

On the “Technology Transfer” Paradox and “Worsening Terms of Trade” Paradox

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Abstract

This paper revisits some seeming paradoxes or puzzles in trade theory. We explore the so-called “technology transfer” paradox, which may be interpreted more generally in terms of what we call the “worsening terms of trade” paradox. We show both paradoxes are no more paradox than the Leontief paradox is. We also assert that, judging from the implications that international technology transfers have for the possible pattern of trade, the seeming paradoxes that require the pattern-of-trade reversals are less likely to occur under conditions of the Heckscher-Ohlin variable input proportions than under the Ricardian fixed proportions.

JEL Classification: D00, F10, F11

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1. Introduction

The present paper ponders on some paradoxes in trade theory. Of particular interest is what Jones and Ruffin (2005) call the “technology transfer” paradox. In our view it may be interpreted generally in terms of what we call the “worsening terms of trade” paradox. We hope to clarify and resolve both paradoxes.

Trade also provokes what may be called the “worsening terms” of *exchange*, which is more an *intra*-national than an *international* phenomenon. Yet this more *intra*-national, distributional conflict comes out as a stumbling block to international trade as

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suggested almost 70 years ago by Stolper-Samuelson (1941).¹ However, we must pass this classic question, referring to Ohta (2005), and confine our present attention to the more recent question involving some taxonomical subtleties.

In what follows Section 1 briefly examines as a starter what the so-called “worsening” (“improving”) terms of trade means, what paradox may be involved therein and how it may be resolved. Falling prices of an exportable good are conventionally labeled as “worsening terms of trade” in the literature. However, a large enough change in prices can reverse the *direction* of trade flows, and of welfare changes accordingly. Involved herein is a seeming paradox, called a “worsening terms of trade” paradox. Intertwined with this paradox is a more recent one called a “technology-transfer” paradox (Ruffin and Jones, 2005), upon which we ponder in Sections 2 and 3. We approach the “technology-transfer” paradox from two directions. The one assumes different tastes internationally in Section 2, and the other different factor proportions *intra*-nationally in Section 3 in any case to resolve the paradox.² The last section concludes, followed by an Appendix as a mathematical note on Section 3.

2. The “Worsening Terms” of Trade Paradox

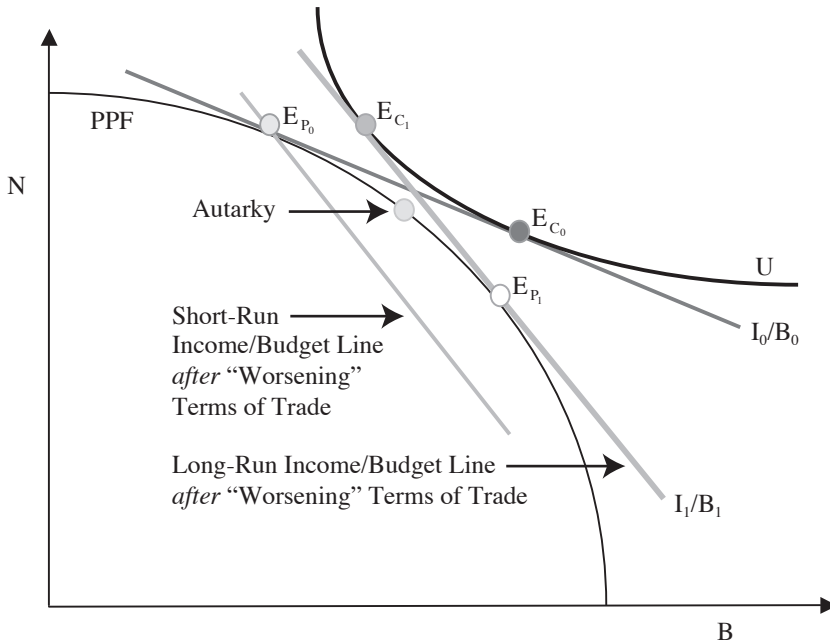
As a starter let us ponder what the so-called “worsening” terms of trade conventionally used really means. According to the convention the “worsening” terms of trade means a fall (or rise) in price of an exportable (or importable) good, which tends to decrease an exporting (or importing) nation’s welfare *monotonically*, with no reversal in trade patterns. However, if a fall in an exporter’s price is large enough, then the export sector may turn to, or be replaced by an import sector; and a nation can be better off as an importer of the good whose price is low enough.

Figure 1 illustrates this point. Depicted herein are a 2-sector aggregate economy with a production possibility frontier PPF, income/budget lines (I/Bs), and related productive and consumptive optima (E_P and E_C). The graph shows how one’s (or a nation’s) productive optimum (E_P) is identified along the “income line” (income identification line, I), and the consumptive optimum (E_C), by comparison, along the budget line (B). Note that the income line here is defined as a line *either* tangent to *or* intersecting with the production possibility frontier. It identifies income as a varying product mix, with relative price incorporated into it as its slope. The income line, which is tangent to PPF, identifies not only one’s income, but also the optimal product mix at the tangency point, called productive optimum (P_E). One’s product mix at productive optimum E_P can readily be transformed to the consumptive optimum E_C at a point along the income line, which in turn turns to the budget line, under free trade.

¹ According to *Business Week*, Dec 6, 2004, the same Paul Samuelson went on even further to say, “comparative advantage cannot be counted on to create... net gains greater than the net losses from trade.” His concern, among other prominent trade experts’, seems to be high-skilled workers in the developed countries rather than the low skilled, who are going to be “exposed to international competition.” They may turn poor under free trade, “although it’s not clear how much it will hurt their wages,” as Jagdish Bagwati is quoted as saying.

² In our discussion here, no country is subject to distortions or variable returns to scale. For these cases, see Chao and Yu (1991) and Choi and Yu (1987).

Figure 1
The “Worsening” Terms of Trade Paradox



The two lines identifying income (I) and budget (B) are thus analytically the same, albeit they are to be conceptually distinguished from each other. Upon optimization an income line identifies one’s productive optimum. Given the productive optimum, free trade enlarges one’s consumption possibility set strictly beyond the production possibility set, and the related consumption possibility frontier should be called “budget line” rather than “income line”. “Consumptive optimum” is to be defined on the budget line, and “productive optimum” on the income line.

It warrants mention that the product mix need not always be optimal. Product prices may change drastically after production, say, at E_{P_0} , but the given product mix may no longer be an optimal mix. The income line may no longer be tangent to, but instead pass through the product mix at E_{P_0} . Such an income line depicts a short-run phenomenon, however. One can determine along the line the short-run consumptive optimum, but it is to be distinguished from an optimal consumption mix in the long run.

Now suppose along this short-run *vis-à-vis* long-run context that the relative price of, say, nuts in terms of bananas represented by the slope of an income/budget line I_0/B_0 fell to a level given by the slope of I_1/B_1 . Then the economy under consideration must undergo the following changes. In the short run the structure of production remains the same, and the subject remains an exporter of nuts, thereby suffering from the “worsening” terms of trade. But in the long run it must transform itself from a nuts exporter to a nuts

importer, thereby producing optimally at E_{P1} and consuming optimally at E_{C1} . Note that Figure 1 depicts no change in utility represented by an indifference curve U before and after price change in the long run.

This is deliberate so it can be seen immediately that a sufficient fall in price will induce productive optimum to be moved to the right of E_{P1} along the PPF, and national welfare must be raised strictly above the U level in Figure 1. Therefore, “worsening” terms of trade, albeit bad luck in the short run, could prove to be good luck in the long run. Just a “change” in price, be it either a fall or a rise, would suffice to show a varying degree of benefit from trade in any case.

If a large enough change in price under given production possibilities set (PPS) could cause a reversal in trade patterns with no necessary welfare deterioration, a large enough expansion of the PPS (called “ultra-biased technical progress” in the literature), by comparison, may cause no reversal in trade patterns even if it resulted in a related fall in an exportable good. In any case, welfare need not fall either directly or monotonically from falling prices of an exportable good.³ Calling changes in prices either “worsening” or “improving” terms of trade while observing a given sector of production, therefore, is a misnomer.

3. The “Technology Transfer” Paradox

What if Countries have Different Tastes?

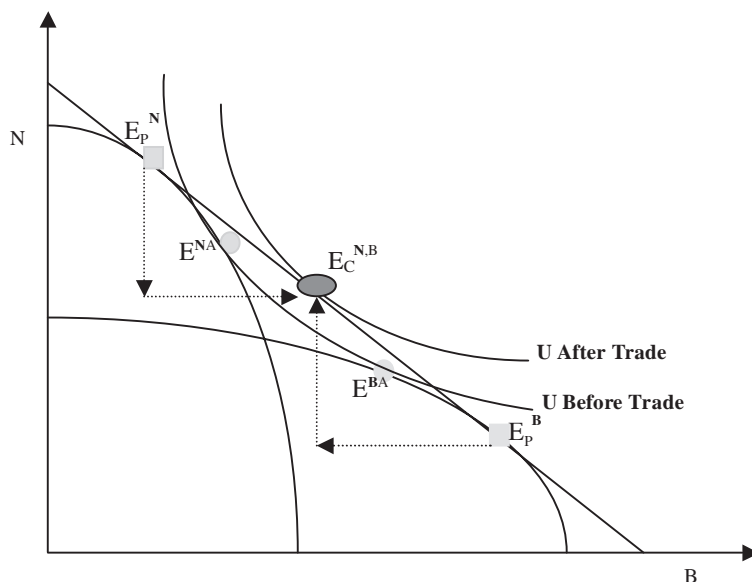
If “worsening terms of trade” is a misnomer, so are some paradoxes in trade. The Jones-Ruffin “technology transfer paradox” may indeed be no more a paradox than the so-called Leontief paradox. More precisely put, both can readily be interpreted within the confines of classical 2x2 Heckscher-Ohlin (HO), Stolper-Samuelson (SS) trade models. As shown by Ohta (2005), taste differentials can be incorporated into a simple 2x2x2 general equilibrium model of trade to account for, among other things, the Leontief paradox.⁴

Consider two countries, labeled N and B, producing nuts and bananas. Assume that N is endowed with more capital and less labor than B. The two nationals share the same tastes for the produces under consideration. The production functions for each good ($i = N, B$) are identical for the two countries and are linear homogeneous with variable factor proportions. Also assumed, as in Figure 2 below, is that Sector N is capital intensive and Sector B is labor intensive in both countries.

³ The so-called “ultra-biased technical progress” and related “immiserizing” growth is due to Harry G. Johnson (1967) and J.N. Bhagwati (1958).

⁴ Kwan Choi (2002), by comparison, uses a *multi*-sector (of more than two) model of trade to criticize the 2x2 HO model for empirical relevance.

Figure 2
The HO Orthodoxy



Derived from these basic assumptions are the following autarky equilibria identified as E^{NA} and E^{BA} on the production possibility frontier PPF of Country N and that of country B. If free trade is introduced, then Country N exports nuts N, and Country B exports bananas B. Country N's capitalists and Country B's workers gain and the other classes lose after trade.⁵

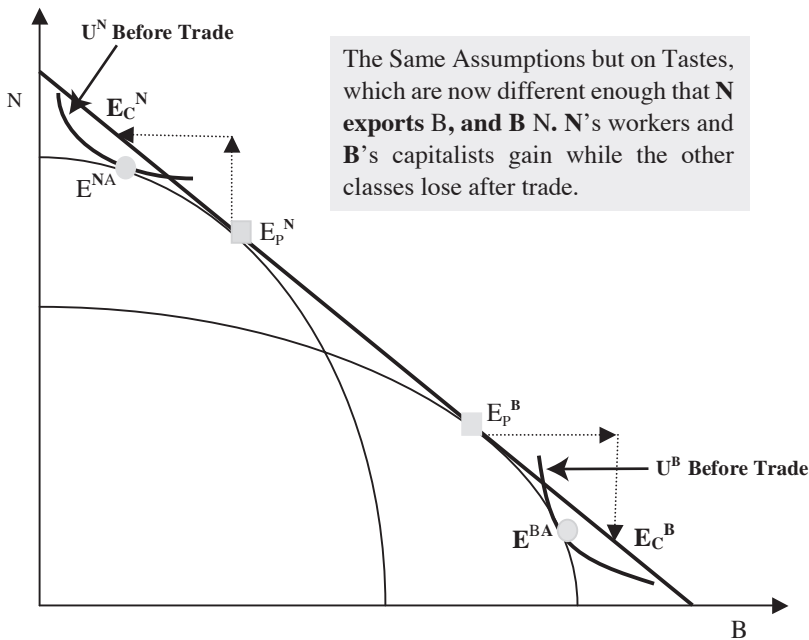
We now turn to a non-HO model, *alias*, HO (Hiroshi Ohta) heresy, which is predicated on the same assumptions as HO's except that tastes are different between the two trading nations. Then it follows that the familiar HO theorem remains unaltered if the taste differences between the two nations remain small enough. But if and when tastes become sufficiently different for the two nations as illustrated by Figure 3, then the HO theorem is reversed and the Leontief paradox resolved. It is its labor-intensive sector that is to be the capital-rich country's export sector, and capital-intensive goods N are to be imported. A capital-rich country importing capital-intensive goods may thus be more *capital poor than capital rich*. If a seemingly capital-rich national has a strong

⁵ These outcomes follow inasmuch as total factor endowment *in terms of capital* for a capital rich country decreases, and that total factor endowment *in terms of labor* increases, after trade; and opposite relations apply to a labor rich country after trade. Trade thus helps the labor abundant country to become less labor abundant, and the capital rich country less capital rich in the classic HO model, which relations are apparent from the national income distribution identity given by $y = wL + rK$. Note that after trade, the relative factor price changes while factor endowments remain constant. Thus, for example, if w/r decreases after trade, then $(w/r)L$ declines while K remains constant so that the total factor endowment for a capital rich country declines *in terms of capital* after trade in HO framework of thought. In other words, after a trade capital rich country's national income increases in wage units and decreases in rental units.

taste for a capital-intensive good, then they need more capital than a seemingly capital-poor nation with a strong taste for labor-intensive goods. So we propose the following.

Proposition: An asymmetric taste differential among trading nations can bridge the Hecksher-Ohlin theorem and the Leontief paradox. (Or the Leontief paradox can readily be resolved within the confines of the Hecsher-Ohlin framework if international taste differentials are large enough.)

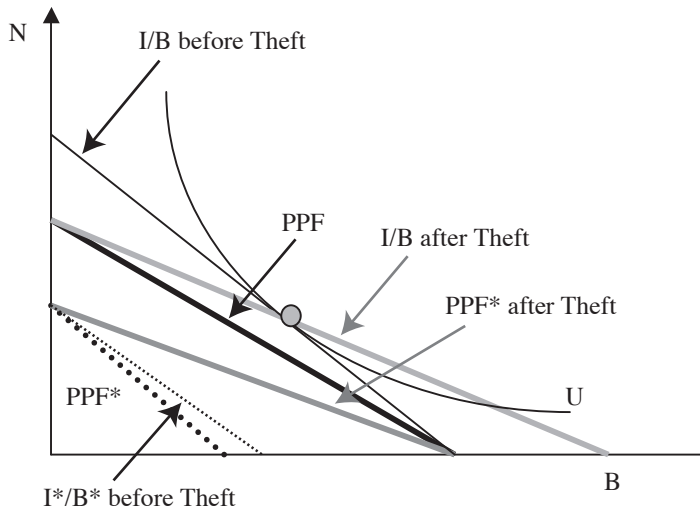
Figure 3
Non-HO Unorthodoxy: The Leontief Paradox Resolved



We now get to a more recent paradox: the technology-transfer paradox *a la* Jones and Ruffin (2005), which is also predicated on an n -sector model of trade, does not require n to exceed 2. This is because a large enough change in terms of trade alone would suffice.

Seemingly *worsening* terms of trade may occur upon break-through innovation abroad, property right transfers even by theft, capital or human-capital flight, financial asset transfers by market speculations, or even a traffic accident at a personal / individual level. But these seemingly disparate examples of radical changes in national or individual endowments have something in common: a related reversal in comparative advantage. The technology transfer paradox *a la* Ruffin and Jones (2007) and Jones and Ruffin (2005) is a focal point to be interpreted simply by Figure 4.

Figure 4
Technology Transfer Paradox *a la* Ruffin-Jones



Following Ruffin and Jones' Figure 3, let us consider a simple two-factor, two-sector, two-country model of trade. Methods of production in two sectors are assumed to be identical in terms of factor ratios in both countries so that their production possibilities frontiers are all linear,⁶ though not needed. Home countries are assumed to have absolute advantages over foreign countries in both sectors, albeit each country having their own comparative advantage. Ruffin and Jones ask what happens to home country's welfare if their absolute advantage in the production of B is lost, say, by theft of technology by a foreign country. Figure 3 assumes that given the home country's solid PPF and the foreign country's dotted PPF* as shown, the home country had *before theft* not only absolute advantage in B, but also comparative advantage therein. So, the home country specializes in the production of B for export, and trades it along the solid I/B line in exchange for N for import. The foreign country, by comparison, specializes in N, and trades it along the dotted I*/B* line in exchange for B for import.

The theft enables the foreign country to produce as many bananas as the home country can. What devastation to the home country, one might lament. Not quite. Figure 4 illustrates how an apparent tragedy may prove to the contrary, as both countries can benefit from a Pareto-Improving theft in effect. Underlying reasons are straightforward to appreciate. Note that the theft under consideration raises the foreign country's productivity while the home country's productivity remains unchanged. If the foreign country catches up and comes abreast with home country in their comparatively advantageous sector, then it is the home country's advantage to change their specialization to the other sector provided that they still possess absolute advantage

⁶ This also requires the production functions to be linear homogeneous.

therein.⁷ Figure 4 shows that they would be strictly better off *after* the seemingly deteriorated terms of trade attributed to theft or any other exogenous factors, if only the rate of deterioration is large enough. The underlying reason is straightforward. Any benefit from trade must be higher if one's trade partner is more productive than less. It would rather be more surprising if the opposite were the case.

Consider this opposite case, the seemingly surprising outcome. Suppose the worsening terms of trade are not large enough, and the welfare level remains strictly lower than before the changes in terms of the trade that took place, not only in the short run but also in the long run. Is this outcome surprising or does it connote any detrimental effects inherent of free trade? The answer is negative in the sense that it only reveals the benefit of trade from any deviation of price, regardless of its direction (either a fall or a rise), from that given under conditions of autarky. The larger the change, the larger the gains from trade. Thus, if a big change in price happened to be followed by a change in trade patterns in an opposite direction, then it certainly is possible that one's welfare declines, but note that it still must be higher than under conditions of autarky unless the change leads them back therein (indicated on PPF, Figure 1).

3. The “Technology Transfer” Paradox

What if Countries Differ in Relative Factor Endowments?

In the Ricardian setting, as illustrated in Ruffin and Jones (2007) and Jones and Ruffin (2005), a transfer of its superior technology – in the production of commodities in which a donor country possesses a comparative (and absolute) advantage – implies a change in the comparative advantage ranking, and hence in the pattern of trade. Along with this reversal in the pattern of trade, as the recipient country makes use of the technology transfer and its production expands, welfare can actually improve for the donor country, generating a seemingly “paradoxical” outcome.

That being said, however, with a little extension (say, with an additional factor of production), it can be verified that the transfer of technology alone would not necessarily give rise to a trade-pattern reversal to begin with. When there is more than a single production factor, the comparative advantages of one country *vis-à-vis* other country and the pattern of trade ought to be gauged not solely on the basis of the differences in exogenous technological parameters, but also on the basis of the differences in relative factor endowments. Accordingly, for example, in the HO model that incorporates the technological progress parameters that are subject to change to accommodate technology

⁷ If the other sector's technology is also stolen, and both countries' PPFs become identical, then there will be no trade thereafter, and the stealer alone gains. Home country's welfare declines from loss of trade, but insofar as knowledge is a public good, having neither rivalry nor excludability in consumption (utilization), any welfare gain from trade may be considered as a “quasi” rent, to disappear in the long run with no rent seeking. Quasi-rent is defined in the literature as economic profit that disappears in the long run under the conditions of perfect competition, which include perfect information besides price-taking behavior of participants. An attempt to exclude knowledge from the ignorant makes an artificial barrier to consumption of a public good for own exclusive consumption of not only the public good in question, but also the private goods that the ignorant produces for the rich to rake in, albeit undeservingly, as a quasi rent.

transfers, the technology transfer paradox is less likely to emerge than in the Ricardian case.

In the Ricardian model, as described above, a technology transfer immediately brings about a trade-pattern-reversal situation, beyond which threshold donor's welfare starts to improve. By contrast, in the HO setting, a pattern of trade predicted by the model prevails even after the transfer, so long as the international technology gap in the unaffected sector is not too large. In other words, if a reversal in trade pattern were to cause the technology transfer paradox, the dominance of the relative factor endowments in determining the trade flow would have to be overturned in this case by the offsetting force driven by the technology gap. More details will be discussed in the Appendix, where a condition is derived for the transfer paradox to occur (or not to occur).

In light of the preceding discussion, confirmation of the following point, we believe, would make the "technology transfer" paradox appear less of a paradox. Underlying the seemingly paradoxical result is a large enough decrease in the post-transfer price of importable goods (i.e., the goods that would otherwise served as exportable in the pre-transfer situation) on the part of the donor country. In the absence of pattern-of-trade reversals, there will be no chance for the paradox. Indeed it sounds less paradoxical if one would capture precisely the implications the technology transfer may have for the possible trade-pattern reversal – as opposed to using a conventional expression such as the "worsening (or improving) terms of trade." Doing the latter, without any reference as to what is exported (imported) under what circumstances, could be misleading in the presence of potential trade-pattern reversal.

4. Concluding Remarks

In conclusion, there is no paradox involved when a large enough change in relative price called "worsening terms of trade" takes place along with the changes in one's comparative advantage and a related rise, not fall, in welfare. What is involved here instead is a large enough change in relative prices, without which the welfare gain must be smaller, and could even be negative, if either the comparative advantage failed to take place or it did take place but its magnitudes were small enough. But any small enough change in relative price with a lower welfare should be preferred to autarky. No paradox is involved herein. Nothing wrong, either. A radical economic change that may take place at home or abroad may not always be abhorred.

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Appendix

Derived below are conditions under which there would be no trade-pattern reversal, and hence no technology-transfer paradox. In other words, as deviation from the condition increases, it opens up the possibility of the technology transfer paradox to emerge.

The 2x2x2 setting considered here is identical to the Heckscher-Ohlin model with the values of the technological shift parameters that may be altered to accommodate the technology transfers. “Home” (donor country) and “Foreign” (recipient country) can produce good X (labor-intensive good) and Y (capital-intensive good) with a constant-returns-to-scale (CRS) technology using capital K and labor L . In Home country, the production functions are

$$X = A_X K_X^\alpha L_X^{1-\alpha}, Y = A_Y K_Y^\beta L_Y^{1-\beta}, \text{ where } 0 < \alpha < 1, 0 < \beta < 1, \text{ and } \alpha < \beta$$

$$L_X + L_Y = \bar{L}, K_X + K_Y = \bar{K}.$$

Likewise for the foreign country (marked with asterisks),

$$X^* = A_X^* K_X^{*\alpha} L_X^{*1-\alpha}, Y^* = A_Y^* K_Y^{*\beta} L_Y^{*1-\beta}$$

$$L_X^* + L_Y^* = \bar{L}^*, K_X^* + K_Y^* = \bar{K}^*.$$

Assuming that the home country is relatively abundant in capital (and foreign country in labor), the relative factor endowments in respective countries are such that

$$\frac{\bar{K}}{\bar{L}} > \frac{\bar{K}^*}{\bar{L}^*}, \text{ also expressed as } \bar{k} > \bar{k}^* \text{ in per capita term.}$$

Consider now the technological shift parameters in the pre-transfer situation with a specification as follows:

$$A_X > A_X^*, A_Y > A_Y^*, \text{ and } \frac{A_Y}{A_X} > \frac{A_Y^*}{A_X^*}$$

As can be seen, it is assumed that the donor possesses superior technologies, in the sector producing exportable goods in particular.⁸ Once a technology transfer – in our case a Home-to-Foreign transfer of the superior technology by which the Home exportable is produced – takes place, it is analytically tantamount to replacing A_Y^* with A_Y as the recipient country adopts the technology. Now, under what circumstances, would the pattern of trade (i.e., capital-abundant country exporting capital-intensive good and labor-abundant country exporting labor-intensive good) be retained even after

⁸ We deal with this particular array of technology parameter values; otherwise the problem will be a degenerated one. For example, if the values are assumed to be identical between countries, then a productivity shock in donor’s exportable and its subsequent transfer to the recipient would not lead to trade-pattern reversals – therefore no technology transfer paradox involved.

the transfer? Given a standard form of utility function, it would suffice to show that the following inequality holds for any given price.^{9, 10}

$$(A1) \quad \frac{Y}{X} > \frac{Y^*}{X^*}.$$

Here, and henceforward, the primed symbols represent post-transfer variables. This inequality (A1) can readily be rewritten, in consideration of the production functions above, as follows.

$$(A2) \quad \frac{A_Y}{A_X} \left(\frac{\beta(1-\alpha)}{\alpha(1-\beta)} \right)^\beta k_X^{\beta-\alpha} \frac{\lambda_Y}{\lambda_X} > \frac{A_Y}{A_X^*} \frac{\beta(1-\alpha)}{\alpha(1-\beta)}^\beta k_X^{*\beta-\alpha} \frac{\lambda_Y^*}{\lambda_X^*}$$

where $\lambda_X = \frac{L_X}{L}$, $\lambda_Y = \frac{L_Y}{L}$, $\lambda_X^* = \frac{L_X^*}{L^*}$, $\lambda_Y^* = \frac{L_Y^*}{L^*}$,

$$k_X = \frac{K_X}{L_X}, \quad \text{and} \quad k_X^* = \frac{K_X^*}{L_X^*}.$$

In order to explore inequality (A2) deeper, we will use equations (A3), (A3)' and (A4) below.

$$(A3) \quad \lambda_X = \frac{k_Y - \bar{k}}{k_Y - k_X}.$$

This result obtains from calculating the marginal product of each factor in two sectors, and equating wages (rents) in the two sectors in each country.

Next, according to the standard HO model, it is straightforward to confirm that the following should be the case.

$$(A3)' \quad k_Y = \frac{\beta(1-\alpha)}{\alpha(1-\beta)} k_X.$$

Also, commodity price equalization under free trade governs the linkage between the labor-capital ratios for Home and Foreign; the linkages in the pre- and post-transfer situations, respectively, are:

$$(A4) \quad \frac{A_X}{A_Y} k_X^{\alpha-\beta} = \frac{A_X^*}{A_Y^*} k_X^{*\alpha-\beta} \quad (\text{pre-transfer situation})$$

⁹ On the consumer side, we follow Ruffin and Jones (2007) and maintain the residents of Home and Foreign share the identical Cobb-Douglas utility function with the same expenditure share on each good.

¹⁰ The general proposition about the exact effects of technology transfer – on the pattern of trade along with changes in the terms of trade, and consequently on the welfare level – depends on the form of utility function as well as on the amount of endowments available in each country. If anything is to be said clearly, it makes sense to sort out case-by-case situations: rather than searching for a condition that is sensitive to assumptions being made, we derive a sufficient condition under which the technological transfer paradox would not occur, regardless of the size of the countries.

$$\frac{A_Y}{A_X} k_X^{\alpha-\beta} = \frac{A_X^*}{A_Y} k_X^{*,\alpha-\beta} \quad (\text{post-transfer situation})$$

Substituting (A4) into (A2) yields

$$(A5) \quad \frac{\lambda_Y}{\lambda_X} > \frac{\lambda_Y'}{\lambda_X'}, \text{ that is } \lambda_X < \lambda_X'.$$

The use of equations (A3) and (A3)' above allows us to simplify inequality (A5) as:

$$(A6) \quad \frac{\bar{k}^*}{\bar{k}} < \frac{k_X^*}{k_X}.$$

Since the right-hand side of inequality (A6) corresponds to $\left(\frac{A_X^*}{A_X}\right)^{\frac{1}{\beta-\alpha}}$, which can be obtained by manipulating the second equation of (A4), the preceding inequality is now expressed as

$$(A7) \quad \frac{\bar{k}^*}{\bar{k}} < \left(\frac{A_X^*}{A_X}\right)^{\frac{1}{\beta-\alpha}}.$$

This is the condition that should be satisfied for the technology transfer paradox not to occur – in which case, as conventionally believed, the donor country becomes worse off when its superior technology in its exportable is made available to its trading partner. The inequality is more likely to be satisfied, the smaller the technology gaps in the production of good X, and the larger the differences in relative factor endowments between Home and Foreign. The possibility of transfer paradox grows otherwise, i.e., the smaller the differences in the factor endowment ratios, the larger the technology gaps in the unaffected sectors (producing X) and/or the smaller the sectoral gaps in output elasticities α and β .¹¹

¹¹ Note that as $\beta - \alpha$ approaches zero in the limit, the right-hand side of inequality (A7) becomes $\lim_{\beta-\alpha \rightarrow 0} \left(\frac{A_X^*}{A_X}\right)^{\frac{1}{\beta-\alpha}} = 0$. Also note that when $\beta = \alpha$ the problem boils down to just another case of Ricardian's because the parameters yield fixed input proportions in equilibrium, thereby turning the resultant production possibility frontier linear.