

## CHAPTER 6

# Factor Endowments and Trade II: The Heckscher-Ohlin Model

A theory of international trade that highlights the variations among countries of supplies of broad categories of productive factors (labor, capital, and land, none of which may be specific to any one sector) was developed by two Swedish economists, Eli Heckscher and Bertil Ohlin.<sup>1</sup> Their model subsequently has been extended in scores of articles and treatises. Some of the new results were startling: Two countries that share the same general technology but differ in their endowments of the basic factors of production may nonetheless find that free trade in commodities forces wage rates in the two countries into absolute equality. Advocates of protection have found support in another proposition: Even a broad-based factor such as labor may unambiguously gain by the imposition of tariffs.

Most of these propositions were carefully proven and adequately qualified in a simple form of the theory—the  $2 \times 2$  model, so called because it analyzed an economy producing two commodities with the use of only two productive factors. This model has proved to be immensely popular not only in the area of international trade but also in fields such as public finance and economic growth. We initially follow Heckscher and Ohlin in assuming that countries share the same technological knowledge, an assumption made to highlight a cause for trade (different relative factor endowments) that is distinct from the technological asymmetries emphasized in the Ricardian model. We begin by restricting discussion to the  $2 \times 2$  case, which leads to a pair of key features that deserve to be highlighted here:

1. The pattern of trade reflects the relative endowment of productive factors—relatively labor-abundant countries tend to export relatively labor-intensive commodities.
2. Freeing up trade benefits the relatively abundant factor of production but harms the relatively scarce factor.

The more realistic case in which many countries are trading freely in many commodities is handled later in the chapter.

<sup>1</sup>E. Heckscher, “The Effect of Foreign Trade on the Distribution of Income,” *Ekonomisk Tidskrift*, 21 (1919): 497–512, retranslated in H. Flam and M. J. Flanders, eds., *Heckscher-Ohlin Trade Theory* (Cambridge, MA: MIT Press, 1991); B. Ohlin, *Interregional and International Trade* (Cambridge, MA: Harvard University Press, 1933). In 1977 Ohlin shared the Nobel Prize in economics for his early work in trade theory.

Once again we label the two commodities, food and clothing. The structure here shares with the two preceding chapters the view that production takes place in a competitive setting in which the technology linking inputs and outputs exhibits constant returns to scale: Doubling all factor inputs exactly doubles output. However, there is an important difference: No longer (as in Chapter 5) does each commodity use an input not required by the other commodity. Instead, both industries compete for the same pair of productive factors, labor and capital. The crucial feature that distinguishes production of food from that of clothing is the *factor intensity* that each requires; the ratio of capital to labor used in food differs from that adopted by the clothing sector.

### 6.1 If Technology Is Rigid

The basic ideas of the Heckscher-Ohlin theory can be conveyed in a simple scenario in which technology is assumed to be very rigid. By this is meant that there is only one way to produce clothing— $a_{LC}$  and  $a_{KC}$  represent fixed input-output coefficients depicting how much labor and how much capital are required to produce a unit of clothing. Similarly, technology is rigid in food production, with  $a_{LF}$  and  $a_{KF}$  representing the fixed quantities of labor and capital required to produce a unit of food. A direct comparison of  $a_{LC}$  with  $a_{LF}$  has no meaning because either coefficient can arbitrarily be changed by altering the units in which one of the goods is measured, for example, from pounds to tons (or from grams to kilograms). What is relevant, however, is a comparison of the capital/labor *ratios* used in the two sectors. We henceforth assume (arbitrarily) that clothing is the relatively labor-intensive sector, and by this we mean that:

$$a_{LC}/a_{KC} > a_{LF}/a_{KF} \quad (6.1)$$

One more piece of information is required before output levels (or trading patterns) can be identified: factor endowments. In particular we need to know how these two countries, which are assumed to share a common (rigid) technology, differ from each other in the proportions of capital to labor each possesses. Once again assume that factors of production stay home, and only commodities are traded. This implies that a country's factor endowment bundle, along with its technology, dictates production possibilities. Assume, now, that the home country is the relatively *labor-abundant* country. By this is meant:

$$L/K > L^*/K^* \quad (6.2)$$

A comparison of the production possibilities schedules of the two countries will reveal the bias that endowment differences impart to the likely pattern of trade. Figure 6.1 illustrates the production possibilities schedule for the foreign country. The labor constraint is precisely of the same kind as found in the Ricardian (Chapter 4) model:

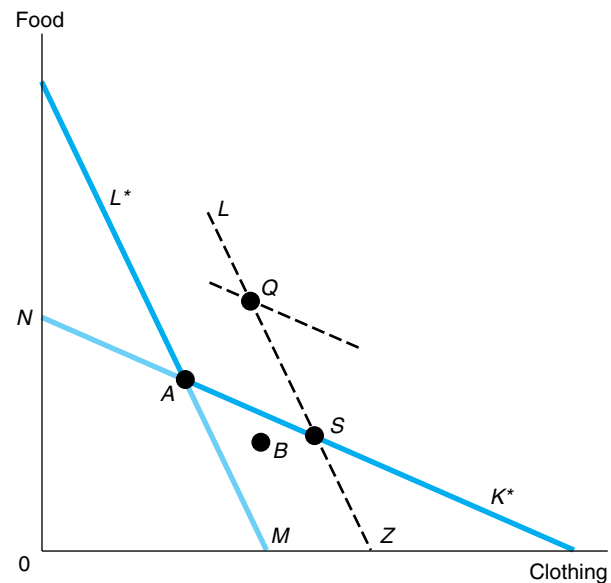
$$a_{LC}x_C^* + a_{LF}x_F^* = L^*$$

Unlike the Ricardian case, however, now capital is also required to produce each of the goods, leading to a linear capital-constraint line:

$$a_{KC}x_C^* + a_{KF}x_F^* = K^*$$

**FIGURE 6.1****Production Possibilities: Rigid Technology**

Inner locus  $NAM$  is the production-possibilities schedule for the foreign country, with full employment of both factors only at intersection  $A$ . The home country's full-employment point would be  $S$  if it had the same technology, the same capital supply, but a 50 percent greater labor force. The home transformation schedule would then be  $NSZ$ .



Note that in both these constraint lines the input-output coefficients do not have asterisks. Technology is assumed to be the same abroad and at home. Two features of the way in which this  $K^*$  line has been drawn in Figure 6.1 are worth stressing: (1) The capital-constraint line is assumed to intersect the labor-constraint line instead of lying everywhere above (in which case foreign capital is so abundant it is free) or everywhere below (in which case foreign labor is in excess supply). (2) The capital-constraint line has been drawn flatter than the labor-constraint line, a direct consequence of our assumption that clothing is the relatively labor-intensive commodity. (Check this out for yourself by computing the slopes of the lines.) The inner locus  $NAM$  forms the foreign country's production possibilities schedule; only for production bundles on or below this locus will the economy not be using more of either capital or labor than is available. Intersection point  $A$  is of particular interest to us; point  $A$  represents the *only* output combination for which both labor and capital are fully employed.

Because the home country is assumed to share the same (rigid) technology, its constraint lines must be parallel to those in Figure 6.1. But the position of its lines reveals its factor endowments. For example, if the home country were exactly 50 percent larger than the foreign country in both endowments, its constraint lines would lie 50 percent farther from the origin, leading to output bundle  $Q$  if home labor and capital are fully employed. Instead, let us abide by our assumption that the home country is relatively labor abundant and suppose only its labor force is 50 percent larger. Thus, full employment and home production would lie at point  $S$  and the home transformation schedule would be  $NSZ$ .<sup>2</sup> Note that the endowment difference between countries has led to a

<sup>2</sup>Figure 6.1 shows that if labor alone expands, the output of capital-intensive food must actually contract, because it must release capital (as well as labor) to the expanding clothing sector. This relationship is known in the literature as the *Rybczynski theorem*. See T. M. Rybczynski, "Factor Endowment and Relative Commodity Prices," *Economica*, 22 (November 1955): 336–341.

magnified or more pronounced difference in the production patterns of the two countries. The generalization that we focus on here for two countries sharing the same rigid technologies and fully employing both labor and capital can be stated as:

*The relatively labor-abundant country produces relatively larger quantities of the labor-intensive commodity.*

Thus, if taste patterns do not differ very much between countries,

*The relatively labor-abundant home country will tend to export the relatively labor-intensive commodity.*

### A Numerical Example

A numerical example may help highlight how endowment differences between countries affect production (and trade) patterns. Suppose the following set of input-output coefficients:

#### Factor Requirements per Unit of Output

|          | Labor        | Capital      |
|----------|--------------|--------------|
| Clothing | $a_{LC} = 3$ | $a_{KC} = 1$ |
| Food     | $a_{LF} = 1$ | $a_{KF} = 2$ |

The capital/labor ratio in food (2/1) exceeds that in clothing (1/3). If the foreign country possesses 200 units of productive labor and 200 units of capital, the only combination of outputs that will fully employ both labor and capital is a clothing output of 40 units and a food output of 80 units. That is, if  $x_C^*$  and  $x_F^*$  denote foreign clothing and food outputs respectively, full employment implies that

$$3x_C^* + x_F^* = 200 \quad (\text{for labor})$$

$$x_C^* + 2x_F^* = 200 \quad (\text{for capital})$$

or that  $x_C^*$  equals 40 and  $x_F^*$  equals 80.

Suppose that the home country's labor force is 50 percent higher, 300 units, and the capital stock is the same. Simple calculation reveals that in order for labor and capital to be fully employed at home,  $x_C$  must be 80 units and  $x_F$  must be 60 units. A comparison with the foreign values shows that the home country, with a 50 percent higher labor force, has a 100 percent higher output of labor-intensive clothing and a lower output of food. Such a production comparison supports the presumption that if these two countries engage in free trade, the home country will export clothing to the foreign country.

How do commodity price changes alter the internal distribution of income? This same numerical example can help explain the connections. Because only relative prices matter, suppose the price of food is \$10 in both countries, before and after trade.<sup>3</sup> But

<sup>3</sup>We have arbitrarily assumed both countries use the same currency (the dollar) because we have simplified by letting food's price always be \$10.

in the home country the relative abundance of labor supports an equilibrium autarky clothing price of \$8, as compared to a higher foreign autarky price of \$12. Letting  $w$  and  $r$ , respectively, denote home wages and rentals on capital, with asterisks showing foreign values, the requirement that in a competitive equilibrium unit costs equal price suggests that:

$$\begin{array}{lll} \text{At home:} & 3w + r = 8 & \text{(clothing)} \\ & w + 2r = 10 & \text{(food)} \\ \text{Abroad:} & 3w^* + r^* = 12 & \text{(clothing)} \\ & w^* + 2r^* = 10 & \text{(food)} \end{array}$$

The only pair of wage rates and rents at home that satisfy this requirement is a wage rate of \$6/5 and a rental of \$22/5. Abroad, because clothing is relatively more expensive in autarky (the foreign country is a relatively labor-scarce country and clothing is relatively labor intensive), it is not surprising to find autarky wages higher, with  $w^*$  equal to \$14/5 and rentals lower than at home at \$18/5. If these two countries trade commodities with each other, equilibrium terms of trade will be established that lie between the autarky price ratios. Suppose this is 1:1—that is, suppose that after trade the world price of clothing is \$10 (as is the price of food). Arithmetic manipulation reveals that wages and rents get equalized between countries: At home the wage rate rises to a value of \$2 and rentals fall to a value of \$4. Abroad, factor prices move in just the opposite direction to yield a value of \$2 for the foreign wage rate and \$4 for rentals.

Two central features of international trade between countries in the  $2 \times 2$  model have been illustrated:

- (1) *Free trade benefits the abundant factor of production and harms the relatively scarce factor of production.*
- (2) *If countries share a common technology, free trade in commodities serves to equalize factor returns despite our assumption that factor markets are purely national and no international factor mobility is allowed.*

This latter feature of the model is referred to as the *Factor-Price Equalization Theorem*. As we see later, it may not always hold, even if countries do indeed share the same technology.

## 6.2 Flexible Technology

The preceding account of production and pricing relationships when a technology that is shared in common by both countries is rigid has served to introduce the basic relationships in Heckscher-Ohlin theory whereby countries tend to export commodities that make intensive use of the factor of production found locally in relative abundance, and free trade helps the nation's relatively abundant factor of production but harms the nation's scarce factor. With rigid technology it is unambiguous what is meant by assuming that clothing production is relatively labor intensive. But if technology is flexible,

the actual choice of technique depends on market values of wages and rentals on capital equipment; relatively high wages will encourage all sectors to adopt relatively capital-intensive methods of production.

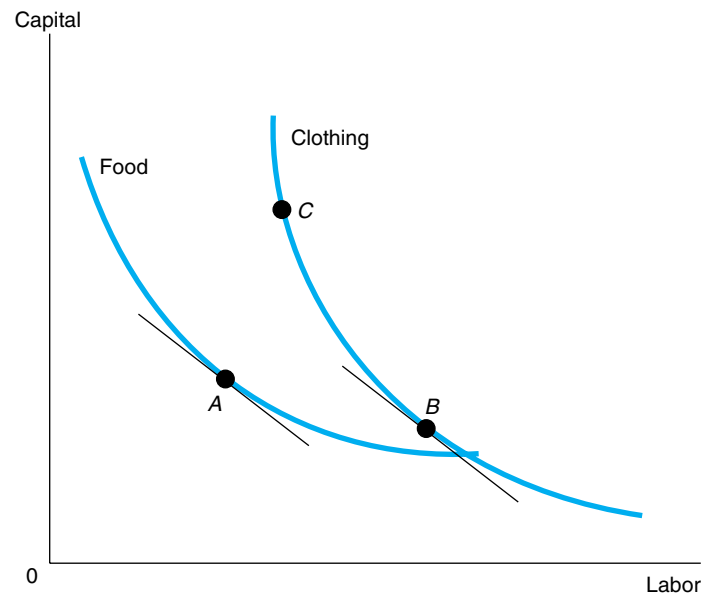
### Factor Intensities

One way of illustrating the variety of techniques available when technology is flexible is the *isoquant*: an array depicting the alternative bundles of capital and labor that can be used to produce the same level of output. Figure 6.2 illustrates such an isoquant for each of the sectors of the economy. (This should remind you of indifference curves described in Chapter 2.) If the ratio of wages to rentals is indicated by the slope of the lines tangent at *A* and *B* in Figure 6.2, these points (*A* and *B*) represent the best choice of technique to produce food and clothing, respectively. Although such a selection reveals that clothing (at *B*) is produced with relatively more labor-intensive techniques than food (at *A*), note that it is technologically *possible* for clothing to be produced with more capital-intensive techniques (compare *C* with *A*). But if both industries must shop for productive factors in the same national market, Figure 6.2's isoquants show that when costs are minimized in each, clothing is relatively labor intensive. Note that there are many isoquants for each good—depending on the output level illustrated. For each commodity these isoquants will be *homothetic*, reflecting our assumption of constant returns to scale. The quantities of each commodity selected in Figure 6.2 are completely arbitrary.

**FIGURE 6.2**

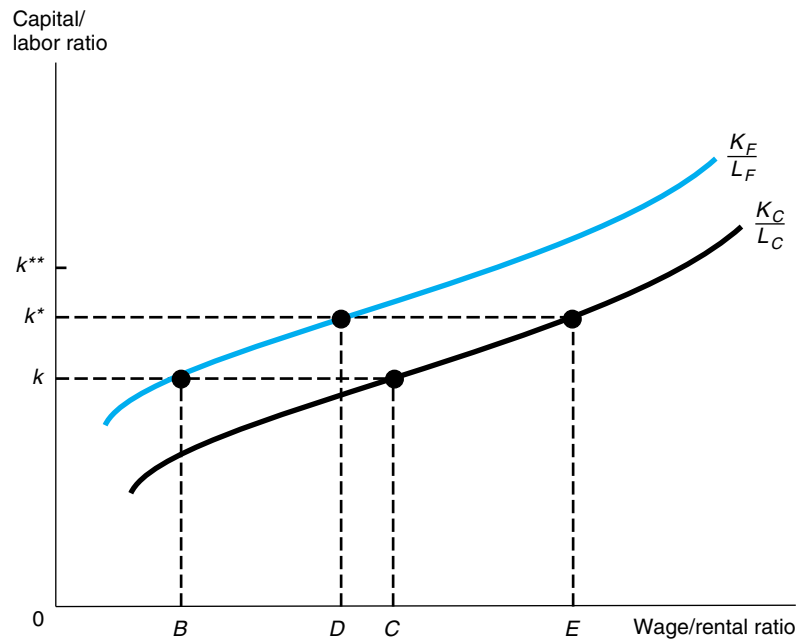
#### Factor-Intensity Comparison

Food is presumed to be produced by capital-intensive techniques compared with clothing. When both industries face the same set of factor prices, the least-cost capital/labor ratio for food (at *A*) exceeds that chosen for clothing (at *B*).



**FIGURE 6.3****Factor Intensities and Factor Endowments**

If the capital/labor endowment ratio at home is  $k$ , the wage/rental ratio must lie in the range  $BC$ . If the capital-abundant foreign country has the endowment ratio  $k^*$ , there is an overlap of possible wage/rental ratios in the two countries,  $DC$ . Free trade may equalize factor prices. Should the foreign endowment ratio be at the higher value  $k^{**}$ , the relative wage rate abroad *must* be higher than at home.



This information about the way in which techniques are flexible can more usefully be suggested in Figure 6.3. The two curves show how the capital/labor ratios selected in each sector depend positively on the ratio of wages to rentals; more expensive labor induces shifts to more capital-intensive techniques in both sectors in order to keep costs at a minimum. In keeping with our assumption that clothing is the relatively labor-intensive sector of the economy, the clothing curve lies below that showing capital/labor ratios in food.<sup>4</sup> Now suppose that the home country's capital/labor endowment ratio is shown by  $k$ . Then, even without knowing anything about demand conditions in autarky or the commodity terms of trade, it is possible to show that the wage/rental ratio *must* be trapped in the range  $BC$ . The reason? If the wage/rental ratio were to be higher than  $OC$ , both industries would attempt to use more capital per unit of labor than is available overall ( $Ok$ ). Such an attempt would drive up rentals and bring the factor-price ratio back within the  $BC$  range. Similarly, if wages are too low (a ratio below  $OB$ ), the attempt to employ more labor-intensive techniques in both sectors than the endowment labor/capital ratio would serve to drive up the wage rate.

One reason why a diagram such as Figure 6.3 is so useful in our study is that it allows us to compare the situation in countries sharing the same technology but differing in factor endowments. Given the home country's endowment ratio at  $k$ , consider

<sup>4</sup>Nothing prevents the possibility that these two curves intersect so that food might be produced with capital-intensive techniques in one country and labor-intensive techniques in another—a case of *factor-intensity reversal*.

the following two possibilities for the foreign country's proportions, assuming it is the capital-abundant country:

- (i) If the foreign endowment ratio is  $k^*$ , the ranges of possible wage/rent ratios in the two countries overlap (region  $DC$ ). This implies that free trade in commodities *may* serve to equate wage rates and rentals in the two countries, but only if commodity prices allow factor price ratios in this range.
- (ii) If the foreign endowment ratio is  $k^{**}$ , there is *no* overlapping range of possible wage/rental ratios in the two countries, even though they are assumed to share the same technology. This implies that regardless of taste patterns and the equilibrium commodity terms of trade, free trade in goods can never serve to equate factor prices between countries. Furthermore, because foreign relative wages are higher than at home, the relative cost of producing labor-intensive clothing must also be higher abroad than at home. The result: With trade the labor-abundant home country *must* be an exporter of labor-intensive clothing.

### A Bowed-Out Transformation Curve

Our previous numerical example for the case of rigid technology can be harnessed to show what happens along a smoothly bowed-out transformation schedule (flexible technology) if a country releases some resources from food to the clothing sector. From an initial equilibrium point such as  $A$  in Figure 6.1, with full employment of capital and labor, suppose the country wishes to produce more clothing. At the initial set of techniques, the amount of capital per unit of labor that would be released by the food sector exceeds the ratio required in clothing—from point  $A$  labor is the binding constraint if clothing output expands. This relative shortage of labor is precisely what forces the wage rate up and rentals down and causes capital/labor ratios in both sectors to increase. As a consequence the labor constraint at the *extensive margin* (i.e., on outputs) is relaxed and the capital constraint on outputs is tightened. The new constraint lines thus intersect at a point such as  $B$ . And the increase in relative wages forces up the relative price of labor-intensive clothing, confirming that the transformation schedule is indeed bowed out.

## 6.3 Possible Trade Patterns and the Distribution of Income

With reference to Figure 6.3, the pattern of trade between these two countries would be clear if the home endowment ratio were  $k$  and the foreign ratio given by  $k^{**}$ : The labor-abundant home country *must* be the exporter of labor-intensive clothing. Why? Its transformation schedule is everywhere flatter than the foreign country's curve is at any point. This is what necessarily having a lower wage/rental ratio guarantees. But suppose the foreign country's capital/labor endowment ratio is only  $k^*$ . Then in Figure 6.3 there is an overlap of possible wage/rental ratios shown by range  $DC$ . If world commodity prices cause factor prices to be in this range, equal in the two countries, then so also must be techniques of production (because they are assumed to share the same technology). Our previous discussion of Figure 6.1 provides the clue for how

*production patterns* would then differ between countries. The relatively labor-abundant home country would be at a point such as  $S$  and the foreign country at  $A$ . To generalize: If countries that share the same technology have endowment proportions sufficiently close together that factor prices are equalized with free trade, the relatively labor-abundant country *must* produce a relatively larger amount of the relatively labor-intensive commodity.

Go back to Figure 2.9 to see how production patterns are influenced by differences in factor endowments. For a relative price of food such as  $OT$ , the capital-abundant foreign country would produce a greater relative amount of capital-intensive food (compare point  $G^*$  with point  $G$ ). Alternatively, if two countries were to produce the two commodities in precisely the same proportions, capital-intensive food could be produced more cheaply in the foreign country than at home (compare  $A^*$  with  $A$  in Figure 2.9). Does this imply that the foreign country *must* be an exporter of food once trade between these two countries is opened up? Not necessarily. Demand also has a role to play. Food might be relatively expensive abroad in autarky if demand there is heavily biased toward food consumption compared with tastes in the home country. But barring such asymmetries in tastes, endowment differences impart a strong bias in influencing the trade pattern.

### Income Distribution in the Move from Autarky to Free Trade

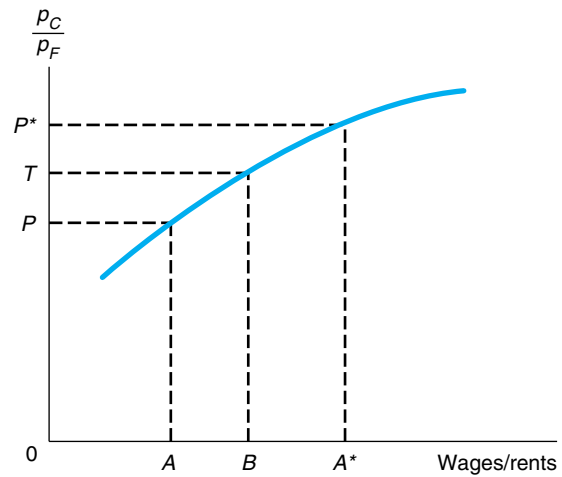
It is now possible to trace the consequences of moving from autarky to free trade for each country. International trade in commodities brings about an equilibrium terms of trade lying between the autarky ratios in the two countries. At home, production of clothing expands (and food contracts) along the production possibilities schedule, with the attendant effect on wages and rents that such a move entails: Expansion of labor-intensive clothing at home raises wages and lowers rents. Abroad, the opposite changes are introduced by trade. As clothing becomes relatively cheaper, both labor and capital leave the clothing sector for the food industry. This move to capital-intensive food production drives up foreign rents and lowers foreign wages.

Before trade, labor-intensive clothing was relatively inexpensive in the labor-abundant home country, and this reflected the relatively low wage at home. International trade allows each country's demand to be freed from its production pattern, which permits home labor *indirectly* to be exported (via clothing exports) and relieves the pressure on scarce foreign labor. As observed, trade consequently raises wages (and lowers rents) at home and lowers wages (and raises rents) abroad. That is, international trade brings wages and rents in the two countries closer together. If countries share the same technology, a remarkable feature of free trade is revealed: Wages and rents *may* be equalized between countries, despite the fact that labor and capital are assumed to be trapped within their own national boundaries.

In this  $2 \times 2$  Heckscher-Ohlin model, a given technology thus implies a strong relationship between prices of commodities (which enter trade) and returns to productive factors (which do not). Figure 6.4 shows this relationship, which is common to both countries *if* each produces both food and clothing. Because clothing is labor intensive, an increase in wages relative to rents must raise clothing's price relative to that of food. Note, however, the magnified effect of a commodity price change on

**FIGURE 6.4****Factor Prices and Commodity Prices**

The Heckscher-Ohlin theory determines that an increase in the relative price of labor-intensive clothing has a magnified effect on the wage/rent ratio. If countries share the same technology, and if before trade the home country is the low-wage country ( $OA$  versus  $OA^*$  abroad), clothing must be relatively cheap at home ( $OP$  versus  $OP^*$ ). With free trade the home country exports clothing and factor prices are equalized at  $OB$  if terms of trade settle at  $OT$ .



factor prices: A 10 percent increase in clothing's relative price would raise the wage/rent ratio by more than 10 percent. Once again, as discussed in Chapter 5, this reflects the necessary pricing relationship when two factors produce a single product: The relative change in the product price (which equals unit costs) must be trapped between the changes in the components of cost (wages and rents). When trade raises the home clothing price from  $OP$  to  $OT$ , labor benefits in real terms, with relative wages rising from  $OA$  to  $OB$ . Trade equalizes factor prices because the initially high foreign relative wage,  $OA^*$ , is reduced to  $OB$  when clothing's price falls from  $OP^*$  to  $OT$  abroad.

These observations concerning the effect of trade on the distribution of income support the following pair of results of the  $2 \times 2$  Heckscher-Ohlin theory.

1. *The Factor-Price Equalization Theorem:* Free trade that equalizes commodity prices between countries sharing the same technology *must* equate wages and rents in the home country with those abroad *if* each country actively produces both commodities. This is a big "if." It presumes that factor endowment proportions do not differ all that much between countries. As Figure 6.3 illustrates, if  $k$  and  $k^{**}$  are the ratios in the two countries, their factor prices *cannot* be equalized with trade. The reason: With free trade at least one of the countries must be completely specialized, and the trade pattern must correspond to the Heckscher-Ohlin dictum that relatively capital-abundant countries export capital-intensive goods.
2. *The Stolper-Samuelson Theorem:* Any interference with trade that drives up the local import price must unambiguously benefit the productive factor used intensively in producing the import-competing good.<sup>5</sup>

<sup>5</sup>This relationship was used initially to describe the impact of tariff protection if imports are labor intensive. See W. F. Stolper and Paul A. Samuelson, "Protection and Real Wages," *Review of Economic Studies*, 9 (November 1941): 58–73, reprinted in Alan Deardorff and Robert Stern, eds., *The Stolper-Samuelson Theorem: A Golden Jubilee* (Ann Arbor: University of Michigan Press, 1994), pp. 37–61.

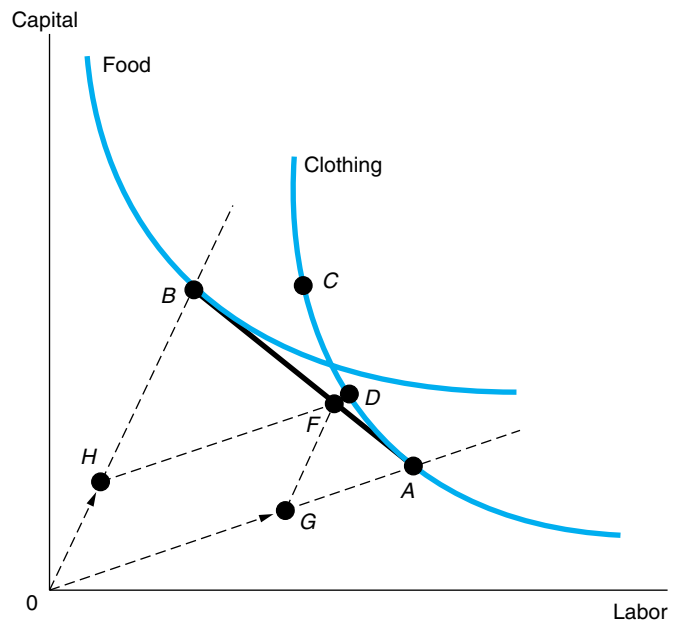
It is important to note that whereas the assumption that countries share identical technologies is crucial for the factor-price equalization result, it is not necessary for the Stolper-Samuelson theorem. The latter reveals that regardless of the technology used at home, if the capital-abundant foreign country protects its labor-intensive clothing imports, it must succeed in raising real wages. This contrasts sharply with the effects described in Chapter 5, whereby a rise in either commodity price produces a more moderate effect on the wage rate: It increases in terms of one good but declines in terms of the commodity that has gone up in price. In the setting described in Chapter 5, labor was the only mobile factor, and specific factor returns (land and capital rents) moved in a more extreme fashion when the relative commodity price changed. In the Heckscher-Ohlin model, both capital and labor are mobile, and changes in commodity prices produce magnified effects on both wages and rents.

### Unit-Value Isoquants

Consider the case of a small country facing given world prices for food and clothing. Combine this information about world prices with the two isoquant diagrams illustrated in Figure 6.2 to display, in Figure 6.5, a pair of isoquants showing given amounts of food and clothing that would sell exactly for \$1 in world markets. These are known as the *unit-value isoquants*. Also illustrated is the tangent chord to the unit-value isoquants, *BFA*. This chord is useful in part in showing that points on either isoquant lying northeast of the chord (e.g., points *C* and *D*) represent techniques of production (for clothing in this case) that would never be observed at these given world prices.

**FIGURE 6.5**  
Unit-Value Isoquants

This diagram assumes world prices for food and clothing are given and the isoquants show quantities of each commodity that would sell for \$1 in world markets. Producing a combination of the two products if the endowment ratio lies in cone *BOA* is preferable to producing just a single commodity.



The argument for point  $C$  is easy because there are ways of producing food instead that could earn \$1 on world markets using less labor and capital (i.e., lying closer to the origin). The argument for a point like  $D$  is more subtle, in that there is no *single* technique for producing food or clothing that dominates  $D$ . However, a point such as  $F$  on the chord is better, and this represents the allocation of labor and capital to a mixture of both commodities: amounts shown by  $OG$  to produce, say, around 62 cents worth of clothing and amount  $OH$  to produce around 38 cents worth of food. The wage/rental factor price ratio indicated by the slope of the tangent chord corresponds to factor prices associated with the given world commodity prices (e.g., as illustrated in Figure 6.4). That is, if a ray from the origin that indicates the endowment capital/labor ratio lies within the cone  $B0A$ , the country will, with trade, produce positive amounts of both food and clothing. By contrast, if the endowment ray lies outside the cone, the country would have to be completely specialized. For example, if the endowment ray is flatter than  $OA$ , the country's transformation schedule would be everywhere flatter than a budget line indicating world prices, and the country would produce nothing but clothing.

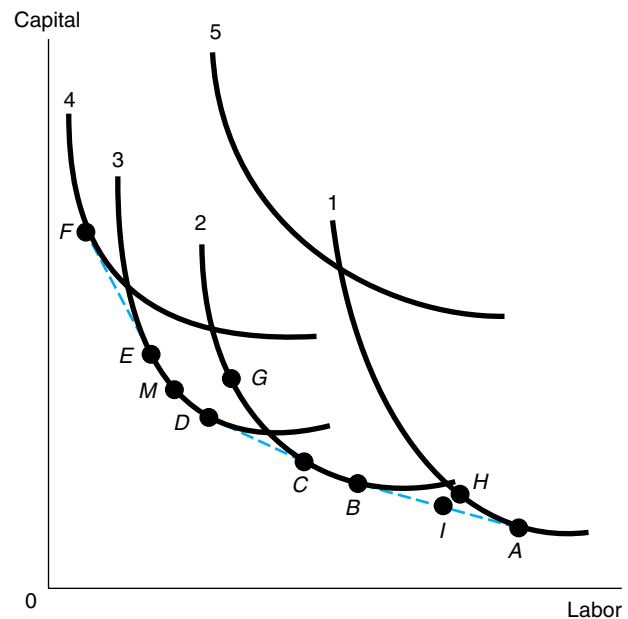
## 6.4 International Trade with Many Commodities

Given this background for the situation of a small country facing given world prices, the possibility that many commodities can be produced and enter world trade is relatively easy to handle. The underlying reason? If labor and capital are the only factors required to produce commodities, international trade allows a country to concentrate its resource base in producing at most two commodities. Recall the Ricardian setting in Chapter 4. With only one factor of production (homogeneous labor), a small country whose technology need not correspond to the pattern of world prices must, in general, produce only a single commodity once it enters trade—the commodity in which it possesses its greatest comparative advantage. Trade allows a massive degree of concentration in production without a sacrifice of a large assortment of commodities available to consumers. If a country has two productive factors, it need produce at most two commodities when it engages in world trade.

Turn, for an illustrative example, to the situation depicted in Figure 6.6 in which the country in autarky has produced five different commodities but with trade can end up producing either one or two. This diagram is a generalization of Figure 6.5 but with unit-value isoquants drawn for five commodities. Note that commodity 5 would not be produced at these prices, regardless of the factor endowments; there would always be a better way of earning a dollar. This reflects the fact that there are other countries in the world with a Ricardian type of technological comparative advantage in producing this commodity. Which one or more of the other commodities the country with this technology would produce would depend on its endowment proportions of capital to labor. If the endowment ray passes through a tangent chord (e.g., at point  $I$ ), the country produces two commodities ( $I$  and 2 in this instance). But the endowment ray may pass through a point such as  $M$ , in which case all its resources are focused on producing a single commodity (3 in this instance).

**FIGURE 6.6**  
**Many Commodities**

With given world prices, the home country's technology determines for each commodity the quantities of labor and capital that produce \$1 worth of output. Production takes place on the inner frontier *ABCDEF* (extended).



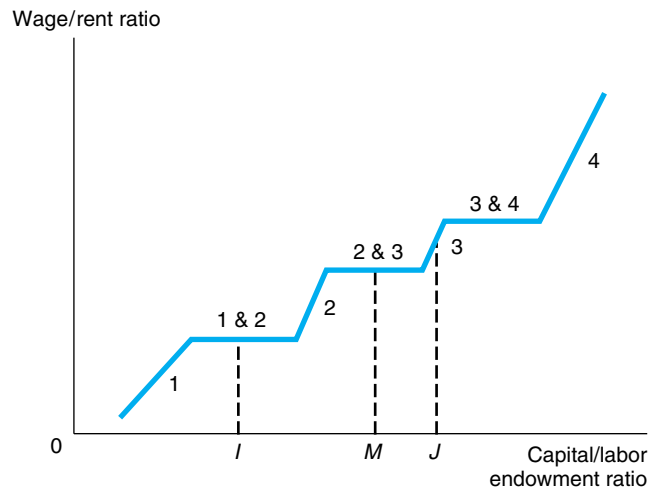
The information displayed in Figure 6.6 can be illustrated differently, in Figure 6.7, in a fashion that explicitly shows how a country with the technology and commodity prices shown in Figure 6.6 can alter its wage/rental ratio by experiencing a growth in its endowment capital/labor ratio. In a general sense, the more capital abundant this country becomes, the higher will be its wage rate relative to the return to capital. But there are plateaus along which a further accumulation of capital can be absorbed without a change in factor prices, by an expansion of the more capital-intensive commodity of the pair produced and a reduction in the more labor-intensive commodity. This is what our earlier study of the two-commodity case revealed: Two countries facing the same commodity price ratios and sharing the same technology could each produce the same pair of commodities, in which case their factor prices would be completely equalized. But if their endowment ratios are further apart, for example, with the home ratio at *I* and with the foreign ratio at *M* (in Figure 6.7), each country would be producing a commodity in common (commodity 2), but a different second commodity. Although each is incompletely specialized, their factor prices are different, with the more capital-abundant foreign country's labor force better paid. Alternatively, as shown by points *M* and *J* in Figure 6.7, both countries might be producing a commodity in common (commodity 3), but with only one of them incompletely specialized.

A basic proposition follows from these remarks:

*Trade allows countries to concentrate productive activities exclusively on a few traded commodities whose factor requirements closely mirror the particular capital/labor endowment proportions found locally, and to satisfy their demands by importing a variety of commodities whose factor requirements (if they were produced at home) would range the entire spectrum from very low to very high capital/labor ratios.*

**FIGURE 6.7****Factor Endowments and Factor Prices**

Generally, the greater the capital/labor endowment ratio, the higher the wage/rent ratio for countries facing fixed world commodity prices. There are, however, plateaus of incomplete specialization where factor prices are uniquely determined by world commodity prices.



The two-commodity example discussed earlier is useful in revealing the basic structure of the model. The advantage of the many-commodity case is that it allows a broader question to be raised, namely, *what* commodities does a country produce and export.

## 6.5 How Concentrated Is Production?

Although our discussion of competitive pressures in the multicommodity model predicts that trade will enforce a high degree of concentration in a country's productive activities, a glance at production patterns in the real world suggests that this conclusion is partially blunted in practice. Consider some of the reasons.

### Transportation Costs

The impact of transport costs on patterns of trade is that they provide a natural protective umbrella for local production. For some items, transport costs bulk large relative to production costs; thus most localities produce their own bricks and pour their own cement. By contrast the introduction of refrigerated trains and ships allowed much greater worldwide concentration in meat packing, vegetable farming, and related areas of commerce. Even flowers are routinely exported from South America to the United States courtesy of speedy air traffic.

### Protection of Local Industries

Although transport costs represent nature's way of providing protection for local industries, import duties and discriminatory taxes are artificial ways of achieving the same end. One consequence of protection policy is that a nation will engage in a wider

variety of productive activities than could be sustained in the brisk climate of free trade. This leads to the obvious question: What costs (or benefits) does a nation incur by stimulating this wider productive base? Part III picks up this theme.

### Specific Factors: Short Run and Long Run

The Heckscher-Ohlin account of trade often has been referred to as a *long-run* theory.<sup>6</sup> It implicitly assumes that sufficient time has elapsed for factors of production, such as skilled labor, various kinds of capital goods, and entrepreneurs, to avoid becoming trapped in depressed industries if possible returns elsewhere in the economy are superior. It also assumes that these factors cannot successfully beat off competition from new productive factors entering an industry with the required skills. Factors are mobile from industry to industry.

Chapter 5 provided an illustration of *short-run* theory. There capital and land represented separate productive factors. However, alternative scenarios had either capital or labor specifically tied to their occupations only in the short run. Examples abound of workers who can be retrained with new skills to enter new occupations only after a number of months or years, or of textile machines that must be scrapped or allowed to depreciate before they can figuratively be beaten into tractors or lathes. A factor such as capital is not instantaneously shiftable. At any time some traded activities earn higher returns to capital than others. Over time, variations in world commodity prices and/or a country's own technology help account for the presence of production in sectors of the economy whose rationale for existence lies in the past. With the passage of time certain industries disappear from the scene, and new ones emerge. Every period carries with it echoes of the past. However, the *range* of such activities in generally capital-rich countries should differ from that in countries abundant in unskilled labor.

## 6.6 Changing Comparative Advantage with Economic Growth

Growth experience in today's world varies widely from country to country. In North America and Europe relatively moderate growth rates (2 or 3 percent) alternate with periods of much slower growth (especially for "old" Europe) or faster (as in the United States in the early years of this century). In many parts of Africa the situation appears more grim, with long periods of zero or negative growth. In the past two decades the success stories were to be found primarily in Asia. Japan in earlier years comes readily to mind, but even more rapid rates of growth were being experienced by the so-called tigers of Southeast Asia: South Korea, Taiwan, Hong Kong, and Singapore, all exceeding 6 percent annual rates as an *average* over the past 20 years. These countries were more recently joined by Thailand, Malaysia, Indonesia, and, especially, China and India.

<sup>6</sup>For example, see Wolfgang Mayer, "Short-Run and Long-Run Equilibrium for a Small Open Economy," *Journal of Political Economy*, 82 (September/October 1974): 955–968; and Michael Mussa, "Tariffs and the Distribution of Income: The Importance of Factor Specificity, Substitutability, and Intensity in the Short and Long Run," *Journal of Political Economy*, 82 (November/December 1974): 1191–1204.

All these countries are “outward-looking,” with export activity fueling the growth process. But more is involved, and Figures 6.6 and 6.7 help tell the story. Growth is accompanied by high rates of capital accumulation, both physical capital and human capital (education).<sup>7</sup> Such capital accumulation raises wage rates, and during this process a country’s comparative advantage shifts away from more labor-intensive activities. Thus years ago Japan saw its shipbuilding and textile industries lost to South Korea and Taiwan, which, in turn, lost their comparative advantage to more labor-abundant countries further behind in the growth process. Taiwan lost its grip as the world’s leader in umbrellas, as well as its established position in shoes and textiles. The very success of industries like these in raising wage rates in Taiwan now supports a shift toward higher technology and capital-intensive sectors. Taiwanese businesspeople eye wage rates in mainland China that are less than 20 percent of those prevailing in Taipei’s tight labor market. As Chapter 8 discusses in more detail, a significant characteristic of modern trade patterns is the great increase in trade in intermediate products, natural resources, and producer goods, facilitating an international fragmentation of production processes whereby more labor-intensive activities get outsourced to low-wage areas.

## 6.7 Heckscher-Ohlin Theory and Empirical Evidence

A strong attraction of the Heckscher-Ohlin model is its numerous predictions about the relationships among actual trade patterns, factor endowments, and product and factor prices. Nonetheless, this model has caused considerable frustration for empirical researchers seeking to test it formally. Consider the factor-price equalization theorem. Casual observation immediately suggests that wages are not equalized among countries. But are the wage levels those of “comparable” labor? The rewards to capital appear much more nearly equalized among countries, but then capital (contrary to the theory’s assumption) is rather mobile among countries (see Chapter 9), and that mobility tends to equalize prices among nations without any reference to the effect of commodity trade. Certainly a given industry does not use the same mixture of factor inputs in different countries, as it would if factor prices were equalized and technologies were identical.<sup>8</sup> Of course it is important to remember that the Heckscher-Ohlin model predicts factor-price equalization only if technologies and factors are comparable between countries and endowment proportions are fairly close to each other.

### Testing the Heckscher-Ohlin Theorem

How can we test the Heckscher-Ohlin theorem systematically? Pioneer investigators reasoned as follows. Take a country that appears exceptionally well endowed with some factor, say, capital. Measure the quantities of capital and labor that it uses to pro-

<sup>7</sup>For example, according to the *Economist* (November 16, 1991), Taiwan accounted for a full 25 percent of doctorates in engineering at American universities.

<sup>8</sup>David Dollar, Edward J. Wolff, and William J. Baumol, “The Factor-Price Equalization Model and Industry Labor Productivity,” in R. C. Feenstra, ed., *Empirical Methods for International Trade* (Cambridge, MA: MIT Press, 1988), pp. 23–47.

duce a unit of each good it exports and each good it produces at home in competition with imports (call such goods “importables”). Add these product-level inputs to obtain the total amounts of capital and labor tied up in producing exports (call them  $K_x$  and  $L_x$ ) and also the total amounts of capital and labor allocated to producing importables at home ( $K_m$  and  $L_m$ ), with actual exports and imports serving as weights. The capital-rich nation should then export a bundle of goods more capital intensive than its bundle of importables:  $K_x/L_x > K_m/L_m$ . W. W. Leontief proposed that after World War II the United States was a standout capital-rich nation suitable for this test. To everyone’s surprise, the test was flunked: Imports were more capital intensive. It turned out, though, that Leontief omitted a big chunk of the U.S. capital stock—education (human capital). With education included in the calculated bundles of factors, the data supported the hypothesis. Even without the human-capital refinement, Leontief’s paradox evaporated by the 1970s.<sup>9</sup>

Researchers soon saw serious shortcomings in the form of this test. How can one be sure the chosen country is an outlier in its factor endowment? Guessing won’t do: One must measure a country’s share of the world endowment of a factor in order to pin down its factor-endowment position. Furthermore, why apply the test to one country, rather than many countries at once? Edward Leamer proposed the following enriched test. Use data on each industry’s input requirements to calculate the quantity of a factor of production needed to produce the bundle of goods that the country consumes. Subtract it from the quantity of that factor in the country’s endowment (if the difference is positive, the country is well endowed with that factor). Using Leontief’s procedure, measure the amount of that factor embodied in the country’s net exports (that is, the amount needed to produce its exports minus the amount required for production at home of its importables). If the Heckscher-Ohlin theorem is correct, the amount of the factor embodied in net exports should increase with the excess of its endowment over its consumption needs.

When Edward Leamer, Daniel Trefler, and others performed this improved test, it offered only the weakest support for the hypothesis. Leamer and associates applied this design to no less than 12 factors of production for 27 countries. The results of their statistical test run in the right direction: When a country’s net exports use a factor intensively, its endowment tends to be rich in that factor. However, for only one of 12 factors is this association statistically significant.<sup>10</sup>

### Looking Elsewhere for Explanations

Daniel Trefler urged that economists, stuck with an attractive but miserably performing model of national trade patterns, should shop around for some new models. He came up with two.<sup>11</sup> The first reaches back to Ricardo: Each factor in Country *A* might be

<sup>9</sup>Robert M. Stern and Keith E. Maskus, “Determinants of the Structure of U.S. Foreign Trade, 1958–76,” *Journal of International Economics*, 11 (May 1981): 207–224.

<sup>10</sup>Harry P. Bowen, Edward E. Leamer, and Leo Sveikauskas, “Multicountry, Multifactor Tests of the Factor Abundance Theory,” *American Economic Review*, 77 (December 1987): 791–809. Their test is a restrictive one that assumes all countries have the same technology and tastes in consumption goods.

<sup>11</sup>Daniel C. Trefler, “The Case of the Missing Trade and Other Mysteries,” *American Economic Review*, 85 (December 1995): 1029–1046.

10 percent more productive than its counterpart in country  $B$ , so that countries' shares of the world factor endowment are miscalculated without productivity weights. The second recognizes that consumption patterns are dissimilar among countries in a way that is important for the test: Because of transportation costs, tariffs, or simply immemorial custom, a country tends to consume the goods that are cheaply produced with its own factor stock. That hypothesis is particularly attractive in light of Trefler's finding regarding the poor performance of Heckscher-Ohlin: One simply cannot find many instances of a country with a factor content in its net exports that is far out of line with the factor content of its consumption (this is the "missing trade"). Trefler found that both the technology-difference and consumption-bias hypotheses add a lot to the explanatory power of the Heckscher-Ohlin theorem. In short, the Heckscher-Ohlin theorem does explain something of nations' trade patterns, but it needs help from its friends.

Another modern explanation of trade patterns lies in the recent revival of economic geography: This focuses on the power of historical accident to dictate long-lasting patterns of specialization. The geographers note that economic activities concentrate not just in particular countries but in particular regions or cities; one mentions Hollywood, Detroit, and Silicon Valley without even needing to say what goods are produced there. These concentrations seldom depend on any particular natural resource or physical trait of the region that one can detect. Close study indicates that these regional concentrations share two properties. First, their original locations often resulted from some accidental event or institution that could just as easily have occurred in another place. Second, their long persistence rests on many external economies and other self-sustaining factors. A trained, specialist labor force develops, along with specialized auxiliary supply and service firms that do not exist anywhere else. Producers more readily pick up each other's productivity-raising secrets, and they strive to outdo each other for personal esteem as well as profit. Customers can readily compare the wares of competing sellers and, being fussy and demanding from close exposure, they impose high standards on the sellers' products.<sup>12</sup>

Once a successful regional cluster emerges, it becomes a source of exports for its nation. Having happened there first (by luck, perhaps), the cost effectiveness of a region's activities is likely to run ahead of production sites anywhere else, even if other countries' factor endowments could supply the same set of (general) inputs at lower cost. The greater the importance of such agglomerations, the more "noise" is created for the Heckscher-Ohlin and other static explanations of trade patterns.

### What Is at Stake: Trade and Wages

The bases for a nation's comparative advantage matter beyond their explanation of its trade pattern. Urgent issues of public policy are also involved. In the United States during the 1980s and 1990s, the differential between the hourly earnings of skilled and unskilled labor increased greatly, with the relative wages of college graduates rising from a 38 percent premium in 1979 to 65 percent in 1993, and the real wages of low-

<sup>12</sup>Michael E. Porter, *The Competitive Advantage of Nations* (New York: Free Press, 1990); Paul Krugman, *Geography and Trade* (Cambridge, MA: MIT Press, 1991).

skilled men indeed falling significantly. (The European industrial countries saw a similar development, but there it resulted in high unemployment rates rather than falling wages for unskilled labor.) At the same time U.S. imports from developing countries increased from 0.4 percent of GNP in 1970 to 2.5 percent in 1990.<sup>13</sup> Was the swelling wage differential related to rising capacities of the developing countries to supply low-skill manufactured goods to the United States? If the United States chiefly exports goods intensive in capital and skills and imports goods intensive in low-skilled labor, that could be the answer. The Stolper-Samuelson theorem predicts this relationship as a consequence of U.S. exports using skilled labor in larger proportion to unskilled labor than do the U.S. goods that compete with imports. But other factors vie to provide explanations to this rising wage inequality, and it proves difficult to sort them out.

An obvious competing hypothesis suggests that the supply of low-skill labor (measured by years of schooling) has increased, driving down low-skill wages. Yet it is easily established that the supply of low-skill labor has been falling relative to more highly educated labor. As William Cline pointed out, the relative increase in skilled labor that actually occurred by itself would have lowered the skill differential by 40 percent.<sup>14</sup>

The other competing hypothesis is quite independent of international trade. It springs from the observation that technological change commonly seems to call for the substitution of skilled for unskilled labor. That is, in innovative processes, capital and skilled labor are complements and substitute for less skilled labor and capital embodying traditional technologies. If the outputs of innovative technologies are welcomed in export markets, that tends further to shrink the relative demand for unskilled labor.

Capital-skill complementarity has been confirmed in numerous studies. Furthermore, it is evident in countries other than the United States. It is strong enough to leave only modest room for other explanations of wage inequality. Numerous studies of the effects of increased supplies of low-skill imports give diverse results but typically find only small room for imports as a cause of the increasing inequality of wages.<sup>15</sup> They leave little doubt that these several explanations interact and all make some contribution to explaining increased wage inequality. When Cline added up the various effects on wage inequality, he concluded that international competition made up approximately one tenth of the total forces.<sup>16</sup>

Cline asked whether U.S. policy makers could have preserved unskilled labor's relative wage by means of tariff protection, as the Stolper-Samuelson theorem suggests. He concluded, however, that low-wage labor would actually not benefit. That is because low-skill workers tend to consume relatively large amounts of unskilled-labor-intensive products and transfer payments, and the low savings rates of low-income workers tend to make their share of consumption larger than their share of income.

<sup>13</sup>Richard B. Freeman, "Are Your Wages Set in Beijing?" *Journal of Economic Perspectives*, 9 (Summer 1995): 15–32.

<sup>14</sup>William R. Cline, *Trade and Income Distribution* (Washington, DC: Institute for International Economics, 1997).

<sup>15</sup>See Robert E. Baldwin and Glen G. Cain, "Shifts in Relative U.S. Wages: The Role of Trade, Technology, and Factor Endowments," *Review of Economics and Statistics*, 82 (November 2000): 580–595.

<sup>16</sup>Cline introduced immigration to the United States in the international influences and also took account of some other effects such as the erosion of monopoly power in the transportation and metal-fabrication industries, whose excess profits had previously been shared by their low-skill workers.

This conclusion about the fate of unskilled labor fits more comfortably into the specific-factors setting of Chapter 5 if unskilled labor is the factor mobile between sectors. Tariff protection that raises the price of import-competing commodities indeed raises the nominal wage rate but only by a fraction of the price hike. The cost of living index for workers could rise by a higher fraction if their consumption of importables exceeds local production.<sup>17</sup>

## 6.8 Summary

In contrast to the discussion in Chapter 5 of production in which output in each sector is obtained by combining labor drawn from a national market with a factor specifically tied to that industry, the Heckscher-Ohlin theory assumes no factor is specific. Labor and capital are costlessly transferable from sector to sector.

Some of the Heckscher-Ohlin properties can be compared to similar ones encountered in Chapter 5:

1. Output in any industry cannot expand without driving up relative costs. Costs are bid up because the return to the factor used relatively intensively in that industry is bid up by a magnified amount.
2. Any change in a country's terms of trade is accompanied by a relatively more profound redistribution of factor incomes. Even a broad-based factor such as labor unambiguously gains if the relative price of labor-intensive goods rises. This particular result contrasts with the conclusion in Chapter 5 that a mobile factor such as labor cannot significantly alter its real wage through changes in commodity prices, although specific factors definitely could. The Heckscher-Ohlin model is less applicable to questions of *short-run* impact of policy changes on income distribution than is the specific-factors model of Chapter 5.
3. Differences in factor endowments influence the direction of trade. A relatively ample endowment of capital leads to exports that intensively require capital.

Perhaps the most striking conclusion of the simple Heckscher-Ohlin model is one not shared by the specific-factors model: Free trade in commodities *may* completely substitute for international mobility of capital and labor in the sense of driving wages and rents to equality for countries sharing the same technology. The sharp contrast between this factor-price equalization result and observed international comparisons of wage rates and returns to capital has contributed much to discredit Heckscher-Ohlin propositions as a whole. In defense of Heckscher-Ohlin theory, the following can be pointed out:

1. If countries differ in technological knowledge (or climate and other influences on the relationship between inputs and outputs), any presumption that free trade brings about absolute factor-price equalization disappears.

<sup>17</sup>This argument is spelled out in R. Ruffin and R. Jones, "Protection and Real Wages: The Neoclassical Ambiguity," *Journal of Economic Theory* (April 1977): 337–348.

2. Even if countries differ in technological knowledge, many propositions of Heckscher-Ohlin theory are unaffected. For example, the impact of a tariff on real wages at home depends only on home technology and not at all on how commodities are produced abroad.
3. When viewed in a multicountry, multicommodity setting, factor-price equalization is less likely to occur even between countries sharing the same technology. Instead, any significant difference between countries in basic capital/labor endowment proportions would be reflected in countries producing different sets of commodities. If they were to produce a commodity in common, the capital-rich country would be likely to adopt more capital-intensive techniques precisely because its labor force was more productive and better paid.

The pattern of trade in a Heckscher-Ohlin world of many countries and many commodities shares much in common with a Ricardian world. Countries concentrate their productive activities around a few commodities whose demands for factors closely reflect total factor availability and import commodities representing a wide dispersion in factor requirements (if they were to be produced at home) compared with those adopted for the export sectors. Factor intensities in a nation's aggregate *output* bundle reflect that country's factor-endowment proportions. Factor intensities in a nation's aggregate *consumption* bundle reflect average world factor endowments if countries have similar tastes. Because trade flows represent the difference between output and consumption, relatively capital-abundant countries, on the average, import relatively labor-intensive commodities. This is an *average* result, however; the wide dispersion in imports still remains.

As countries grow over time, the range of goods produced for export changes systematically. Growth in physical and human capital leads to higher real wage rates, which alters comparative advantage away from traditional labor-intensive commodities toward commodities reflecting higher capital/labor ratios and superior quality. This pattern was strongly reflected in the particularly high-growth economies of Southeast Asia.

Transport costs and tariffs serve to widen a country's range of productive activities. Resources specific to certain activities also convey a comparative advantage not captured solely by capital/labor rankings. In the short run, many types of capital (and perhaps skilled labor) are not mobile between sectors. This tends to lessen the concentration of production. The spirit of the Heckscher-Ohlin theory still remains to suggest that differences between countries in their endowment of broad classes of productive factors such as capital and labor will be reflected in differences in patterns of production and trade.

In a famous empirical test of the Heckscher-Ohlin theorem, Leontief investigated whether the exports of the United States—a capital-rich country—embody more capital relative to labor than do the goods that the United States produces in competition with imports. To everyone's surprise, he found that U.S. exports were labor intensive compared to import-competing goods. Subsequent research has partly resolved this paradox by showing that U.S. exports are intensive in human capital, and the capital intensity of import-competing goods is associated with the prevalence of raw materials.

Empirical tests of the theorem have shifted recently to a global level. Countries rich in a particular factor generally have been found to make net exports of goods requiring that factor intensively, but the relationship is weak and leaves room for other explanations (economic geography, home biases in consumption patterns).

The relative decline of wages of unskilled U.S. labor invites an explanation based on expanding trade with other countries, especially developing nations, with larger endowments of unskilled labor. This force has been at work, although technological change favoring the substitution of skilled for unskilled labor is much more important.

## CHAPTER PROBLEMS

- Suppose only one technique can be used in clothing production. To produce a unit of clothing requires four labor-hours and one unit of capital; in food production each unit requires a single labor-hour and one unit of capital. At an initial equilibrium suppose the wage rate and the capital rental are each valued at \$2. If both goods are produced, what must be their prices? Now keep the price of food constant and raise the price of clothing to \$15. Trace through the effects on the distribution of income. Rank the relative changes in the wage rate, the price of clothing, the price of food (unchanged by assumption), and the rent on capital. Relate your results to the Stolper-Samuelson theorem.
- Retain the assumptions about technology in Problem 1:

$$a_{LC} = 4 \quad a_{KC} = 1 \quad a_{LF} = 1 \quad a_{KF} = 1$$

Draw a diagram with capital on the vertical axis and labor on the horizontal. Draw a ray through the origin with a slope of unity and show how outputs of food can be measured along this ray. Draw a flatter ray, with a slope of  $1/4$ , and show how outputs of clothing can be measured along this ray. Suppose the economy possesses 1000 units of labor.

- Find the full-employment levels of output of each good if the capital stock is 500 units.
  - Find the lowest and highest capital stocks that still allow full employment of both factors.
  - Draw the transformation schedule for each of the cases in 2a and 2b.
- Assume that input-output coefficients are fixed. The table shows capital requirements per unit output ( $a_{Kj}$ ) and labor requirements per unit output ( $a_{Lj}$ ) to produce one unit each of commodities 1 through 5. Also shown are prevailing world prices for each commodity.

|          | Commodity |      |      |      |      |
|----------|-----------|------|------|------|------|
|          | 1         | 2    | 3    | 4    | 5    |
| $a_{Kj}$ | 4         | 2    | 1    | 1    | 1    |
| $a_{Lj}$ | 1         | 1    | 1    | 2    | 4    |
| Price    | \$16      | \$14 | \$10 | \$14 | \$16 |

- a. If the economy has a labor/capital endowment ratio of 3:1, what does it produce? What are the wage rate and rents on capital?
  - b. If the world price of commodity 1 should triple, would there be any change in this country's production pattern? Factor prices? Real income?
  - c. At the initial prices shown in the table, how would factor prices differ in an economy with the same technology but a capital/labor endowment ratio of 3:1?
  - d. For the economy with the original labor/capital endowment ratio of 3:1, how would production patterns and factor prices change if commodity 3's price on world markets should rise by 40 percent?
  - e. Describe the pattern of trade for an economy with a capital/labor endowment ratio of 1:1.
4. Using Figures 6.6 and 6.7, show how an increase in the world price of commodity 2 would affect real wages in two countries sharing the same technology, both of them producing commodity 2, but with the home country having an endowment ratio  $0I$  (Figure 6.7) and the foreign country with endowment ratio  $0M$ .
  5. In Figure 6.A.1 the production box diagram shows that a country with given endowments of capital and labor could not produce food by capital-intensive techniques at one set of outputs while switching to labor-intensive techniques at another. Show the inconsistency involved if the contract curve crosses the diagonal.
  6. The text describes an example in which a country with the same capital endowment as another, but a greater endowment of labor, must actually produce less of one good if they both face the same terms of trade (this is the Rybczynski theorem). Establish this result by superimposing the box diagrams of the two countries so that they share a common food origin (lower-left corner). How do the two contract curves compare?

## SUGGESTIONS FOR FURTHER READING

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## APPENDIX

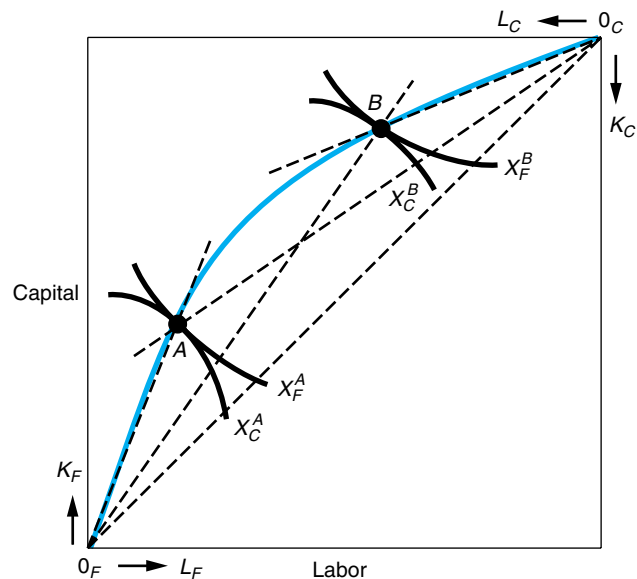
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### The Production Box

The concept of a consumption box diagram was described in the appendix to Chapter 2. The analogy that now proves useful is that of the production box diagram shown in Figure 6.A.1. The dimensions of the box are the home country’s fixed total endowments of capital and labor. Any point inside the box represents a possible allocation of capital and labor to the food sector, whose origin is the lower-left corner of the box, and to clothing, whose origin is the upper-right corner. The *contract curve*  $0_F A B 0_C$  shows all capital and labor allocations for which isoquants for food and clothing have the same slope. Points  $A$  and  $B$  are two such allocations. Points along the contract curve are efficient—for example, for given output  $X_F^A$  of food, the allocation that maximizes clothing output is shown by  $A$ . Each point on the contract curve shows not only (efficient) allocations of capital and labor to each sector, it also shows total food and clothing outputs (by the values of the two isoquants tangent at that point). Thus the points on the contract curve map into the outputs along the country’s production possibilities schedule. That is, each point on the home country’s transformation schedule corresponds to an allocation of labor and capital to the two industries shown by a particular point on the contract curve.

**FIGURE 6.A.1****The Production Box Diagram**

Points on the contract curve  $0_F A B 0_C$  show efficient, competitive allocations of the economy's fixed overall endowments of labor and capital.



Consider the background adjustments in factor proportions and income distribution that would accompany a move from point  $A$  to point  $B$  in Figure 6.A.1; this corresponds to an increase in food production and a reduction in the quantity of clothing produced along the production possibilities schedule. The diagram shows (by the slopes of rays from each origin to  $A$  and  $B$ ) that such a move lowers the capital/labor ratios used in *both* industries because it drives up the ratio of rents to wages. Such a relative cheapening of labor encourages firms in *both* sectors to adopt more labor-intensive techniques. Thus, at  $B$ , food is produced with a lower capital/labor ratio than at  $A$ . At  $B$  the pair of tangent isoquants are flatter than at  $A$ , the lower slope reflecting a lower wage/rent ratio.

How can both sectors change factor intensities in the same direction if the economy's overall factor supplies remain unchanged? By changing the composition of output. At  $A$  both industries adopt a *higher* capital/labor ratio than at  $B$ , but this is made possible by *lowering* the output of capital-intensive food relative to clothing. Not only is it *possible* that capital/labor ratios move in the same direction (despite the fact that the endowment ratio is fixed), they *must* move in the same direction because techniques in both sectors respond to the same change in factor prices.<sup>18</sup>

<sup>18</sup>Suppose you have taken two exams and received a 70 on one and a 90 on the other—with an announced average of 80. You know that because your professor is somewhat of a wimp and susceptible to pressure, by complaining you might raise these two grades, respectively, to a 74 and a 93. However, your wimpy professor may have the last word and keep your average at 80 by raising the weighting of your first test score.

