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Technology and Income Distribution Issues in Trade Models

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Neo-classical models of international trade have proved useful in the analysis of two kinds of income distribution effects of changes in growth and technology in a globalized world. With countries inter-connected by international trade, economic shocks such as improvements in technology that take place in a specific sector of a specific country are like stones thrown into a pond; not only do shocks disturb the originating sector and country, they also send out general equilibrium types of reverberations to other sectors and other countries. These reverberations affect both the distribution of income between countries and, as well, the functional distribution of income within trading regions.

Attention is often focused on wage rates (and/or unemployment), although that may take the form either of concern with the so-called double factorial terms of trade (the foreign wage rate compared with the home wage rate), or instead with how local wages fare compared with land rents or returns to capital or highly skilled labor. This paper pays special attention to the inter-country effects of technology shocks in a globalized trading world, and accentuates the usefulness of the standard Ricardian model of trade.

The Ricardian model was the one selected by Prof. Paul Samuelson in his celebrated 2004 paper in the *Journal of Economic Perspectives* in which he warned that some in the profession are perhaps too enthusiastic in promoting the widespread benefits of globalization without warning of the general result whereby one country’s growth may well harm the terms of trade of other countries who find price reductions and job losses in
their export sectors. In addition, countries without recourse to local energy sources may find their real incomes adversely affected by the high growth rates in countries such as China and India that serve to drive up prices of energy imports.

A general optimistic view of international trade and its positive effects in a globalized world is based in large part on a result concerning the gains from trade that is absolutely basic: Any country that is initially in a state of autarky can gain if it engages in relatively free trade with other countries. This is indeed a strong result, but it does not say that once a country is engaged in trade further enlargements in the degree of globalization must yield even larger gains from trade. That is, greater globalization may hurt some existing trading areas. Nevertheless, two recent papers (Ruffin and Jones, 2007, and Jones and Ruffin, 2008) have utilized the Ricardian model to show that even if a country is hurt by a small terms of trade deterioration, it may end up being helped if the deterioration shock is large enough. My purpose here is to discuss the basic nature of such results within a wider investigation as to the fall-out effects of technological change in one country (and one sector) on real incomes both at home and in the country’s trading partners.

The Ricardian trade model is characterized by a huge simplification: each country is capable of producing a variety of commodities by employing only the services of labor. Clearly unrealistic, especially coming from an economist also known for emphasizing differential land rents in agriculture, it has nonetheless proved its worth as a vehicle for economic reasoning for almost two hundred years. The model thrusts into prominence inter-country (as well as inter-commodity) differences in the “productivity” of a

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1 Samuelson’s article caused quite a storm in the popular press, e.g. see the New York Times coverage, Sept. 9, 2004. Samuelson’s article has frequently been interpreted as a criticism of trade theory’s support for free trade. More recently, it has been cited in the coverage of the U.S. 2008 primary presidential campaign (David Ranson, Wall Street Journal, February 6, 2008).
country’s inputs, with such differences providing the basis for the law of comparative advantage. “Technology” becomes an amalgam of all those characteristics that help to determine the quantity of labor that is required to produce one unit output of each commodity, characteristics that include training and education of the workforce and climatic conditions as well as a more narrow conception of technology embodied in “blueprints” or sets of instructions on how to apply labor in the production process. In discussing technology in this paper I shall assume that technical progress is represented by new and better sets of blueprints that may, via multinationals or other means, be made available to other countries, usually requiring payments, but also capable of being stolen or transferred without compensation.

A general question that can be asked and answered at the outset concerns the effect of a small improvement in the technology of producing the \( k \)th commodity in one country on another country that does not produce the \( k \)th commodity. First, assume that there is some other commodity that they both do produce in common, and that for convenience it is selected as numeraire. (Common production serves to lock their nominal wage rates together). Technology in each country thus establishes the initial wage rate in each and therefore the prices of all commodities produced in that country. Now suppose that in the country (call it Home) that does produce commodity \( k \) an improvement in technology reduces the labor coefficient for commodity \( k \), (which is not produced in Foreign). The price of the \( k \)th commodity faced by consumers is reduced in both countries by the extent of the relative size of reduction in labor costs in Home. The world must gain, with (for these two countries) the gain reflected in the sum of their two demands for commodity \( k \), \( (D_k + D_k^*) \), multiplied by the absolute value of the price reduction. In Foreign the real
income gain is $D_k^*$ (Foreign consumption) times the price reduction so that at Home real incomes are improved as well, by $D_k$ times the price reduction. Both countries gain; trading relationships serve to spread the world’s gain to all consuming countries, proportional to their consumption.² “A rising tide lifts all boats.”

The spillover effects just described would be seriously altered if two countries produce a commodity in common in the initial trade equilibrium and if one of these countries (only) experiences technology improvement in the production of the commonly produced commodity. As proved in Jones (1979), such a country must gain in real income by a greater amount than does the world as a whole; the other country must lose. This setting fits the description provided by Samuelson (2004) in which one country (China) improves its productivity in a commodity produced as well by the other country (United States). The U.S. would lose even if it is an importer of the commodity from China, since (assuming that commodity remains the numeraire) the Chinese wage rate would be bid up, and with it the prices of all goods exported to the U.S.

So far nothing has been said about conditions of demand. It was assumed that the two countries produced some commodity ($k$) in common, and this of course linked the wage rates in the two countries together, establishing all prices except for that of the commodity in which one of the countries had an improvement. However, countries need not produce any commodity in common, in which case the link between wage rates in the two countries would be severed. In such a case the pattern of demand becomes important. Suppose one of the commodities produced by Home experiences a labor cost reduction, further enhancing Home’s comparative advantage in that commodity. The

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² The transformation curve of the producing (Home) country shifts out, more than balancing the deterioration in its terms of trade. Further details for this and other cases of infinitesimal changes in technology are found in Jones (1979).
relative price of that commodity is reduced by the amount of the improvement compared with the cost and price of all other commodities produced by Home, and the profile of relative prices of all commodities produced in Foreign remains the same, except that the link between the wage rates (and thus price levels) between the countries depends as well on demand patterns. At initial Foreign prices the single price reduction at Home stimulates both a substitution effect and income effect in both countries’ demand for the bundle of commodities produced in Foreign. On the one hand, the price reduction at Home will tend to cause consumers in both countries to switch from consuming Foreign goods (and all other Home goods) towards the Home commodity that has gone down in price (assuming all commodities are substitutes). This substitution effect will tend to reduce the prices of all Foreign commodities along with Foreign’s wage rate. On the other hand, at initial prices the technological improvement represents an increase in world real income, shared by both countries (at the initial price), and this tends to increase all Foreign prices. A natural in-between case posits a balance between substitution and income effects – a result guaranteed if both countries share common Cobb-Douglas demand conditions.\(^3\) In what follows I maintain this demand assumption.

Although a country’s own research efforts are often responsible for improvements in productivity, an alternative involves the transfer of technology from an advanced economy to one with larger labor coefficients. Murray Kemp and Koji Shimomura (1988) pointed out that a country that has an absolute advantage in producing a

\(^3\) This was the assumption made by Dornbusch, Fischer and Samuelson (1977) to simplify their exposition of the continuum case. In reaction to this assumption, in Jones (1979) I examined both the case in which demand elasticities could be very low (leading to possible real income losses of the immiserizing growth variety for Home) or very high (making possible real income losses to Foreign). Subsequent analyses by Samuelson (2004), Ruffin and Jones (2007) and Jones and Ruffin (2008) simplified by retaining the assumption that demand in both countries exhibited constant and equal expenditure shares on all commodities, as in Cobb-Douglas.
commodity that it nonetheless imports because another country has a comparative (but not absolute) advantage in producing the commodity would gain if it sold its technology for producing that commodity.\(^4\) It could even gain if it gave the blueprints away! Why? Its terms of trade would improve. (On the other hand, if demand elasticities were sufficiently low the less advanced country could be immiserized by such a gift).

It might be thought that the logic behind such gains for transferring technology to produce a country’s imports would signal as well that any gift of the superior technology possessed for producing a country’s export commodity must, instead, lower real income in the giving country. Such logic was disproved in Ruffin and Jones (2007) for a two-commodity case. The argument was made in more simple terms in Jones and Ruffin (2008) for the case of many commodities in the Ricardian model. The key in either case is to assume that such a transfer of technology not only allows Foreign to become a competitive producer to Home’s own production, it would typically completely wipe out Home’s production of that commodity. Once the two countries share the same technology for producing one of Home’s original export commodities (in which it is assumed to have an absolute advantage or else technology transfer makes no sense), the higher-wage Home country loses its ability to compete at all in producing this commodity with low-wage Foreign. And it is this finite change in prices and wages that leads to the possibility that is counter to Samuelson’s scenario whereby if China gets a little better at producing a commodity produced as well by the U.S., but not enough to wipe out U.S.

\(^4\) This argument is also found in Beladi, Jones and Marjit (1997).
production, the U.S. loses. Large shocks that cause a country to change its production pattern can have a non-monotonic effect on real incomes.\textsuperscript{5}

To keep the discussion here within bounds I shall assume a two-country world, made up of Home and Foreign. This simplification still permits asking about the effect of one country’s productivity improvement on real wages and incomes of another country that also produces the same commodity without sharing the benefit of a reduction in the labor input/output coefficient. Although “comparative advantage”, as expressed in the relative labor costs of production in Home and Foreign, provides the key to patterns of trade, I shall adopt the stance of Jones and Ruffin (2008) and assume, first, that a unit of each commodity is defined as the amount that can be produced by a single unit of Home’s labor, second, that the numeraire is picked as any commodity produced at Home (so that Home’s nominal wage rate is unity), and, finally, that Home has an absolute advantage in the production of all commodities. That is, letting $a_j^*$ indicate the amount of Foreign labor required to produce a unit of commodity $j$, all foreign $a_j^*$ exceed unity.

Furthermore, suppose that if $n$ commodities can be produced in Home and Foreign,

\begin{equation}
    a_1^* > a_2^* > \cdots > a_n^* > 1
\end{equation}

That is, Home’s greatest comparative advantage lies in the first commodity, and its least in the $n^{th}$. Further to emphasize the potential paradoxical flavor of the outcome whereby a transfer of technology without compensation is made to Foreign, Jones and Ruffin (2008) assume that the technology that is passed on to Foreign (perhaps by Foreign theft)

\textsuperscript{5} Much of trade theory uses the calculus, and thus small shocks, in comparative statics exercises. This allows the pattern of production to remain the same. Given that international trade allows countries greatly to concentrate production to relatively few traded items, with large shocks (such as technology transfer) the pattern of production can easily be altered. See Jones (2008) for other examples (e.g. involving price changes, international capital flows, or fragmentation of production processes) of non-monotonic real income response to large shocks.
is for the first commodity, the one in which Home possesses its greatest comparative advantage.

The first result to be expected from such transfer is that if Foreign is large enough to satisfy world demand for the first commodity, it will become its sole producer. Foreign’s wage rate is lower than that at Home, so that Home would be uncompetitive in producing the first commodity if Foreign should obtain the superior Home technology. Could this possibly end up raising real wages (and real incomes) in Home? Yes, it could, but not necessarily. (Once more, the economist needs two hands – on the one and on the other). The key to unraveling the possibilities lies in the observation that the relative size of Home and Foreign, coupled with the profile of technology whereby Home has an initial absolute advantage in producing all commodities, determines Foreign’s relative wage rate. Generally speaking, in a diagram with the ratio of Foreign to Home wage rates on the vertical axis (and this reduces to $w^*$ since Home’s nominal wage is always unity) and the relative size of Foreign’s labor force, $L^*/L$, on the horizontal, the locus is roughly downward sloping, and would be precisely that in the continuum case popularized by Dornbusch, Fischer, and Samuelson (1977). However, assuming a finite number of commodities ($n$), wages in the two countries are locked together if they produce a commodity in common, whereas if there is no such commodity any increase in $L^*/L$ will drive down $w^*$ since Foreign’s production of all the commodities it produces will increase (for given home $L$), causing their prices to fall and, as well, $w^*$, until Foreign can once again compete with a commodity produced by Home. This behavior is captured in Figure 1, which is taken from Jones and Ruffin (2008). In the horizontal $BC$ range both countries produce the $k^{th}$ commodity. In the $AB$ range, Foreign’s wage is falling from
\((1/a_{k+1}^*)\) until it reaches the level that allows it to compete in producing the \(k^{th}\) commodity. Two further values for \(w^*\) are also revealed in Figure 1. If Foreign’s relative size is very small, it will not be able to produce enough of its best commodity \((n)\) to satisfy the world market, so its wage rate is linked to that of Home by the relative productivity in producing commodity \(n\). At the other extreme, if Home were so small it could not supply the entire world demand for its best good, Foreign would have to produce it as well, with \(w^*\) driven down to \((1/a_1^*)\). The recorded values of points \(A, B,\) and \(C\) presume equal Cobb-Douglas expenditure shares for each commodity.\(^6\)

Following the argument in Jones and Ruffin (2008), consider (their) Figure 2. The dashed locus shows the relationship between \(w^*\) and \((L^*/L)\) before technology transfer and the solid locus the new post-transfer locus. After transfer, commodity \(I\) becomes Foreign’s best. However, given that this is a superior technology to the best it had before, Foreign can completely satisfy the world demand for the first commodity with a smaller labor force than it initially required to satisfy the world’s demand for the \(n^{th}\) commodity. Further increases in \(L^*/L\) will drive \(w^*\) down from its unit value (which it has if both countries produce the first commodity with the same technology). At point \(A\) in Figure 2 \(w^*\) has fallen to \((1/a_n^*)\). (The Cobb-Douglas assumption assures such a result). Points such as \(A\) and \(B\) in Figure 2 are called “turning points”. For example, if Foreign’s relative labor supply has increased until point \(A\) is reached, initially (pre-transfer) it will just have finished being the world’s only supplier of commodity \(n\). After the technology transfer, at point \(A\) Foreign becomes an incipient producer of commodity \(n\) (having already produced the entire world’s demand for the first commodity). As a

\(^6\) If Home produces the first \(k\) commodities and Foreign is specialized to commodities \((k+1)\) through \(n\), the ratio of their national incomes, \([w^*L^*/wL]\) (with \(w\) equal to unity), must equal \([(n-k)/k]\).
consequence, if the ratio of labor forces is at a turning point (such as \( A \)), there is no change in Foreign’s \( w^* \), while the price of commodity 1 has fallen (since it is now produced by Foreign, whose wage rate has been driven below unity). Home workers face a lower price level than before the transfer of technology, and with their nominal wage still equal to unity, they unambiguously gain by the uncompensated transfer of technology of their best export commodity.

If the relative country size is not at a turning point, two effects on the price level follow technology transfer: (i) The world price of the transferred commodity (1) falls, tending to lower the price level for all, and (ii) the upward shift in Foreign’s wage schedule points to an increase in the price of all commodities (save the first) that are exported from Foreign to Home. This serves to raise the price level facing workers at Home and thus to lower the real wage. In the neighborhood of turning points the price level clearly falls, whereas with reference to Figure 2 it is clear that Home is most likely to suffer a fall in the real wage if, both before and after transfer, the two countries produce a commodity in common, albeit a different commodity in the two cases. This is explicitly shown in Figure 3 for a value of \((L*/L)\) given by point \( A \): Before technology transfer the prices of commodities 1 through \( k \) are all unity (all produced by Home), Foreign’s wage rate is \((1/a_k^*)\), and prices of commodities \((k+1)\) through \( n \) are given by the series \((a_{k+1}^*/a_k^*), (a_{k+2}^*/a_k^*), \ldots, (a_n^*/a_k^*)\). As a consequence of the unrequited transfer of technology for the first commodity to Foreign, its price falls from unity to \((1/a_{k+1}^*)\), the new (higher) Foreign wage rate. As for the sequence of commodities previously produced by Foreign, commodities \((k+1)\) through \( n \), prices have all been raised by the proportion \((a_k^*/a_{k+1}^*)\), the relative increase in Foreign \( w^* \). The price
deflator for the home nominal wage of unity in the Cobb-Douglas case is the $n^{th}$ root of
the product of commodity prices, and in the situation where $(L^*/L)$ is shown by point $A$ in
Figure 3, the product of commodity prices is less than unity (and thus Home gains by the
loss of the technology for producing its best export commodity if and only if:

\[
\left\{\frac{1}{a_{k+1}^*}\right\} \{a_k^*/a_{k+1}^*\}^{(n-k)} < 1
\]

This is formally proved in Jones and Ruffin (2008). The first bracketed term is smaller
than unity and refers to the drop in the price of the first commodity as its production
shifts from Home to Foreign. The second term, larger than unity, shows the product of
the increase in prices of all commodities produced by Foreign. The first term reflects the
difference between Home and Foreign wage rates, while the second reflects the extent to
which Foreign’s wage rate has risen.

Note that the drop in the price of what was originally Home’s best export commodity
does not appear directly as a worsening of Home’s terms of trade. Instead, with the loss
of this industry, Home becomes an importer of the first commodity, and its consumers
gain to the extent that the price has been reduced from unity to $(1/a_{k+1}^*)$. This is part of
an overall “terms-of-trade” effect for Home, the other part consisting of a price rise for all
the other commodities imported by Home, the second bracketed term in (2). Here is
where the “profile of comparative advantage” possessed by Home is critical. Prices of all
these commodities imported by Home have been raised by the proportion $(a_k^*/a_{k+1}^*)$.
This reflects the fact that by taking over production of the first commodity, the
commodity in which Foreign possesses the least comparative advantage but must produce
is no longer commodity $k$, but commodity $(k+1)$, in which Foreign has a greater
comparative advantage. If the difference in comparative productivity in these two
commodities is not very large, Foreign’s wage rate will not increase by much, thus limiting the deterioration in Home’s terms of trade.

The two-commodity case considered in Ruffin and Jones (2007) highlights the importance of the profile of comparative advantage. Suppose, as above, commodity units have arbitrarily been selected so that Home needs only one unit of labor to produce one unit of either commodity, and that Home has a comparative advantage in producing the first commodity, (and a comparative disadvantage in producing the second). If there is an uncompensated transfer of Home’s superior technology in producing the first commodity, and if as a consequence Home’s labor force moves from being completely specialized in the first commodity to being completely specialized in the second, Home nonetheless gains by the transfer if Home’s absolute advantage in producing the second is not much less than in producing the first. This would be captured by inequality (3) being satisfied:

(3) \( (a_2^*)^2 > a_1^* \)

The comparison with the two-commodity case is also revealing in that whereas in the two-commodity case the extent of Home’s absolute advantage in producing the first commodity is crucial (see inequality (3)), this is not the case in expression (2), the criterion for gain in the worst-case scenario in the multi-commodity case. What is crucial, instead, is the comparison between Home’s comparative and absolute advantage in producing the \( k^{th} \) commodity and that of the new commodity now produced at Home, commodity \( (k+1) \). As a consequence, although selecting the first commodity as the one whose technology is transferred sounds like it would inflict the most damage to Home real incomes, it is not different than transferring Home’s superior technology for any of its original export items.
There is, however, a natural limit to possible gain for Home of unrequited transfers of its superior technology. Suppose it were to transfer its technological knowledge in all commodities to Foreign. The world would obviously gain, but could the Home country as well? The answer is an unequivocal no. For such a transfer puts Home back in the same position it was in when in autarky, which is inferior to its original pre-transfer, free trade position. However, as the Ruffin and Jones (2007) results indicate, Home might gain by a transfer of all its superior technology for every export commodity, while maintaining its superior technology for all its import commodities. An aggregative condition of inequality (3) provides the criterion.

As Prof. Paul Samuelson and others have frequently remarked, the doctrine of comparative advantage is not only extremely important and powerful, it is also subtle and often quite difficult to understand. In the context of Samuelson’s (2004) argument, it can show how globalization can hurt some countries, but as argued in Ruffin and Jones (2007) and Jones and Ruffin (2008) although relatively small shocks can harm some countries, larger shocks that serve to alter production patterns may in the end benefit countries who would be harmed if the pattern of production were not disturbed.
References:


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: Turning Points
Figure 3: Technology Transfer and Foreign Wage Improvement