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# FIRless FIRwoes: How Preferences Can Interfere with the Theorems of International Trade

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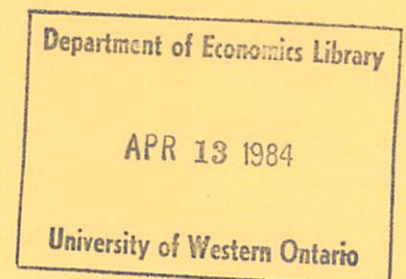
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Alan V. Deardorff

This paper contains preliminary findings from research  
work still in progress and should not be quoted without  
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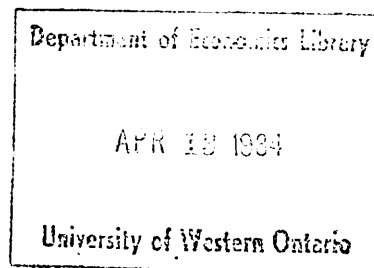
FIRless FIRwoes: How Preferences Can Interfere  
with the Theorems of International Trade

by

Alan V. Deardorff

University of Michigan

March 30, 1984



\*This paper is based on Deardorff (1983), a short paper which failed to generate the interest I thought it deserved. In the spirit of the Washington bureaucracy, I am responding to the failure of that paper by making it larger and changing its name. I would like to thank Ted Bergstrom, Jon Eaton and Bob Stern for their helpful comments, as well as other members of the Research Seminar in International Economics at Michigan and those who participated in the trade theory conference at the University of Western Ontario, March 17, 1984.

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I. Introduction

It is well known that factor intensity reversals (FIRs) can play havoc with the theorems of the Heckscher-Ohlin-Samuelson (HOS) model of international trade. It is therefore customary to exclude them by assumption, with or without a solid empirical basis for doing so.<sup>1</sup> Without FIRs, the standard 2x2x2 HOS model performs nicely, providing the theorems that we all know and love. Other difficulties have sometimes arisen in our efforts to extend the theorems of trade theory to more than two dimensions. Still, there has been some success at such extensions, both contributed to and nicely summarized by Ethier (1984). My intention in this paper, however, is to suggest that further

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1. Minhas (1962) claimed to have identified enough empirically relevant FIRs to make application of the HOS model questionable. His methodology was criticized by a number of authors, as surveyed by Bhagwati (1969), but Stern (1975) noted more recent work that leaves the empirical importance of FIRs still up in the air. The HOS model without FIRs has continued to provide the core of international trade theory in spite of this literature.

progress in generalizing these theorems will be limited, at least until we can come to terms with the problems posed in two dimensions by FIRs. For the same kinds of problems arise also in many dimensions, even when FIRs themselves are assumed away. The problem seems to be that certain properties of preferences among many goods can replicate arbitrarily closely the effects of FIRs, even when FIRs are not themselves present. Thus until we can find an acceptable regularity assumption that applies simultaneously to both technology and preferences, our efforts to characterize behavior in a many dimensional HOS model will be of only limited success.

The basis for these concerns consists of a simple example, which I present below in section II. In this example, free trade in four goods between two countries with only two primary factors can cause the factor prices to diverge -- that is, to move in opposite directions away from each other as the countries move from autarky to free trade. This occurs without FIRs, but for reasons that are best understood by first looking at a two-good model with a double FIR. Thus the factor price equalization theorem is violated in the extreme in this example, and one can not even speak of a tendency toward factor prices being equalized. This is not a complete novelty, since Land (1959), with an assist by Stewart (1976), has also shown an example in which factor prices are drawn further apart by trade. But in my example, unlike Land's, factor prices move apart in opposite directions, providing a more dramatic and easily understood

picture of their effects.

These effects are discussed further in section III, where I examine five of the major propositions of pure trade theory in the light of this example. I first discuss the factor price equalization theorem itself, looking for the intuition behind what is after all a very counter-intuitive example. Then I turn to the Heckscher-Ohlin Theorem. This theorem, which in its many-dimensional interpretation is central to the modern understanding of the pattern of international trade, can be salvaged even in this example as I have shown implicitly in Deardorff (1982). However the version of the theorem that is valid is almost trivial in this context, and is not at all what one might like the theorem to say. In fact the pattern of trade in this example does not correspond to what one would normally expect from the Heckscher-Ohlin Theorem.

The last two theorems of the HOS model per se that I will consider here are the Stolper-Samuelson and Rybczynski Theorems. Regarded as strictly local relationships between goods and factor prices and quantities, my example poses no problems for these theorems, which already have enough troubles accommodating the complexities of many dimensions. However if one interprets these theorems as drawing out the implications of factor scarcity and abundance -- as Stolper and Samuelson (1941) surely did and as Rybczynski (1955) arguably may have -- then my example overturns their otherwise extremely plausible messages.

Lastly I turn to a result that is not usually considered a part of the HOS model, but which surely deserves to be mentioned alongside the other theorems: Mundell's (1957) result that trade in goods serves as a substitute for trade in factors. Again, in the example of this paper, just the opposite is the case.

In section IV I begin an effort to sort out the significance of these results. One implication, as I have tried to suggest in my title, is that it is not very useful to frame the discussion in terms of the existence or nonexistence of FIRs. To clinch this point I show in section IV that, by redefining goods, one can turn any model with FIRs into one without and vice versa. FIRs are meaningful only in the textbook two-good model, where the limited number of goods constrains the relationships that can exist among them. With many goods a well behaved model will require some other assumption about preferences, together with technology, if we are to salvage in a meaningful form many of our familiar results.

What assumption should this be? I don't know, and I hope others will be induced to look for one by my example. All that I can offer at this point is an assumption that I think is far too extreme: that all utility and production functions are Cobb-Douglas. In section V I show that this assumption suffices to guarantee that factor prices are drawn closer together by free trade. Thus my example and its disturbing implications cannot occur in such a Cobb-Douglas world. At this time I can only

speculate on what weaker and, I would hope, more plausible assumptions might serve the same purpose.



## II. The Example

It is well known that Samuelson's (1949) factor-price equalization theorem requires a very restrictive list of assumptions. Among these are perfectly free trade and incomplete specialization. The former certainly does not hold in fact, and some would argue that the latter is also unrealistic, at least for many developing countries.<sup>2</sup> Therefore it would be useful to have available a weaker result that would be more generally valid than Samuelson's but in the same spirit. One might try to show, for example, that factor prices, when not equalized, are drawn closer together by trade.<sup>3</sup> Unfortunately, Land (1959) has shown that this need not be the case.<sup>4</sup>

In this section, I provide another example of factor-price divergence that is more dramatic than Land's. My example is also simpler and is thus more useful as a guide to the further theoretical investigation later in the paper. In my example, a particular configuration of preferences among four goods leads to

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2. See Krueger (1977).

3. This is what Ohlin (1933) originally proposed. Samuelson (1971) argues that this is in fact what happens in a specific-factors model where only labor is mobile between sectors.

4. Johnson (1967) objected that Land's counterexample was inconsistent with equality of supply and demand in all markets. Stewart (1976), however, showed how demands could respond to price differences in such a way as to validate Land's example.

behavior exactly like a two-good model with a double FIR. It then follows that factor prices in two countries may move in opposite directions and farther apart with trade. This in turn has unfortunate implications for other aspects of the trade equilibrium, which I will discuss later in section III. In the search for conditions under which a many-good HOS model will display the properties that we associate with it in two dimensions, a clear example like this of what can interfere with factor-price convergence is essential.

First a word about the Land-Stewart counterexample. In a model with three goods, two factors, and two countries, they showed how a move from autarky to free trade could cause the wage-rental ratio,  $s = w/r$ , to fall in both countries. They also showed that this decline could be greater in the country where  $s$  was initially lower. Thus relative factor prices were moved farther apart by trade. Given that divergence in this form -- when prices in both countries move in the same direction -- could be sensitive to the way in which they are measured, it would be more compelling if a case could be found in which factor prices move away from each other in opposite directions.<sup>5</sup>

Such a case is in fact familiar from the two-good model when

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5. Dixit and Norman (1980, p. 102) mention the difficulty of identifying an appropriate measure of distance between vectors of factor prices. This difficulty is avoided in my example here, since the ratios of factor prices move apart in opposite directions.

there are multiple FIRs. If there are two factor intensity reversals, then the relationship between relative factor prices,  $s$ , and the relative price of two goods,  $p = p_I/p_{II}$ , is not monotonic but instead S-shaped as shown in Figure 1.<sup>6</sup> If factor endowments of two countries, A and B, differ by an appropriate amount, then their autarky factor prices may be  $s^A$  and  $s^B$  as shown. As drawn, the relative autarky price of good I is higher in A than in B, even though I is locally labor-intensive in both countries and A is abundantly endowed with labor.<sup>7</sup> Now when the countries are opened to trade, the prices of the goods will come together as shown. But the relative prices of the factors will fall in A and rise in B, becoming farther apart. Also, since marginal products depend monotonically on capital-labor ratios, and these in turn vary monotonically with  $s$ , it follows that this same divergence characterizes individual factor prices relative to the prices of either good.

Now consider a different model. Suppose that there are no factor-intensity reversals after all but that the countries can

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6. See Samuelson (1949) for the derivation of this relation when there is no factor-intensity reversal. See Chacholiades (1978, pp. 273-280) and the references cited therein for the cases of single and multiple factor-intensity reversals.

7. Relative factor intensities determine the slope of the curve, since a rise in the relative wage raises the relative price of the labor-intensive good. Thus in the Figure, good I is labor intensive for both high and low wage-rental ratios, but capital intensive in between. Relative factor abundance can be measured either by relative autarky factor prices or by relative physical endowments. In this case the two definitions agree.

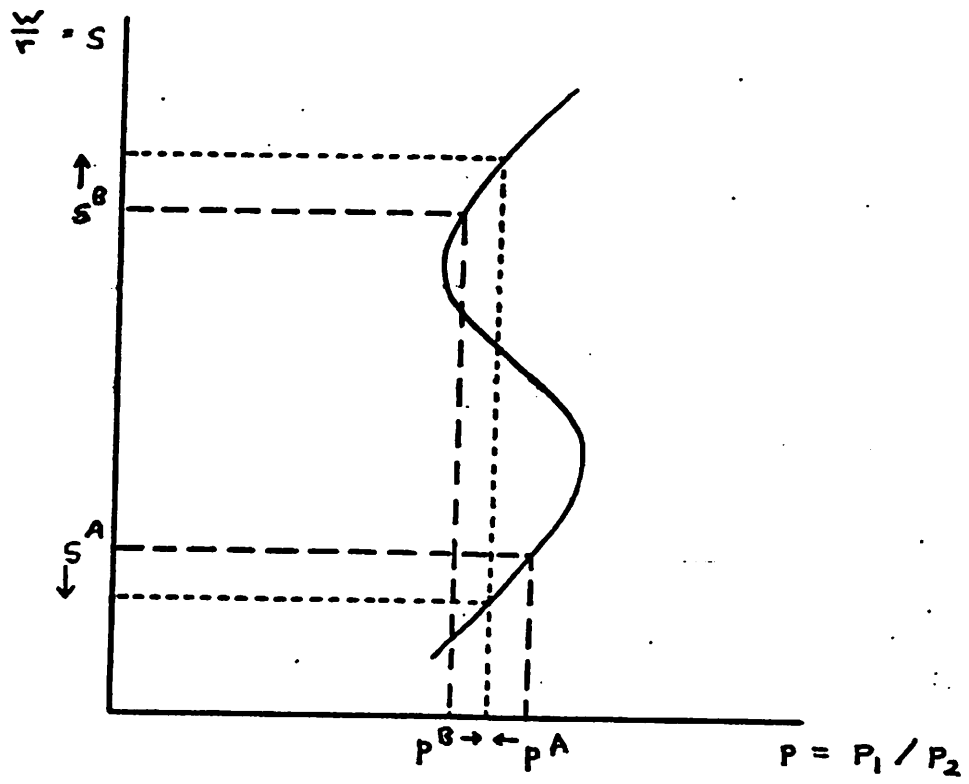


FIGURE 1

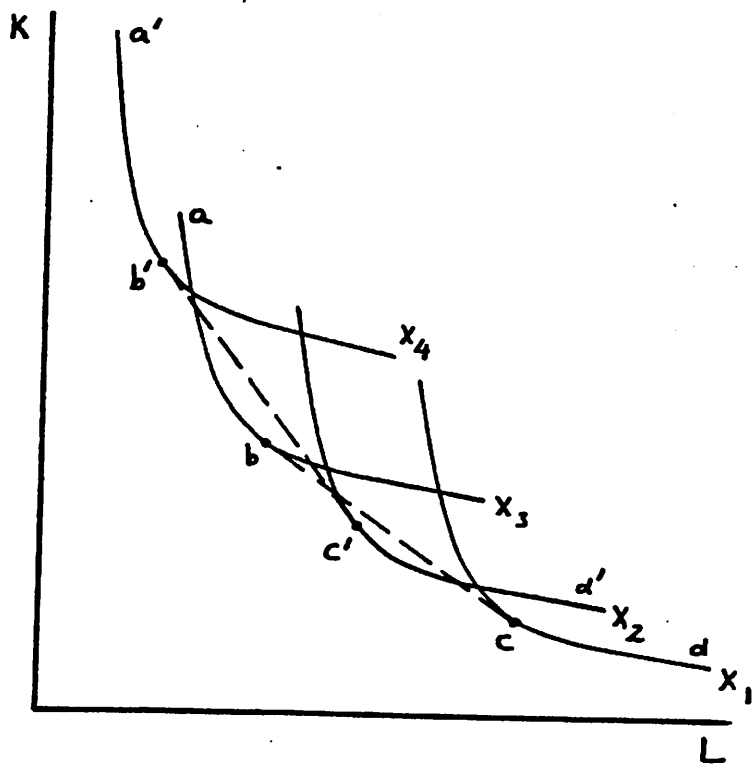


FIGURE 2

produce four goods instead of two. Let the unit isoquants for the four goods be those shown in Figure 2. It is difficult in general to characterize equilibrium completely in such a model. Suppose, however, that the following very special assumption is made about preferences in both countries: Goods  $X_1$  and  $X_3$  are perfect substitutes, as are goods  $X_2$  and  $X_4$ . With this assumption the two pairs of goods can be aggregated, and the model is equivalent to a model with only two goods.

The feasible factor inputs for producing a unit of the  $X_1$ - $X_3$  aggregate include all convex combinations of inputs for producing one unit of  $X_1$  and one unit of  $X_3$ . Thus the unit isoquant for the  $X_1$ - $X_3$  aggregate is the convex hull of the separate  $X_1$  and  $X_3$  isoquants: the curve  $abcd$ . Similarly, the unit isoquant for the  $X_2$ - $X_4$  aggregate is the curve  $a'b'c'd'$ . These two aggregate unit isoquants intersect three times, and therefore display two factor-intensity reversals just as in the example of Figure 1. Thus the four-good model with this particular combination of pairwise perfect substitutes will behave exactly like the two-good model with a double FIR. Factor prices may diverge with trade, exactly as in Figure 1, and will do so if relative factor endowments differ by an appropriate amount.

What happens may be seen more fully in Figure 3, which is an elaboration of Samuelson's familiar diagram for relating the relative prices of goods and factors to factor intensities. Let  $k_i$ ,  $i=1, \dots, 4$ , be the capital-labor ratios that will be employed

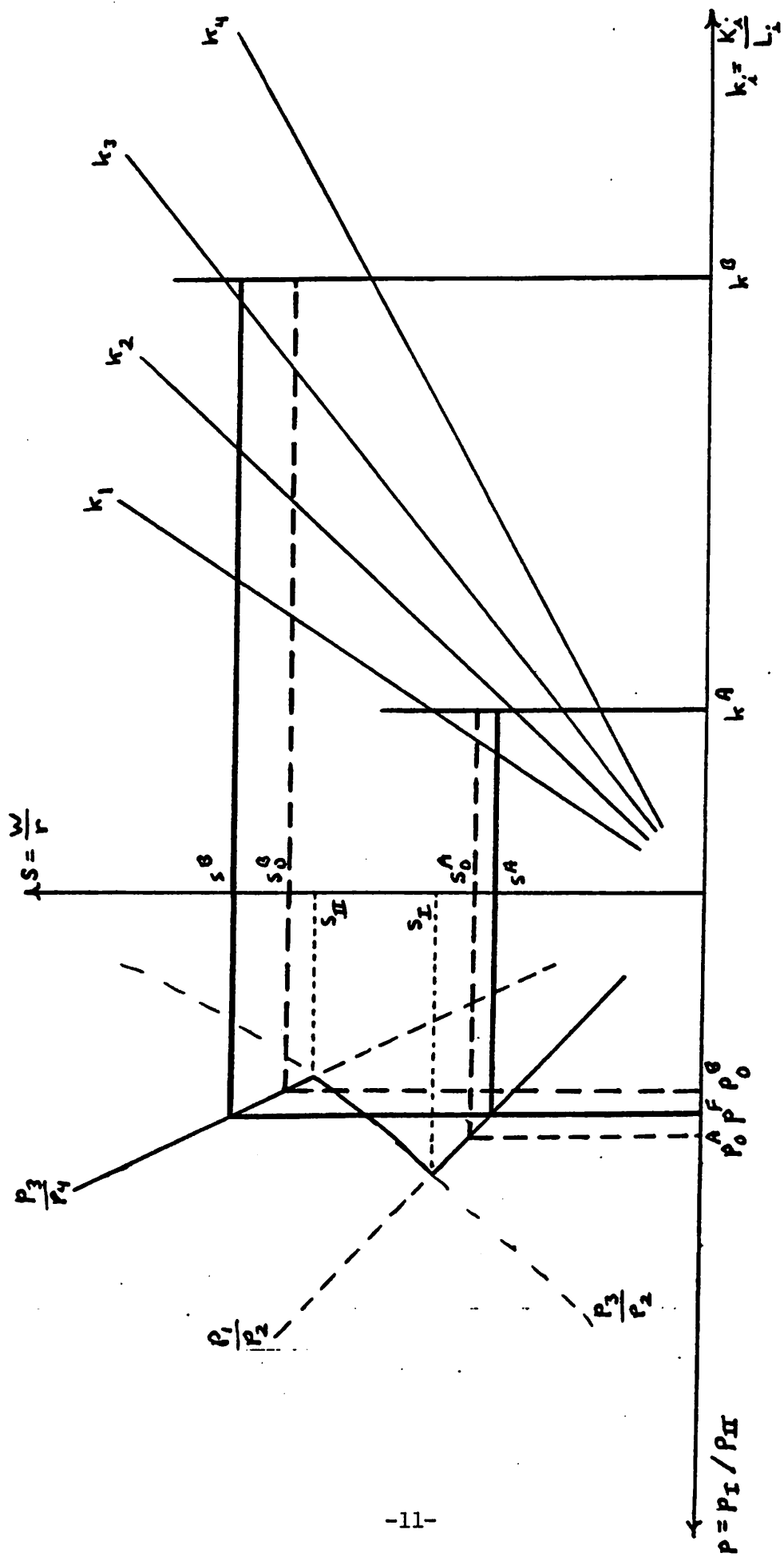


FIGURE 3

in producing each of the four goods. In the right-hand quadrant, four curves indicate how these  $k_j$  depend on the wage-rental ratio,  $s$ . In the absence of FIRs, these curves do not intersect.

Based on the relative factor intensities indicated by these curves, the left-hand quadrant shows several ratios of goods prices. These too depend on  $s$  as long as both goods in the ratio are produced. Thus both  $p_1/p_2$  and  $p_3/p_4$  increase with  $s$ , since  $X_1$  and  $X_3$  are labor intensive relative to  $X_2$  and  $X_4$  respectively. On the other hand,  $p_3/p_2$  declines with  $s$  since  $X_3$  is capital intensive compared to  $X_2$ .

These relative prices can be compared along a single axis only because of our assumption that goods  $X_1$  and  $X_3$  are perfect substitutes, as are goods  $X_2$  and  $X_4$ . Thus in any kind of equilibrium it must be true that  $p_1 = p_3 = p_I$  and  $p_2 = p_4 = p_{II}$ , where  $p_I$  and  $p_{II}$  may be thought of as the prices to consumers of satisfying their demands for a unit of either good in the respective pairs.

The three relative price curves cross one another in two places, indicated along the  $s$  axis as  $s_I$  and  $s_{II}$ . The first of these represents the only wage-rental ratio consistent with producing all three of goods  $X_1$ ,  $X_2$ , and  $X_3$ , given that the prices of the first and last of these must be equal. Thus  $s_I$  is the slope of the common tangent to the  $X_1$  and  $X_3$  unit isoquants in Figure 2, the line  $bc$ . Similarly,  $s_{II}$  is the slope of the

line  $b'c'$  in Figure 2. It is then clear, also from Figure 2, that  $X_1$  will be produced only if  $s$  is less than  $s_I$ ,  $X_4$  will be produced only if  $s$  is greater than  $s_{II}$ , and so forth, so that  $s_I$  and  $s_{II}$  serve to delineate the possible patterns of specialization.

Now to get an example of factor-price divergence, introduce the capital-labor endowment ratios,  $k^A$  and  $k^B$ , in the right-hand quadrant. Autarky equilibria are illustrated by heavy broken lines, while a free trade equilibrium is illustrated by heavy solid lines. Thus in autarky, country A, because it is so labor abundant, specializes completely in goods  $X_1$  and  $X_2$ . Its wage-rental ratio is  $s_0^A$ , and its relative price of good one in terms of good two is  $p_0^A$ . The prices of goods three and four are only implicit, since they are not produced, but both would cost more per unit to produce than the prices of the goods with which they are substitutes.<sup>8</sup> Similarly, country B, with much more capital per man, specializes completely in goods three and four, with factor prices,  $s_0^B$ , and goods prices  $p_0^B$ , the latter of which in B is the relative price of good 3 in terms of good 4.

What is important about these autarky equilibria, in terms of generating factor price divergence, is that the relative price of the type I good in terms of the type II good is higher in A

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 8. For example, from the  $p_3/p_2$  curve it can be seen that the price of good three, were it to be produced at factor prices  $s_0^A$ , would be higher relative to good two than is the autarky price of good one.



than in B, even though A is labor abundant and in both countries the type I good that is produced is labor intensive compared to the type II good that is produced. As a result, when trade is permitted, the relative price of type I goods falls in A and rises in B, reducing demand for labor in A and raising it in B.

Specifically, the free trade equilibrium involves a single relative price for type I compared to type II goods,  $p^F$ , which therefore equals both  $p_1/p_2$  and  $p_3/p_4$  in both countries. The wage-rental ratio in A falls to  $s^A$ , while that in B rises to  $s^B$ . In the right-hand quadrant one can also infer, from the intersections of the factor-price and endowment lines in the two countries, that country A moves closer to specialization in  $X_2$ , while country B moves closer to specialization in  $X_3$ . Thus A exports  $X_2$  and B exports  $X_3$ . Goods  $X_1$  and  $X_4$  are not themselves traded, though they both compete with imports with which they are perfect substitutes in demand.

As illustrated in Figure 3, both countries continue to produce two goods in the free trade equilibrium. This, of course, is not inevitable. One or both could easily completely specialize in producing only its export good. Interestingly, and in contrast to more conventional results, such complete specialization will occur here if the endowment ratios of the two countries are somewhat closer together. It would still be the case, however, that relative factor prices would be drawn further apart by trade, and the example of Figure 3 therefore has a valid

counterpart with complete specialization.

This particular example of factor-price divergence is made tractable by having the pairs of goods be perfect substitutes. It is clear however that the same kind of result could occur if the pairs of goods were only very close substitutes. Thus it follows that, with more than two goods, demand conditions and factor intensities together can cause factor prices to move in opposite directions and farther apart with trade.<sup>9</sup> Factor intensities are important for this, but factor intensity reversals are not. Any proof of a tendency toward factor-price equalization will therefore have to do more than just rule out FIRs. Relationships among goods in demand will also have to be considered, a task that has normally been avoided in trade theory. I will have more to say about this in section V.

Note incidentally that this example does not arise from preferences being either nonidentical across countries or nonhomothetic. My assumed pattern of substitutability is quite consistent with the familiar assumption of internationally identical homothetic preferences. Thus to rule it out one needs an assumption that is stronger than the one usually made.

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9. It is not perfect or near perfect substitution per se that is the cause of this result, since a different pairing of goods as substitutes would not have given rise to it. For example, had the pairs  $(X_1, X_2)$  and  $(X_3, X_4)$  been perfect substitutes, the case above would have reduced to a quite well-behaved two-good model.

### III. Implications for the Theorems of Trade

Implicit in the example of section II are several disturbing implications for the theorems of the HOS model. These may already be obvious to the reader, but I believe it is worth going through them in any case.

#### The Factor Price Equalization Theorem

It is already clear that factor price equalization fails to occur in this example. The question I wish to consider is, "Why?" At a formal level the answer is obvious: in the free trade equilibrium, countries A and B fail to produce two goods in common. Instead they specialize, country A producing only one or both of goods  $X_1$  and  $X_2$  and B producing only  $X_3$  and possibly  $X_4$ . There are therefore no equations relating good and factor prices that are common to the two countries and that could be solved to yield common factor prices.

But this technical explanation for the failure of complete factor price equalization really misses the point. The preoccupation of trade theory since Samuelson (1949) with complete factor price equalization has diverted attention from the reasons for Ohlin's original insight that factor prices ought

to be drawn together by trade.<sup>10</sup> This insight was sufficiently powerful that it needs to be reconsidered in the light of the example in this paper.

Ohlin's insight, as I understand it, was that factor prices are determined by factor scarcity, and that trade, by opening up factor markets to indirect competition with factors abroad, alters this relative scarcity. Thus a country's scarce factor will be relatively expensive in autarky, as it earns the usual scarcity rent. With trade, however, the products of that scarce factor must compete with their counterparts produced by the same factor, which is relatively more abundant abroad. This trade erodes the scarcity rent of scarce factors, causing their originally high relative returns to fall. Similarly, a country's relatively abundant factor will have its autarky price depressed by that abundance. But with the opening of trade it finds new markets for what it can best produce, and the result is that the demand for it, and thus its price, can rise. Thus in Ohlin's terms, the tendency for factor prices to converge with trade is a straightforward implication of supply and demand, and has nothing to do with the particular mathematical properties of homogeneous production functions that seem, almost coincidentally, to give rise in special cases to full factor price equalization.

Given this strong economic explanation for factor price

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10. Though again there are exceptions, such as Samuelson himself in (1971).

convergence, why then does it fail to occur in my example? The reason is that factors of production face competition, indirectly through the goods they produce, not just with identical goods producible with identical factors abroad. Instead, in a world of many goods, there is a whole complex set of relationships in demand that matter too. Specifically, in my example, a scarce factor competes through trade not just with identical goods produced abroad, but also with other goods that happen to be close substitutes for what it produces.<sup>11</sup> If these close substitutes happen to be relatively expensive abroad, compared to other goods produced there, then the domestic scarce factor may win this competition in spite of its own scarcity. Likewise, if competition through close substitutes pits the domestic abundant factor against other products that happen to be relatively cheap abroad, then its relative return may fall. Since this competition is with different goods whose factor intensities are unrelated to those used at home, knowledge of relative scarcity and abundance of factors provides no information as to how this competition will work itself out.

The example here focuses on goods that are close substitutes. I would guess that extremes of complementarity in demand could also give rise to similar behavior. The point is that, once one moves beyond the simplicity of a two good model,

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11. In fact, in my example, identical goods are not produced abroad at all, so this aspect of competition does not arise. It is only the close substitutes that matter.

where interesting patterns of substitutability and complementarity cannot arise, the issue of how factors compete with one another through international trade depends crucially on these aspects of demand. One result of this is that even the tendency toward factor price equalization is not assured in a general many-good model.

### The Heckscher-Ohlin Theorem

One would think that the Heckscher-Ohlin Theorem ought also to collapse in this example. Surprisingly this is not the case of the only statement of the Theorem that has been proved in a general model. In Deardorff (1982) I proved two versions of the Heckscher-Ohlin Theorem -- one for the factor content of trade, the other for its commodity composition -- in a model sufficiently general to encompass this example as a special case. To do so, however, I found it necessary to define factor content and factor intensity in terms of techniques used to produce traded goods in their country of origin. What my example here illustrates is just how misleading this particular statement of the theorem may be.

In my example here, the Heckscher-Ohlin Theorem in this form can be seen to hold quite easily. In the trade equilibrium, country A exports  $X_2$  and B exports  $X_3$ , neither of the other goods being traded at all. Thus each country exports a good that is more intensive in the use of its abundant factor than what it

imports.

However, true as this may be, this is not a very useful guide to what the countries will trade if one starts from autarky. Each country produces only two goods in autarky, and it is impossible in general to tell which it will specialize in with trade. In the example, if the relative endowments and therefore relative autarky factor prices had happened to be just a little further apart than shown in Figure 3, factor prices would have moved together with trade, and A and B would have exported goods  $X_1$  and  $X_4$ , respectively. Thus it is impossible to tell, based only on relative factor endowments, whether trade will lead a country to specialize in goods that are more capital intensive or less capital intensive among those it initially produces.

To say, then, that a labor abundant country's exports will be more labor intensive than its imports is to say very little, especially in a world where endowments differ so much that virtually any good produced abroad will have to be more capital intensive than any produced at home. It would be more interesting to know how the factor intensity of a country's exports will compare to the factor intensity of the industries that its imports will replace. The version of the Heckscher-Ohlin Theorem in Deardorff (1982) tells one nothing about this, since factor intensities of imports there refer to the country of origin. I noted there that these intensities could be different from those needed to produce the goods in the

importing country. But even if that is not the case -- as, for example, if factors are used everywhere with fixed coefficients -- the Theorem still does not tell us about the factor intensities of displaced industries. Imports displace production not only of goods identical to themselves, but also of goods that are close substitutes in demand. Again, the Heckscher-Ohlin Theorem cannot tell us what we really want to know without first considering properties of demand.

### The Stolper-Samuelson Theorem

At one level, the Stolper-Samuelson Theorem is a technical and local relationship between good and factor prices, and whether it holds or not in the two-factor world considered here is mainly a matter of how many goods are produced. Generalizations of Stolper-Samuelson, surveyed in Ethier (1984), mostly consider whether similar local relationships can be found in models with a larger number of factors.

Some years ago, Bhagwati (1959) noted three different interpretations of the Stolper-Samuelson Theorem, all of which go somewhat beyond the simple goods-price-factor-price relationship by dealing with effects of protection and by identifying factors as scarce and abundant. Of these what he called the "Restrictive Stolper-Samuelson Theorem" is least general but has, I think, the strongest intuitive appeal. It says that free trade lowers the real wage of the scarce factor, and raises the real wage of the



abundant factor, both as compared to autarky. Since free trade opens factor markets to indirect competition from abroad, the idea that it should cause a lessening of scarcity rents has great appeal. I have wondered for some time whether a more useful generalization of the Stolper-Samuelson Theorem might be possible in these terms. I speculated, for example, that in a model of many factors one could find the changes in real factor returns moving from autarky to free trade to be, say, negatively correlated with some measure of their relative scarcity.

Unfortunately, even this relationship, weak as it would be, is clearly not generally valid, since it fails to hold even with two factors in the example of this paper. Here the local relationship between goods prices and real factor prices is valid so long as two goods are produced in a country, and with this qualification the real returns follow the relative returns, *s.* However, since relative returns move apart with trade, so do real returns, and it follows that real returns to scarce factors rise and real returns to abundant factors fall with trade.

The reason for this result is really the same as I discussed above in connection with the factor-price-equalization theorem: trade creates competition among factors through the goods they help to produce, but that competition need not be with identical goods. Instead factors compete with foreign goods that substitute closely for their own products. Whether these are relatively cheap or expensive abroad has nothing to do with the

scarcity of abundance of the domestic factors. Thus a comparison of domestic and foreign factors in terms of their relative scarcity can give a misleading impression of how that competition will work itself out.

### The Rybczynski Theorem

Much has been made of the duality between the Stolper-Samuelson and Rybczynski Theorems.<sup>12</sup> Like the former, the focus of further development of the latter since Rybczynski's (1955) original contribution has been on the theorem as a local relationship. There is however an interesting and intuitively appealing global version of his result that also is more in the spirit the problem Rybczynski himself was addressing at the time. This version incorporates both factor scarcity and the effects of a country's growth on its terms of trade.

A global version of the Rybczynski Theorem might say the following: further accumulation of a country's already abundant factor will turn the terms of trade against it, while accumulation of its scarce factor will turn the terms of trade in its favor. The first part of this is clearly valid in the two-by-two model with no FIRs and both goods normal in consumption, since the growth will then be ultra-biased towards

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12. See Jones (1965).

13. See Corden (1956).

exports.<sup>13</sup> The second part, for accumulation of the scarce factor, is also valid in the two-by-two model but with the additional assumption that both goods are initially produced. In its entirety, this version of the Rybczynski Theorem suggests a generalization to higher dimensions that would focus on whether changes in factor endowments are positively or negatively correlated with their initial relative scarcity. Also, it is intuitively appealing, if we think of countries as trading embodied factor services, to think of accumulation of the scarce factor, say, as reducing the demand for imports of the services of the scarce factor and thus lowering their price.

Unfortunately once again, my example in this paper indicates, indirectly this time, that such a proposition cannot be generally true. Consider country A, where labor is abundant. Suppose, as shown in Figure 3, that endowments are such that even in the free trade equilibrium it continues to produce some of good  $X_1$  as well as  $X_2$  which it exports. At constant prices an increase in its endowment of labor will, by the familiar local version of the Rybczynski Theorem, cause it to increase its output of  $X_1$  and reduce its output of  $X_2$ , since the former is the more labor intensive of the two goods. This change is therefore ultra-biased against exports and will, by the familiar reasoning, lead to an improvement in the terms of trade. Analogously, it is now accumulation of A's scarce factor, capital, that will worsen its terms of trade.

How can accumulation of the abundant factor fail to worsen the terms of trade? It is not that such accumulation fails to cheapen the factor itself. It is easily seen, with both  $X_1$  and  $X_2$  produced in A, that when accumulation of labor raises the relative price of  $X_2$  it also lowers the relative wage. Instead what is happening is a consequence of the unusual pattern of trade already noted. While country A's exports are more labor intensive than her actual imports, they are not more labor intensive than her import substitutes. Thus when A accumulates labor, production of import substitutes expands and production for export declines, leading to an improvement in the terms of trade.

#### The Mundell Theorem

A final result to consider, though not normally listed as one of the theorems of the HOS model, is so closely related to the other theorems that it deserves to be considered here. That is Mundell's (1957) result that trade acts as a substitute for the international mobility of factors. In the two-by-two model, not only does trade serve the same purpose as factor mobility in bringing factor prices closer together internationally, it is also true that the more trade is permitted, the less movement of factors will occur if such movement becomes free, and the more factor movement there is, the smaller will be the volume of free trade.

In my example here, however, most of these results are overturned. Trade moves relative (and thus also absolute) factor prices further apart than in autarky, and thus increases the incentive for international factor movement. Likewise it follows that, within limits, some international movement of factors can occur that will increase the volume of trade. Start, for instance, from the free trade equilibrium of my example with factor endowments initially given at the levels shown in Figure 3. Now let a small amount of labor, say, move from the low wage country, A, to the high wage country, B. At initial prices the local Rybczynski Theorem implies that A's outputs of  $X_1$  will fall and of  $X_2$  will rise, while B's outputs of  $X_3$  will rise and of  $X_4$  will fall. Both of these changes tend to increase trade. Some adjustment of prices may be needed to restore equilibrium, but it is likely that the new equilibrium will involve larger quantities of  $X_2$  and  $X_3$  being exchanged by the two countries.

That trade and factor movements can be complements in this way suggests an interesting scenario that might play itself out if the opening of trade were to so widen factor price differentials as to overcome some initially prohibitive barriers to factor movement. Suppose, for example, that we start in autarky with factor prices differing, but not quite by enough to induce, say, migration of labor. Suppose next that opening to trade has the effects described in section II. If the widening of the factor-price differential is just large enough, labor will begin to move from A to B, expanding trade as described above.

This will not, however, necessarily lower the factor price differential, and the movement is likely to continue until at least one country becomes completely specialized in producing only the good it exports. Thus we have a situation in which removal of barriers to trade can induce movement of factors, which in turn further stimulates trade and leads to specialization, all very much the opposite of what Mundell envisioned with the two-by-two model.

#### IV. Do FIRs Really Matter?

The impression given by the textbook two-by-two HOS model is that the absence of FIRs is crucial for the validity of at least some of its familiar propositions. This has led to some empirical effort, such as that of Minhas (1962) already noted, to assess the empirical relevance of FIRs and thus to evaluate the HOS model on that basis. Whatever the outcome of that empirical investigation, it seems clear now that much of this effort has been misdirected.

The importance of FIRs is a special feature of the two dimensional model that does not carry over to more dimensions. All of the problems that may be caused by FIRs in two dimensions can show up equally easily in many dimensions without them. Thus the absence of FIRs is not sufficient for the HOS model to be well behaved.<sup>14</sup>

To emphasize this point I will note here that, once one recognizes some flexibility in the definition of commodities, one can make FIRs appear and disappear at will, just by redefining goods. Thus a model with FIRs can be turned into an equivalent

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14. Nor is it necessary. Even in two dimensions FIRs can exist without negating the standard theorems. This is certainly true if the FIR lies outside the range spanned by the countries' factor endowments. But even if countries lie on opposite sides of reversals, as they do in Figure 1, it is still possible for trade to behave normally if endowments differ by more than shown there.

one without FIRs, and any odd behavior in that model should not be attributed to the FIRs. Also in a similar manner, any model without FIRs can be turned into an equivalent one with FIRs, and one should therefore not regard the observance of FIRs in the real world as cause for alarm. On the contrary, FIRs seem to be quite harmless little beasts in general, and, if they appear, are mere figments of our aggregation.<sup>15</sup>

To see this, first note how easily FIRs can be defined away. Suppose that by one definition of goods one finds a FIR in the technologies for producing two goods, X and Y, that occurs at a capital-labor ratio  $k_0$ . Suppose too that at or near  $k_0$  good X has the larger elasticity of substitution.<sup>16</sup> Then define good X to be actually two different goods depending on whether it is produced with more or less capital per worker than  $k_0$ . That is, if X is produced with  $k \geq k_0$  we call it X' and if X is produced with  $k < k_0$  we call it X''. The isoquants of these two new goods then consist of segments of the original X isoquant, supplemented with horizontal and vertical segments, respectively, that begin at  $k_0$ . Letting these two goods be perfect substitutes in demand,

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15. An example of this in the literature appears in Jones (1974), who presents a model of many traded goods and a single nontraded good. Though there are no FIRs in the technologies of the many goods, the model becomes identical to one with a single FIR once the traded goods are aggregated into a single good using their fixed international prices.

16. This is safe. The goods cannot have the same elasticity of substitution over an interval of capital-labor ratios and still have a FIR within that interval.



we now have an exactly equivalent model with no FIRs.<sup>17</sup>

By a similar procedure, FIRs can be created by redefining goods in a model where there are none initially. Take any good, X, with a conventionally curved isoquant. Pick a couple of capital-labor ratios arbitrarily,  $k_1$  and  $k_2$ , and define two different goods depending on whether they use the factors in a ratio that is between these or not. That is, let X be X' if produced with  $k \in [k_1, k_2]$  and let X be X'' otherwise. Then the X' isoquant will be vertical or horizontal outside this interval, while the X'' isoquant will have a downward sloping straight segment within it. As long as X' and X'' are assumed to be perfect substitutes in demand, these constructed portions of their isoquants will never be used, and the new model will behave exactly the same as the old model, even though the new one has one more good. And of course, these two newly defined goods, X' and X'', do display a FIR.<sup>18</sup>

Such creation and destruction of FIRs by redefining goods would of course be unacceptable if a particular and precise

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17. An alternative and perhaps simpler procedure would be to convert each good to a continuum of goods, each using a different and fixed technique of production chosen from the original isoquants.

18. Again we could achieve the result more simply by allowing a continuum of goods. In a conventional two good model, turn just one of the goods into a continuum of goods with fixed techniques, as in the preceding footnote. Then each one of these new goods displays a FIR relative to the other original good for which factor substitution is still possible.

definition of a "good" were already very firmly entrenched. But this is not the case, as our willingness to use a two good model makes clear. Nor is the idea of differentiating goods on the basis of how they are produced at all unusual, since this is a common feature of industrial classification systems. Thus if we accept that the concept of a "good" should be flexible, the concept of a FIR can no longer play a compelling role in our analysis.

This does not mean, however, that the qualifications normally imposed by FIRs on the theorems of trade have been inappropriate. On the contrary, the discussion in section III should make it clear that these difficulties may be more pervasive than we thought, not less. Unless and until further analysis suggests an acceptable alternative assumption to the absence of FIRs -- one that will get rid of these problems even in a many good model with or without FIRs -- we should take these problems seriously.

Nor does it mean that FIRs should now be ignored in the textbook development of trade theory. With only two goods, FIRs provide the only way of illustrating these difficulties and should be discussed on that account if none other. I would suggest, in fact, that FIRs be given more attention than they have before, and that it be explained that they serve as a substitute for the problems of complementarities and substitutabilities that can only be captured in higher

**dimensions.**

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#### V. An Alternative to the Absence of FIRs?

It might seem from the discussion in section III that I am pessimistic about the usefulness of the theorems of trade. I am not. But at the moment I am unable to defend my optimism. I believe that the theorems do tell us things that are largely valid, and that ultimately it will be possible to find a set of empirically defensible assumptions that will permit us to prove these theorems in some form. As yet, however, such assumptions have not been found, in my opinion.

Most generalizations of the theorems of trade rely on factor price equalization, and thus on the countries of the world having sufficiently similar factor endowments to lie all within the same "diversification cone". What that means empirically, we don't know, but casual observation of the world, including its less developed parts, surely suggests that this is inappropriate.

Allowing specialization, we fall squarely in the middle of the problems addressed in section III, and we need to find a way of dealing with them on their own terms. My example in section II suggests that these problems arise when goods are closer substitutes for some goods than for others, and my intuition suggests that similar problems might arise with analogous

variations in complementarity.<sup>19</sup> To rule out such features of preferences is, I think, too strong an assumption, but it may provide a good starting point in the search for a more empirically acceptable assumption. In that hope, I now show very briefly that at least one simple model is well behaved.

Consider, then, a model with two countries, two factors, and many goods, and let all utility and production functions be Cobb-Douglas.<sup>20</sup> This assures that all elasticities of substitution are unity, and thus that such extremes of substitutability as were contained in the example of section II are ruled out. It is easy to show in such a Cobb-Douglas world that factor prices must be drawn closer together by trade, even when (as I consider the normal case) they are not completely equalized.

To see this, note first that Cobb-Douglas preferences together with Cobb-Douglas production functions imply indirect preferences by consumers for factors that are also Cobb-Douglas. That is, let consumers in both countries spend fractions  $b_i$ ,  $i=1, \dots, n$ , on each of  $n$  goods and let the labor shares in

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19. It was such complementarities that ultimately provided the "weak link in the chain of comparative advantage" in Deardorff (1979).

20. Dornbusch, Fischer and Samuelson (1980) use Cobb-Douglas utility and production functions in part of their analysis of the Heckscher-Ohlin Model with a continuum of goods, though they also relax this assumption in the case of production. My result below could be gotten as easily with a continuum of goods, simply by replacing summations with integrals.

producing each of these goods anywhere be  $a_i$ ,  $i=1, \dots, n$ . Then the fraction of each consumer's expenditure that is eventually paid to the labor producing good  $i$  is  $c_i = a_i b_i$ . For any  $n' \leq n$ , let  $\beta(n')$  be the fraction of expenditure on goods  $1, \dots, n'$ ,

$$(1) \quad \beta(n') = \frac{\sum_{i=1}^{n'} b_i}{\sum_{i=1}^n b_i}$$

and let  $\theta(n')$  be the fraction of  $\beta(n')$  that goes to labor,

$$(2) \quad \theta(n') = \frac{\sum_{i=1}^{n'} a_i b_i}{\sum_{i=1}^{n'} b_i}$$

Then the wage-rental ratio of either country in autarky,  $s_0^j$ ,  $j=A, B$ , can be derived from the shares of labor and capital.

Omitting the country superscripts, one gets the following in both countries:

$$(3) \quad \frac{wL}{rK} = \frac{\theta(n)y}{[1-\theta(n)]y}$$

where  $y$  is the country's income, and therefore,

$$(4) \quad s_0 = \frac{w}{r} = \frac{\theta(n)}{1-\theta(n)} \frac{K}{L}$$

where  $K$  and  $L$  are the respective capital and labor endowments.

Next note that with free trade and unequal factor prices, the labor abundant country -- call it A -- will produce only goods that are more labor intensive than those produced in country B, with the possible exception of a single good, call it

$i_c$ , that may be produced in common.<sup>21</sup> Let the goods be numbered in the order of decreasing labor intensity, so that

$$(5) \quad a_1 > a_2 > \dots > a_n.$$

Then with free trade and no commonly produced good, the ratio of country A's factor incomes will be

$$(6) \quad \frac{wL}{rK} = \frac{\theta(i')\beta(i')Y}{[1-\theta(i')]\beta(i')Y}$$

where  $i'$  is the most capital-intensive good produced in country A and  $Y$  is world income,  $y^A + y^B$ . It follows that country A's free trade wage-rental ratio will be:<sup>22</sup>

$$(7) \quad s^A = \frac{w^A}{r^A} = \frac{\theta(i')}{1-\theta(i')} \frac{K^A}{L^A}$$

It is now straightforward to compare wage-rental ratios. First note from (4) that autarky wage-rental ratios in the two countries depend only on the capital-labor endowment ratios,  $K/L$ , since  $\theta(n)$  is the same in both. Thus we find immediately that  $s_0^A < s_0^B$ , since A is labor abundant.

Next note in (2) that  $\theta(n')$  is simply a weighted average of the  $a_i$  from  $i=1, \dots, n'$ . From (5) it follows that  $\theta(n')$  declines as  $n'$  increases. Comparing (4) and (7), since  $i' < n$ , it follows

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21. See Deardorff (1979).

22. If there is a good,  $i_c$ , produced in common, then  $s^A$  lies between that of equation (7) and the value that would be obtained replacing  $i'$  in (7) with  $i_c$ . The argument still goes through.

that  $s_0^A < s^A$ .

Finally, the wage-rental ratio in B with trade is analogous to (7) but with  $\theta$  replaced by  $(1-\theta)$ . By reasoning similar to the above one can complete the following chain of inequalities:

$$(8) \quad s_0^A < s^A < s^B < s_0^B$$

Thus wage-rental ratios are drawn closer together by trade in this special Cobb-Douglas model.

It follows that, if one is willing to assume Cobb-Douglas production functions and preferences, then none of the problems noted in section III need arise.



## VI. Conclusion

I view this paper as calling attention to a problem that needs to be solved by trade theorists. The example set forth in section II is not implausible, but I rather doubt that it is representative of the real world. The particular pattern of substitutability that makes the example behave as it does is quite asymmetric and thus, I suspect, unlikely to occur. What we need is some assumption on preferences and technology together, similar in spirit but less restrictive than the Cobb-Douglas assumption of section V, that will rule out such an extreme result. I hope that with this paper I will stimulate others to begin the search for such an assumption.

After several decades in which trade theory has focused primarily on properties of production functions,<sup>23</sup> it is important that we now give equally careful attention to the demand side of the economy. That we have not had to do so in the past was largely due to the fact that there is not much room for preferences to matter in a two-good world. But as we now extend trade theory into higher dimensions, preferences may come into their own as, if nothing else, an irritating complication in the

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23. See however Jones (1980) who has explored the roles of various assumptions about demand in trade theory. Also, Melvin (1969) has explored implications of a particular demand assumption in a Ricardian model, and Melvin (1983) has looked at taste differences within a country when there are transport costs.

analysis.

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