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Quasi-Specific Factors: Worker Comparative Advantage in the Two-Sector Production Model

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This paper integrates the Heckscher-Ohlin, specific-factors, and Ricardian models of production with applications to international trade and labor economics. In international trade, factors of production need not be divided over trade policy and factor price equalization need not prevail. In labor economics, we show that the earning of economic rents is not inconsistent with competitive markets in general equilibrium and that process and skill-based innovations have contrasting effects on wage inequality.

While the ratio of skilled to unskilled wages was rising sharply in the United States during the 1980s (Juhn, et. al. 1993), the same was not true in Japan, France, and the United Kingdom (Butler and Dueker, 1999). This divergent behavior cannot be explained by a standard Heckscher-Ohlin model of production; for changes that drive factor prices in one economy also drive them in all economies in an integrated world. Thus, if the world economy is favoring goods that use skilled workers, skilled workers around the world would experience an improvement in their relative incomes. This paper presents a modest revision

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of the Heckscher-Ohlin model that is compatible with these facts.

The model I explore is one in which in the long-run under conditions of perfect competition capital is more mobile between industries than labor. The empirical justification for this assumption is that workers possess comparative advantage, while, in the long-run at least, capital is perfectly fungible. For example, Sattinger (1978) points out that the skewed distribution of earnings arises from comparative advantage in individuals. Accordingly, this paper develops a tractable model that integrates three well-known general equilibrium models--the Heckscher-Ohlin model, the Ricardian model of worker comparative advantage, and the specific factors model. Such a model sheds some fresh light on a number of important issues in labor economics and international trade and allows a sharp distinction between skill-based productivity gains and process innovations on the industry level. The model also has refutable implications that can be compared to alternative hypotheses.

The Heckscher-Ohlin (HO) model of production is useful for the insights it yields into the relationships between commodity and factor prices, output and factor supplies, and the role of factor intensities. The Ricardian model of comparative advantage is useful for highlighting the role of relative productivity differences in determining how factors specialize in particular industries (Rosen, 1978; Ruffin, 1988). Finally, the specific factors model has been used to focus on the contrast between mobile and immobile factors within an economy (Samuelson, 1971; Jones, 1971a; Mussa, 1974; Neary, 1978) and their role in determining the course of real factor returns. By combining the three models, a change in the relative price of, say, the capital-intensive good can can affect the ratio of skilled to unskilled wages differently between countries that are identical in all respects except factor endowment. Leamer (1995) and Jones and Ruffin (1975) deal with a similar model--Leamer with a set of Leontief production functions for each type of labor and Jones and Ruffin with a set of neoclassical production functions for each country. But the present model achieves sharper results by making the simplifying assumption that each type of labor is a perfect substitute within a single neoclassical production function for each industry.

Section I presents an overview of the model and its applications; and section II specifies the detailed equilibrium conditions. Sections III and IV examine the Stolper-Samuelson and factor price equalization theorems. Section V investigates the Rybczynski theorem. Section VI summarizes the impact of different kinds of technological change. Section VII sketches how to include the case of many types of labor, including a continuum. Finally, section VIII summarizes the paper.

I. Preview and Applications

A specific factor is one that is always used in a particular industry and has an effective value of zero in any other industry; a quasi-specific factor is one that has a positive value in another industry and, thus, can be induced to leave the industry if its economic rents vanish.

Now consider a standard two-sector model in which there are two goods (1 and 2) and three productive factors: capital, quasi-specific effective labor for industry 1; and quasi-specific effective labor for industry 2. The two types of quasi-specific effective labor are produced under constant returns by either type 1 labor or type 2 labor. However, type 1 labor has a comparative advantage in producing effective labor for industry 1 and type 2 has a comparative advantage in producing effective labor for industry 2. For simplicity, we will refer to type i workers as having a comparative advantage in industry i, although strictly speaking such a comparative advantage is indirect. Capital is perfectly mobile between the two industries. Each type of labor can be used in either industry, but because of comparative advantage it may be the case that each labor type is completely specialized. When each labor type is completely specialized it is because economic rents are being earned, and there is no incentive to work in the other industry. Each good is produced by a standard constant-returns-to-scale production function with two inputs. Factor endowments are fixed.

Figure 1 shows the production-possibility curve for the economy. In the range, AB, industry 1 is very small because the price of good 1 is low. This means that there are no economic rents earned by the workers who have a comparative advantage in that industry: they must work in industry 2 as well because otherwise they would be unemployed. If w_i is the wage of type i effective labor, in the range AB the ratio w_1/w_2 is fixed. This is so because when two types of labor are used in an industry, in this case industry 2, wages exactly reflect productivity differences (which are assumed fixed). Now as the price of good 1 rises, eventually economic rents will appear for workers with a comparative advantage in that good; at that point, all type 1 workers will be in industry 1. We now enter the BC range of the production-possibility curve. In this range, both types of workers are completely specialized and the model works exactly like the specific factors model (Jones, 1971a; Samuelson, 1971). As the price of good 1 rises, the wage ratio w_1/w_2 must also rise because capital is attracted away from industry 2 towards industry 1, driving down the return to type 2 labor just as in the specific factors model. It is in this range that changes in wage inequality occur in response to relative price changes. As the price of good 1 continues to rise, the economic rent of type 2 workers eventually evaporates and some of these workers move into industry 1. This is the CD range of the production-possibility frontier; again, the ratio w_1/w_2 is fixed. In the AB and CD ranges the model works exactly the Heckscher-Ohlin model; but one of the factors is earning an economic rent. The link between real wages and commodity prices is then entirely governed by factor-intensity conditions. Now price changes cause magnification effects--or Stolper-Samuelson effects--on labor and capital incomes (Jones, 1965).

Clearly, the testable implication of the model is to show that after controlling for technological change periods in which wage inequality is changing would be one in which the returns to capital would not be changing according to the predictions of the Stolper-Samuelson model. A simple method would be to show that during periods in which wage inequality is not changing very much, wages are highly correlated across industries; whereas in periods of rapidly changing wage inequality the correlation of wages across industries would be significantly smaller. I do not in this paper conduct such a test.

The advantage of including Ricardian comparative advantages inside the Heckscher-Ohlin model of competitive production is that one preserves the simplicity of Heckscher-Ohlin without sacrificing a somewhat richer and more intellectually satisfying interpretation of economic data.

Trade economists should find such a model useful because they can work with a model that allows them to get away from some of the more peculiar results of the HO model, such as factor price equalization or the Stolper-Samuelson theorem. These propositions imply that in an integrated world market what happens in one country will happen to all; so divergent trends in the ratio of skilled to unskilled wages would be inexplicable. In the present model, the fact that the skill premium rose in the United States in the 1980s but did not in France, Japan, and the United Kingdom would be explained by differences in factor endowment.

Moreover, the Stolper-Samuelson theorem states that factor intensities, not comparative advantage, determines the course of real returns when prices change. Thus, in a Stolper-Samuelson world all workers would want to protect the labor-intensive industry, whether working in that industry or not. In the present model, each worker may want to protect the industry in which he or she has a comparative advantage (we will say more about this issue later).[2]

Turning to the labor economics literature, the sharing of economic rents has been interpreted as indicating non-competitive labor markets (e.g. Blanchflower, et. al., 1996). However, in the present model no such interpretation is warranted because economic rents are price-determined in a competitive environment.

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[2]Magee (1980) presents evidence that in 19 out of 22 industries capital and labor agreed on protection versus free trade.

The literature on the behavior of the ratio of skilled to unskilled wages has been extensive. For example, in Juhn, et. al. (1993), it is reported that the ratio of skilled to unskilled wages stayed roughly constant in the 1960s but rose sharply in the 1980s. The 1970s were a transition period in which the education premium fell while the unobserved skill premium rose. Juhn, et. al. (1993) report that from 1960 to 1989, the wage premium for skilled workers rose by approximately 45 per cent. This issue has been linked to trends in international trade, demand, or technology that favor skilled workers (Berman, et. al., 1994). The present model shows that permanent trends in relative commodity prices or technological progress even in industries in which skilled workers have a comparative advantage will only result in temporary changes in relative wages.[3] Thus, over very long periods, the ratio of skilled to unskilled wages may not show a secular trend. There is some evidence for this. In the first half of the century, a number of studies found the skilled wage premium fell. In particular, Keat (1960) finds that from 1900 to 1949 the ratio of skilled to unskilled wages fell by roughly 33 percent. Thus, taking the entire period 1900 to 1989 into account, there is remarkable stability in the ratio of skilled to unskilled wages.

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[3]For the view that the rise in wage inequality may continue if present trends persist see Gregg and Manning, 1997.

II. The Model

Let us begin with a specific factors model. Two sectors use mobile capital and specific effective labor to produce goods under constant returns to scale. For given commodity prices and given endowments of capital and the two types of effective labor, capital moves between the sectors until its rental rate is equalized; this determines both the outputs of the two goods as well as the returns to the effective labor supplies.

Formally, industry i (i = 1,2) has the constant-returns-to-scale production function with all the usual concavity properties:

$$x_i = F_i(K_i, E_i),$$

(1) where E_i is the effective labor used in industry i.

A convenient way to analyze the model is to utilize the constant-returns-to-scale assumption (Samuelson, 1953; Jones, 1971a). Let a_{Ki} and a_{Ei} denote the amounts of capital and effective labor per unit of good i. The price of each good, p_i, must equal the unit cost of production; thus,

$$a_{Ki}r + a_{Ei}w_i = p_i \qquad (2)$$

where r and w_i are the prices of capital and effective labor. To keep the notation simple we suppress the dependence of the a_{ij}'s depend on the factor prices w_i and r. The two equations in (2), for given commodity prices, are not sufficient to determine the three factor prices. As in Jones (1971a), we must add the full employment conditions

$$a_{K1}x_1 + a_{K2}x_2 = K \tag{3}$$

$$a_{Ei}x_i = E_i \quad (i = 1,2) \tag{4}$$

The five equations (2)-(4) suffice to determine the two x_i's, the two wages, and r for given values of the p_i's, the E_i's, and K.

To introduce Ricardian comparative advantage we need only suppose that effective labor is produced by the Ricardian production function:

$$E_i = L_{1i}/b_{1i} + L_{2i}/b_{2i} \ , \tag{5}$$

where L_{ji} is the amount of type j labor employed in the production of effective labor of type i. The b_{ji}'s are the fixed Ricardian production coefficients; and, of course, represent the amount of raw labor required to produce a unit of effective labor. We could, of course, assume any number of such Ricardian factors (even a continuum); however, in the interests of simplicity, we will restrict our present analysis to only two such labor types. Later we shall indicate the implications of adding more Ricardian factors.

We assume that

$$b_{11}/b_{12} < b_{21}/b_{22}. \tag{6}$$

We are here assuming that type i labor has a comparative advantage in industry i, that is, in producing the effective labor used in industry i.

We cannot solve the model as in the specific factors model because the quantities L_{ji} are not yet determined. However, in the range BC of Figure 1 each labor type is specialized in the industry in which it has a comparative advantage, that is $L_{12} = L_{21} = 0$. We can then solve for the factor prices by appending the equations

$$E_j = L_j/b_{jj}$$

(7) where L_j is the supply of type j labor to the economy. The resulting effective wage rates (the w_j's) can now be determined.

This solution will in fact prevail (for given p_i's) provided no worker has an incentive to work in another industry. Let w_{ji} denote the wage type $\underline{j}$ worker earns in industry i. Of course, workers earn the value of their marginal product in producing effective labor. Given (5), it is easy to see that

$$w_{ji} = w_i/b_{ji} \tag{8}$$

In general, however, we cannot have workers of both types earning higher wages in same industry if both industries are to be viable. Type 1 workers cannot earn higher wages in industry 2, that is:

$$w_1/b_{11} \qquad w_2/b_{12} \tag{9}$$

Similarly, type 2 workers cannot earn higher wages in industry 1, that is:

$$w_2/b_{22} \qquad w_1/b_{21}$$

(10) The differences between the two sides of the

above inequalities simply measure the economic rents earned by each type of labor. Both (9) and (10) will hold provided

$$b_{21}/b_{22} \qquad w_1/w_2 \quad b_{11}/b_{12} \tag{11}$$

This, of course, is exactly the same as the link between commodity prices and cost ratios in the Ricardian theory of international trade, with effective labor prices replacing commodity prices. It is impossible for the effective wage ratio to be outside the range depicted in (9); for, otherwise, all labor would be in one industry.

When the commodity price ratio is such that strict inequalities prevail in (11), the model will work exactly like the specific factors model. Let us denote the relative price of good 1 as $p = p_1/p_2$. In the open range defined by (11)--replacing the weak inequalities by strict ones--as p rises, so will the effective wage ratio w_1/w_2. However, in the specific factors model a change in p has an ambiguous effect on the real return to capital--the mobile factor in this case--and clear-cut effects on the specific-factors (see Ruffin and Jones, 1977). However, in our case the quasi-specific factors, raw labor, may leave an industry if the return falls to the point of wiping out their economic rents. Now, as p rises, the output of good 1 will rise solely due to the attraction of capital out of industry 2 into industry 1. As the effective wage ratio rises, however, it will eventually hit the upper bound of (11). At this point type 2 workers are indifferent between working in the two industries. **It now seems clear that at this particular price ratio the model takes on a quite different flavor. Indeed, the model now becomes Heckscher-Ohlin with some of the attendant characteristics.**

This conclusion is very significant because it means that in a model with quasi-specific factors, we do not get simple relationships between commodity prices and real factor returns, as in either the HO or specific factors model. If, for example, the price of the capital-intensive good rises, at first the workers that have a comparative advantage in that good benefit while all other workers are hurt. But as the price continues to rise a point will be reached where all workers are hurt. On the other hand, if the price of labor-intensive good rises, the workers who have a comparative advantage in that industry benefit, other workers are hurt; but eventually all workers are helped as the price continues to rise.

These are useful results. We know from empirical studies that when profits in an industry rise, so-called skilled workers in that industry also benefit whereas the unskilled do not benefit so much (see Blanchflower, *et. al*, 1990). This fact may be explained by the current model. The current model implies, however, that such a relationship eventually depends on the factor-intensity of the industry in question, and that at extreme values factor intensities matter. This may help explain why Stolper-Samuelson effects are difficult to observe (see footnote 2); they apply to the extremes, not to the "normal" cases.

If capital is regarded as the mobile factor--i.e., the factor without long-run comparative advantages--then this model also suggests that for middle ranges of commodity prices the link between commodity prices and the real returns to capital is ambiguous. This, too, has some explanatory value. Few seem to care about the effects of tariffs, taxes, or subsidies on the returns to capitalists as much as the returns to labor. One explanation would be that labor's returns are more profoundly effected because it is the quasi-specific factor.

Let me now show these results formally. Suppose p changes so that the ratio of effective wage rates equals the lower or upper bound of (11); that is, $w_1/w_2 = b_{j1}/b_{j2}$. Now the pricing equations (2) become:

$$a_{K1}r + a_{E1}b_{j1}w_2/b_{j2} = p$$

$$a_{K2}r + a_{E2}w_2 = 1 \tag{12}$$

The input-output coefficients $a_{ji} = a_{ji}(r, w_i)$, $j = K, E_i$. Using the subsidiary relation $w_1/w_2 = b_{j1}/b_{j2}$ we can obviously solve for r and the w_i's for any given commodity prices. Notice that as p rises, w_1/w_2 eventually rises from b_{11}/b_{12} to b_{21}/b_{22}; in the sequel it will be necessary to study the ramifications of this phenomenon.

How can we solve for outputs? When p is high enough so that $w_1/w_2 = b_{21}/b_{22}$, where both labor types work in industry 1, the output equations are:

$$
\begin{aligned}
&a_{K1}x_1 + a_{K2}x_2 = K \\
&a_{E1}x_1 = L_1/b_{11} + L_{21}/b_{21} \\
&a_{E2}x_2 = (L_2 - L_{21})/b_{22}
\end{aligned}
\tag{13}
$$

However, if we combine the last two equations in (13) we obtain

$$
\begin{aligned}
&a_{K1}x_1 + a_{K2}x_2 = K \\
&a_{E1}x_1 + a_{E2}x_2 b_{22}/b_{21} = L_1/b_{11} + L_2/b_{21}
\end{aligned}
\tag{14}
$$

In the low p case, where $w_1/w_2 = b_{11}/b_{12}$ so that both labor types work in industry 2, the output equations are:

$$
\begin{aligned}
&a_{K1}x_1 + a_{K2}x_2 = K \\
&a_{E1}x_1 b_{11}/b_{12} + a_{E2}x_2 = L_1/b_{12} + L_2/b_{22}
\end{aligned}
\tag{14'}
$$

Equations (12) and (14) or (14') parallel the standard HO model in the sense that we solve the pricing equations, (12), first and then the output equations, (14) or (14'), for the x_i's. We will subsequently have occasion to analyze the quantity $L_1/b_{1j} + L_2/b_{2j}$, which is maximum amount of type j effective labor that the economy can generate. With this interpretative difference in factor endowments and the presence of economic rents in the earnings of one of the labor types it remains to study whether the standard properties of the Heckscher-Ohlin model hold.

III. Stolper-Samuelson

The relationship between commodity prices and factor prices in the HO region of the economy is embedded in equations (12). It might appear that Stolper-Samuelson might have to be modified owing to the presence of the ratio b_{j1}/b_{j2}. However, it is there because $w_1 = w_2 b_{j1}/bj_2$; therefore, $\hat{w}_1 = \hat{w}_2$, where the circumflex over a variable means a logarithmic derivative, e.g., $\hat{p} = dp/p$. Totally differentiating equations (12) we find that the equations of motion are identical in all respects to the standard HO model (see Jones, 1965):

$$
\begin{aligned}
&\epsilon_{K1}\hat{r} + \epsilon_{E1}\hat{w}_2 = \hat{p} \\
&\epsilon_{K2}\hat{r} + \epsilon_{E2}\hat{w}_2 = 0
\end{aligned} \tag{15}
$$

We define $\epsilon_{Ki} = ra_{Ki}/p_i$ and $\epsilon_{Ei} = w_i a_{Ei}/p_i$, where the shares must add to unity. To solve it is convenient to define

$$D(j) = \epsilon_{K1}\epsilon_{E2} - \epsilon_{E1}\epsilon_{K2} \tag{16}$$

We let D depend on j because, rewriting:

$$D(j) = (w_2 r/p)[a_{K1}a_{E2} - a_{K2}a_{E1}b_{j1}/b_{j2}] \tag{16'}$$

The index j in equation (16') denotes the labor type that is used in both industries. Thus, we have

$$\hat{w}_2/\hat{p} = -\epsilon_{K2}/D(j) \tag{17}$$

$$\hat{r}/\hat{p} = \epsilon_{E2}/D(j) \tag{18}$$

We must, of course, determine the sign of D(j). If the capital share is higher in good 1 than in good 2, good 1 is capital-intensive so that $\epsilon_{K1}/\epsilon_{E1} > \epsilon_{K2}/\epsilon_{E2}$ or that D(j) is positive. Here it is important to note that we must define the capital-intensity of an industry by the financial ratios rather than the physical ratios, a_{Ki}/a_{Ei}; for the physical ratios cannot really be compared since the denominator is in different units. Clearly, the effects of relative prices on real returns not only fit into the Stolper-Samuelson mold, they are of the same order of magnitude in the low-p (where $w_1/w_2 = b_{11}/b_{12}$) or the high-p case (where $w_1/w_2 = b_{21}/b_{22}$).

There is, however, one key difference between the present model and the standard HO model: factor intensity reversals are possible with fixed factor endowments. This is clear from (16'). Comparing with (16) we see that if the production functions are Cobb-Douglas, where the $€_{ij}$'s are constant, factor-intensity reversals are not possible; however, in general, we must admit this possibility. As an example, if the production functions are Leontief, as b_{j1}/b_{j2} jumps from b_{11}/b_{12} to b_{21}/b_{22}, it is possible for the sign of D(j) to change. Therefore, the link between commodity prices and factor prices can differ in the two HO regions of the economy.

Since factor intensity reversals are irrelevant for our purposes, we make the assumption that the sign of D(j) does not change. This will be the case if the elasticities of substitution are not too much different from unity. The workings of the model are shown by Figure 2 under the assumption that good 1 is capital-intensive. In the upper panel, we show the relationship between the commodity price ratio and the effective wage ratio. In the range p (p',p'') we have the specific-factors model, with all type 1 labor in industry 1 and type 2 labor in industry 2; as the relative price of good 1 rises, so does the effective wage of type 1 labor compared to type 2 regardless of any factor intensity conditions. In the lower panel, we show that the relationship between the relative price of good 1 and the real earnings of type 1 labor is monotonically decreasing. This is so because when $p < p'$ or $p > p''$ the model takes on the key Heckscher-Ohlin characteristics; with good 1 capital-intensive, the real return to labor falls with the relative price of good 1. On the other hand, the relationship between p and the real return of type 2 labor is non-monotonic; for in the specific-factors range of the model as the price of good 1 rises the return to type 2 labor falls regardless of factor intensities. Indeed, it must be the case that for one of the types of labor there is a montonic relationship; while for the other it is non-monotonic. Thus, Figure 2 is perfectly general when there are no factor-intensity reversals, although the comparison between the real wages of the two types of workers can be anything (depending on absolute advantage).

What is interesting about this model is that the Heckscher-Ohlin character of the model appears at the extremes. This is not really surprising. The power of HO comes from competition from mobile factors: unless relative prices are at an extreme enough level to bring about competition between factors of different types, factor specificity will rule the day.

IV. Factor Price Equalization

Suppose we now have two countries, home and foreign, identical in all respects except factor endowments. The home country is well endowed with type 2 labor and/or capital. Figure 3 shows the relationship between commodity price and effective wage ratios for the home (H) and foreign (F) countries under the assumption that good 1 is capital-intensive. Imagine first that the two countries are exactly the same as in the foreign country, so that curve F describes the relationship. The specific-factor range is the interval (p',p"). Adding more type 2 labor to the home country would clearly raise w_1/w_2 for any p; so the H curve would have to be above the F curve.

Why would more capital shift up the H curve compared to the F curve? Again suppose all endowments are the same as in F. Now add a bit more of mobile capital to the home country. The curve will shift up because more capital will favor the capital-intensive industry, and type 1 labor has a comparative advantage in that industry. This is easy to show: This comes directly from applying the "hat" calculus to equation (2). We are asking what happens to the effective wage ratio for fixed prices. When endowments change, factor prices change; from Shephard's Lemma it follows that $\epsilon_{Ki}\hat{r} + \epsilon_{Ei}\hat{w}_i = 0$. Since $\hat{w}_i = -\hat{r}\epsilon_{Ki}/\epsilon_{Ei}$, it follows that

$\hat{w}_1 - \hat{w}_2 = \hat{r}(\epsilon_{K2}/\epsilon_{E2} - \epsilon_{K1}/\epsilon_{E1})$. Clearly, an increase in K depresses r--so $\hat{r}$ is negative. If good 1 is capital-intensive, so $\epsilon_{K2}/\epsilon_{E2} < \epsilon_{K1}/\epsilon_{E1}$, then w_1/w_2 must rise.

Now we can discuss factor price equalization (FPE). The main proposition is that if p (p^o, p''), there cannot be FPE. However, FPE can obtain if either $p < p^o$ or $p > p''$; and it will obtain, of course, if the factor endowments of the two countries are sufficiently close. Let us take the case where $p > p''$. In this case, equations (12) and (14) govern the model. The effective wage ratio is $w_1/w_2 = b_{21}/b_{22}$. Provided both goods are produced and there are no factor-intensity reversals, equations (12) for $j = 2$ will determine the factor prices in both countries as long as the factor endowments of the two countries lie in the same cone of diversification (that is, the set of endowments consistent with a single set of factor prices).[4]

Under all other circumstances FPE fails. For example, if p (p^o, p'), then in the foreign country the wage ratio is governed by $w_1/w_2 = b_{11}/b_{12}$, with type 1 labor working in both industries, but in the home country we are on the H curve itself and the relative price of type 1 labor is higher--FPE cannot hold.

V. The Rybczynski Theorem

I now want to investigate the Rybczynski theorem. We will show that if the Stolper-Samuelson theorem holds, so does

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[4]See Chipman (1966).

Rybczynski. This may not seem remarkable; but in Jones (1971b) it is shown that when different factor prices are paid in two industries Stolper-Samuelson does not imply Rybcyznski. However, there is a crucial distinction between factor market distortions as analyzed by Jones (1971b) and the current model: different factor prices reflect productivity differences in the present case so we would not expect the Jones result.

Let us just consider the case where the price of good 1 is such that some type 2 labor is involved in industry 1, that is, equations (14) apply. Earlier, we saw that factor intensity could be defined by using the financial ratios $€_{Ki}/€_{Li}$. We now need to define the physical factor intensities. This is somewhat tricky because we no longer have a homogeneous labor force. Let us examine the last equation in (14), that is:

$$a_{E1}x_1 + a_{E2}x_2b_{22}/b_{21} = L_1/b_{11} + L_2/b_{21} \ .$$

The quantity $L_1/b_{1j} + L_2/b_{2j}$ is the maximum amount of effective labor of type j that can be produced in the economy; call this quantity V_j. When relative prices are fixed, so are the a_{ij}'s as in the standard model. Let us define $€_{Ki} = a_{Ki}x_i/K$ (as usual); but define $€_{Eij} = a_{Ei}x_i/V_j$. Consider now a change in factor endowments only. Now, differentiation of (14) leads to:

$$€_{K1}\hat{x}_1 + €_{K2}\hat{x}_2 = \hat{K}$$

$$€_{E11}\hat{x}_1 + €_{E21}\hat{x}_2b_{22}/b_{21} = \hat{V}_1. \qquad (19)$$

Recall the definition for the financial ratios in (16'): D(2) =

$(w_2r/p)[a_{K1}a_{E2} - a_{K2}a_{E1}b_{21}/b_{22}]$. In this case, type 2 labor is used in both industries. Now for the physical case, note that

$$\text{€}(2) = \text{€}_{K1}\text{€}_{E21}b_{22}/b_{21} - \text{€}_{K2}\text{€}_{E11}$$

$$= (x_1x_2/KV_1)(a_{K1}a_{E2}b_{22}/b_{21} - a_{K2}a_{E1}). \qquad (20)$$

Obviously, D(2) is positive or negative as €(2) is positive or negative. Accordingly, solving for $\hat{X}_i$ we find

$$\hat{X}_1 = \hat{K}\text{€}_{E21}b_{22}/\text{€}(2)b_{21} - \hat{V}_1\text{€}_{K2}/\text{€}(2) \qquad (21)$$

$$\hat{X}_2 = \hat{V}_1\text{€}_{K1}/\text{€}2) - \hat{K}\text{€}_{E11}/\text{€}(2) \qquad (22)$$

Clearly, since €(2) is positive when good 1 is capital-intensive, we obtain the familiar Rybczynski result that an increase in K increases (decreases) the output of good 1 (good 2) while an increase potential effective labor V_1 increases (decreases) the output of good 2 (good 1). A similar result would obtain if type 1 labor were used in both industries. We thus obtain the theorem that in any of the HO ranges of the economy the familiar Stolper-Samuelson and Rybczynski results obtain; however, unlike the standard HO model, there can be factor intensity reversals between the HO regions.

VI. Technological Change

We now consider the impact of technological change on production patterns and factor prices, holding commodity prices constant. Given the two-level production function, it is obvious that technical change can either effect the production of effective labor ("skill-based technological change") or technical change in the industry itself by virtue of new insights into combining capital and effective labor ("process technical change"). I will only consider cases of neutral technical change. Moreover, just because the model permits a distinction between the two types of technological change does not mean that the real world works that way. Nevertheless, we proceed as if it does and ask whether it makes any difference.

If the Ricardian production function does not change, that is, if the productivity of raw labor remains constant, an improvement in the conversion of effective labor and capital into goods will have an impact that is similar to a change in commodity prices. As pointed out by Findlay and Grubert (1959) and analyzed in detail by Jones (1965), one can consider neutral technological progress as fully equivalent to an increase in the price of a good. If we consider the unit value isoquant for any good, if the price increases the isoquant moves in uniformly along any ray from the origin; the same occurs with neutral technological progress. Accordingly, whether there is an increase in the price of a good or neutral technological progress, one achieves a parallel impact on resource allocation and factor prices. Thus, holding commodity prices constant, neutral technological improvement in an industry will bring about expansion of such an industry and will, of course, benefit those factors with a comparative advantage in that industry or the factor in which the industry is intensive in the Heckscher-Ohlin region of the economy. Such technical change will only change wage inequality if it occurs in the specific-factors region of the economy; otherwise, either all wages rise or fall.

What is the impact of skill-based technological change? It should be obvious that if a group of workers become more productive their market wages will rise relative to other groups. This has a quite different impact on observed wages; but if such technological change reflects investments in human capital it is questionable whether wages net of these costs show divergent trends. To properly analyze this it is necessary to include learning-by-doing and human capital investments. However, the end result is higher productivity and it may be useful to just consider the consequences of autonomous improvements in some worker's productivity. Let us suppose that good 1 is the skill-based good so that type 1 labor can be considered skilled labor compared to type 2 labor. The ratio b_{2j}/b_{1j} is type 1 labor's productivity advantage over type 2 labor in industry j.

To be concrete I assume that type 1 wages are higher than type 2 wages. Now suppose that type 1 labor becomes uniformly more productive in all industries. Since each b_{1j} falls by the same percentage, the ratio b_{11}/b_{12} remains constant. The effect of this on wage structure depends on the region in which the economy is operating.

First consider the case in which the economy operates in either one of the HO regions of the economy. In this case, $w_1/w_2 = b_{j1}/b_{j2}$ so that nothing happens to effective wages, as is clear from the pricing equations (12). However, type 1 wages will rise by the improvement in their productivity ($w_{1j} = w_j/b_{1j}$) and wage inequality will rise by exactly the same proportion because wages of type 2 workers remain exactly the same ($w_{22} = w_2/b_{22}$). However, due to Rybczynski effects, whether the economy moves away from or deeper into the HO region depends on whether the relative price of capital-intensive goods is low or high. When type 1 labor becomes more productive, Rybczynski effects become relevant and the output of the capital-intensive good must fall, as is clear from either (14) or (14'). If the price of the capital-intensive good is already low, the economy will become more deeply entrenched in the initial HO region; if the price of the capital-intensive good is high, the economy will move towards the specific factors region on the economy.

If the productivity enhancement occurs when the economy is in the specific-factors region of the economy, an improvement in type 1 labor's productivity will cause wage inequality to rise by more than the rise in productivity. This is because the effective wage of type 1 workers will rise while the effective wage of type 2 workers will fall, thus enhancing the impact of the improvement in type 1 workers' skills. However, the economy's production of good 1 will rise relative to good 2. Eventually, the economy will find itself in the Heckscher-Ohlin region of the economy. Once this occurs, a uniform improvement in type 1 labor's productivity will have no impact on the effective wage ratio, for given commodity prices, but will have a proportionate impact on the real earnings of type 1 labor.

VII. Some Possible Extensions

Let us now consider extending the model to include more Ricardian factors. For concreteness imagine a third Ricardian factor--call it z--such that

$$b_{11}/b_{12} < b_{z1}/b_{z2} < b_{21}/b_{22} \qquad (22)$$

Clearly, it is now possible for the effective wage ratio to be equal to b_{z1}/b_{z2}. At this point, type z labor is employed in both industries--but type 1 labor and type 2 labor are earning economic rents and so are entirely specialized. However, the effective wage ratio will be fixed until all type z labor is absorbed in one industry or the other. In the range of commodity prices where type z labor works in both industries, any change in prices will exert Stolper-Samuelson effects on the effective wage rates--just as before. For example, if good 1 is capital-intensive, an increase in p will depress both w_1 and w_2 by equal percentages. However, the model no longer works like the specific-factors model. Clearly, the more labor-types that exist in the economy the smaller will be the specific-factors range of the economy. Indeed, with a continuum of labor types, it would appear that the model would always behave exactly like the HO model in small comparative statics exercises--with this exception: factor price equalization would be very unlikely.

However, if a continuum is considered unrealistic, the case of a finite number of labor types leads to some interesting conclusions. For example, if there are three labor types, the most likely scenario is for two labor types to work in one industry and one in the other industry. In this case, the model retains its specific factors flavor. If the price of any good increases, the real returns to all those specific factors working in an industry will increase, regardless of factor intensity conditions. Such a result appears to help explain the results of Blanchflower, et. al. (1990), where they found that increasing the profits of an industry appear to be shared by the "skilled" workers in that industry. Whether their conclusion is best explained by the current competitive model or their non-competitive model is an issue that needs to be explored by examining the additional implications of the two models.

VIII. Summary.

This paper shows that by integrating the Heckscher-Ohlin, specific-factors, and Ricardian models of production it is possible to achieve a tractable model capable of addressing important issues in labor economics and international trade. In international trade, factors of production need not be divided over trade policy and factor price equalization need not prevail. In labor economics, we show that the earning of economic rents is not inconsistent with competitive markets in general equilibrium and that process and skill-based innovations have contrasting effects on wage inequality. Process innovations may lead to wage inequality, but cannot cause a permanent trend; skill-based (for labor) innovations will cause trends in wage inequality, and may strengthen or weaken Heckscher-Ohlin properties.

The paper suggests that even in the absence of relative skill upgrading by unskilled workers that secular trends in the skill premium may not occur even though more and more resources are devoted to high-skilled goods. For the United States there is some evidence that this is the case since 1900 (Keat, 1960; Juhn, et. al., 1993). The skill premium fell in the first half of the century; and rose in the last half of the century. Thus, around mid-century, one would then expect to find more skilled workers in blue-collar industries, as documented Goldin and Katz (1998) for 1940. Skill premiums rose sharply in the 1980s but in the 1990s they appear to have stabilized in the face of large changes in technology and growth in international trade. Moreover, the skill premium did not rise in other major countries during the 1980s (Butler and Dueker, 1999). The model appears consistent with these facts. However, the model can be rejected by showing that Stolper-Samuelson effects are no stronger in, say, the 1990s than in the 1980s. How to do this is an empirical challenge.

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