} = 1) = w^* L^*$. A small increase

in L^* lowers w^* , but not proportionately. Therefore, $dME(\bar{z}, \bar{z}=1)/dL^* > 0$. Next, assume $\omega = \gamma$. $ME(\bar{z}, \bar{z}) = w^*L^*$, but w^* is now fixed at $1/\gamma$. A small increase in L^* raises the market expansion effects of trade. Finally, assume $\omega > \gamma$ so $\bar{z}=0$. Recall $ME(\bar{z}, \bar{z})$ is falling in \bar{z} , and a rise in L^* depresses both w^* and \bar{z} . \parallel

Proof of Corollary 1.2. Amplify the differences across countries by rotating the $A(z)$ schedule around \bar{z} by decreasing all $a^*(z)$ for $z \in (\bar{z}, 1]$ and increasing all $a^*(z)$ for $z \in [0, \bar{z})$. This rotation leaves our growth comparisons unchanged. This is true in both versions of the model. To change the pattern of absolute advantage multiply $a(z)$ and $a^*(z)$ by any positive number. This multiplication leaves our previous results unchanged. \parallel

Proof of Corollary 1.3. Imagine $\omega < \gamma$ in some equilibria of the Footloose version, fix a_I , and consider a marginal fall in γ that lowers a^* . Since the foreign R&D technologies were not in use in the previous equilibrium, they would not be in use now; therefore, this change has no effect on either the market expansion effects or the specialization gains. Next suppose $\omega = \gamma$, and lower γ marginally. The specialization gains remain at zero, but now w^* must rise to maintain $w^* = 1/\gamma$. In this diversified equilibria, $ME(\bar{z}, \bar{z}) = w^*L^*$. As a result, the market expansion effects must rise as γ falls. Finally, assume $\omega > \gamma$. With $\omega > \gamma$ equilibrium is governed by (A1.2) and $1/w^* \equiv A(\bar{z})$. Totally differentiating yields the result that $[dw^*/d\gamma] < 0$, but $[[dw^*/d\gamma][\gamma/w^*]] < 1$. Hence γw^* rises with γ . Rewriting (5.1) we find:

$$g^T - g^A = -E^A \int_0^1 [q(z)n(z)b(z)/a_I] dz + \int_0^1 [q(z)n(z)b(z)][[(L/\gamma w^*) + \rho A_I + L^*/\gamma]/a_I] dz.$$

Hence $d(g^T - g^A)/d\gamma < 0$, since γw^* rises with an increase in γ . \parallel

4. Intermediate calculations for (6.3)

By employing (2.1) and the product demands, the “once-off” gain $[U^T - U^A]$ can be written:

$$[U^T - U^A] = \int_0^1 b(z) \ln \{ [E^T/E^A][p^A(z, t=0)/p^T(z, t=0)] \} dz. \tag{A4.1}$$

In autarky $p^A(z, t=0) = w^A a(z) \phi(j^A, z) = a(z) \phi(j^A, z)$, since $w^A = 1$. With trade $p^T(z, t=0) = w^T a(z) \phi(j^T, z)$ for $z \in [0, \bar{z}]$ where $w^T = 1$. For $z \in [\bar{z}, 1]$, $p^T(z, t=0) = w^T a^*(z) \phi(j^T, z)$ where $w^T = w^*$. By assumption the home country owns only a fraction μ of the leading-edge technologies at the outset of trade. Therefore, $\phi(j^A, z) = \phi(j^T, z)$ in a fraction μ of all industries and hence making the above substitutions in (A4.1) yields (6.3) in the text.

5. Proof of Proposition 2

Define $[U^T - U^A] \equiv V(\mu)$ and recall μ has no effect on the model’s positive properties. If $\mu = 1$, the first and third terms in (6.3) vanish and $V(\mu = 1) > 0$. Next, assume $\mu = 0$ and rewrite (6.3) as:

$$[U^T - U^A] = \int_0^1 b(z) \ln [E^T/E^A [1 - n(z)]] dz + \int_{\bar{z}}^1 b(z) \ln [a(z)/w^* a^*(z)] dz. \tag{A5.1}$$

If $E^T/E^A [1 - n(z)] > 1$ for all z , then “once-off” effects are necessarily positive. If $i(z) > 0$ in autarky under any $b(z)$, then $n(z) > \rho a_I / [L + \rho a_I]$ for all z . But then $1 - n(z) < 1 - \rho a_I / [L + \rho a_I] = L / [L + \rho a_I] = E^T/E^A$ when $\mu = 0$. Hence $E^T/E^A [1 - n(z)] > 1$ for all z , and $V(\mu = 0) > 0$. (I am grateful to Alwynn Young for bringing this case to my attention.) Therefore, we have shown $V(\mu = 0) > 0$ and $V(\mu = 1) > 0$. It is easy to show $V''(\mu) < 0$ for any μ , while $V'(\mu = 1) < 0$. Hence, $V(\mu) > 0$ for all $\mu \in [0, 1]$.

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