The Technology Transfer Paradox

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This paper examines whether a country that enjoys a superior technology in all commodities in a two-country, multi-commodity Ricardian setting could actually gain if its technology in which it possesses its greatest comparative advantage is stolen or transferred to the other country without any compensation. Such a paradoxical possibility is shown always to exist with strong Cobb-Douglas shared demand conditions for certain ranges of relative country size. .

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One aspect of globalization concerns the increased ease of the transfer of technology among countries. This may take the form of outright sales in arms-length market transactions or of transfer activities within a multi-national firm. Alternatively, there may be an illegal transfer, wherein technological knowledge possessed by a firm in one country is transferred to another without any payment for the superior information. This latter kind of uncompensated technology transfer raises a critical question: Could the real income of the country originally the only possessor of the superior technology actually be *raised* by such "outsourcing"? A positive answer would seem especially problematic in the case in which the technology that is stolen or given away is for a commodity the advanced country is exporting. And how could such a paradoxical result be reconciled with the *negative* effects on an advanced country's real income if by innovation a less developed country obtains a *small* improvement in its existing production of a commodity being exported by the advanced country? That is the setting and the conclusion reached in the recent article by Paul Samuelson (2004), in which a country such as China gets better at producing a commodity being exported by an advanced country such as the United States.[1] Without disagreeing with Samuelson's findings, in this paper we show how the advanced country may nonetheless gain by an uncompensated technology transfer sufficiently great to drive the advanced country out of producing its best export commodity. We label this outcome *The Technology Transfer Paradox.*[2]

[1] And this leads to a deterioration in the advanced country's terms of trade. This article proved to be controversial. For details see the coverage in the *New York Times* (September 9, 2004).
[2] For the simple two-commodity case this paradoxical outcome has been illustrated by Ruffin and Jones (2006).

Section 2 describes possible Ricardian equilibria in the two-country, many-commodity case, followed, in Section 3, by a discussion of the effect on an advanced country's real income of an uncompensated transfer of technology of producing that country's commodity that is highest on its list of comparative advantage. Section 4 provides some extensions and Section 5 some concluding remarks. In an Appendix we illustrate more details with a 4-commodity case and, as well, illustrate possibilities in the continuum model of Dornbusch, Fischer and Samuelson (1977).

2. Before Technology Transfer

In a two-country (Home and Foreign), many-commodity Ricardian setting, relative country size is important. If Foreign is relatively large, it must produce a large fraction of commodities in world markets, and in order to compete successfully, its wage rate must be sufficiently low. Thus if a diagram were drawn with the vertical axis showing Foreign's wage rate relative to Home's wage rate, w^*/w, and a horizontal axis showing the relative size of Foreign's labor supply, L^*/L, the relationship between the two would be downward sloping. In the continuum model this negative slope would literally be correct. With a finite number of commodities, the model we select as more appropriate to the issue, such a locus would be downward sloping only in regions in which no commodity is produced in common in the two countries – each is specialized to a different group of commodities. However, for regions of relative country size in which they have a commodity produced in common, the relative wage rate between countries is fixed by the relative productivities of labor in producing the common commodity in the two countries.

In what follows we make a completely innocent assumption that serves to simplify the exposition. Let commodities *1* through *n* be producible in both countries using only labor, and let all commodity units be selected so that firms in Home take only a single unit of labor to produce one unit of each commodity. Furthermore, let the *numeraire* be selected as a commodity produced by Home. Therefore Home's nominal wage rate is always unity, as is the price of any commodity produced by Home. To highlight the purpose of the paper in showing the consequences of a transfer without compensation of the technology for producing a commodity at Home to Foreign, we also assume that Home has a technological superiority in every commodity, so that all unit labor requirements in Foreign exceed unity. Assume that commodities are numbered such that

(1) $a_1^* > a_2^* > \ldots\ldots.. > a_n^* > 1$

That is, Foreign's greatest comparative advantage is in producing the n^{th} commodity, and its lowest is in producing the first, where a_i^* indicates the absolute labor costs per unit production of the i^{th} commodity in Foreign.

With Home's nominal wage rate always unity, the relationship between the ratio of wage rates to relative country size is, for selected parts of the range, illustrated in Figure *1*, with w^* on the vertical axis. With Home having unit productivity in all commodities, the ratio of Foreign to Home Productivity is measured by the reciprocals $1/a_n^*,\ldots 1/a_1^*$ on the vertical axis. Consider, first, the pair of cases in which one of the countries is relatively so small that it cannot supply the entire world market even for the commodity in which it has its greatest comparative advantage. If this is Foreign, with both countries producing commodity *n* in order to satisfy world demand, their wage rates are locked together by their productivities, with Foreign's wage rate at $1/a_n^*$. At the other extreme, if it is Home that is relatively so small that Foreign must use some of its labor as well to produce the commodity in which Home has the greatest comparative advantage, Foreign's wage rate must be at the minimum level of $1/a_1*$.

In Figure 1's middle range, suppose relative country size, *L*/L*, lies strictly between *A* and *B*, with Home producing commodities *1* through *k* and Foreign the remaining *(n-k)* commodities. In this range Foreign's wage rate must be less than $1/a_{(k+1)}*$ so that it can be the only producer of commodities *(k+1)* and higher, but greater than $1/a_k*$, so that Foreign is not able to compete in the market for commodity *k*. A slight increase in Foreign's relative size increases its production of commodities *(k+1)* through *n*, and this can be accommodated in world markets only by a reduction in all their prices, and, with them, Foreign's wage rate. This continues if *L*/L* grows until point *B* is reached, at which point Foreign's wage rate has been reduced to $1/a_k*$, and further increases in *L*/L* will see Foreign taking over increasing shares of world production of the k^{th} commodity until Foreign becomes the only producer of the k^{th} commodity (when *L*/L* reaches point *C*), after which the cycle repeats itself.

So far nothing has been said about taste patterns. We start by adopting a popular assumption of a very "neutral" kind: Tastes are of the Cobb-Douglas variety, the same for both Home and Foreign, and (until later) of the same expenditure share for every commodity.[3] What this implies is that if each country is specialized in producing a subset of commodities, say *1* through *k* for Home and *(k+1)* through *n* for Foreign, the ratio of the number of commodities produced in Foreign to those produced in Home corresponds to the ratio of their national incomes as reflected in total payments to labor. Thus:

[3] This is the same assumption about demand made by Samuelson (2004) and by Ruffin and Jones (2006) in their two-commodity case.

(2) $w^* (L^*/L) = (n - k)/ k$

Referring back to Figure 1, relationship (2) allows us to identify the relative labor supplies corresponding to points *A*, *B*, and *C*. If the (relative) size of Foreign's labor force reaches point *A*, the assignment of commodities to countries shown in equation (2) is satisfied because Foreign has just become the world's sole supplier of commodity *(k+1)*, as well as all higher numbered commodities. The journey from *A* to *B* is down a rectangular hyperbola as Foreign increases its production of commodities *(k+1)* through *n*, encouraging a proportional fall in prices and a drop in Foreign's wage rate, w^*, until, at point *B*, Foreign can just begin to produce some of the k^{th} commodity. Although each country's specialization pattern at *B* is the same as at *A*, the fact that Foreign's wage rate is lower at *B* leads to the value for *B* compared with *A* shown in Figure 1. Foreign's wage rate is now linked to the unit wage rate at Home by technology; and when L^*/L increases to point *C*, Foreign takes over the world's entire production of commodity *k*.

3. A Transfer of Technology

Concerns have been expressed by the media and others that some of the better technology assumed to be possessed by the United States is being lost to foreign countries via the activities of multi-nationals or by other means, and that this causes damage to American workers.[4] In our many-country Ricardian setting it is supposed that the absolute advantage that Home possesses in producing all commodities compared with Foreign is based entirely on superior blueprints at Home. Furthermore, it is assumed that Foreign

[4] See the quote by Charles Schumer and Paul Craig Roberts cited in Ruffin and Jones (2006).

obtains the blueprints for the *best* commodity in the list of exports for Home, *i.e*. that for the first commodity, and that absolutely no payment is made for such transfer.[5]

Earlier an important simplifying (and entirely innocent) assumption was made that fixed Home's nominal wage rate at unity. As a consequence the question of the effect of transfer on Home real incomes depends entirely on what happens to the price level.[6] Such a transfer of technology to Foreign with its lower nominal wage rate must serve to reduce the world price of the first commodity (and wipe out Home's entire production). If this new acquisition of better technology serves to increase Foreign's wage rate, the prices of all commodities produced only abroad (except for the first commodity) would also increase. Could the effect on the price index of the price reduction for the first commodity outweigh any increases in commodity prices for Home's imports? This depends upon the effect of the transfer on Foreign's wage rate, and, as our analysis shows, the change in w^* depends upon the relative size of the two countries' labor forces.

This question is pursued in Figure 2, which concentrates on the scenario in which Foreign's labor supply is relatively small. The dashed locus depicts the situation before the technology transfer, and shows that until the relative size of Foreign's labor force reaches $a_n^*/(n-1)$ both countries are required to share production of commodity *n*, the commodity representing Foreign's greatest comparative advantage. After the technology transfer, Foreign's best commodity becomes commodity *1*, which formerly was Home's best. The solid post-transfer locus reveals that if Foreign's labor force is sufficiently small its wage rate will be at the Home level of unity since both produce a new

[5] Any Home firms possessing such blueprints will of course lose. The question is whether Home as a country is necessarily worse off, where in the model all income is in the form of wages.
[6] Technically, the uniform Cobb-Douglas assumptions made imply that the price index is the geometric mean of all commodity prices. This will decrease if and only if the product of all prices itself falls.

commodity (*1*) in common. This improvement in productivity for Foreign's workers implies not only a higher wage rate, but that Foreign can supply the entire market for the first commodity at a lower relative labor supply, {1/(n-1)}, than it previously took to produce all the world's demand for commodity *n*. If (*L*/L*) were to increase from this level, the world price of the first commodity would fall and *w** would be driven down until eventually, when (*L*/L*) reaches $\{a_n^*/(n-1)\}$, Foreign's wage rate falls to $1/a_n^*$.

Note the significance of point *A* in Figure 2: If (L*/L) were equal to $\{a_n^*/(n-1)\}$, the technology transfer would leave the Foreign wage rate precisely at its previous level! This is a guaranteed consequence of the uniform Cobb-Douglas assumption that leads to equation (2). At point *A* originally Foreign had just *completed* its provision for the entire world market's demand for commodity *n*, which was originally its best. After transfer, at this size labor force it would just *begin* to produce commodity *n*, which has now slipped to second best in its ranking by comparative advantage. Whether it has just satisfied the world market for *n* or is just about to enter that market, Foreign's wage rate relative to Home's unitary wage must reflect its relative productivity, $1/a_n^*$.

A point such as *A*, at which technology transfer leaves Foreign's wage rate unaltered, is what we call a *turning point*, and the uniform Cobb-Douglas assumption guarantees that such points cyclically reappear, such as at point *B* in Figure 2 and, in general, whenever *L*/L* equals $\{a_{(k+1)}^*(n-k)/k\}$, where *w** equals $1/a_{(k+1)}^*$ (e.g. at point A in Figure 1). With technology transfer Foreign shifts out of producing commodity *(k+1)* and into Home's former best export commodity while Home shifts its labor into good *(k+1)*. At turning points there is a seamless change, with no pressure exerted on w*, resulting in Home gaining because it can now purchase its former export at a lower price and pay the same prices for all other commodities. The after-transfer Foreign wage schedule in Figure 2 is *not* just an upward-shifted locus of the original wage schedule; there is a leftward shift as well, expressing Foreign's productivity gain in having acquired Home's better technology for producing the first commodity.

Home gains from this technology transfer are not constrained just to the turning points; Home would also gain for nearby levels of Foreign's relative labor supply. If being in the neighborhood of turning points ensures that technology transfer actually benefits Home, Figure 2 suggests that the greatest danger to Home real incomes comes from situations in which w^* is raised by the maximal amount, and this occurs when both before and after transfer Home and Foreign produce a commodity in common, a different commodity after the transfer. The reason? The before-and-after Foreign wage rate disparity is greatest when w^* corresponds to the productivity of Foreign's labor force in two neighboring commodities instead of being partway between them. And it is this disparity that hurts Home by causing an increase in the price of all commodities not produced by Home. In contrast, Home's real wage is helped by the drop in the price of the commodity whose technology has been transferred. Such a price fall – caused by the *difference* between Home and Foreign wage rates - will be greater the larger, relatively, is Foreign's labor force. Whereas Home's nominal wage rate is unity, that ruling in Foreign monotonically decreases the higher the value of L^*/L.

An explicit formulation of the comparison between the product of commodity prices before and after transfer when w^* increases by the maximal amount can be obtained by assuming that initially the two countries share in the production of commodity k (with L^*/L in the *BC* range of Figure 1). This implies that the prices of commodities *1* through *k* are all unity. Foreign's wage rate must be $1/a_k*$, making the sequence of prices for commodities *(k+1)* through *n* equal to:

$$a_{(k+1)}*/a_k*,\ a_{(k+2)}*/a_k*, \ldots\ldots\ldots, a_n*/a_k*$$

Let Π_O represent the product of commodity prices in this initial situation:

(3) $$\Pi_O = \{a_{(k+1)}*\ a_{(k+2)}* \ldots\ldots a_n*\} / (a_k*)^{(n-k)}$$

Note that this product is less than unity because all Foreign-produced commodities except for commodity *k* have prices less than unity. In the after-transfer situation Foreign becomes sole producer of the first commodity and shares production of commodity *(k+1)* with Home. Letting Π_A denote the after-transfer product of commodity prices,

(4) $$\Pi_A = \{a_{(k+2)}*\ a_{(k+3)}* \ldots\ldots a_n*\} / (a_{(k+1)}*)^{(n-k)}$$

(Foreign still produces (n-k) commodities because it also produces the first commodity after transfer). Comparing (3) with (4) it is clear that Π_A is smaller than Π_O, and thus Home gains by the technology transfer, if and only if condition (5) is satisfied:

(5) $$\Pi_A/\Pi_O = \{1/a_{(k+1)}*\} \{a_k*/a_{(k+1)}*\}^{(n-k)} < 1$$

The first term, less than unity, reveals the *discrepancy* between Home and Foreign wage rates, which helps Home, while the second term is greater than unity, reflecting the *rise* in *w** and thus the price of every commodity (save the first) produced in Foreign.[7]

What happens to this ratio of price products in (5) if Foreign's relative size increases until initially both countries produce commodity *(k-1)* and, after transfer, produce commodity *k* in common? Would there be any reason to expect this ratio to decline with relative Foreign size? On the one hand the drop in the price of the commodity whose technology has been transferred tends to be greater the higher is *L*/L;* successive turning

[7] In Ruffin and Jones (2006) this condition for Home gain for two commodities reduces to $(a_2*)^2 > a_1*$.

points are at ever lower levels of Foreign's wage rate, so that the first term in (5)'s inequality becomes smaller the lower is *k*, the number of commodities produced at Home. On the other hand, a lower value for *k* (for given *n*) implies that a larger number of commodities is produced in Foreign and imported by Home. This is what is captured by the second term in (5), with every such commodity price multiplied upwards by the term $\{a_k^*/a_{(k+1)}^*\}$, the ratio of post transfer Foreign wage to pre-transfer w^*.

Further insight into this question can be obtained by comparing the expression in (5), illustrated by point *A* in Figure 3, with the size of Π_A/Π_O for a larger value of L^*/L (illustrated by point B in Figure 3) in which initially the two countries produce commodity *(k-1)* in common and, after transfer, commodity *k* in common. Call this new value $(\Pi_A/\Pi_O)'$:

$$(6) \qquad (\Pi_A/\Pi_O)' = \{1/a_k^*\}\,\{a_{(k-1)}^*/a_k^*\}^{(n-k+1)}$$

To compare with (5) multiply both (5) and (6) by a_k^*. This reveals that

$$(7) \qquad (\Pi_A/\Pi_O)' \leq (\Pi_A/\Pi_O) \quad \text{iff} \quad a_{(k-1)}^*/a_k^* \leq a_k^*/a_{(k+1)}^*$$

Comparisons between terms such as $a_k^*/a_{(k+1)}^*$ and $\{a_{(k-1)}^*/a_k^*\}$ refer to the *rate of increase* in Home's absolute advantage as production moves towards Home's best commodity. If this rate of increase remains constant, so also will the change in the consumer price index as Foreign gets larger. The Appendix illustrates a special case in which the profile of Home's absolute advantage is linear. Π_A/Π_O gets progressively lower. The Appendix also reveals the importance of this comparison in the continuum case.

4. Extensions

These results, showing the possibility of Home gains with technology transfer, can be extended:

(1) Suppose that the technology that Foreign takes from Home without compensation is not for Home's best commodity, *1*, but for some other commodity that initially is only produced by Home. Does this make it more likely that Home could benefit by the uncompensated transfer? Perhaps surprisingly, the answer is no. The discussion in Figure 2 does not depend upon the transferred commodity being the first. Turning points remain the same, and in their neighborhood Home must gain by the transfer. Condition (5) provides the criterion for Home gain in the worst-case scenario in which before and after Foreign wage rates are at their maximal spread (between a pair of turning points)[8]. Note that the condition does not refer to the commodity whose technology has been transferred, but only to the characteristics of the profile of comparative and absolute advantage near the break point between Home and Foreign production.

(2) Suppose instead of the uniform array of Cobb-Douglas taste patterns the world has a lower spending share on commodity 1 and higher relative shares on the other commodities. With reference to Figure 2 after technology transfer Foreign could supply the entire world market at a relative labor force smaller than $1/(n-1)$. Thus turning point *A* becomes, instead, a turning region, including some values to the left of *A*. If, instead, the share devoted to the first commodity exceeds that for others, there will be no turning

[8] Depending upon the technology, there may not be any points such as *A* or *B* in Figure 3 in which the two countries share production of a (different) commodity in common both before and after transfer. But a comparison of the two situations that would occur if w^* changed by this maximal amount provides sufficient conditions for Home gain.

points, although it is still possible that Home can gain. But note: If Home transfers its superior technology in *all* commodities, Home must be a loser. The reason: Home would lose all its gains from trade if world relative prices matched its own autarky prices. In this Ricardian case, literature also shows how Home can gain if it transfers its superior technology for the commodity or commodities that it imports.[9]

(3) What kind of paradox is represented by a technology transfer that is unrequited, but leads to an improvement in Home's real wage rate? The theory of international trade, of course, contains a number of paradoxes, and it is appropriate to ask how this one fits into the pantheon comprised of the others. The transfer welfare paradox (for gifts of commodities) depends on countries exhibiting different taste patterns, whereas here tastes are similar between countries. The immiserizing growth paradox entails an outward shift in Home's transformation surface. Here the transformation surface is not affected. The technology transfer paradox differs in requiring that the shock to the original equilibrium be sufficiently large that production patterns change. Consider, for example, a situation such as that described by Samuelson (2004). Both Home (say the United States) and Foreign (say China) produce a commodity in common (i.e. equilibrium is on a flat in the w*-locus). If China gets a bit better at producing the commonly produced commodity but U.S. production gets reduced only by 10% or so, Home (the U.S.) must lose.[10] But if the productivity change in producing this commodity in China is so large that the U.S. industry gets completely wiped out, the U.S. *may* gain. That is, this paradox displays the

[9] See Kemp and Shimomura (1988) and Beladi, Jones, and Marjit (1997).

[10] This loss does not depend upon whether the U.S. is an importer or exporter of this commodity. For a general analysis of technology changes that do not disrupt the pattern of production see Jones (1979).

property that results appropriate when shocks are small may prove to have non-monotonic effects on welfare if shocks are large enough to alter production patterns.[11]

5. Concluding Remarks

Most developed countries have experienced changes in their patterns of production and international trade over time. By their own investment activities new positions of comparative advantage are acquired, accompanied by their losing their comparative advantage in other commodities. This loss is an inescapable consequence of success in new ventures raising their real wage rates and of less developed countries acquiring new technology and skills in producing commodities such as textiles, steel, or automobiles. Years ago Ray Vernon (1966) sketched out a *product cycle* theory describing this evolution of production and trading patterns.

It has recently been emphasized by Samuelson (2004) and others that if foreign countries develop increased expertise in commodities that a Home developed country is exporting, at Home real incomes will fall with a deterioration in Home's terms of trade. Thus increasing degrees of globalization that are characterized by Foreign technological advances rather than those at Home can do damage to income levels at Home. In this paper we consider improvements in Foreign technology that *surpass*, in scope, those considered either by Samuelson or by critics of globalization. We stack the deck in asking whether an advanced country can actually *gain* by an uncompensated transfer to a foreign country of its advanced technology in producing the export commodity in which it possesses its *greatest* comparative advantage. The answer we give in this case of

[11] For a discussion of other non-monotonic results, e.g. to the Stolper-Samuelson theorem, see Jones (2006).

technology transfer is it depends, but if Cobb-Douglas demand shares are all alike, the advanced home country *must* gain by such unrequited transfer near the so-called *turning points.*

A crucial question concerns the effect of such transfer on the relative wage rates of Home and Foreign (i.e. the double *factoral terms of trade*). At the critical turning points relative wage rates are not affected by the transfer, whereas for other values of relative country size the technology transfer raises Foreign's wage rate, which serves as well to increase the prices faced by Home labor for all commodities (except the first) produced by Foreign and imported by Home. If Foreign's wage rate does increase as a consequence of transfer, there emerge two conflicting effects on the consumer price index facing Home's workers, *viz.* a falling price for the commodity whose technology has been transferred, on the one hand, and an increase in prices of other goods imported by Home on the other. Our normalization assumption, whereby all input-output labor coefficients for Home are set at unity, leading as well to a unit value for Home's wage rate, coupled with strong Cobb-Douglas assumptions regarding taste patterns, suffice to show that if the product of world commodity prices falls, Home laborers must experience an increase in real income (real wages).

What is striking in our scenario is that it is precisely the *complete loss* of Home's original best industry that allows a reduction in its world price and thus works in favor of the increase in real wages at Home. In many advanced countries workers have benefited, as consumers, from lower priced and better quality TV sets, cameras, automobiles and electronic goods after Foreign has taken over their production. Without denying the importance of new technological developments in advanced countries, of the type envisaged by Vernon (1966), what we have argued is that even *without* such advances, pure improvements abroad, such as represented by stealth or uncompensated acquisition of some of our better technology, may serve to raise real wages and incomes in the advanced home country. Trade patterns are altered, and the subtle mechanisms of comparative advantage can yield net gains to the advanced country.

There is a *cyclical* pattern of gains and losses to Home that depends on Foreign's relative size. With strong demand assumptions there exist repeated neighborhoods of such relative size in which technology transfer *must* yield net gains to Home.

Appendix:

A. A 4-Commodity Case

To illustrate the importance of the profile of comparative advantage, here we consider a special case in which four commodities can be produced, but Home possesses an absolute advantage in all four, with a ranking that is linear:

(A.1) $a_1^* = 4.5 \quad a_2^* = 3.5 \quad a_3^* = 2.5 \quad a_4^* = 1.5$

Figure A.1 illustrates how the ratio of the product of commodity prices after technology transfer to the value before transfer, Π_A/Π_B, varies depending upon relative country size. The locus is divided into four regions. In the first of these there are two segments: If L^*/L is small enough (lower than 1/3), both countries must produce the commodity in which Foreign possesses the greatest comparative advantage both before and after transfer, so the price index is unity in both cases. In the second segment Foreign can satisfy the world's demand for commodity 1, and so w^* and p_1 fall until w^* reaches $1/a_4^*$ at the first turning point. There are three segments in the next pair of regions, II and III. In segments a(II) and a(III) Foreign's wage rate is tied to Home's by their productivity in a commonly produced commodity after transfer (commodity 4 in a(II) and commodity 3 in a(III), as well as commodity 2 in a(IV)). Before transfer Foreign produces no commodity in common with Home, and therefore as its labor force expands, its wage rate falls in the a(i) segments. Just the reverse happens in regions c(II) and c(III), with Foreign's wage rate tied to Home's by a productivity comparison in the commonly produced commodity originally, but with this link cut (and w^* thus falling as L^*/L rises) after transfer.

It is in the b(i) segments that a productivity link between wage rates exists before *and* after technology transfer, leading to plateaus for Π_A/Π_O. The growth rate of Home's comparative advantage, as indicated by the sequence of productivity ratios towards Home's best:

$a_3^*/a_4^* = 5/3$; $a_2^*/a_3^* = 7/5$; $a_1^*/a_2^* = 9/7$,

is seen to fall, leading to declining values for Π_A/Π_B from b(II) through b(IV). The move from b(I) to b(II), however, is upwards, and this involves the extent of Home's absolute advantage in Foreign's best commodity, *4*. The ratio of a_4^* to unity (signifying no absolute dis-advantage for Foreign) is 3/2, which is smaller than the 5/3 value for a_3^*/a_4^*. Thus b(I), always with height of unity, is lower than b(II).

Note that at turning points the locus reaches a local minimum because w^* locally does not increase, so that the only effect on the price index is the lowering of p_1, and as L^*/L increases, this positive effect on Home's wage rate gets stronger. The increasing length of each region reflects the fact that as Foreign gets larger, it must produce more commodities.

B. The Continuum Case

In dealing with Ricardian models, use is sometimes made of the continuum case discussed in Dornbusch, Fischer and Samuelson (1977). Figure A.2 uses the setting in which w^* is shown relative to L^*/L as in Figures 1-3, but instead of a step function as in the finite case, the relationship is smoothly downward sloping. Two alternative situations are shown before transfer: Curves 1_O and 2_O. They intersect at point *E*, indicating the given value of *0F* for the size of the relative foreign labor force. Foreign technology that is originally reflected in curve 1_O, shows a more rapid rise in Foreign's comparative advantage moving leftwards from point *E* than does curve 2_O. Both these curves show that before transfer there is no commodity in which Foreign has an absolute advantage over Home.

Technology transfer is now assumed to take place, not just in Home's best commodity (which has infinitesimal measure) but in a set of industries at the top of Home's ranking by comparative advantage (and thus at the tail end of Foreign's ranking). This is shown by the horizontal segment (at $w^* = 1$), *1G*, common both to after-transfer curves 1_A and 2_A. There is a vertical drop from point *G* to point *H* for curve 1_A and from point *G* to point *J* for curve 2_A. To complete the after-transfer curves, shift curves 1_O and 2_O to the right by precisely the horizontal distance *1G*. This same distance would also be shown by *ED* where in both situations point *E* indicates Foreign's relative size.[12] The world prices of the transferred commodities fall from initial unit value to that shown by point *C* in the first curve and point *B* in the second. However, the prices of all commodities (exclusive of the transferred segment) produced in Foreign and imported by Home increase by the proportion *CE/EF* for the first alternative curve and by the lower proportion *BE/EF* for the second alternative. Thus Home is less likely to have this transfer improve its real income in the first alternative, both because prices of the transferred commodities fall by less, and because prices of Home's other imported commodities increase by more.

It is clear from the diagram that in the continuum case there can be no turning points – technology transfer must increase Foreign's real wage rate for given country sizes. One

[12] As the diagram suggests, Foreign's wage rate must increase. Otherwise after transfer the value of Home imports would rise and exports fall – an untenable disequilibrium.

defining characteristic of the continuum model is that both countries always produce a commodity in common, but with infinitesimal measure. This will be a different commodity in both alternatives at initial point *E* than it is after transfer at *C* (for the first alternative) or *B* (for the second), a commodity in which Foreign's absolute productivity is higher than originally so that its real wage *must* increase. Furthermore, since the before-and-after comparison always has the two countries producing a commodity in common, the analysis leading up to equation (4) and inequality (5) has relevance in the continuum case. From point *E* the move after transfer is a move towards a more productive use of labor in both cases, but more so in the first alternative than in the second. Home is more likely to gain by transfer in the second alternative.

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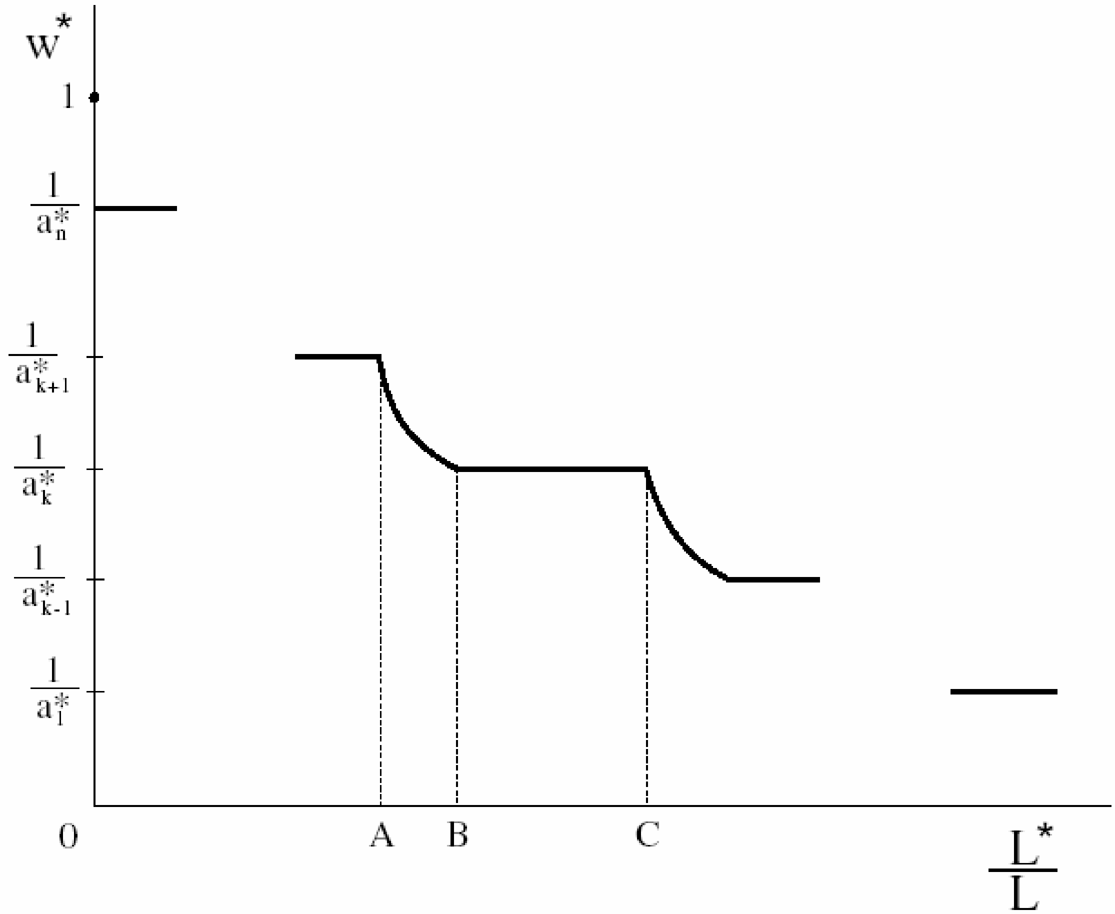

Figure 1: Before Technology Transfer

If Cobb-Douglas Tastes:

$$A = a^*_{k+1} \frac{(n-k)}{k}$$

$$B = a^*_k \frac{(n-k)}{k}$$

$$C = a^*_k \frac{(n-[k-1])}{[k-1]}$$

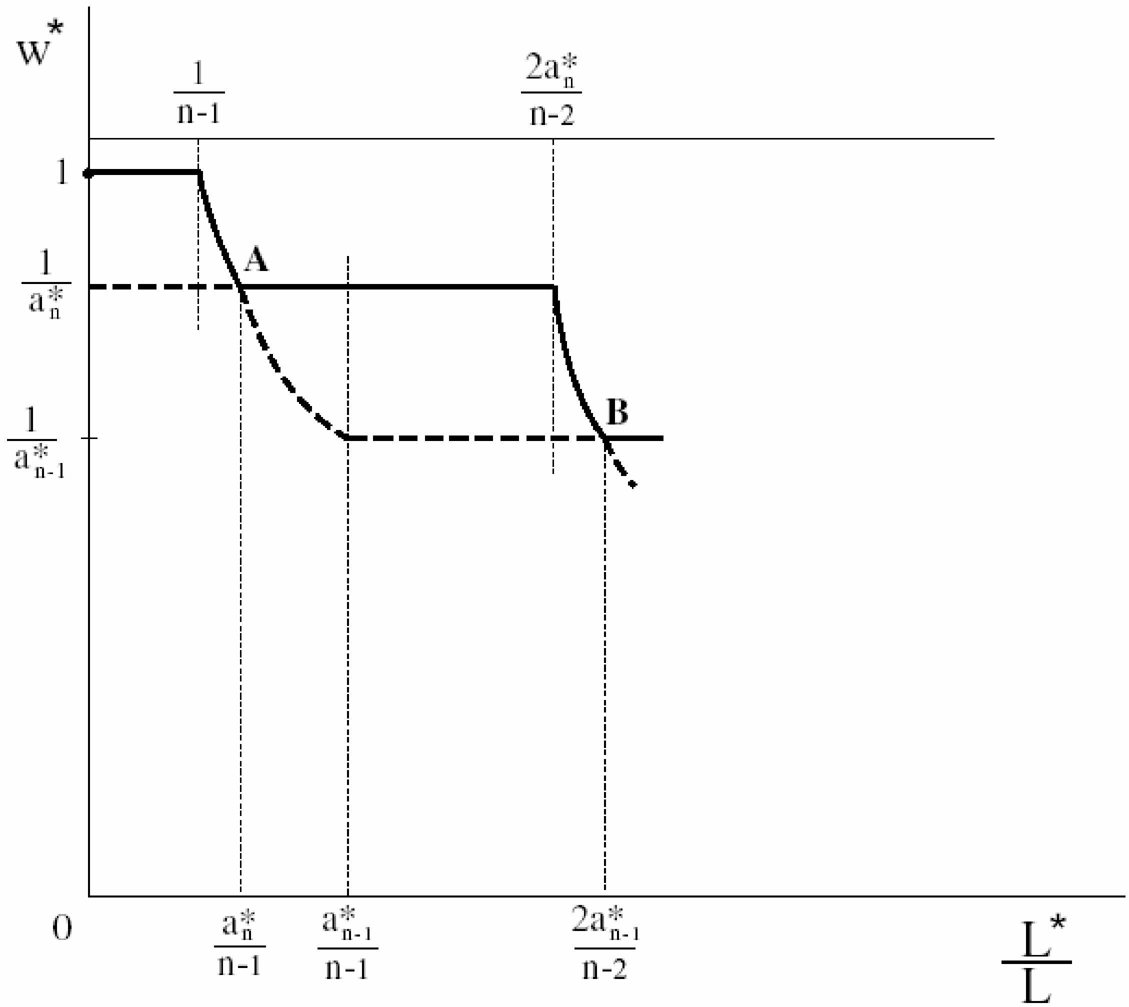

Figure 2: Technology Transfer and Turning Points

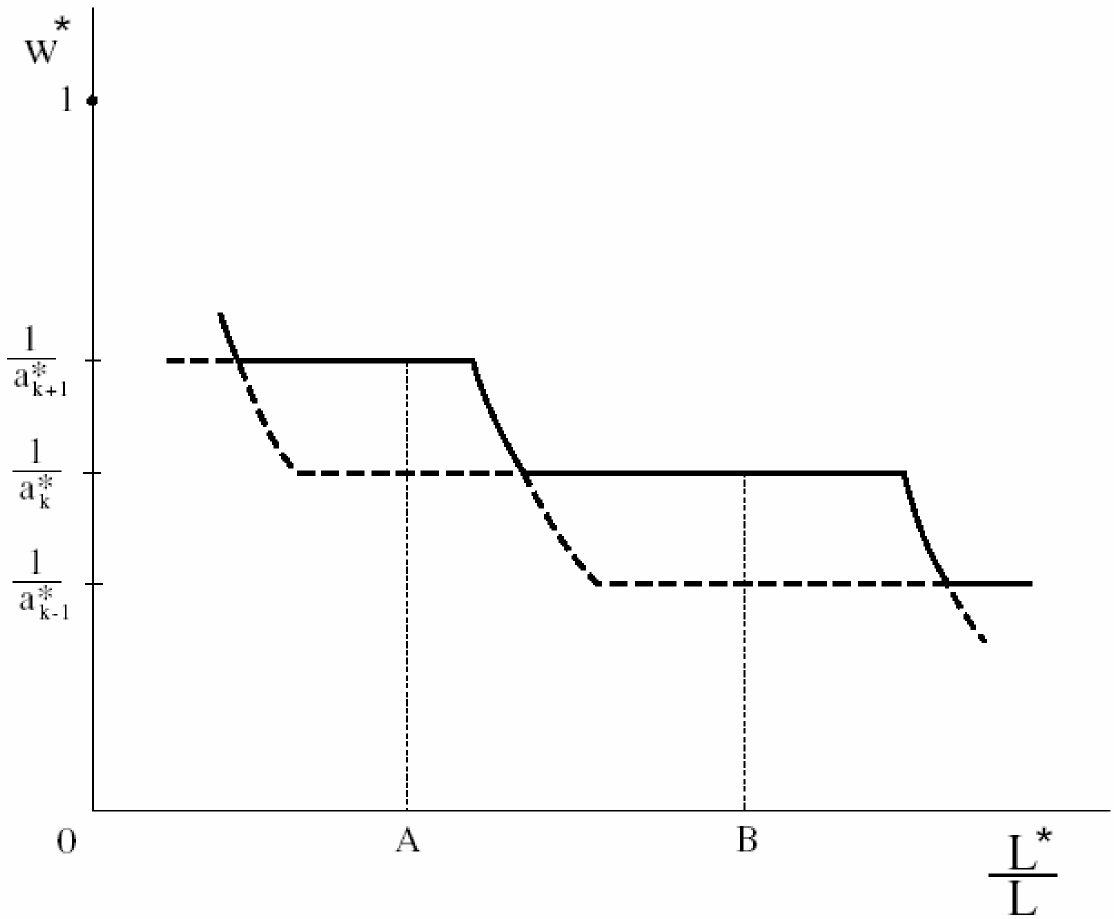

Figure 3: Shared Production: A Comparison

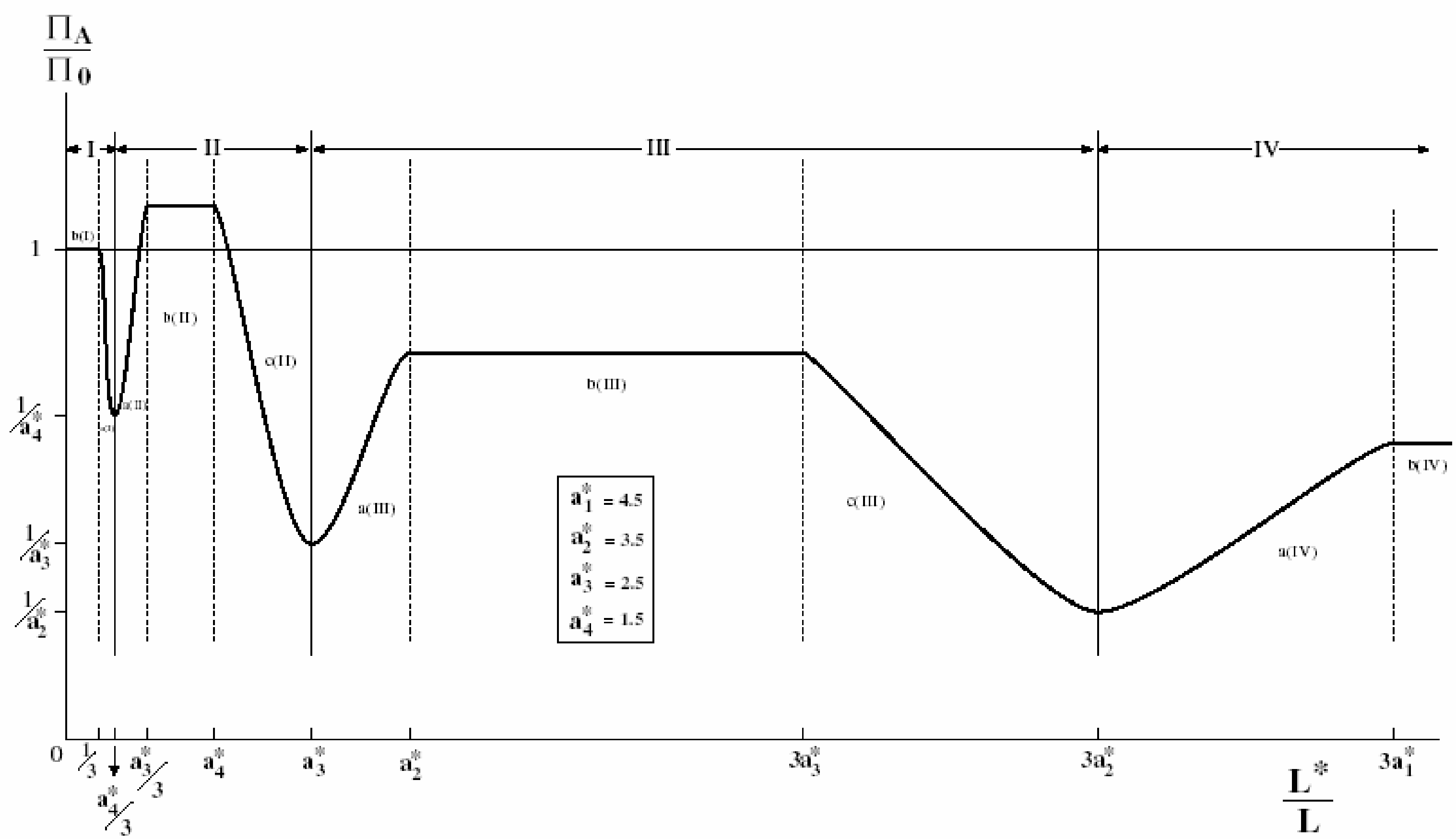

FIGURE A.1: Home Possible Gains After Transfer

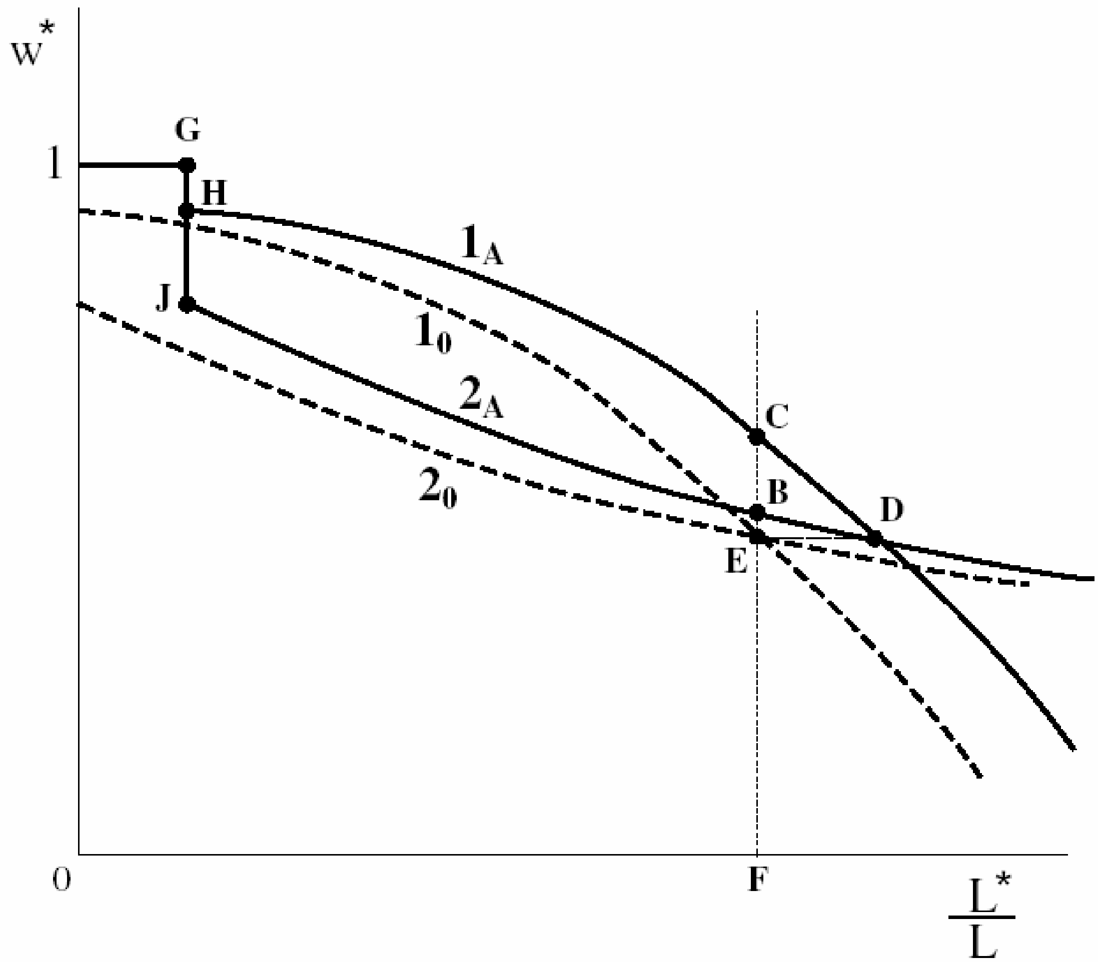

FIGURE A.2: The Continuum Case