International Technology Transfer:

Who Gains and Who Loses?[1]

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There is much concern these days over the transfer of technology and jobs to countries such as China and India, instances in which American companies move production facilities to areas of low labor costs. Charles Schumer (the senior Senator from New York state) and Paul Craig Roberts (2004) have put it this way:

> We are concerned that the United States may be entering a new economic era in which American workers will face direct global competition at almost every job level – from the machinist to the software engineer to the Wall Street analyst. Any worker whose job does not require daily face-to-face interaction is now in jeopardy of being replaced by a lower-paid, equally skilled worker thousands of miles away. American jobs are being lost not to competition from foreign companies, but to multinational corporations, often with American roots, that are cutting costs by shifting operations to low-wage countries.

Leaving aside issues of overall employment levels, we focus here on the effects of international technology transfers in a simple general competitive equilibrium model. Indeed, bypassing the peculiar characteristics of multinational corporations, we ask a simple question: If a country's superior technology is given away to producers abroad (or if they steal this technology), what are the international income distribution consequences? Ignoring the possible longer-term effects on the incentive to innovate, it

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is clear that the world as a whole benefits if better technology is spread abroad, so that it should be possible to arrange side-payments so that everyone benefits. In the absence of such compensation, however, who gains and who loses from such international technology transfer? The literature on the transfers internationally of purchasing power or commodities suggests that in all likelihood the giver loses and the recipient gains. But technology is different – it is like a public good in that the giver still has its resources and technology.

In what follows we consider a sequence of scenarios in which the "home" country, which we assume possesses an *absolute* advantage in labor productivity in producing a pair of commodities (call them 1 and 2), with a *comparative* advantage in producing the first commodity, transfers some of its technology advantage to a "foreign" country, the only other trading partner. The simple labor-only Ricardian model provides the setting. In such a model labor is immobile between countries and labor productivities can differ. Here we assume that such differences are attributable not to inherent or learned labor skills or to differences in "climate", but rather to "blueprints" that can be given away (or stolen).[2] The case that perhaps proves most surprising is one in which the home country's superior technology in the commodity in which it has a comparative advantage is transferred abroad. Even if the home country were not to obtain a cent in return for such a transfer, it is possible (but not necessary) that the home country would nonetheless gain. A particular numerical example is provided to illustrate this surprising possibility,

[2] We also assume away a country having greater stocks of capital, this being a one-factor Ricardian model, chosen for its simplicity.

and an Appendix explores more generally the circumstances under which the home country would gain by such a transfer.

1. The Pre-Transfer Equilibrium

In the initial trading equilibrium between these two countries, the terms of trade settle somewhere within the range set by the comparative cost ratios in the two countries, ratios that would reflect autarky prices. Let a_i denote the labor cost of producing the i^{th} commodity at home, and a_i^* the labor cost per unit produced abroad. We begin by assuming that the sizes of the two labor forces relative to productivities are such that in the trading equilibrium the terms of trade settle at a value strictly between the autarky ratios so that each country is completely specialized in the commodity in which it possesses a comparative advantage. (The Appendix considers cases of incomplete specialization as well). The two production blocks in Figure 1 illustrate a two-country equilibrium. The origin for the home country's production block is shown by *0* in the southeast corner, and the origin for the foreign country is denoted by *0** in the northwest corner. The offer curve for the home country is 0_TCH, and that for the foreign country is 0_TC*F. As illustrated, import demand in each country is elastic, but that is not necessary (although we assume the market equilibrium is stable). Equilibrium terms of trade are shown by the slope of the λ-ray from the trading origin, 0_T.

2. The Transfer of Import-Competing Technology

Figure 2 illustrates a pair of possible gifts or transfers of technology from the home country to the foreign country. First is the case considered by Beladi, Jones and Marjit

(1997), in which the home country passes on its superior technology for producing what at home would be an import-competing good (produced at home only in autarky). Compared with the initial foreign production block (reproduced in Figure 2), such a transfer allows greater foreign production of good 2 (the foreign export commodity), but does not alter production possibilities for the first commodity. The foreign autarky consumption point would be altered to point C*' (with consumption measured relative to the new 0*' origin), and the foreign offer curve is shifted to 0_TC*'F'. The terms of trade for the home country unambiguously improve, as shown by the new equilibrium ray $0_T\lambda$'. That is, even if the home country receives *no* payment for the gift of its superior technology in producing the second commodity it must benefit from the gift. The rationale: The home country was entirely dependent upon foreign supply of the second commodity in the initial trading equilibrium, so that the transfer encourages more foreign production, which must improve the terms of trade for the home country. (And increased foreign income spills over in part to greater demand for the home exportable).

The second scenario envisaged in Figure 2 corresponds with the home country passing on not only its superior technology for the second commodity, but also some *part* of its superior technology in producing the home export (first) commodity. Assuming this is possible, the transfer is designed to maintain the original comparative advantage position in the foreign country. That is, foreigners now posses a better technology for producing the first commodity, with a labor coefficient indicated by $\{a_2/a_2^*\}$times the original a_1^*. This serves to expand the foreign production block such that an autarky price ratio would be preserved, with consumption point *C*"* (relative to the new consumption origin, *0*’*). [3] Once again the terms of trade have improved for the home country to ray *0* ***l***’.

This second scenario is the one discussed in Kemp and Shimomura (1988). It reflects the common truth that if there is a uniform expansion in foreign production possibilities, caused by technological improvements or a balanced expansion of inputs, home terms of trade must be improved.[4] At the initial price ratio increased foreign incomes would spill over to improve the home country’s terms of trade.

Note two further aspects of this pair of scenarios. First of all, both transfers lead to exactly the same equilibrium values for each country’s exports, imports, and the terms of trade. Although the production block for the foreign country is superior in the second scenario, with trade it does not produce any of the commodity in which it (still) has a comparative disadvantage.[5] Secondly, although not illustrated by Figure 2, the specter of immiserizing growth for the foreign country cannot be ruled out. In Figure 2 we have drawn demands to be elastic, but sufficiently low elasticities coupled with a large value for the foreign import propensity (and noting that for foreigners this is a case either of pure export-led growth or balanced growth) could result in a drop in real incomes. Even if the home country charges nothing for such technology transfer, the receiving foreign country could thus lose by the receipt of the better technology. Figure 2 illustrates the much more balanced picture in which both countries gain from such transfer. Of course

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[3]If foreign tastes were homothetic (which they need not be), line segment 0*C* (not drawn) would be parallel to line segment 0*’C*” (also not drawn). However, the latter would be longer, reflective of the improved set of production possibilities.

[4] This assumes only two countries engaged in trade. Otherwise the home and foreign country might have the same trade pattern.

[5] This presumes that the foreign country is not so large that the trading equilibrium forces it to produce some of the first commodity in order to satisfy its tastes.

the home country would gain even more if it were paid by the foreign country for the advanced technology.

3. Transfer of All Home Technology

It has been assumed that the home country possesses an absolute advantage in producing both commodities. In such a case the world clearly gains if such technology is transferred completely to the foreign country. As opposed to the second scenario in the preceding section, the foreign country's comparative advantage in producing the second commodity is no longer maintained. Indeed, after transfer the foreign country has *no* comparative advantage – its cost ratio would exactly match that in the home country. No diagram is necessary to reveal what happens to the home country. It gains nothing by free trade (there would be no need for trade) and its welfare is the same as in autarky. Therefore if the starting point is free trade at prices differing from autarky before the technology transfer, such transfer unambiguously harms the home country and benefits foreigners. All the gains have been reaped by the foreign country.

4. Technology Transfer in Home Exportables

The final case we wish to consider is in many ways the most interesting and arguably the most likely. It is the scenario in which the advanced technology utilized in the commodity in which the home country has a comparative advantage and thus exports is itself the object of transfer. Such transfer could be the result of reverse engineering abroad, as familiarity with the product might yield up the secrets that went into home production. Alternatively, home exports might be accompanied by outsourcing or foreign investment so that some production takes place abroad. What can be said about the distribution of gainers and losers if indeed there is such a technology transfer?

In the preceding section it was noted that a transfer of *all* superior technology from the home to the foreign country helps the foreign country but wipes out all gains from trade that initially accrue to the home country in a free-trade equilibrium. Earlier, we noted that a transfer only of the superior technology the home country is assumed to possess in the commodity in which it has a comparative *dis*advantage must shower gains upon the home country. Therefore, it might seem reasonable to argue that if, instead of transferring all technology, only that in the commodity in which the home country possesses a comparative advantage is made available to foreigners, the home country must lose even more than in the preceding section. Surprisingly, however, although the home country might end up a loser, the possibility exists that it gains from a unilateral free transfer of the superior technology embodied in its current export commodity!

The rationale for this possibility serves to highlight the meaning of the concept of comparative advantage. If only the superior home technology in current home exports (the first commodity) is transferred, the *comparative* advantage ranking between countries is reversed. Given that we assumed that home technology is superior in the second commodity as well, the home country now becomes an exporter of the commodity (2) it previously imported. Figure 3 illustrates this shift in the pattern of trade. The diagram depicts the production block for the home country, with consumption origin, *0*. Initially the home country is completely specialized in producing its export commodity at point *A*, with free-trade equilibrium terms of trade shown by budget line, Aλ. Consumption is at point C, with a home indifference curve tangent to this budget line. Home production after the technology transfer shifts completely to point B, with equilibrium terms of trade illustrated by a budget line such as Bλ'. The technology transfer must serve to lower the relative price of home's initial export commodity (1), and if this price is lowered to the slope of Bλ' or more, the home country must actually gain. Productivity improvements abroad in the commodity the home country initially exports may eventuate in an actual gain for home residents if at home the ranking of commodities by comparative advantage is re-ordered by the alteration in productivities.

Would such a possibility of home gain when superior technology in the commodity the home country exports is transferred abroad exist if the home country had an *absolute disadvantage* in the other commodity? No. In such an event this transfer would not bring about a re-ordering of commodities according to comparative advantage. The home country would remain an exporter of the first commodity. If the foreign country remains completely specialized in the second commodity, in which it still has a comparative advantage, no change in the terms of trade takes place. Otherwise, if the foreign country becomes incompletely specialized and starts producing the first commodity, more is placed on the market and the terms of trade will move against the home country.

5. A Numerical Example

The possibility exists that the home country might actually gain by transferring abroad its superior technology in producing its export commodity (in which it has a comparative advantage). This can usefully be illustrated in a numerical example. Here liberties have been taken. First of all, we assume that the foreign country has a significantly larger labor force than does the home country (China vs. America?). Secondly, the home country's technological superiority before transfer is significant in both sectors. These two factors combine to imply that after the transfer the foreign country's production potential becomes so large that it must be incompletely specialized.

Table 1 below cites the unit labor costs for each country. The home country is assumed to have a labor supply of 100 units whereas the foreign country has the much larger labor supply of 480 units. Consumption by each country in autarky, and subsequently with trade both before and after a technology transfer, depends upon demand conditions, and in this example we assume extremely simple Cobb-Douglas functions, identical between countries, and with identical expenditure shares on each commodity.[6]

	Good 1	Good 2
Home	1	1
Foreign	6	4

Table 1: Unit Labor Costs

It is easy to work out that in autarky at home consumption of each commodity is 50 units while abroad consumption of the relatively expensive first commodity is only 40 units with consumption of the second commodity being a greater 60 units. Free trade

[6] That is, the common utility function is $U = (C_1C_2)^{1/2}$. In a diagram such as Figure 1 the elastic stretch of the home offer curve, CH, would be replaced by a vertical line from C, and for the foreign country by a horizontal line from C*.

allows each country to specialize completely in the commodity in which it has a comparative advantage and consume at free trade prices that will lie between the autarky prices in each country. If commodity 2 is taken as numeraire, free-trade p_1 would be 6/5 because the foreign country is producing 120 units of commodity 2 and the home country is producing 100 units of commodity 1 with equal expenditure shares. Table 2 exhibits free trade consumption figures (with autarky consumption shown in parentheses). The second commodity has become relatively less expensive to home buyers, thus allowing consumption to expand from 50 to 60 units, while abroad it is the first commodity that has its relative price reduced, allowing good 2's consumption to rise from 40 to 50. Each country gains from free trade.

	Good 1	Good 2
Home	50 (50)	60 (50)
Foreign	50 (40)	60 (60)

Table 2: Free Trade (Autarky) Consumption

Now consider the effects on a free-trade equilibrium of a gift or transfer of technology by the home country only in the commodity in which it initially has a comparative advantage (commodity 1). This is a huge transfer – it lowers the unit labor cost of the foreign country six-fold, from 6 to 1. The ranking of commodities by comparative advantage gets reversed. The consequence for the home sector producing the first commodity is admittedly very severe (even more so than suggested by the Schumer-Roberts quote) – it gets wiped out. If it were to be specialized in the first commodity, the foreign country could now produce 480 units, but this would exceed the world demand at a world price ratio given by the autarky ratio in the foreign country. Hence the foreign country must be incompletely specialized in the new equilibrium. Despite the fact that the foreign country's price ratio reverts to what it would be in autarky, the technology transfer has hugely increased its welfare, as reflected in Table 3's illustration that consumption of the first commodity has increased from 50 units (in the original free-trade situation) to 240 units after technology transfer. This figure, although large, fits the not-surprising situation in which the foreign country receives such a huge productivity boost. But consider the situation in the home country, in which employment in the original export sector has vanished. The home country now shifts its entire labor force to the second sector. The relative price of this sector has increased, inducing a reduction in consumption from 60 to 50 units, but consumption of the first commodity has increased four-fold, from 50 to 200 units.[7] In the appendix we derive the exact condition for the home country always to gain from the transfer, namely that the absolute advantage in producing the new import commodity be sufficiently great because that is the one that will be exported after the gift of the home country's even more superior original export commodity (1).

	Good 1	Good 2
Home	200 (50)	50 (60)
Foreign	240 (50)	60 (60)

Table 3: Post (Pre) Technology Transfer with Free Trade

[7] According to the Cobb-Douglas utility function, $U = (C_1C_2)^{1/2}$, the gain from trade before the transfer was 9.5%, but after the transfer rises to 100% [$(50x50)^{1/2}$ = 50 vs. $(200x50)^{1/2}$ = 100].

Although this example is extreme, the economic reasoning is fundamental. A transfer of technology (willingly or not) in a country's export sector may have severe consequences for production in that sector, but when resources (here laborers) are mobile, the shift towards the new sector that emerges with the greater comparative advantage *may* result in an increase in the country's well-being, even if no payment is made for the technology transfer. In the United States over the years positions of comparative advantage in such industries as manufacture of television sets (or automobiles) have been lost, but workers driving home in their Subaru RV's to watch the Super Bowl on their new Sony plasma TV have little cause for complaint. Cheap imports, whether once exported or not, are the source of the gains from trade.

6. Concluding Remarks

The remarks by Schumer and Roberts quoted in the introduction are shared by many, both in the United States and in other developed countries. International trade in commodities has traditionally been criticized for its disruptive force in labor markets, especially when standard rankings according to comparative advantage get rearranged. In recent years the critics of "globalization" have become more vocal since lowered costs of transport, communication and other service links have encouraged greater degrees of outsourcing of entire production processes or fragments thereof. Concomitant with these changes in some cases has been the acquisition by less developed countries of technology pioneered in other countries and superior to their own local productivity levels. Such technology seems to be transferable more easily than in previous years, either because of activities of multinational companies or because of arms-length transactions perhaps with the help of better-educated foreign workers and management who may have been trained in more developed countries. In this paper we have explored the consequences of technology transfer in an extremely simple trade model whose focus is indeed the difference between countries in relative and absolute productivities.

However transferred, technology is different from standard commodities in that it is like a public good – use of it by others need not preclude its use at home. In our analysis we have by-passed the question of the *terms* under which technology is transferred by assuming that foreigners make no payments. This might set up the presumption that they will gain and we will lose by the transfer – they get something for nothing from us. That just the opposite might happen was illustrated early in the paper for the scenario in which we have a superior technology in the commodity that we import, and freely allow foreigners access to that technology. We gain by the resulting improvement in our terms of trade, and if such a relative price change is sufficiently great, welfare levels abroad could even be reduced. This is the case of immiserizing growth, one of the more celebrated "chestnuts" found in every international text, although most would argue that both countries would benefit from such a sharing of the technology. A greater surprise may be attached to a case in which superior technology in what is currently the export sector at home is transferred and this causes the home country to lose its comparative advantage in that sector. It *may* be the case that the new export sectors thus created leave workers who have left their old jobs even better off than if home superior technology had been kept secret. However, one advantage that critics such as Schumer and Roberts possess lies in their focus on jobs that are lost, and not on the subsequent adjustment that creates new employment possibilities. Once again, the subtle mysteries of the laws of comparative advantage are required to understand the way in which international markets work.

Appendix

The purpose of this Appendix is to clarify the role of technology transfer in the home country's export good. As in the text, we assume the home country has a comparative advantage in producing the first commodity, although an absolute advantage in producing both commodities. The setting, as before, is the Ricardian model, and we maintain as well the assumption that both countries share the same Cobb-Douglas utility function with the same expenditure share on each commodity. The original (pre-transfer) array of relative labor coefficients is shown in (1):

(1) $1 < a_2^*/a_2 < a_1^*/a_1$

Furthermore, it is assumed that differences between countries in productivities are a reflection of different blueprints (instead of different inherent or acquired labor skills, climate, or the existence of any co-operating factors). These blueprints can be sold or, as we assume, given away (or stolen) without payment. We let *p* denote the relative price of the first commodity.

The actual pattern of production, in both the pre-transfer situation as well as after the technology gift, depends upon whether each country is completely specialized or whether one of the countries produces both commodities in equilibrium. Before examining this issue note that in the pre-transfer situation the home country will always produce at least some quantity of the first commodity. After transfer of home's technology for producing the first commodity, the pattern of *comparative* advantage changes, with the foreign relative cost of producing the first commodity now falling short of that in the home country. This array is shown in (1'), where a prime represents post-transfer values:

(1') $1 \ (= a_1{*}'/a_1) \ < a_2{*}/a_2$

Now consider per-capita utility levels at home (and, later, abroad). The utility function is $(c_1c_2)^{1/2}$, where the c_i represent per-capita consumption of commodity *i*. Equal expenditure shares require c_1 to equal (1/2) (w/p) and c_2 to equal (1/2)w, so that per-capita utility at home is shown by (2):

(2) $u = w/2p^{1/2}$

(The same expression holds in the post-transfer situation, although the equilibrium terms of trade will differ).

In the pre-transfer situation the home country produces some of the first commodity, establishing the wage rate. In the post-transfer situation it produces the second commodity. Therefore pre-transfer and post-transfer wage rates are shown by:

(3) $w = p/a_1 \qquad w' = 1/a_2$

Primes denote post-transfer values. Substituting these values into the per-capita utility function shown in (2) yields the following expressions for pre- and post-transfer utility levels at home:

(4) $u = p^{1/2}/2a_1 \qquad u' = 1/2a_2(p')^{1/2}$

Note how in the pre-transfer situation, in which the home country is an exporter of the first commodity, an increase in *p* represents an improvement in its terms of trade and thus raises utility levels. By contrast, the post-transfer situation reveals that the home country imports the first commodity, so that an increase in its relative price serves to lower utility.

We are concerned with the question, does the home country gain by such a transfer of the blueprints for producing the first commodity, which was initially exported by the home country, even if it receives no compensation in return? Let *g* represent the ratio of post-transfer to pre-transfer utility, so that:

(5) $g \equiv u'/u = a_1/a_2(pp')^{1/2}$

Note the important role played by the geometric mean of pre- and post-transfer relative prices, $(pp')^{1/2}$. In order for the home country to gain by such a transfer, this geometric mean must fall short of the home country's original autarky price ratio, a_1/a_2. We comment on this condition later.

The analysis of per-capita utility levels abroad follows a similar logic. Noting that before transfer they produce the second commodity and afterwards the first (with labor input ratio given by a_1), their pre- and post-transfer wage rates are shown in (6):

(6) $w^* = 1/a_2^*$ $\qquad w^{*\prime} = p'/a_1$,

so that foreign utility levels are given by

(7) $u^* = 1/2a_2^*p^{1/2}$ $\qquad u^{*\prime} = (p')^{1/2}/2a_1$

Letting g* indicate the relative improvement in foreign utility levels,

(8) $g^* \equiv u^{*\prime}/u^* = a_2^*(pp')^{1/2}/a_1$

Once again the role of the geometric mean of the two relative prices is revealed. An increase in this mean serves to increase g^* and to reduce home g. Indeed these rates of increase are mirror images of each other, as shown by their product in (9):

(9) $gg^* = a_2^*/a_2$

This product is a constant. It is the index of the productivity advantage the home country possesses in producing the second commodity, that in which the foreign country has an initial comparative advantage, although an absolute disadvantage. The product, gg^*, is thus greater than unity, revealing that the world gains by the technology transfer. Not surprisingly, we easily show later that the foreign country gains by such a transfer, leaving open the possibility that the home country might gain or lose.

The missing piece in these remarks is the value of the equilibrium price ratios before and after transfer. Much depends on relative country size, since a strong asymmetry between countries in this regard showers all the gains from trade on the relatively small country (relative to productivity differences between countries), with the price ratio reflected in the autarky comparative cost ratio in the large country. Consider, first, the situation before transfer. Given the Cobb-Douglas utility functions, it is possible to show that both countries will be completely specialized (home in commodity 1 and foreign in commodity 2) if relative country size, L^*/L, is bounded as in (10):

(10) $a_2^*/a_2 < L^*/L < a_1^*/a_1$

(The home country's absolute advantage in both goods implies that the foreign country must have a larger labor force.) World demand for the first commodity, $(1/2p)[pL/a_1 + L^*/a_2^*]$, will be at a maximum value if prices are shown by the home autarky ratio, $p = a_1/a_2$. At this price ratio world demand is $(1/2)[L/a_1 + (a_2/a_1)(L^*/a_2^*)]$, which, by (10), exceeds maximal home supply, L/a_1. Therefore *p* must be greater than the home autarky ratio. The upper bound in (10) can be established in similar fashion. With both countries completely specialized in this range, the equilibrium price ratio is seen to be:

(11) $p = (L^*/a_2^*) / (L/a_1)$

This price takes on the home autarky level, a_1/a_2, for values of (L^*/L) smaller than these bounds, and the foreign autarky level, a_1^*/a_2^*, for values of (L^*/L) larger than a_1^*/a_1. In the range shown by (10), for given labor force at home greater values for foreign labor must serve to improve the home country's terms of trade and its per-capita utility.

Turning, now, to the situation after the transfer of home technology in producing the first commodity, the range of relative labor supplies that entail each country being completely specialized with trade is lowered to that shown in (10'):

(10') $1 < L^*/L < a_2^*/a_2$

The foreign country has the same absolute advantage in producing the first commodity, but a comparative advantage in producing it – a switch from the ranking before the transfer. In this range supply and demand are brought into balance when

(11') $p' = (L/a_2) / (L^*/a_1)$

Should the foreign labor supply be smaller than that at home, the home country becomes incompletely specialized, with *p* reflecting the home autarky ratio, a_1/a_2. At the other bound, where L^*/L exceeds a_2^*/a_2, *p* reflects the foreign autarky ratio (after transfer), a_1/a_2^*.

Figure 4 collects this information about the values of the equilibrium commodity price ratio before and after transfer, and how they are dependent upon relative country size. Note that as far as the home country is concerned, having a larger foreign country serves to improve its terms of trade (if the price ratio moves at all). Before the transfer this improvement is an increase in *p*, since it exports the first commodity, and, after transfer and the switch in the pattern of trade, it is a reduction in *p*. Thus the curve *p'* shows the home country's terms of trade improving if L^*/L is less than a_2^*/a_2, but remain constant for relatively higher foreign country size (since it would then be incompletely specialized.) As the expressions for per-capita utility in each country emphasize, in (5) and (8), the behavior of the geometric mean of these two price series matters. This (dotted) curve in Figure 4 falls in the early range, and rises when L^*/L is in the range indicated by (10). It is always greater than a_1/a_2^*, confirming, by equation (8), that the foreign country always gains by receiving these blueprints without having to pay.

Concentrate, now, on the possibility that the home country can gain as well by such a technology transfer. The criterion for this to happen is provided by requiring the value in equation (5) to exceed unity, or

(12) $g > 1$ iff $a_1/a_2 > (pp')^{1/2}$

This is clearly satisfied in the range between unity and (a_2^*/a_2) in Figure 4. The rationale is simple: In this range before transfer the home country is incompletely specialized and does not gain from trade. A transfer of technology creates trade, with the home country importing the first commodity. Therefore it gains. By continuity, for some values of

(L^*/L) above (a_2^*/a_2) the geometric mean is also small enough to ensure gains. Here the home country originally is completely specialized to the first commodity, which it exports, but the technology transfer causes the home country to switch production completely to trade at the foreign country's new autarky level ($p' = a_1/a_2^*$), and it gains by this transfer. However, increases in (L^*/L) imply that originally the home country had larger gains from trade, making it more difficult to have the technology transfer represent a net home gain over this larger level. The geometric mean obviously achieves its maximum level for high enough (L^*/L) that the foreign country is incompletely specialized both before and after the transfer. In Figure 4 the numbers chosen for the technology in each country have been selected so that the maximum value for the geometric mean corresponds exactly with (a_1/a_2). Substitution of the associated values of *p* and *p'* for those values of (L^*/L) leads to the conclusion that *regardless* of how large, relatively, the foreign country is, the transfer of technology leads to both countries gaining if:

$$a_2^*/a_2 > (a_1^*/a_1)^{1/2} \qquad (12)$$

Figure 4 illustrates the borderline case in which an equality holds in (12).

The meaning of criterion (12) is clear: If the commodity in which the home country possesses a comparative disadvantage is not too far in its relative cost from the commodity in which in has a comparative advantage, it would benefit the home country to make its superior technology in its best commodity available, even at no charge, to the foreign country. For the particular form of utility functions we have assumed, criterion (12) takes the form of comparing the ratio of foreign to domestic costs for the original import commodity to the square root of the (larger) cost ratio for home's original export commodity. If this criterion is satisfied, technology transfer is to the home country's benefit regardless of how much larger the foreign labor force is. Figure 4 illustrates the borderline case. In any case, as Figure 4 illustrates, such a transfer must benefit the home country as long as the foreign country is not too much larger than the home country.[8]

In asking about potential gains from such transfer to the home country, two characteristics of technology are crucial. First, it requires that the home country have an absolute advantage in both commodities. As Figure 4 illustrates, if (a_2^*/a_2) moves leftwards towards unity (so that technological requirements for producing the second commodity are the same in the two countries), the geometric mean of the prices always exceeds home (a_1/a_2) and the home country cannot gain by the transfer. As well, if the home country's relative superiority in producing the first commodity should be even greater than shown in Figure 4, the home country would not benefit by the transfer for values of (L^*/L) exceeding the square of (a_2^*/a_2). Thus two aspects of the technological comparison between countries in the commodity originally imported by the home country are important: (i) the extent of home's absolute advantage in this commodity and, for relatively large labor supplies abroad, (ii) how close the productivity comparison is with the corresponding ratio for the commodity initially being exported. If this is not close (i.e. if inequality (12) is not satisfied), for relatively large values of (L^*/L) trade in the pre-transfer case in which the home country's exports of the first commodity are so extensive that the gains from trade exceed what would be obtained if the transfer caused the home country to switch its trade pattern.

[8] This result perhaps gives a new meaning to the theory of the *second best*.

Although a particularly simple form for utility functions has been assumed, the qualitative characteristics of our results hold more generally. The initial trade pattern may lead to few or no gains from trade if the home economy is relatively large (compared with its productivity superiority), so that a transfer of technology that benefits the foreign country may serve to encourage more gains from trade for the home country as it switches to its second best activity. But if initially there are large gains from trade from exporting the commodity in which it has the greater relative productivity, it may not be possible for home utility to be improved by the technology export that alters the pattern of trade.

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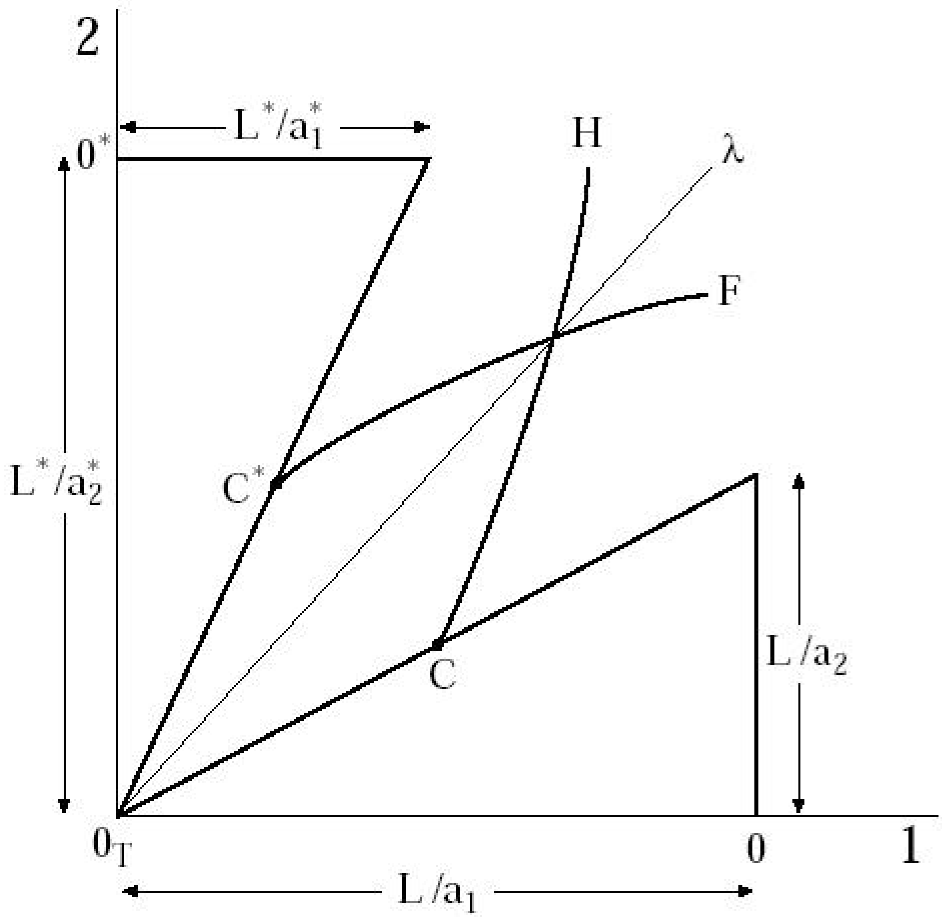

FIGURE 1: INITIAL TRADE

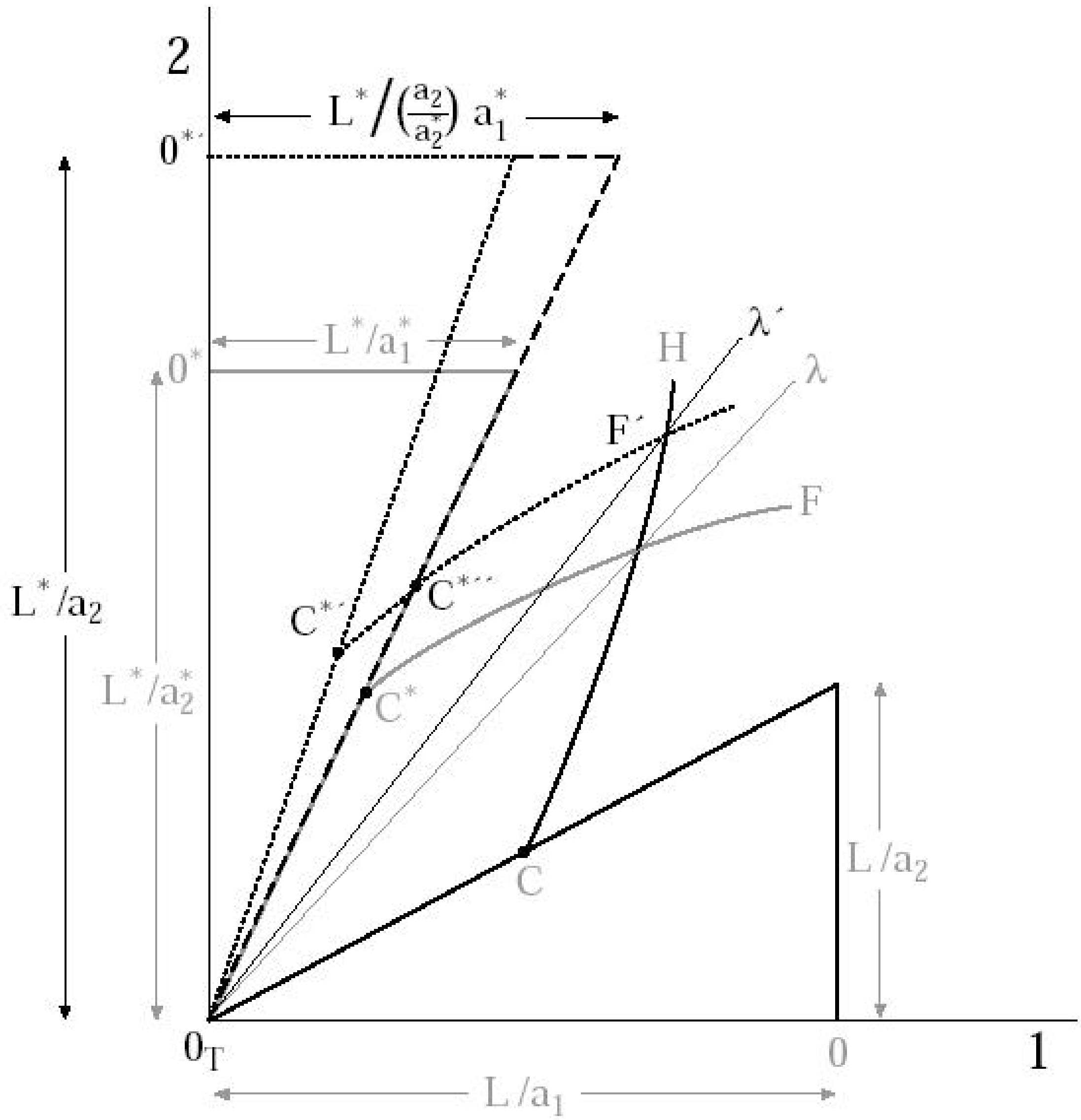

FIGURE 2: TECHNOLOGY TRANSFERS: IMPORTABLES

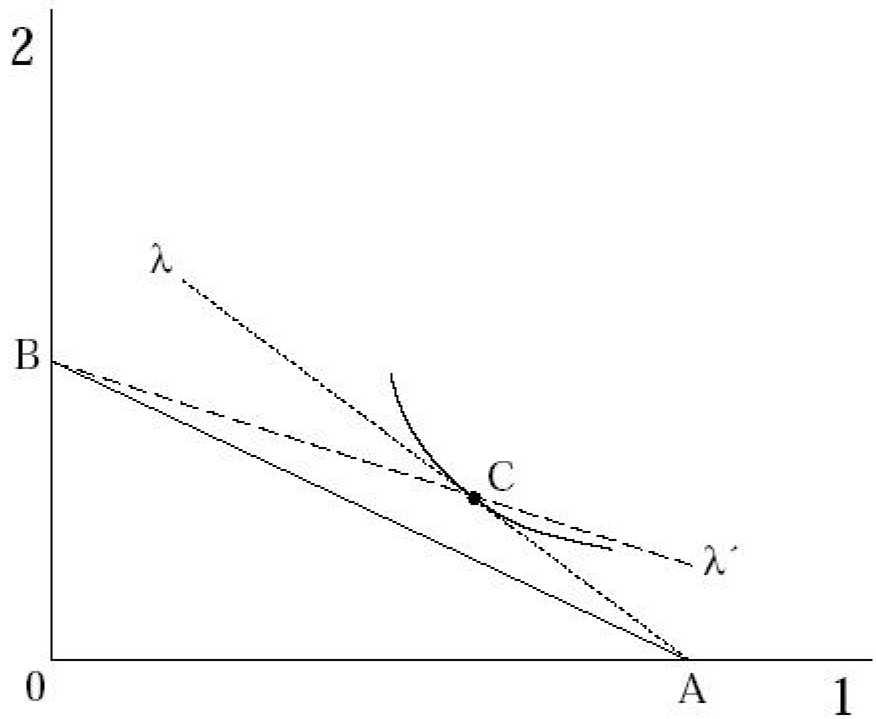

FIGURE 3: TECHNOLOGY TRANSFER: EXPORTABLES

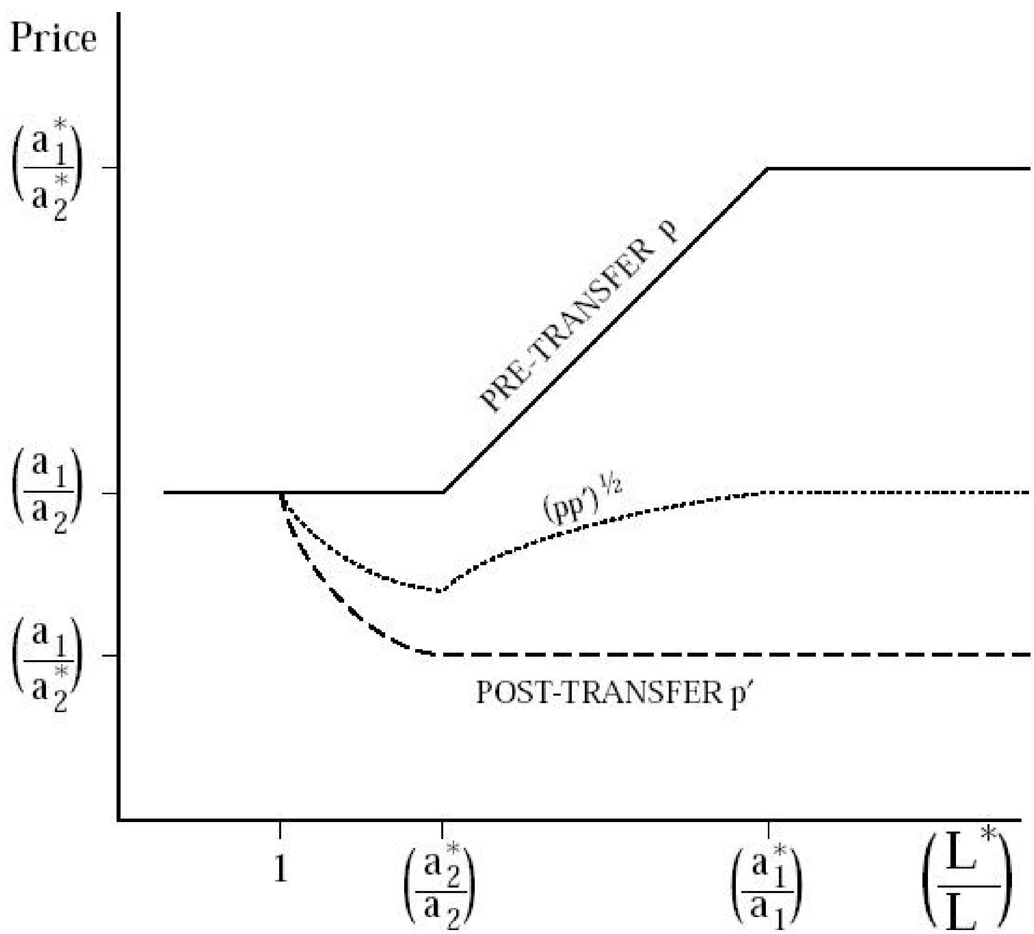

FIGURE 4: PRICE CHANGE WITH TECHNOLOGY TRANSFER