

## Resources and Trade: The Heckscher-Ohlin Model

If labor were the only factor of production, as the Ricardian model assumes, comparative advantage could arise only because of international differences in labor productivity. In the real world, however, while trade is partly explained by differences in labor productivity, it also reflects differences in countries' *resources*. Canada exports forest products to the United States not because its lumberjacks are more productive relative to their U.S. counterparts but because sparsely populated Canada has more forested land per capita than the United States. Thus a realistic view of trade must allow for the importance not just of labor, but also of other factors of production such as land, capital, and mineral resources.

To explain the role of resource differences in trade, this chapter examines a model in which resource differences are the *only* source of trade. This model shows that comparative advantage is influenced by the interaction between nations' resources (the relative **abundance of factors** of production) and the technology of production (which influences the relative **intensity** with which different **factors** of production are used in the production of different goods). Some of these ideas were presented in the specific factors model of Chapter 4, but the model we study in this chapter puts the interaction between abundance and intensity in sharper relief by looking at long-run outcomes when all factors of production are mobile across sectors.

That international trade is largely driven by differences in countries' resources is one of the most influential theories in international economics. Developed by two Swedish economists, Eli Heckscher and Bertil Ohlin (Ohlin received the Nobel Prize in economics in 1977), the theory is often referred to as the **Heckscher-Ohlin theory**. Because the theory emphasizes the interplay between the proportions in which different factors of production are available in different countries and the proportions in which they are used in producing different goods, it is also referred to as the **factor-proportions theory**.

To develop the factor-proportions theory, we begin by describing an economy that does not trade and then ask what happens when two such economies trade with each other. Since the factor-proportions theory is both an important and a controversial theory, we conclude the chapter with a discussion of the empirical evidence for and against the theory.

## LEARNING GOALS

After reading this chapter, you will be able to:

- Explain how differences in resources generate a specific pattern of trade.
- Discuss why the gains from trade will not be equally spread even in the long run and identify the likely winners and losers.
- Understand the possible links between increased trade and rising wage inequality in the developed world.

## Model of a Two-Factor Economy

In this chapter, we'll focus on the simplest version of the factor-proportions model, sometimes referred to as "2 by 2 by 2": two countries, two goods, two factors of production. In our example we'll call the two countries Home and Foreign. We will stick with the same two goods, cloth (measured in yards) and food (measured in calories), that we used in the specific factors model of Chapter 4. The key difference is that in this chapter, we assume that the immobile factors that were specific to each sector (capital in cloth, land in food) are now mobile in the long run. Thus land used for farming can be used to build a textile plant, and conversely, the capital used to pay for a power loom can be used to pay for a tractor. To keep things simple, we model a single additional factor that we call capital, which is used in conjunction with labor to produce either cloth or food. In the long run, both capital and labor can move across sectors, thus equalizing their returns (rental rate and wage) in both sectors.

### Prices and Production

Both cloth and food are produced using capital and labor. The amount of each good produced, given how much capital and labor are employed in each sector, is determined by a production function for each good:

$$\begin{aligned} Q_C &= Q_C(K_C, L_C), \\ Q_F &= Q_F(K_F, L_F), \end{aligned}$$

where  $Q_C$  and  $Q_F$  are the output levels of cloth and food,  $K_C$  and  $L_C$  are the amounts of capital and labor employed in cloth production, and  $K_F$  and  $L_F$  are the amounts of capital and labor employed in food production. Overall, the economy has a fixed supply of capital  $K$  and labor  $L$  that is divided between employment in the two sectors.

We define the following expressions that are related to the two production technologies:

$$\begin{aligned} a_{KC} &= \text{capital used to produce one yard of cloth} \\ a_{LC} &= \text{labor used to produce one yard of cloth} \\ a_{KF} &= \text{capital used to produce one calorie of food} \\ a_{LF} &= \text{labor used to produce one calorie of food} \end{aligned}$$

These unit input requirements are very similar to the ones defined in the Ricardian model (for labor only). However, there is one crucial difference: In these definitions, we speak of the quantity of capital or labor *used* to produce a given amount of cloth or food, rather than the quantity *required* to produce that amount. The reason for this change from the Ricardian model is that when there are two factors of production, there may be some room for choice in the use of inputs.

In general, those choices will depend on the factor prices for labor and capital. However, let's first look at a special case in which there is only one way to produce each good. Consider the following numerical example: Production of one yard of cloth requires a combination of two work-hours and two machine-hours. The production of food is more automated; as a result, production of one calorie of food requires only one work-hour along with three machine-hours. Thus, all the unit input requirements are fixed at  $a_{KC} = 2$ ;  $a_{LC} = 2$ ;  $a_{KF} = 3$ ;  $a_{LF} = 1$ ; and there is no possibility of substituting labor for capital or vice versa. Assume that an economy is endowed with 3,000 units of machine-hours along with 2,000 units of work-hours. In this special case of no factor substitution in production, the economy's production possibility frontier can be derived using those two resource constraints for capital and labor. Production of  $Q_C$  yards of cloth requires  $2Q_C = a_{KC} \times Q_C$  machine-hours and  $2Q_C = a_{LC} \times Q_C$  work-hours. Similarly, production of  $Q_F$  calories of food requires  $3Q_F = a_{KF} \times Q_F$  machine-hours and  $1Q_F = a_{LF} \times Q_F$  work-hours. The total machine-hours used for both cloth and food production cannot exceed the total supply of capital:

$$a_{KC} \times Q_C + a_{KF} \times Q_F \leq K, \text{ or } 2Q_C + 3Q_F \leq 3,000 \quad (5-1)$$

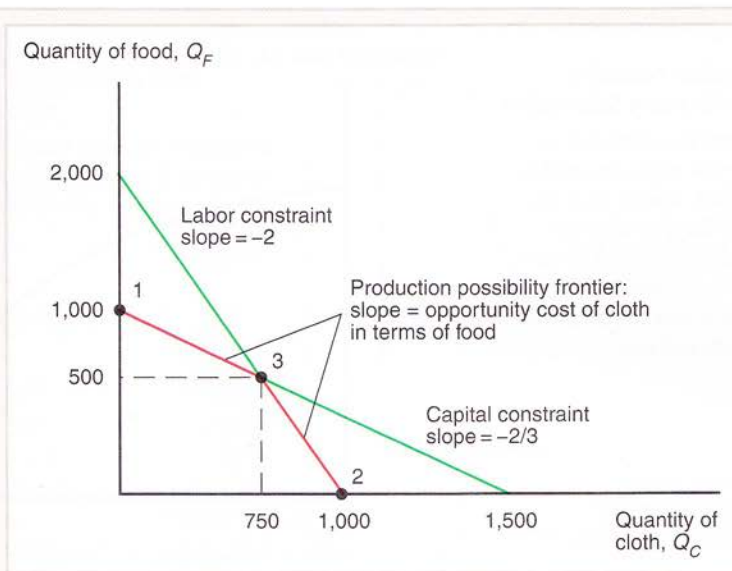
This is the resource constraint for capital. Similarly, the resource constraint for labor states that the total work-hours used in production cannot exceed the total supply of labor:

$$a_{LC} \times Q_C + a_{LF} \times Q_F \leq L, \text{ or } 2Q_C + Q_F \leq 2,000 \quad (5-2)$$

Figure 5-1 shows the implications of (5-1) and (5-2) for the production possibilities in our numerical example. Each resource constraint is drawn in the same way that we drew the production possibility line for the Ricardian case in Figure 3-1. In this case, however, the economy must produce subject to *both* constraints. So the production possibility frontier is the kinked line shown in red. If the economy specializes in food production (point 1), then it can produce 1,000 calories of food. At that production point, there is spare labor capacity: Only 1,000 work-hours out of 2,000 are employed. Conversely, if the economy specializes in cloth production (point 2), then it can produce 1,000 yards of cloth. At that production point, there is spare capital capacity: Only 2,000 machine-hours out of 3,000 are employed. At production point 3, the economy is employing all of its labor and capital resources (1,500 machine-hours and 1,500 work-hours in cloth production, and 1,500 machine-hours along with 500 work-hours in food production).<sup>1</sup>

The important feature of this production possibility frontier is that the opportunity cost of producing an extra yard of cloth in terms of food is not constant. When the economy is producing mostly food (to the left of point 3), then there is spare labor capacity. Producing two fewer units of food releases six machine-hours that can be used to produce three yards of cloth: The opportunity cost of cloth is  $2/3$ . When the economy is producing mostly cloth (to the right of point 3), then there is spare capital capacity. Producing two fewer units of food releases two work-hours that can be used to produce one yard of cloth: The opportunity cost of cloth is 2. Thus, the opportunity cost of cloth is higher when more units of cloth are being produced.

<sup>1</sup>The case of no factor substitution is a special one in which there is only a single production point that fully employs both factors; some factors are left unemployed at all the other production points on the production possibilities frontier. In the more general case below with factor substitution, this peculiarity disappears, and both factors are fully employed along the entire production possibility frontier.



**Figure 5-1**

**The Production Possibility Frontier Without Factor Substitution: Numerical Example**

If capital cannot be substituted for labor or vice versa, the production possibility frontier in the factor-proportions model would be defined by two resource constraints: The economy can't use more than the available supply of labor (2,000 work-hours) or capital (3,000 machine-hours). So the production possibility frontier is defined by the red line in this figure. At point 1, the economy specializes in food production, and not all available work-hours are employed. At point 2, the economy specializes in cloth, and not all available machine-hours are employed. At production point 3, the economy employs all of its labor and capital resources. The important feature of the production possibility frontier is that the opportunity cost of cloth in terms of food isn't constant: It rises from  $2/3$  to 2 when the economy's mix of production shifts toward cloth.

Now let's make the model more realistic and allow the possibility of substituting capital for labor and vice versa in production. This substitution removes the kink in the production possibility frontier; instead, the frontier  $PP$  has the bowed shape shown in Figure 5-2. The bowed shape tells us that the opportunity cost in terms of food of producing one more unit of cloth rises as the economy produces more cloth and less food. That is, our basic insight about how opportunity costs change with the mix of production remains valid.

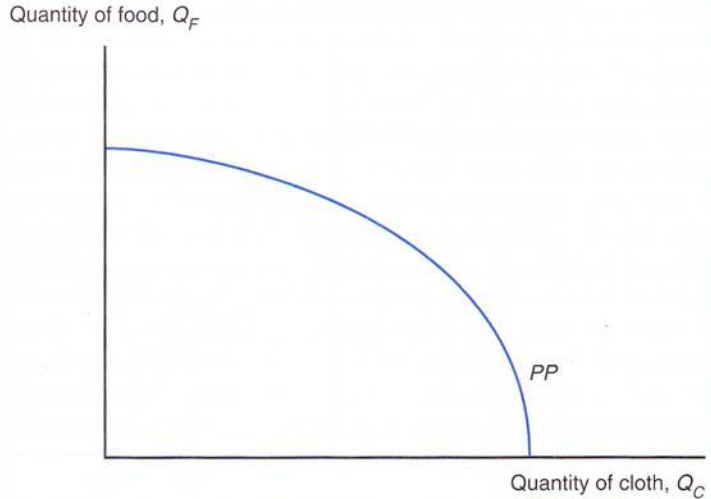
Where on the production possibility frontier does the economy produce? It depends on prices. Specifically, the economy produces at the point that maximizes the value of production. Figure 5-3 shows what this implies. The value of the economy's production is

$$V = P_C \times Q_C + P_F \times Q_F,$$

where  $P_C$  and  $P_F$  are the prices of cloth and food, respectively. An isovalue line—a line along which the value of output is constant—has a slope of  $-P_C/P_F$ . The economy produces at the point  $Q$ , the point on the production possibility frontier that touches the highest possible isovalue line. At that point, the slope of the production possibility frontier is equal to  $-P_C/P_F$ . So the opportunity cost in terms of food of producing another unit of cloth is equal to the relative price of cloth.

**Figure 5-2****The Production Possibility Frontier with Factor Substitution**

If capital can be substituted for labor and vice versa, the production possibility frontier no longer has a kink. But it remains true that the opportunity cost of cloth in terms of food rises as the economy's production mix shifts toward cloth and away from food.

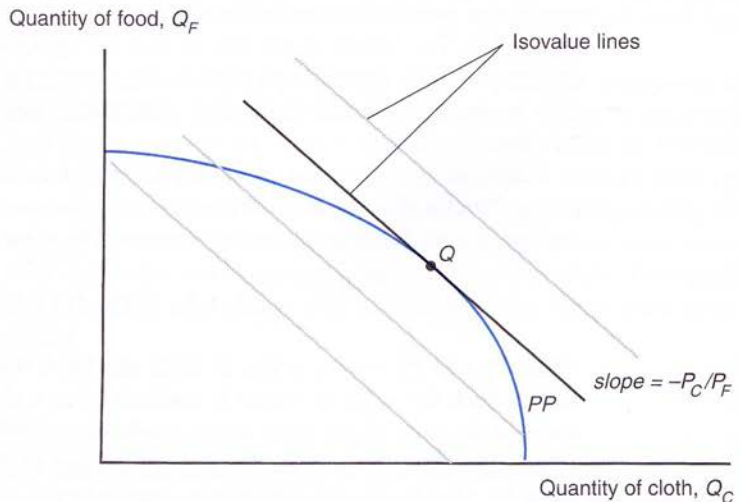
**Choosing the Mix of Inputs**

As we have noted, in a two-factor model producers may have room for choice in the use of inputs. A farmer, for example, can choose between using relatively more mechanized equipment (capital) and fewer workers, or vice versa. Thus, the farmer can choose how much labor and capital to use per unit of output produced. In each sector, then, producers will face not fixed input requirements (as in the Ricardian model) but trade-offs like the one illustrated by curve *II* in Figure 5-4, which shows alternative input combinations that can be used to produce one calorie of food.

What input choice will producers actually make? It depends on the relative costs of capital and labor. If capital rental rates are high and wages low, farmers will choose to produce using relatively little capital and a lot of labor; on the other hand, if the rental rates are low and wages high, they will save on labor and use a lot more capital. If  $w$  is the wage

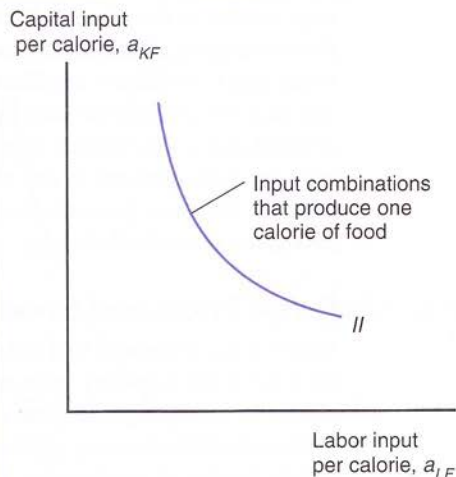
**Figure 5-3****Prices and Production**

The economy produces at the point that maximizes the value of production given the prices it faces; this is the point that is on the highest possible isovalue line. At that point, the opportunity cost of cloth in terms of food is equal to the relative price of cloth,  $P_C/P_F$ .



**Figure 5-4****Input Possibilities in Food Production**

A farmer can produce a calorie of food with less capital if he or she uses more labor, and vice versa.

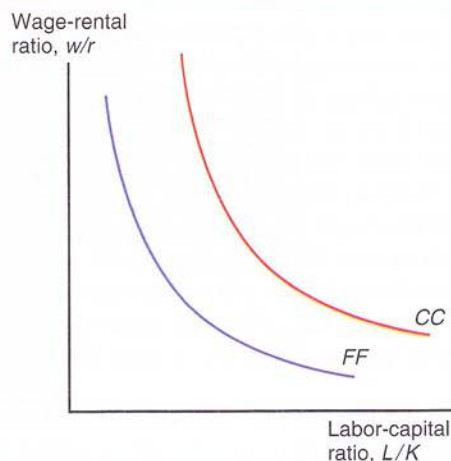


rate and  $r$  the rental cost of capital, then the input choice will depend on the ratio of these two **factor prices**,  $w/r$ .<sup>2</sup> The relationship between factor prices and the ratio of labor to capital use in production of food is shown in Figure 5-5 as the curve  $FF$ .

There is a corresponding relationship between  $w/r$  and the labor-capital ratio in cloth production. This relationship is shown in Figure 5-5 as the curve  $CC$ . As drawn,  $CC$  is shifted out relative to  $FF$ , indicating that at any given factor prices, production of cloth will always use more labor relative to capital than will production of food. When this is true, we say that production of cloth is *labor-intensive*, while production of food is *capital-intensive*. Notice that the definition of intensity depends on the ratio of labor to capital used in production, not the ratio of labor or capital to output. Thus a good cannot be both capital- and labor-intensive.

**Figure 5-5****Factor Prices and Input Choices**

In each sector, the ratio of labor to capital used in production depends on the cost of labor relative to the cost of capital,  $w/r$ . The curve  $FF$  shows the labor-capital ratio choices in food production, while the curve  $CC$  shows the corresponding choices in cloth production. At any given wage-rental ratio, cloth production uses a higher labor-capital ratio; when this is the case, we say that cloth production is *labor-intensive* and that food production is *capital-intensive*.



<sup>2</sup>The optimal choice of the labor-capital ratio is explored at greater length in the appendix to this chapter.

The  $CC$  and  $FF$  curves in Figure 5-5 are called relative factor demand curves; they are very similar to the relative demand curve for goods. Their downward slope characterizes the substitution effect in the producers' factor demand. As the wage  $w$  rises relative to the rental rate  $r$ , producers substitute capital for labor in their production decisions. The previous case we considered with no factor substitution is a limiting case, where the relative demand curve is a vertical line: The ratio of labor to capital demanded is fixed and does not vary with changes in the wage-rental ratio  $w/r$ . In the remainder of this chapter, we consider the more general case with factor substitution, where the relative factor demand curves are downward sloping.

## Factor Prices and Goods Prices

Suppose for a moment that the economy produces both cloth and food. (This need not be the case if the economy engages in international trade, because it might specialize completely in producing one good or the other; but let us temporarily ignore this possibility.) Then competition among producers in each sector will ensure that the price of each good equals its cost of production. The cost of producing a good depends on factor prices: If wages rise, then other things equal to the price of any good whose production uses labor will also rise.

The importance of a particular factor's price to the cost of producing a good depends, however, on how much of that factor the good's production involves. If food production makes use of very little labor, for example, then a rise in the wage will not have much effect on the price of food, whereas if cloth production uses a great deal of labor, a rise in the wage *will* have a large effect on the price. We can therefore conclude that there is a one-to-one relationship between the ratio of the wage rate to the rental rate,  $w/r$ , and the ratio of the price of cloth to that of food,  $P_C/P_F$ . This relationship is illustrated by the upward-sloping curve  $SS$  in Figure 5-6.<sup>3</sup>

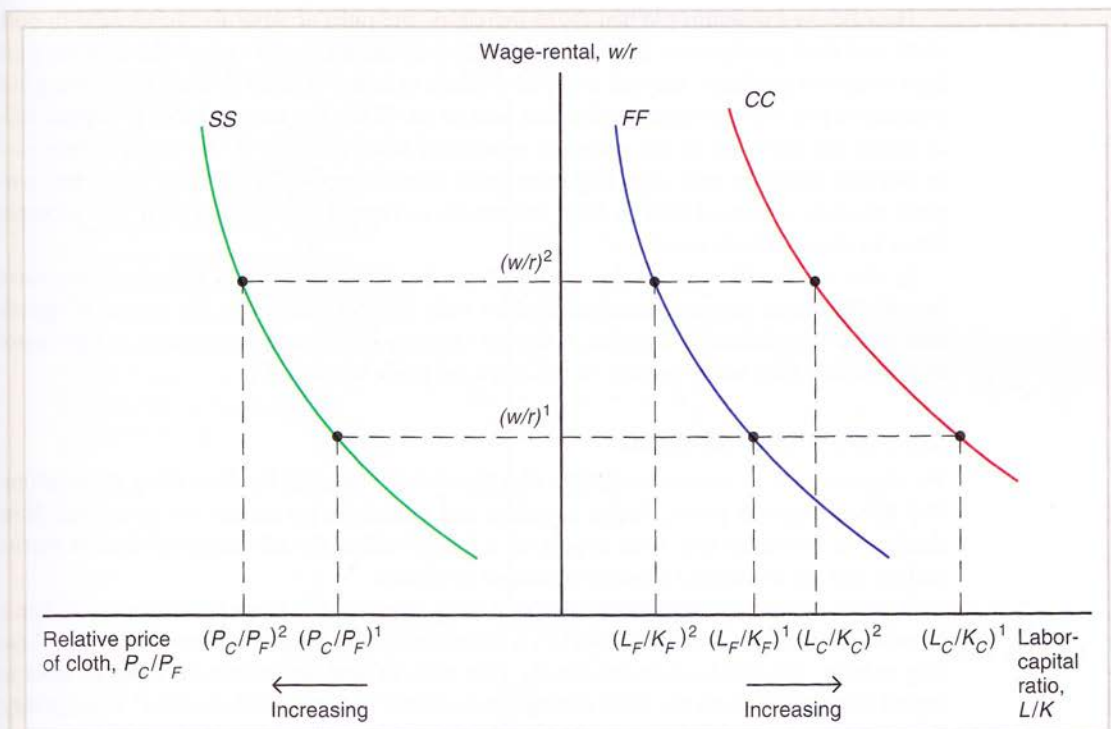
**Figure 5-6**

### Factor Prices and Goods Prices

Because cloth production is labor-intensive while food production is capital-intensive, there is a one-to-one relationship between the factor price ratio  $w/r$  and the relative price of cloth  $P_C/P_F$ ; the higher the relative cost of labor, the higher must be the relative price of the labor-intensive good. The relationship is illustrated by the curve  $SS$ .



<sup>3</sup>This relationship holds only when the economy produces both cloth and food, which is associated with a given range for the relative price of cloth. If the relative price rises beyond a given upper-bound level, then the economy specializes in cloth production; conversely, if the relative price drops below a lower-bound level, then the economy specializes in food production.

**Figure 5-7****From Goods Prices to Input Choices**

Given the relative price of cloth  $(P_C/P_F)^1$ , the ratio of the wage rate to the capital rental rate must equal  $(w/r)^1$ . This wage-rental ratio then implies that the ratios of labor to capital employed in the production of cloth and food must be  $(L_C/K_C)^1$  and  $(L_F/K_F)^1$ . If the relative price of cloth rises to  $(P_C/P_F)^2$ , the wage-rental ratio must rise to  $(w/r)^2$ . This will cause the labor-capital ratio used in the production of both goods to drop.

Let's look at Figures 5-5 and 5-6 together. In Figure 5-7, the left panel is Figure 5-6 (of the SS curve) turned counterclockwise 90 degrees, while the right panel reproduces Figure 5-5. By putting these two diagrams together, we see what may seem at first to be a surprising linkage of the prices of goods to the ratio of labor to capital used in the production of each good. Suppose that the relative price of cloth is  $(P_C/P_F)^1$  (left panel of Figure 5-7); if the economy produces both goods, the ratio of the wage rate to the capital rental rate must equal  $(w/r)^1$ . This ratio then implies that the ratios of labor to capital employed in the production of cloth and food must be  $(L_C/K_C)^1$  and  $(L_F/K_F)^1$ , respectively (right panel of Figure 5-7). If the relative price of cloth were to rise to the level indicated by  $(P_C/P_F)^2$ , the ratio of the wage rate to the capital rental rate would rise to  $(w/r)^2$ . Because labor is now relatively more expensive, the ratios of labor to capital employed in the production of cloth and food would therefore drop to  $(L_C/K_C)^2$  and  $(L_F/K_F)^2$ .

We can learn one more important lesson from this diagram. The left panel already tells us that an increase in the price of cloth relative to that of food will raise the income of workers relative to that of capital owners. But it is possible to make a stronger statement: Such a change in relative prices will unambiguously raise the purchasing power of workers and lower the purchasing power of capital owners by raising real wages and lowering real rents in terms of *both* goods.



How do we know this? When  $P_C/P_F$  increases, the ratio of labor to capital falls in both cloth and food production. But in a competitive economy, factors of production are paid their marginal product—the real wage of workers in terms of cloth is equal to the marginal productivity of labor in cloth production, and so on. When the ratio of labor to capital falls in producing either good, the marginal product of labor in terms of that good increases—so workers find their real wage higher in terms of both goods. On the other hand, the marginal product of capital falls in both industries, so capital owners find their real incomes lower in terms of both goods.

In this model, then, as in the specific factors model, changes in relative prices have strong effects on income distribution. Not only does a change in the prices of goods change the distribution of income; it always changes it so much that owners of one factor of production gain while owners of the other are made worse off.<sup>4</sup>

## Resources and Output

We can now complete the description of a two-factor economy by describing the relationship between goods prices, factor supplies, and output. In particular, we investigate how changes in resources (the total supply of a factor) affect the allocation of factors across sectors and the associated changes in output produced.

Suppose that we take the relative price of cloth as given. We know from Figure 5-7 that a given relative price of cloth, say  $(P_C/P_F)^1$ , is associated with a fixed wage-rental ratio  $(w/r)^1$  (so long as both cloth and food are produced). That ratio, in turn, determines the ratios of labor to capital employed in both the cloth and the food sectors:  $(L_C/K_C)^1$  and  $(L_F/K_F)^1$ , respectively. Now we assume that the economy's labor force grows, which implies that the economy's aggregate labor to capital ratio,  $L/K$ , increases. At the given relative price of cloth  $(P_C/P_F)^1$ , we just saw that the ratios of labor to capital employed in both sectors remain constant. How can the economy accommodate the increase in the aggregate relative supply of labor  $L/K$  if the relative labor demanded in each sector remains constant at  $(L_C/K_C)^1$  and  $(L_F/K_F)^1$ ? In other words, how does the economy employ the additional labor hours? The answer lies in the allocation of labor and capital across sectors: The labor-capital ratio in the cloth sector is higher than that in the food sector, so the economy can increase the employment of labor to capital (holding the labor-capital ratio fixed in each sector) by allocating more labor and capital to the production of cloth (which is labor-intensive).<sup>5</sup> As labor and capital move from the food sector to the cloth sector, the economy produces more cloth and less food.

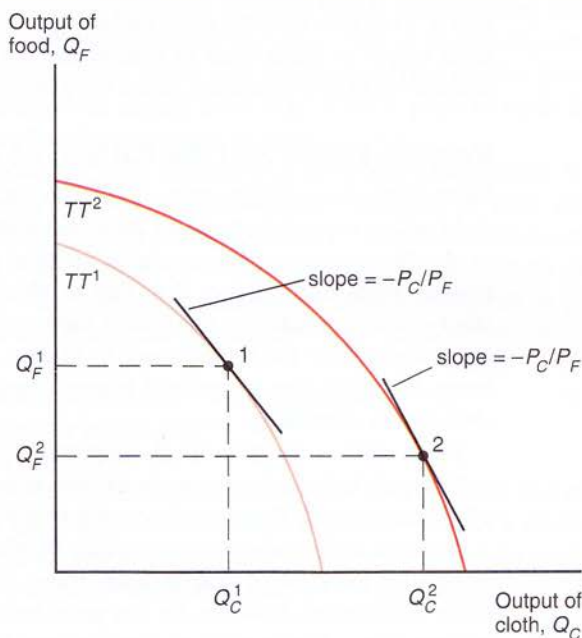
The best way to think about this result is in terms of how resources affect the economy's production possibilities. In Figure 5-8 the curve  $TT^1$  represents the economy's production possibilities before the increase in labor supply. Output is at point 1, where the slope of the production possibility frontier equals minus the relative price of cloth,  $-P_C/P_F$ , and the economy produces  $Q_C^1$  and  $Q_F^1$  of cloth and food. The curve  $TT^2$  shows the production possibility frontier after an increase in the labor supply. The production possibility frontier shifts out to  $TT^2$ . After this increase, the economy can produce more of both cloth and food than before. The outward shift of the frontier is, however, much larger in the direction of cloth than of food—that is, there is a **biased expansion of production possibilities**, which occurs when the production possibility frontier shifts out much more in one direction than in the other. In this case, the expansion is so strongly biased toward cloth production that at unchanged relative prices, production moves from

<sup>4</sup>This relationship between goods prices and factor prices (and the associated welfare effects) was clarified in a classic paper by Wolfgang Stolper and Paul Samuelson, "Protection and Real Wages," *Review of Economic Studies* 9 (November 1941), pp. 58–73, and is therefore known as the *Stolper-Samuelson effect*.

<sup>5</sup>See the appendix for a more formal derivation of this result and additional details.

**Figure 5-8****Resources and Production Possibilities**

An increase in the supply of labor shifts the economy's production possibility frontier outward from  $TT^1$  to  $TT^2$ , but does so disproportionately in the direction of cloth production. The result is that at an unchanged relative price of cloth (indicated by the slope  $-P_C/P_F$ ), food production actually declines from  $Q_F^1$  to  $Q_F^2$ .



point 1 to point 2, which involves an actual fall in food output from  $Q_F^1$  to  $Q_F^2$  and a large increase in cloth output from  $Q_C^1$  to  $Q_C^2$ .

The biased effect of increases in resources on production possibilities is the key to understanding how differences in resources give rise to international trade.<sup>6</sup> An increase in the supply of labor expands production possibilities disproportionately in the direction of cloth production, while an increase in the supply of capital expands them disproportionately in the direction of food production. Thus an economy with a high relative supply of labor to capital will be relatively better at producing cloth than an economy with a low relative supply of labor to capital. *Generally, an economy will tend to be relatively effective at producing goods that are intensive in the factors with which the country is relatively well endowed.*

We will further see below that there is some strong empirical evidence confirming that changes in a country's resources lead to growth that is strongly biased toward the sectors that intensively use the factor whose supply has increased. We document this for the economies of Japan, South Korea, Taiwan, Hong Kong, and Singapore, which all experienced very rapid growth in their supply of skilled labor over the last half-century.

## Effects of International Trade Between Two-Factor Economies

Having outlined the production structure of a two-factor economy, we can now look at what happens when two such economies, Home and Foreign, trade. As always, Home and Foreign are similar along many dimensions. They have the same tastes and therefore have identical

<sup>6</sup>The biased effect of resource changes on production was pointed out in a paper by the Polish economist T. M. Rybczynski, "Factor Endowments and Relative Commodity Prices," *Economica* 22 (November 1955), pp. 336–341. It is therefore known as the *Rybczynski effect*.

relative demands for food and cloth when faced with the same relative prices of the two goods. They also have the same technology: A given amount of labor and capital yields the same output of either cloth or food in the two countries. The only difference between the countries is in their resources: Home has a higher ratio of labor to capital than Foreign does.

### Relative Prices and the Pattern of Trade

Since Home has a higher ratio of labor to capital than Foreign, Home is *labor-abundant* and Foreign is *capital-abundant*. Note that abundance is defined in terms of a ratio and not in absolute quantities. For example, the total number of workers in the United States is roughly three times higher than that in Mexico, but Mexico would still be considered labor-abundant relative to the United States since the U.S. capital stock is more than three times higher than the capital stock in Mexico. “Abundance” is always defined in relative terms, by comparing the ratio of labor to capital in the two countries; thus no country is abundant in everything.

Since cloth is the labor-intensive good, Home’s production possibility frontier relative to Foreign’s is shifted out more in the direction of cloth than in the direction of food. Thus, other things equal, Home tends to produce a higher ratio of cloth to food.

Because trade leads to a convergence of relative prices, one of the other things that will be equal is the price of cloth relative to that of food. Because the countries differ in their factor abundances, however, for any given ratio of the price of cloth to that of food, Home will produce a higher ratio of cloth to food than Foreign will: Home will have a larger *relative supply* of cloth. Home’s relative supply curve, then, lies to the right of Foreign’s.

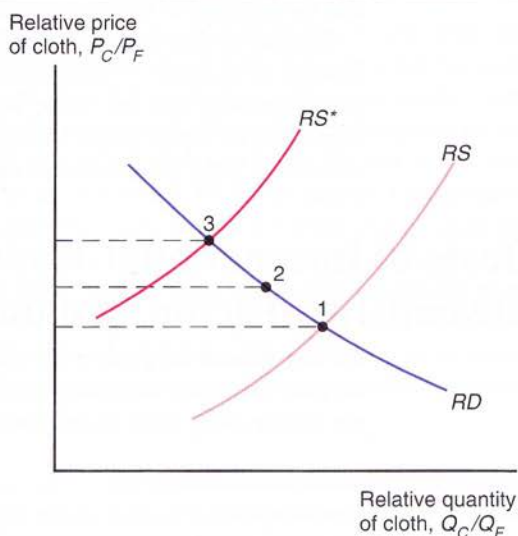
The relative supply schedules of Home ( $RS$ ) and Foreign ( $RS^*$ ) are illustrated in Figure 5-9. The relative demand curve, which we have assumed to be the same for both countries, is shown as  $RD$ . If there were no international trade, the equilibrium for Home would be at point 1, while the equilibrium for Foreign would be at point 3. That is, in the absence of trade the relative price of cloth would be lower in Home than in Foreign.

When Home and Foreign trade with each other, their relative prices converge. The relative price of cloth rises in Home and declines in Foreign, and a new world relative price of

**Figure 5-9**

#### Trade Leads to a Convergence of Relative Prices

In the absence of trade, Home’s equilibrium would be at point 1, where domestic relative supply  $RS$  intersects the relative demand curve  $RD$ . Similarly, Foreign’s equilibrium would be at point 3. Trade leads to a world relative price that lies between the pre-trade prices, that is, at point 2.



cloth is established at a point somewhere between the pretrade relative prices, say at point 2. In Chapter 4, we discussed how an economy responds to this trade opening based on the direction of the change in the relative price of the goods: The economy exports the good whose relative price increases. Thus, Home will export cloth (the relative price of cloth rises in Home), while Foreign will export food. (The relative price of cloth declines in Foreign, which means that the relative price of food rises there).

Home becomes an exporter of cloth because it is labor-abundant (relative to Foreign) and because the production of cloth is labor-intensive (relative to food production). Similarly, Foreign becomes an exporter of food because it is capital-abundant and because the production of food is capital-intensive. These predictions for the pattern of trade (in the two-good, two-factor, two-countries version that we have studied) can be generalized as the following theorem, named after the original developers of this model of trade:

**Heckscher-Ohlin Theorem:** *The country that is abundant in a factor exports the good whose production is intensive in that factor.*

In the more realistic case with multiple countries, factors of production, and numbers of goods, we can generalize this result as a correlation between a country's abundance in a factor and its exports of goods that use that factor intensively: *Countries tend to export goods whose production is intensive in factors with which the countries are abundantly endowed.*<sup>7</sup>

## Trade and the Distribution of Income

We have just discussed how trade induces a convergence of relative prices. Previously we saw that changes in relative prices, in turn, have strong effects on the relative earnings of labor and capital. A rise in the price of cloth raises the purchasing power of labor in terms of both goods while lowering the purchasing power of capital in terms of both goods. A rise in the price of food has the reverse effect. Thus international trade can have a powerful effect on the distribution of income, even in the long run. In Home, where the relative price of cloth rises, people who get their incomes from labor gain from trade, but those who derive their incomes from capital are made worse off. In Foreign, where the relative price of cloth falls, the opposite happens: Laborers are made worse off and capital owners are made better off.

The resource of which a country has a relatively large supply (labor in Home, capital in Foreign) is the **abundant factor** in that country, and the resource of which it has a relatively small supply (capital in Home, labor in Foreign) is the **scarce factor**. The general conclusion about the income distribution effects of international trade in the long run is: *Owners of a country's abundant factors gain from trade, but owners of a country's scarce factors lose.*

This conclusion is similar to the one reached in our analysis of the case of specific factors. There we found that factors of production that are "stuck" in an import-competing industry lose from the opening of trade. Here we find that factors of production that are used intensively by the import-competing industry are hurt by the opening of trade. The theoretical argument regarding the aggregate gains from trade is identical to the specific factors case: Opening to trade expands an economy's consumption possibilities (see Figure 4-11), so there is a way to make everybody better off. However, there is one crucial difference regarding the income distribution effects in these two models. The specificity of factors to particular industries is often only a temporary problem: Garment makers cannot become computer manufacturers

<sup>7</sup>See Alan Deardorff, "The General Validity of the Heckscher-Ohlin Theorem," *American Economic Review* 72 (September 1982), pp. 683-694, for a formal derivation of this extension to multiple goods, factors, and countries.

overnight, but given time the U.S. economy can shift its manufacturing employment from declining sectors to expanding ones. Thus income distribution effects that arise because labor and other factors of production are immobile represent a temporary, transitional problem (which is not to say that such effects are not painful to those who lose). In contrast, effects of trade on the distribution of income among land, labor, and capital are more or less permanent.

We will see shortly that the trade pattern of the United States suggests that compared with the rest of the world, the United States is abundantly endowed with highly skilled labor and that low-skilled labor is correspondingly scarce. This means that international trade has the potential to make low-skilled workers in the United States worse off—not just temporarily, but on a sustained basis. The negative effect of trade on low-skilled workers poses a persistent political problem, one that cannot be remedied by policies that provide temporary relief (such as unemployment insurance). Consequently, the potential effect of increased trade on income inequality in advanced economies such as the United States has been the subject of a large amount of empirical research. We review some of that evidence in the box that follows, and conclude that trade has been, at most, a contributing factor to the measured increases in income inequality in the United States.



## Case Study

### North-South Trade and Income Inequality

The distribution of wages in the United States has become considerably more unequal since the late 1970s. In 1979, a male worker with a wage at the 90th percentile of the wage distribution (earning more than the bottom 90 percent but less than the top 10 percent of wage earners) earned 3.6 times the wage of a male worker at the bottom 10th percentile of the distribution. By 2005, that worker at the 90th percentile earned more than 5.4 times the wage of the worker at the bottom 10th percentile. Wage inequality for female workers has increased at a similar rate over that same time-span. Much of this increase in wage inequality was associated with a rise in the premium attached to education. In 1979, a worker with a college degree earned 1.5 times as much as a worker with just a high school education. By 2005, a worker with a college degree earned almost twice as much as a worker with a high school education.

Why has wage inequality increased? Many observers attribute the change to the growth of world trade and in particular to the growing exports of manufactured goods from newly industrializing economies (NIEs) such as South Korea and China. Until the 1970s, trade between advanced industrial nations and less-developed economies—often referred to as “North-South” trade because most advanced nations are still in the temperate zone of the Northern Hemisphere—consisted overwhelmingly of an exchange of Northern manufactures for Southern raw materials and agricultural goods, such as oil and coffee. From 1970 onward, however, former raw material exporters increasingly began to sell manufactured goods to high-wage countries like the United States. As we learned in Chapter 2, developing countries have dramatically changed the kinds of goods they export, moving away from their traditional reliance on agricultural and mineral products to a focus on manufactured goods. While NIEs also provided a rapidly growing market for exports from the high-wage nations, the exports of the newly industrializing economies obviously differed greatly in factor intensity from their imports. Overwhelmingly, NIE exports to advanced nations consisted of clothing, shoes, and other relatively unsophisticated products (“low-tech goods”) whose production is intensive in unskilled

labor, while advanced-country exports to the NIEs consisted of capital- or skill-intensive goods such as chemicals and aircraft (“high-tech goods”).

To many observers the conclusion seemed straightforward: What was happening was a move toward factor-price equalization. Trade between advanced countries that are abundant in capital and skill and NIEs with their abundant supply of unskilled labor was raising the wages of highly skilled workers and lowering the wages of less-skilled workers in the skill- and capital-abundant countries, just as the factor-proportions model predicts.

This is an argument with much more than purely academic significance. If one regards the growing inequality of income in advanced nations as a serious problem, as many people do, and if one also believes that growing world trade is the main cause of that problem, it becomes difficult to maintain economists’ traditional support for free trade. (As we have previously argued, in principle taxes and government payments can offset the effect of trade on income distribution, but one may argue that this is unlikely to happen in practice.) Some influential commentators have argued that advanced nations will have to restrict their trade with low-wage countries if they want to remain basically middle-class societies.

While some economists believe that growing trade with low-wage countries has been the main cause of rising income inequality in the United States, however, most empirical researchers believed at the time of this writing that international trade has been at most a contributing factor to that growth, and that the main causes lie elsewhere.<sup>8</sup> This skepticism rests on three main observations.

First, the factor-proportions model says that international trade affects income distribution via a change in relative prices of goods. So if international trade was the main driving force behind growing income inequality, there ought to be clear evidence of a rise in the prices of skill-intensive products compared with those of unskilled-labor-intensive goods. Studies of international price data, however, have failed to find clear evidence of such a change in relative prices.

Second, the model predicts that relative factor prices should converge: If wages of skilled workers are rising and those of unskilled workers are falling in the skill-abundant country, the reverse should be happening in the labor-abundant country. Studies of income distribution in developing countries that have opened themselves to trade have shown that at least in some cases, the reverse is true. In Mexico, in particular, careful studies have shown that the transformation of the country’s trade in the late 1980s—when Mexico opened itself to imports and became a major exporter of manufactured goods—was accompanied by rising wages for skilled workers and growing overall wage inequality, closely paralleling developments in the United States.

Third, although trade between advanced countries and NIEs has grown rapidly, it still constitutes only a small percentage of total spending in the advanced nations. As a result, estimates of the “factor content” of this trade—the skilled labor exported, in effect, by advanced countries embodied in skill-intensive exports, and the unskilled labor, in effect, imported in labor-intensive imports—are still only a small fraction of the total supplies of skilled and unskilled labor. This suggests that these trade flows cannot have had a very large impact on income distribution.

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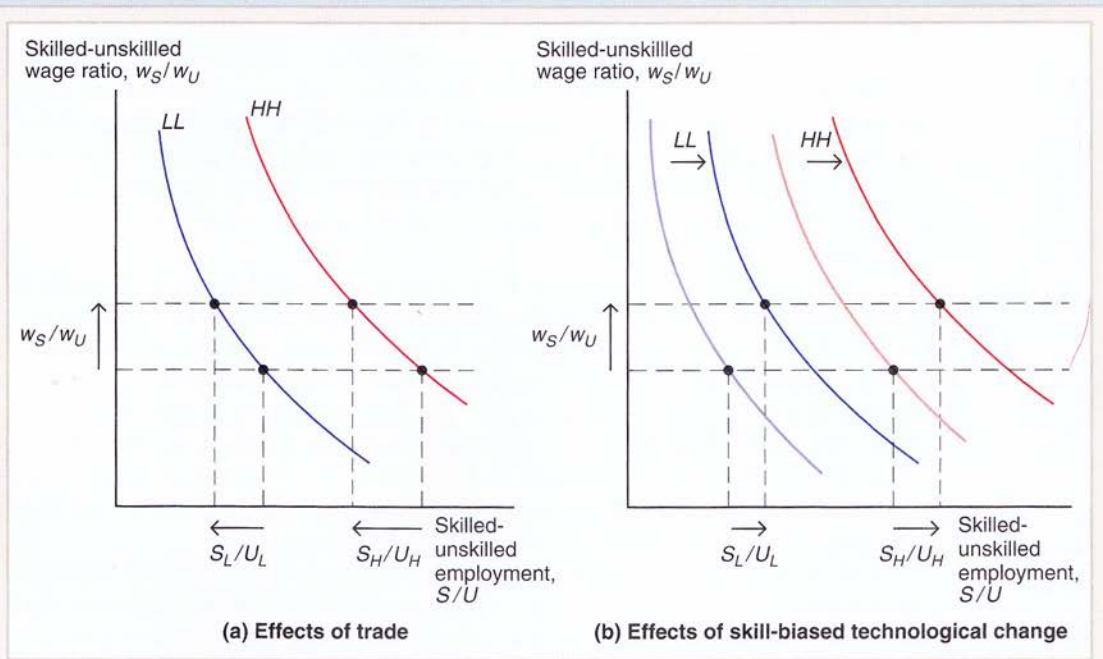
<sup>8</sup>Among the important entries in the discussion of the impact of trade on income distribution have been Robert Lawrence and Matthew Slaughter, “Trade and U.S. Wages: Giant Sucking Sound or Small Hiccup?” *Brookings Papers on Economic Activity: Microeconomic* 2 (1993), pp. 161–226; Jeffrey D. Sachs and Howard Shatz, “Trade and Jobs in U.S. Manufacturing,” *Brookings Papers on Economic Activity* 1 (1994), pp. 1–84; and Adrian Wood, *North-South Trade, Employment, and Income Inequality* (Oxford: Oxford University Press, 1994). For a survey of this debate and related issues, see Robert Lawrence, *Single World, Divided Nations?: International Trade and OECD Labor Markets* (Paris: OECD Development Centre, 1996).

What, then, is responsible for the growing gap between skilled and unskilled workers in the United States? The view of the majority is that the villain is not trade but rather new production technologies that put a greater emphasis on worker skills (such as the widespread introduction of computers and other advanced technologies in the workplace).

How can one distinguish between the effects of trade and those of technological change on the wage gap between skilled and unskilled workers? Consider the variant of the model we have described where skilled and unskilled labor are used to produce “high-tech” and “low-tech” goods. Figure 5-10 shows the relative factor demands for producers in both sectors: the ratio of skilled-unskilled workers employed as a function of the skilled-unskilled wage ratio ( $LL$  curve for low-tech and  $HH$  for high-tech).

We have assumed that production of high-tech goods is skilled-labor intensive so the  $HH$  curve is shifted out relative to the  $LL$  curve. In the background, there is an  $SS$  curve (see Figure 5-7) that determines the skilled-unskilled wage ratio as an increasing function of the relative price of high-tech goods (with respect to low-tech goods).

In panel (a), we show the case where increased trade with developing countries generates an increase in wage inequality (the skilled-unskilled wage ratio) in those countries (via an



**Figure 5-10**

**Increased Wage Inequality: Trade or Skill-Biased Technological Change?**

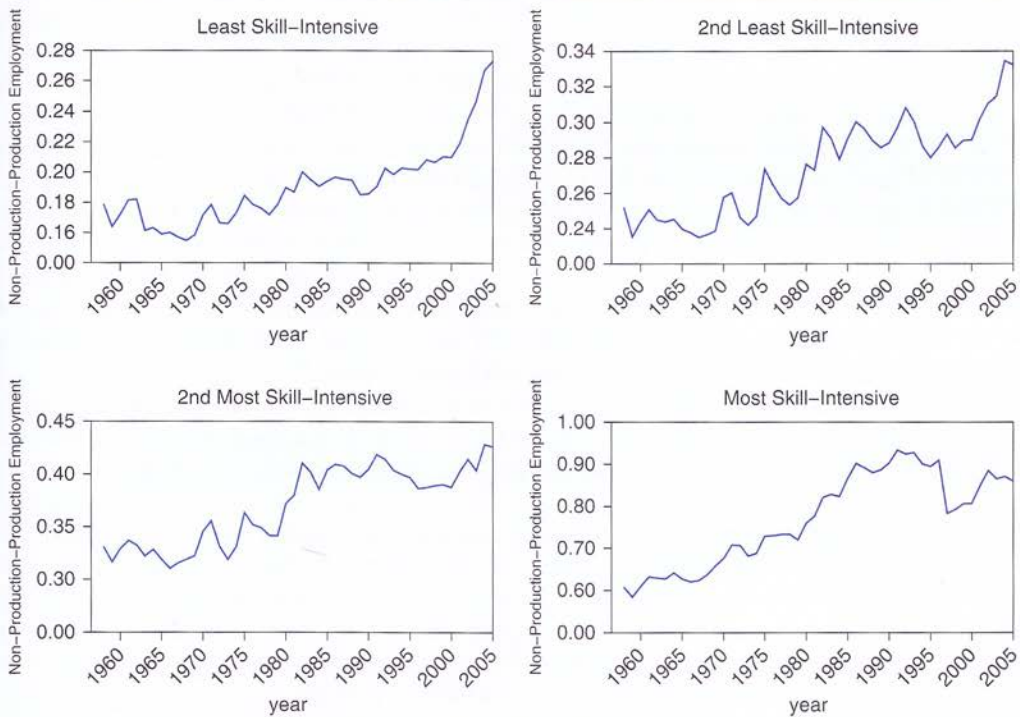
The  $LL$  and  $HH$  curves show the skilled-unskilled employment ratio,  $S/U$ , as a function of the skilled-unskilled wage ratio,  $w_S/w_U$ , in the low-tech and high-tech sectors. The high-tech sector is more skill-intensive than the low-tech sector, so the  $HH$  curve is shifted out relative to the  $LL$  curve. Panel (a) shows the case where increased trade with developing countries leads to a higher skilled-unskilled wage ratio. Producers in both sectors respond by *decreasing* their relative employment of skilled workers:  $S_L/U_L$  and  $S_H/U_H$  both decrease. Panel (b) shows the case where skill-biased technological change leads to a higher skilled-unskilled wage ratio. The  $LL$  and  $HH$  curves shift out (increased relative demand for skilled workers in both sectors). However, in this case producers in both sectors respond by *increasing* their relative employment of skilled workers:  $S_L/U_L$  and  $S_H/U_H$  both increase.

increase in the relative price of high-tech goods). The increase in the relative cost of skilled workers induces producers in both sectors to *reduce* their employment of skilled workers relative to unskilled workers.

In panel (b), we show the case where technological change in both sectors generates an increase in wage inequality. Such technological change is classified as “skill-biased,” as it shifts out the relative demand for skilled workers in both sectors (both the *LL* and the *HH* curves shift out). Then, a given relative price of high-tech goods is associated with a higher skilled-unskilled wage ratio (the *SS* curve shifts). In this case, the technological change induces producers in both sectors to *increase* their employment of skilled workers relative to unskilled workers.

We can therefore examine the relative merits of the trade versus **skill-biased technological change** explanations for the increase in wage inequality by looking at the changes in the skilled-unskilled employment ratio within sectors in the United States. A widespread increase in these employment ratios for all different kinds of sectors (both skilled-labor-intensive and unskilled-labor-intensive sectors) in the U.S. economy points to the skill-biased technological explanation. This is exactly what has been observed in the U.S. over the last half-century.

In Figure 5-11, sectors are separated into four groups based on their skill intensity. U.S. firms do not report their employment in terms of skill but use a related categorization of



**Figure 5-11**

#### Evolution of U.S. Non-Production-Production Employment Ratios in Four Groups of Sectors

Sectors are grouped based on their skill intensity. The non-production-production employment ratio has increased over time in all four sector groups.



production and non-production workers. With a few exceptions, non-production positions require higher levels of education—and so we measure the skilled-unskilled employment ratio in a sector as the ratio of non-production employment to production employment.<sup>9</sup> Sectors with the highest non-production to production employment ratios are classified as most skill-intensive. Each quadrant of Figure 5-11 shows the evolution of this employment ratio over time for each group of sectors (the average employment ratio across all sectors in the group). Although there are big differences in average skill intensity across the groups, we clearly see that the employment ratios are increasing over time for all four groups. This widespread increase across most sectors of the U.S. economy is one of the main pieces of evidence pointing to the technology explanation for the increases in U.S. wage inequality.

Yet, even though most economists agree that skill-biased technological change has occurred, recent research has uncovered some new ways in which trade has been an indirect contributor to the associated increases in wage inequality, by accelerating this process of technological change. These explanations are based on the principle that firms have a choice of production methods that is influenced by openness to trade and foreign investment. For example, some studies show that firms that begin to export also upgrade to more skill-intensive production technologies. Trade liberalization can then generate widespread technological change by inducing a large proportion of firms to make such technology-upgrade choices.

Another example is related to foreign outsourcing and the liberalization of trade and foreign investment. In particular, the NAFTA treaty (see Chapter 2) between the United States, Canada, and Mexico has made it substantially easier for firms to move different parts of their production processes (research and development, component production, assembly, marketing) across different locations in North America. Because production worker wages are substantially lower in Mexico, U.S. firms have an incentive to move to Mexico the processes that use production workers more intensively (such as component production and assembly). The processes that rely more intensively on higher-skilled, non-production workers (such as research and development and marketing) tend to stay in the United States (or Canada). From the U.S. perspective, this break-up of the production process increases the relative demand for skilled workers and is very similar to skill-biased technological change. One study finds that this outsourcing process from the United States to Mexico can explain 21 to 27 percent of the increase in the wage premium between non-production and production workers.<sup>10</sup>

Thus, some of the observed skill-biased technological change, and its effect on increased wage inequality, can be traced back to increased openness to trade and foreign investment. And, as we have mentioned, increases in wage inequality in advanced economies are a genuine concern. However, the use of trade restrictions targeted at limiting technological innovations—because those innovations favor relatively higher-skilled workers—is particularly problematic: Those innovations also bring substantial aggregate gains (along with the standard gains from trade) that would then be foregone. Consequently, economists favor longer-term policies that ease the skill-acquisition process for all workers so that the gains from the technological innovations can be spread as widely as possible.

<sup>9</sup>On average, the wage of a non-production worker is 60% higher than that of a production worker.

<sup>10</sup>See Robert Feenstra and Gordon Hanson, "The Impact of Outsourcing and High-Technology Capital on Wages: Estimates for the United States, 1979–1990," *Quarterly Journal of Economics* 144 (August 1999), pp. 907–940.

## Factor-Price Equalization

In the absence of trade, labor would earn less in Home than in Foreign, and capital would earn more. Without trade, labor-abundant Home would have a lower relative price of cloth than capital-abundant Foreign, and the difference in relative prices of *goods* implies an even larger difference in the relative prices of *factors*.

When Home and Foreign trade, the relative prices of goods converge. This convergence, in turn, causes convergence of the relative prices of capital and labor. Thus there is clearly a tendency toward **equalization of factor prices**. How far does this tendency go?

The surprising answer is that in the model, the tendency goes all the way. International trade leads to complete equalization of factor prices. Although Home has a higher ratio of labor to capital than Foreign does, once they trade with each other, the wage rate and the capital rent rate are the same in both countries. To see this, refer back to Figure 5-6, which shows that given the prices of cloth and food, we can determine the wage rate and the rental rate without reference to the supplies of capital and labor. If Home and Foreign face the same relative prices of cloth and food, they will also have the same factor prices.

To understand how this equalization occurs, we have to realize that when Home and Foreign trade with each other, more is happening than a simple exchange of goods. In an indirect way, the two countries are in effect trading factors of production. Home lets Foreign have the use of some of its abundant labor, not by selling the labor directly but by trading goods produced with a high ratio of labor to capital for goods produced with a low labor-capital ratio. The goods that Home sells require more labor to produce than the goods it receives in return; that is, more labor is *embodied* in Home's exports than in its imports. Thus Home exports its labor, embodied in its labor-intensive exports. Conversely, since Foreign's exports embody more capital than its imports, Foreign is indirectly exporting its capital. When viewed this way, it is not surprising that trade leads to equalization of the two countries' factor prices.

Although this view of trade is simple and appealing, there is a major problem with it: In the real world, factor prices are *not* equalized. For example, there is an extremely wide range of wage rates across countries (Table 5-1). While some of these differences may reflect differences in the quality of labor, they are too wide to be explained away on this basis alone.

To understand why the model doesn't give us an accurate prediction, we need to look at its assumptions. Three assumptions crucial to the prediction of factor-price equalization are in reality certainly untrue. These are the assumptions that (1) both countries produce

**TABLE 5-1** Comparative International Wage Rates (United States = 100)

Country	Hourly Compensation of Production Workers, 2005
United States	100
Germany	140
Japan	92
Spain	75
South Korea	57
Portugal	31
Mexico	11
China*	3

\*2004

Source: Bureau of Labor Statistics, *Foreign Labor Statistics Home Page*.

both goods; (2) technologies are the same; and (3) trade actually equalizes the prices of goods in the two countries.

1. To derive the wage and rental rates from the prices of cloth and food in Figure 5-6, we assumed that the country produced both goods. This need not, however, be the case. A country with a very high ratio of labor to capital might produce only cloth, while a country with a very high ratio of capital to labor might produce only food. This implies that factor-price equalization occurs only if the countries involved are sufficiently similar in their relative factor endowments. (A more thorough discussion of this point is given in the appendix to this chapter.) Thus, factor prices need not be equalized between countries with radically different ratios of capital to labor or of skilled to unskilled labor.

2. The proposition that trade equalizes factor prices will not hold if countries have different technologies of production. For example, a country with superior technology might have both a higher wage rate and a higher rental rate than a country with an inferior technology. As described later in this chapter, recent work suggests that it is essential to allow for such differences in technology to reconcile the factor-proportions model with actual data on world trade.

3. Finally, the proposition of complete factor-price equalization depends on complete convergence of the prices of goods. In the real world, prices of goods are not fully equalized by international trade. This lack of convergence is due to both natural barriers (such as transportation costs) and barriers to trade such as tariffs, import quotas, and other restrictions.

## Empirical Evidence on the Heckscher-Ohlin Model

The essence of the Heckscher-Ohlin model is that trade is driven by differences in factor abundance across countries. We just saw how this leads to the natural prediction that goods trade is substituting for factor trade, and hence that goods trade across countries should *embody* those factor differences. This is a very powerful prediction that can be tested empirically. However, we will see that the empirical successes of such tests are very limited—mainly due to the same reasons that undermine the prediction for factor-price equalization (especially the assumption of common technologies across countries). Does this mean that differences in factor abundance do *not* help explain the observed patterns of trade across countries? Not at all. We will see how the pattern of trade between developed and developing countries does fit quite well with the predictions of the Heckscher-Ohlin model.

### Trade in Goods as a Substitute for Trade in Factors

**Tests on U.S. Data** Until recently, and to some extent even now, the United States has been a special case among countries. Until a few years ago, the United States was much wealthier than other countries, and U.S. workers visibly worked with more capital per person than their counterparts in other countries. Even now, although some Western European countries and Japan have caught up, the United States continues to be high on the scale of countries as ranked by capital-labor ratios.

One would then expect the United States to be an exporter of capital-intensive goods and an importer of labor-intensive goods. Surprisingly, however, this was not the case in the 25 years after World War II. In a famous study published in 1953, economist Wassily Leontief (winner of the Nobel Prize in 1973) found that U.S. exports were less capital-intensive than U.S. imports.<sup>11</sup> This result is known as the **Leontief paradox**.

<sup>11</sup>See Wassily Leontief, "Domestic Production and Foreign Trade: The American Capital Position Re-Examined," *Proceedings of the American Philosophical Society* 97 (September 1953), pp. 331–349.

**TABLE 5-2** Factor Content of U.S. Exports and Imports for 1962

	Imports	Exports
Capital per million dollars	\$2,132,000	\$1,876,000
Labor (person-years) per million dollars	119	131
Capital-labor ratio (dollars per worker)	\$17,916	\$14,321
Average years of education per worker	9.9	10.1
Proportion of engineers and scientists in work force	0.0189	0.0255

**Source:** Robert Baldwin, "Determinants of the Commodity Structure of U.S. Trade," *American Economic Review* 61 (March 1971), pp. 126–145.

Table 5-2 illustrates the Leontief paradox as well as other information about U.S. trade patterns. We compare the factors of production used to produce \$1 million worth of 1962 U.S. exports with those used to produce the same value of 1962 U.S. imports. As the first two lines in the table show, Leontief's paradox was still present in that year: U.S. exports were produced with a lower ratio of capital to labor than U.S. imports. As the rest of the table shows, however, other comparisons of imports and exports are more in line with what one might expect. The United States exported products that were more *skilled-labor-intensive* than its imports, as measured by average years of education. We also tended to export products that were "technology-intensive," requiring more scientists and engineers per unit of sales. These observations are consistent with the position of the United States as a high-skill country, with a comparative advantage in sophisticated products.

Why, then, do we observe the Leontief paradox? Some studies have argued that this paradox was specific to the time period considered.<sup>12</sup> Others point to the needed assumption of common technologies used by the United States and its trading partners, which is likely to be violated. One such violation that would explain the paradox goes as follows: The United States has a special advantage in producing new products or goods made with innovative technologies, such as aircraft and sophisticated computer chips. Such products may well be *less* capital-intensive than products whose technology has had time to mature and become suitable for mass production techniques. Thus the United States may be exporting goods that heavily use skilled labor and innovative entrepreneurship, while importing heavy manufactures (such as automobiles) that use large amounts of capital.

**Tests on Global Data** Since the United States may be a special case, economists have also attempted to broaden the test to incorporate more countries, as well as more factors of production. An important such study by Harry P. Bowen, Edward E. Leamer, and Leo Sveikauskas<sup>13</sup> extended the predictions for the factor content of trade to 27 countries and 12 factors of production. The theory behind the test is the same as for Leontief's test for the United States: Based on the factor content of exports and imports, a country should be a net exporter of a factor of production with which it is relatively abundantly endowed (and conversely, net importer of those with which it is relatively poorly endowed).

<sup>12</sup>Later studies point to the disappearance of the Leontief paradox by the early 1970s. For example, see 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), pp. 207–224. These studies show, however, the continuing importance of *human capital* in explaining U.S. exports.

<sup>13</sup>See Harry P. Bowen, Edward E. Leamer, and Leo Sveikauskas, "Multicountry, Multifactor Tests of the Factor Abundance Theory," *American Economic Review* 77 (December 1987), pp. 791–809.

**TABLE 5-3** Testing the Heckscher-Ohlin Model

Factor of Production	Predictive Success*
Capital	0.52
Labor	0.67
Professional workers	0.78
Managerial workers	0.22
Clerical workers	0.59
Sales workers	0.67
Service workers	0.67
Agricultural workers	0.63
Production workers	0.70
Arable land	0.70
Pasture land	0.52
Forest	0.70

\*Fraction of countries for which net exports of factor runs in predicted direction.

**Source:** Harry P. Bowen, Edward E. Leamer, and Leo Sveikauskas, "Multicountry, Multifactor Tests of the Factor Abundance Theory," *American Economic Review* 77 (December 1987), pp. 791–809.

Table 5-3 shows one of the key tests of Bowen et al. The authors calculated the ratio of each country's endowment of each factor to the world supply of that factor. They then compared these ratios with each country's share of world income. If the factor-proportions theory was right, a country would always export factors for which the factor share exceeded the income share, and import factors for which it was less. In fact, for two-thirds of the factors of production, trade ran in the predicted direction less than 70 percent of the time. This result confirms the Leontief paradox on a broader level: Trade often does not run in the direction that the Heckscher-Ohlin theory predicts. As with the Leontief paradox for the United States, explanations for this result have centered on the failure of the common technology assumption.

**The Case of the Missing Trade** Another indication of large technology differences across countries comes from discrepancies between the observed volumes of trade and those predicted by the Heckscher-Ohlin model. In an influential paper, Daniel Treffer<sup>14</sup> at the University of Toronto pointed out that the Heckscher-Ohlin model can also be used to derive predictions for a country's volume of trade based on differences in that country's factor abundance with that of the rest of the world (since, in this model, trade in goods is substituting for trade in factors). In fact, factor trade turns out to be substantially smaller than the Heckscher-Ohlin model predicts.

A large part of the reason for this disparity comes from a false prediction of large-scale trade in labor between rich and poor nations. Consider the United States, on one side, and China on the other. In 2008, the United States had about 23 percent of world income but only about 5 percent of the world's workers; so a simple factor-proportions theory would suggest that U.S. imports of labor embodied in trade should have been huge, something like four times as large as the nation's own labor force. In fact, calculations of the factor content of U.S. trade showed only small net imports of labor. Conversely, China had 7 percent of world income but approximately 20 percent of

<sup>14</sup>Daniel Treffer, "The Case of the Missing Trade and Other Mysteries," *American Economic Review* 85 (December 1995), pp. 1029–1046.

**TABLE 5-4** Estimated Technological Efficiency, 1983 (United States = 1)

Country	
Bangladesh	0.03
Thailand	0.17
Hong Kong	0.40
Japan	0.70
West Germany	0.78

**Source:** Daniel Trefler, "The Care of the Missing Trade and Other Mysteries," *American Economic Review* 85 (December 1995), pp. 1029–1046.

the world's workers in 2008; it therefore "should" have exported most of its labor via trade—but it did not.

Allowing for technology differences also helps to resolve this puzzle of "missing trade." The way this resolution works is roughly as follows: If workers in the United States are much more efficient than those in China, then the "effective" labor supply in the United States is much larger compared with that of China than the raw data suggest—and hence the expected volume of trade between labor-abundant China and labor-scarce America is correspondingly less.

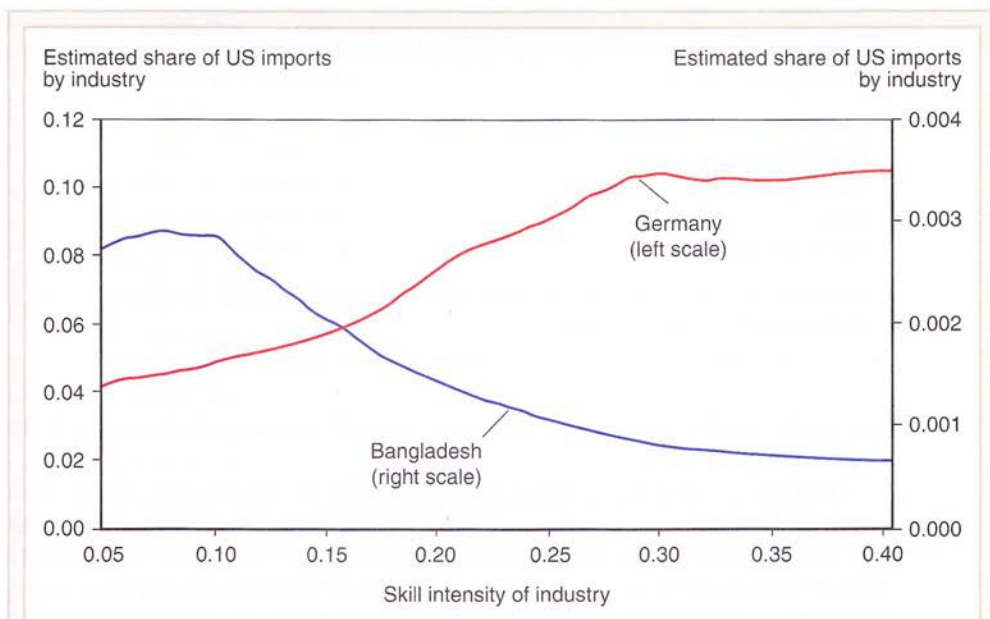
If one makes the working assumption that technological differences between countries take a simple multiplicative form—that is, that a given set of inputs produces only  $\delta$  times as much in China as it does in the United States, where  $\delta$  is some number less than 1—it is possible to use data on factor trade to estimate the relative efficiency of production in different countries. Table 5-4 shows Trefler's estimates for a sample of countries; they suggest that technological differences are in fact very large. However, this exercise does not prove that technology differences do have this simple multiplicative form. If they don't, then some country could have bigger technological advantages in particular sectors, and the predictions for the pattern of trade would be a mix between those of the Ricardian and Heckscher-Ohlin models.

### Patterns of Exports Between Developed and Developing Countries

Although the overall pattern of international trade does not seem to be very well accounted for by a pure Heckscher-Ohlin model, comparisons of the exports of labor-abundant, skill-scarce nations in the third world with the exports of skill-abundant, labor-scarce nations do fit the theory quite well. Consider, for example, Figure 5-12, which compares the pattern of U.S. imports from Bangladesh, whose work force has low levels of education, with the pattern of U.S. imports from Germany, which has a highly educated labor force.

In Figure 5-12, which comes from the work of John Romalis of the University of Chicago,<sup>15</sup> goods are ranked by skill intensity: the ratio of skilled to unskilled labor used in their production. The vertical axes of the figure show U.S. imports of each good from Germany and Bangladesh, respectively, as a share of total U.S. imports of that good. As you can see, Bangladesh tends to account for a relatively large share of U.S. imports of low-skill-intensity goods such as clothing, but a low share of highly skill-intensive goods. Germany is in the reverse position.

<sup>15</sup>John Romalis, "Factor Proportions and the Structure of Commodity Trade," *American Economic Review* 94 (March 2004), pp. 67–97.



**Figure 5-12**

**Skill Intensity and the Pattern of U.S. Imports from Two Countries**

**Source:** John Romalis, "Factor Proportions and the Structure of Commodity Trade," *American Economic Review* 94 (March 2004), pp. 67–97.

Changes over time also follow the predictions of the Heckscher-Ohlin model. Figure 5-13 shows the changing pattern of exports to the United States from Western Europe, Japan, and the four Asian "miracle" economies—South Korea, Taiwan, Hong Kong, and Singapore—which moved rapidly from being quite poor economies in 1960 to relatively rich economies with highly skilled work forces today.

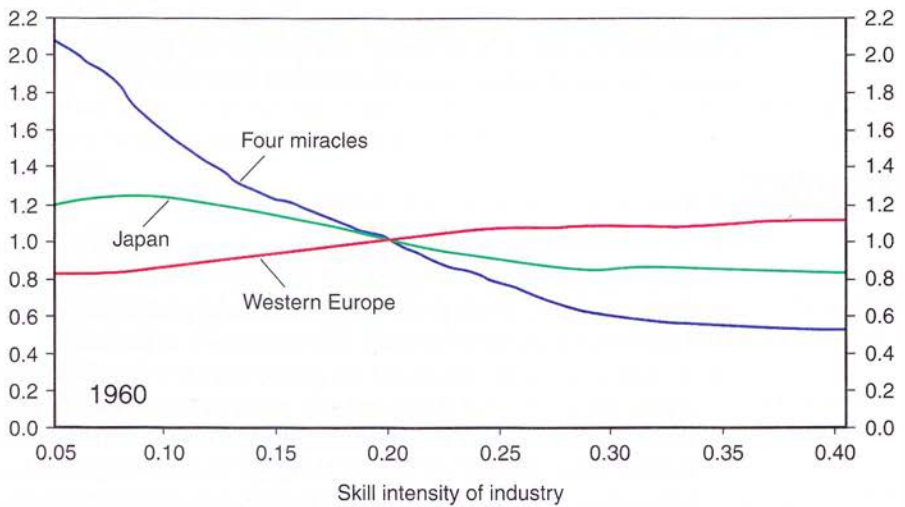
Panel (a) of Figure 5-13 shows the pattern of exports from the three groups in 1960; the miracle economies were clearly specialized in exports of low-skill-intensity goods, and even Japan's exports were somewhat tilted toward the low-skill end. As shown in panel (b), by 1998, however, the level of education of Japan's work force was comparable to that of Western Europe, and Japan's exports reflected that change, becoming as skill-intensive as those of European economies. Meanwhile, the four miracle economies, which had rapidly increased the skill levels of their own work forces, had moved to a trade pattern comparable to that of Japan a few decades earlier.

A key prediction of the Heckscher-Ohlin model is that changes in factor abundance lead to biased growth toward sectors that use that factor intensively in production. We can see that the experience of those Asian economies fit very well with these predictions: As the supply of skilled labor increased, they increasingly specialized in the production of skill-intensive goods.

### Implications of the Tests

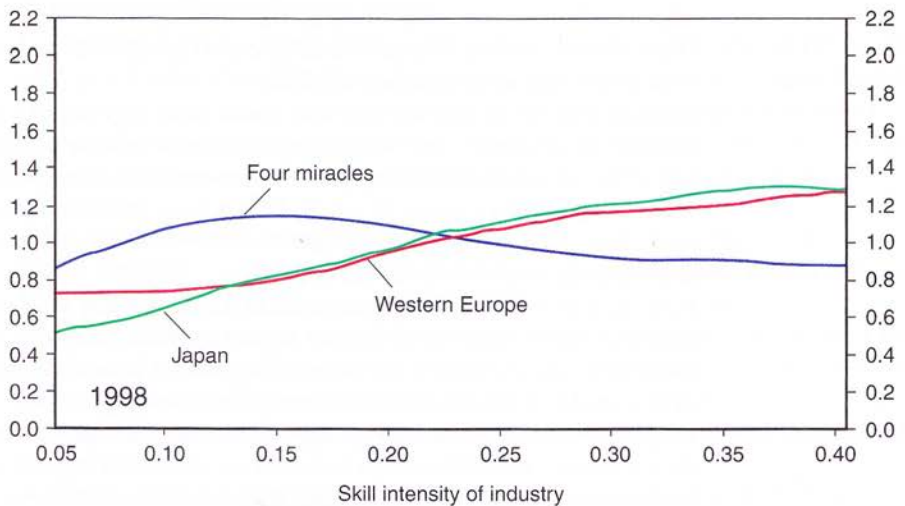
We have just seen that the empirical testing of the Heckscher-Ohlin model has produced mixed results. In particular, the evidence is weak concerning the prediction of the model that, absent technology differences between countries, trade in goods is a substitute for trade in factors: The factor content of a country's exports does not always reflect that

Share of U.S. imports by industry



(a) 1960

Share of U.S. imports by industry



(a) 1998

**Figure 5-13****Changing Patterns of Comparative Advantage**

country's abundant factors; and the volume of trade is substantially lower than what would be predicted based on the large differences in factor abundance between countries. However, the pattern of goods trade between developed and developing countries fits the predictions of the model quite well.



The Heckscher-Ohlin model also remains vital for understanding the *effects* of trade, especially its effects on the distribution of income. Indeed, the growth of North-South trade in manufactures—a trade in which the factor intensity of the North’s imports is very different from that of its exports—has brought the factor-proportions approach into the center of practical debates over international trade policy.

## SUMMARY

1. To understand the role of resources in trade, we develop a model in which two goods are produced using two factors of production. The two goods differ in their *factor intensity*, that is, at any given wage-rental ratio, production of one of the goods will use a higher ratio of capital to labor than production of the other.
2. As long as a country produces both goods, there is a one-to-one relationship between the relative prices of *goods* and the relative prices of *factors* used to produce the goods. A rise in the relative price of the labor-intensive good will shift the distribution of income in favor of labor, and will do so very strongly: The real wage of labor will rise in terms of both goods, while the real income of capital owners will fall in terms of both goods.
3. An increase in the supply of one factor of production expands production possibilities, but in a strongly *biased* way: At unchanged relative goods prices, the output of the good intensive in that factor rises while the output of the other good actually falls.
4. A country that has a large supply of one resource relative to its supply of other resources is *abundant* in that resource. A country will tend to produce relatively more of goods that use its abundant resources intensively. The result is the basic Heckscher-Ohlin theory of trade: Countries tend to export goods that are intensive in the factors with which they are abundantly supplied.
5. Because changes in relative prices of goods have very strong effects on the relative earnings of resources, and because trade changes relative prices, international trade has strong income distribution effects. The owners of a country’s abundant factors gain from trade, but the owners of scarce factors lose. In theory, however, there are still gains from trade, in the limited sense that the winners *could* compensate the losers, and everyone would be better off.
6. In an idealized model, international trade would actually lead to equalization of the prices of factors such as labor and capital between countries. In reality, complete *factor-price equalization* is not observed because of wide differences in resources, barriers to trade, and international differences in technology.
7. Empirical evidence is mixed on the Heckscher-Ohlin model, but most researchers do not believe that differences in resources alone can explain the pattern of world trade or world factor prices. Instead, it seems to be necessary to allow for substantial international differences in technology. Nonetheless, the Heckscher-Ohlin model does a good job of predicting the pattern of trade between developed and developing countries.

## KEY TERMS

abundant factor, p. 91

biased expansion of production possibilities, p. 88

equalization of factor prices, p. 97

factor abundance, p. 80

factor intensity, p. 80

factor prices, p. 85

factor-proportions theory, p. 80

Heckscher-Ohlin theory, p. 80

Leontief paradox, p. 98

scarce factor, p. 91

skill-biased technological change, p. 95

## PROBLEMS



1. Go back to the numerical example with no factor substitution that leads to the production possibility frontier in Figure 5-1.
  - a. What is the range for the relative price of cloth such that the economy produces both cloth and food? Which good is produced if the relative price is outside of this range?

For parts (b) through (f), assume that the price range is such that both goods are produced.

  - b. Write down the unit cost of producing one yard of cloth and one calorie of food as a function of the price of one machine-hour,  $r$ , and one work-hour,  $w$ . In a competitive market, those costs will be equal to the prices of cloth and food. Solve for the factor prices  $r$  and  $w$ .
  - c. What happens to those factor prices when the price of cloth rises? Who gains and who loses from this change in the price of cloth? Why? Do those changes conform to the changes described for the case with factor substitution?
  - d. Now assume that the economy's supply of machine-hours increases from 3,000 to 4,000. Derive the new production possibility frontier.
  - e. How much cloth and food will the economy produce after this increase in its capital supply?
  - f. Describe how the allocation of machine-hours and work-hours between the cloth and food sectors changes. Do those changes conform with the changes described for the case with factor substitution?
2. In the United States, where land is cheap, the ratio of land to labor used in cattle raising is higher than that of land used in wheat growing. But in more crowded countries, where land is expensive and labor is cheap, it is common to raise cows by using less land and more labor than Americans use to grow wheat. Can we still say that raising cattle is land-intensive compared with farming wheat? Why or why not?
3. "The world's poorest countries cannot find anything to export. There is no resource that is abundant—certainly not capital or land, and in small poor nations not even labor is abundant." Discuss.
4. The U.S. labor movement—which mostly represents blue-collar workers rather than professionals and highly educated workers—has traditionally favored limits on imports from less-affluent countries. Is this a shortsighted policy or a rational one in view of the interests of union members? How does the answer depend on the model of trade?
5. Recently, computer programmers in developing countries such as India have begun doing work formerly done in the United States. This shift has undoubtedly led to substantial pay cuts for some programmers in the United States. Answer the following two questions: How is this possible, when the wages of skilled labor are rising in the United States as a whole? What argument would trade economists make against seeing these wage cuts as a reason to block outsourcing of computer programming?
6. Explain why the Leontief paradox and the more recent Bowen, Leamer, and Sveikauskas results reported in the text contradict the factor-proportions theory.
7. In the discussion of empirical results on the Heckscher-Ohlin model, we noted that recent work suggests that the efficiency of factors of production seems to differ internationally. Explain how this would affect the concept of factor-price equalization.

## FURTHER READINGS

- Donald R. Davis and David E. Weinstein. "An Account of Global Factor Trade." *American Economic Review* 91 (December 2001), pp. 1423–1453. The authors review the history of tests of the Heckscher-Ohlin model and propose a modified version—backed by extensive statistical analysis—that allows for technology differences, specialization, and transportation costs.
- Alan Deardorff. "Testing Trade Theories and Predicting Trade Flows," in Ronald W. Jones and Peter B. Kenen, eds. *Handbook of International Economics*. Vol. 1. Amsterdam: North-Holland, 1984. A survey of empirical evidence on trade theories, especially the factor-proportions theory.
- Gordon Hanson and Ann Harrison. "Trade and Wage Inequality in Mexico." *Industrial and Labor Relations Review* 52 (1999), pp. 271–288. A careful study of the effects of trade on income inequality in our nearest neighbor, showing that factor prices have moved in the opposite direction from what one might have expected from a simple factor-proportions model. The authors also put forward hypotheses about why this may have happened.
- Ronald W. Jones. "Factor Proportions and the Heckscher-Ohlin Theorem." *Review of Economic Studies* 24 (1956), pp. 1–10. Extends Samuelson's 1948–1949 analysis (cited below), which focuses primarily on the relationship between trade and income distribution, into an overall model of international trade.
- Ronald W. Jones. "The Structure of Simple General Equilibrium Models." *Journal of Political Economy* 73 (December 1965), pp. 557–572. A restatement of the Heckscher-Ohlin-Samuelson model in terms of elegant algebra.
- Ronald W. Jones and J. Peter Neary. "The Positive Theory of International Trade," in Ronald W. Jones and Peter B. Kenen, eds. *Handbook of International Economics*. Vol. 1. Amsterdam: North-Holland, 1984. An up-to-date survey of many trade theories, including the factor-proportions theory.
- Bertil Ohlin. *Interregional and International Trade*. Cambridge: Harvard University Press, 1933. The original Ohlin book presenting the factor-proportions view of trade remains interesting—its complex and rich view of trade contrasts with the more rigorous and simplified mathematical models that followed.
- Robert Reich. *The Work of Nations*. New York: Basic Books, 1991. An influential tract that argues that the increasing integration of the United States in the world economy is widening the gap between skilled and unskilled workers.
- John Romalis. "Factor Proportions and the Structure of Commodity Trade." *The American Economic Review* 94 (March 2004), pp. 67–97. A recent, state-of-the-art demonstration that a modified version of the Heckscher-Ohlin model has a lot of explanatory power.
- Paul Samuelson. "International Trade and the Equalisation of Factor Prices." *Economic Journal* 58 (1948), pp. 163–184; and "International Factor Price Equalisation Once Again." *Economic Journal* 59 (1949), pp. 181–196. The most influential formalizer of Ohlin's ideas is Paul Samuelson (again!), whose two *Economic Journal* papers on the subject are classics.



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## Factor Prices, Goods Prices, and Production Decisions

In the main body of this chapter, we made three assertions that are true but that were not carefully derived. First was the assertion, embodied in Figure 5-5, that the ratio of labor to capital employed in each industry depends on the wage-rental ratio  $w/r$ . Second was the assertion, embodied in Figure 5-6, that there is a one-to-one relationship between relative goods prices  $P_C/P_F$  and the wage-rental ratio. Third was the assertion that an increase in a country's labor supply (at a given relative goods price  $P_C/P_F$ ) will lead to movements of both labor and capital from the food sector to the cloth sector (the labor-intensive sector). This appendix briefly demonstrates those three propositions.

### Choice of Technique

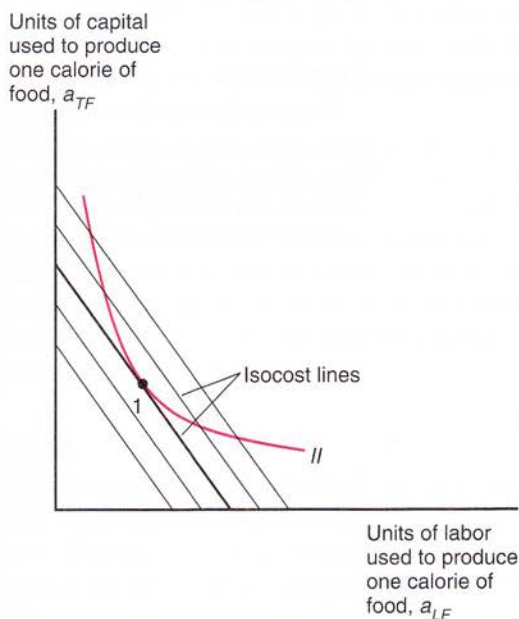
Figure 5A-1 illustrates again the trade-off between labor and capital input in producing one unit of food—the *unit isoquant* for food production shown in curve *II*. It also, however, illustrates a number of *isocost lines*: combinations of capital and labor input that cost the same amount.

An isocost line may be constructed as follows: The cost of purchasing a given amount of labor  $L$  is  $wL$ ; the cost of renting a given amount of capital  $K$  is  $rK$ . So if one is able to

**Figure 5A-1**

#### Choosing the Optimal Labor-Capital Ratio

To minimize costs, a producer must get to the lowest possible isocost line; this means choosing the point on the unit isoquant (curve *II*) where the slope is equal to minus the wage-rental ratio  $w/r$ .



produce a unit of food using  $a_{LF}$  units of labor and  $a_{KF}$  units of capital, the total cost of producing that unit,  $c$ , is

$$c = wa_{LF} + ra_{KF}.$$

A line showing all combinations of  $a_{LF}$  and  $a_{KF}$  with the same cost has the equation

$$a_{KF} = (c/r) - (w/r) a_{LF}.$$

That is, it is a straight line with a slope of  $-w/r$ .

The figure shows a family of such lines, each corresponding to a different level of costs; lines farther from the origin indicate higher total costs. A producer will choose the lowest possible cost given the technological trade-off outlined by curve  $II$ . Here, this occurs at point 1, where  $II$  is *tangent* to the isocost line and the slope of  $II$  equals  $-w/r$ . (If these results seem reminiscent of the proposition in Figure 4-5 that the economy produces at a point on the production possibility frontier whose slope equals minus  $P_C/P_F$ , you are right: The same principle is involved.)

Now compare the choice of labor-capital ratio for two different factor-price ratios. In Figure 5A-2 we show input choices given a low relative price of labor,  $(w/r)^1$ , and a high relative price of labor,  $(w/r)^2$ . In the former case, the input choice is at 1, in the latter case at 2. That is, the higher relative price of labor leads to the choice of a lower labor-capital ratio, as assumed in Figure 5-5.

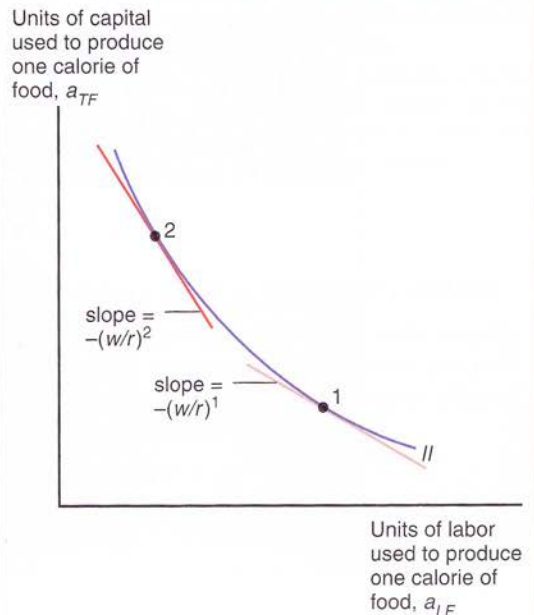
## Goods Prices and Factor Prices

We now turn to the relationship between goods prices and factor prices. There are several equivalent ways of approaching this problem; here we follow the analysis introduced by Abba Lerner in the 1930s.

**Figure 5A-2**

### Changing the Wage-Rental Ratio

A rise in  $w/r$  shifts the lowest-cost input choice from point 1 to point 2; that is, it leads to the choice of a lower labor-capital ratio.



**Figure 5A-3****Determining the Wage-Rental Ratio**

The two isoquants  $CC$  and  $FF$  show the inputs necessary to produce *one dollar's worth* of cloth and food, respectively. Since price must equal the cost of production, the inputs into each good must also cost one dollar. This means that the wage-rental ratio must equal minus the slope of a line tangent to both isoquants.

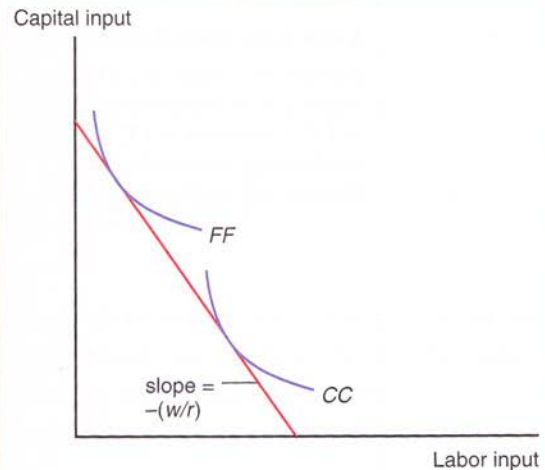


Figure 5A-3 shows capital and labor inputs into both cloth and food production. In previous figures we have shown the inputs required to produce one unit of a good. In this figure, however, we show the inputs required to produce *one dollar's worth* of each good. (Actually, any dollar amount will do, as long as it is the same for both goods.) Thus the isoquant for cloth,  $CC$ , shows the possible input combinations for producing  $1/P_C$  units of cloth; the isoquant for food,  $FF$ , shows the possible combinations for producing  $1/P_F$  units of food. Notice that as drawn, cloth production is labor-intensive (and food production is capital-intensive): For any given  $w/r$ , cloth production will always use a higher labor-capital ratio than food production.

If the economy produces both goods, then it must be the case that the cost of producing one dollar's worth of each good is, in fact, one dollar. Those two production costs will be equal to one another only if the minimum-cost points of production for both goods lie on the *same* isocost line. Thus the slope of the line shown, which is just tangent to both isoquants, must equal (minus) the wage-rental ratio  $w/r$ .

Finally, now, consider the effects of a rise in the price of cloth on the wage-rental ratio. If the price of cloth rises, it is necessary to produce fewer yards of cloth in order to have one dollar's worth. Thus the isoquant corresponding to a dollar's worth of cloth shifts inward. In Figure 5A-4, the original isoquant is shown as  $CC^1$ , the new isoquant as  $CC^2$ .

Once again we must draw a line that is just tangent to both isoquants; the slope of that line is minus the wage-rental ratio. It is immediately apparent from the increased steepness of the isocost line (slope =  $-(w/r)^2$ ) that the new  $w/r$  is higher than the previous one: A higher relative price of cloth implies a higher wage-rental ratio.

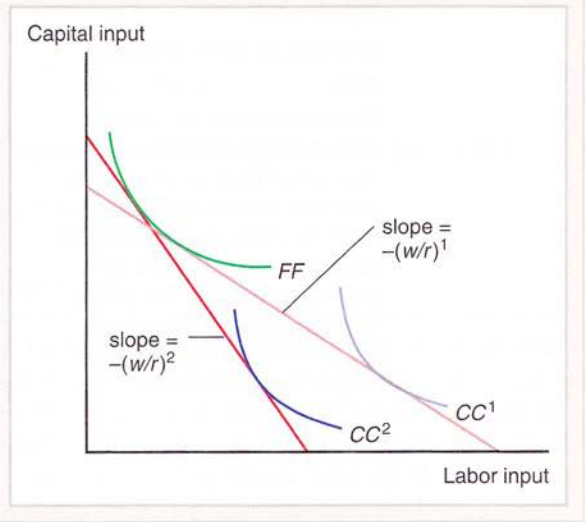
### More on Resources and Output

We now examine more rigorously how a change in resources—holding the prices of cloth and food constant—affects the allocation of those factors of production across sectors and how it thus affects production responses. The aggregate employment of labor to capital  $L/K$  can be written as a weighted average of the labor-capital employed in the cloth sector ( $L_C/K_C$ ) and in the food sector ( $L_F/K_F$ ):

$$\frac{L}{K} = \frac{K_C}{K} \frac{L_C}{K_C} + \frac{K_F}{K} \frac{L_F}{K_F} \quad (5A-1)$$

**Figure 5A-4****A Rise in the Price of Cloth**

If the price of cloth rises, a smaller output is now worth one dollar; so  $CC^1$  is replaced by  $CC^2$ . The implied wage-rental ratio must therefore rise from  $(w/r)^1$  to  $(w/r)^2$ .



Note that the weights in this average,  $K_C/K$  and  $K_F/K$ , add to 1, and are the proportions of capital employed in the cloth and food sectors. We have seen that a given relative price of cloth is associated with a given wage-rental ratio (so long as the economy produces both cloth and food), which, in turn, is associated with given labor-capital employment levels in both sectors ( $L_C/K_C$  and  $L_F/K_F$ ). Now consider the effects of an increase in the economy's labor supply  $L$  at a given relative price of cloth:  $L/K$  increases while  $L_C/K_C$  and  $L_F/K_F$  both remain constant. For equation (5A-1) to hold, the weight on the higher labor-capital ratio,  $L_C/K_C$  must increase. This implies an increase in the weight  $K_C/K$  and a corresponding decrease in the weight  $K_F/K$ . Thus, capital moves from the food sector to the cloth sector (since the total capital supply  $K$  remains constant in this example). Furthermore, since  $L_F/K_F$  remains constant, the decrease in  $K_F$  must also be associated with a decrease in labor employment  $L_F$  in the food sector. This shows that the increase in the labor supply, at a given relative price of cloth, must be associated with movements of *both* labor and capital from the food sector to the cloth sector. The expansion of the economy's production possibility frontier is so biased toward cloth that—at a constant relative price of cloth—the economy produces *less* food.

As the economy's labor supply increases, the economy concentrates more and more of both factors in the labor-intensive cloth sector. If enough labor is added, then the economy specializes in cloth production and no longer produces any food. At that point, the one-to-one relationship between the relative goods price  $P_C/P_F$  and the wage-rental ratio  $w/r$  is broken; further increases in the labor supply  $L$  are then associated with decreases in the wage-rental ratio along the  $CC$  curve in Figure 5-7.

A similar process would occur if the economy's capital supply were to increase—again holding the relative goods price  $P_C/P_F$  fixed. So long as the economy produces both cloth and food, the economy responds to the increased capital supply by concentrating production in the food sector (which is capital-intensive): Both labor and capital move to the food sector. The economy experiences growth that is strongly biased toward food. At a certain point, the economy completely specializes in the food sector, and the one-to-one relationship between the relative goods price  $P_C/P_F$  and the wage-rental ratio  $w/r$  is broken once again. Further increases in the capital supply  $K$  are then associated with increases in the wage-rental ratio along the  $FF$  curve in Figure 5-7.