Trade and Resources: The Heckscher-Ohlin Model

God did not bestow all products upon all parts of the earth, but distributed His gifts over different regions, to the end that men might cultivate a social relationship because one would have need of the help of another. And so He called commerce into being, that all men might be able to have common enjoyment of the fruits of the earth, no matter where produced.

Libanius (AD 314–393), *Orations* (III)

Nature, by giving a diversity of geniuses, climates, and soils, to different nations, has secured their mutual intercourse and commerce. . . . The industry of the nations, from whom they import, receives encouragement: Their own is also [i]ncreased, by the sale of the commodities which they give in exchange.

David Hume, *Essays, Moral, Political, and Literary*, 1752, Part II, Essay VI, "On the Jealousy of Trade"

In Chapter 2, we examined U.S. imports of snowboards. We argued there that the resources found in a country would influence its pattern of international trade. Canada's export of snowboards to the United States reflects its mountains and cold climate, as do the exports of snowboards to the United States from Austria, Spain, Switzerland, Slovenia, Italy, Poland, and France. Because each country's resources are different and because resources are spread unevenly around the world, countries have a reason to trade the goods made with these resources. This is an old idea, as shown by the quotations at the beginning of this chapter; the first is from the fourth-century Greek scholar Libanius, and the second is from the eighteenth-century philosopher David Hume.

In this chapter, we outline the **Heckscher-Ohlin model,** a model that assumes that trade occurs because countries have different resources. This model contrasts with the Ricardian model, which assumed that trade occurs because countries use their technological comparative advantage to specialize in the production of different goods. The model is named after the Swedish economists Eli Heckscher, who wrote about his views of international trade in a 1919 article, and his student Bertil Ohlin, who further developed these ideas in his 1924 dissertation.

The Heckscher-Ohlin model was developed at the end of a "golden age" of international trade (as described in Chapter 1) that lasted from about 1890 until 1914, when World War I started. Those years saw dramatic improvements in transportation: the steamship and the railroad allowed for a great increase in the amount of international trade. For these reasons, there was a considerable increase in the ratio of trade to GDP between 1890 and 1914. It is not surprising, then, that Heckscher and Ohlin would want to explain the large increase in trade that they had witnessed in their own lifetimes. The ability to transport machines across borders meant that they did not look to differences in technologies across countries as the reason for trade, as Ricardo had done. Instead, they assumed that technologies were the same across countries, and they used the uneven distribution of resources across countries to explain trade patterns.

Even today, there are many examples of international trade driven by the land, labor, and capital resources found in each country. Canada, for example, has a large amount of land and therefore exports agricultural and forestry products, as well as petroleum; the United States, Western Europe, and Japan have many highly skilled workers and much capital and these countries export sophisticated services and manufactured goods; China and other Asian countries have a large number of workers and moderate but growing amounts of capital and they export less sophisticated manufactured goods; and so on. We study these and other examples of international trade in this chapter.

Our first goal is to describe the Heckscher-Ohlin model of trade. The specific-factors model that we studied in the previous chapter was a short-run model because capital and land could not move between the two industries we looked at. In contrast, the Heckscher-Ohlin model is a long-run model because all factors of production can move between industries. It is difficult to deal with three factors of production (labor, capital, and land) in both industries, so, instead, we assume that there are just two factors (labor and capital).

After predicting the long-run pattern of trade between countries using the Heckscher-Ohlin model, our second goal is to examine the empirical evidence on the Heckscher-Ohlin model. Although you might think it is obvious that a country's exports will be based on the resources the country has in abundance, it turns out that this prediction does not always hold true in practice. To obtain better predictions from the Heckscher-Ohlin model, we extend it in several directions, first by allowing for more than two factors of production and second by allowing countries to differ in their technologies, as in the Ricardian model. Both extensions make the predictions from the Heckscher-Ohlin model match more closely the trade patterns we see in the world economy today.

The third goal of the chapter is to investigate how the opening of trade between the two countries affects the payments to labor and to capital in each of them. We use the Heckscher-Ohlin model to predict which factor(s) gain when international trade begins and which factor(s) lose.

1 Heckscher-Ohlin Model

In building the Heckscher-Ohlin model, we suppose there are two countries, Home and Foreign, each of which produces two goods, computers and shoes, using two factors of production, labor and capital. Using symbols for capital (K) and labor (L), we can add up the resources used in each industry to get the total for the economy. For example, the amount of capital Home uses in shoes K_S, plus the amount of capital used in computers K_C, adds up to the total capital available in the economy $\overline{K}$, so that $K_C + K_S = \overline{K}$. The same applies for Foreign: $K^*_C + K^*_S = \overline{K}^*$. Similarly, the amount of labor Home uses in shoes L_S, and the amount of labor used in computers L_C, add up to the total labor in the economy $\overline{L}$, so that $L_C + L_S = \overline{L}$. The same applies for Foreign: $L^*_C + L^*_S = \overline{L}^*$.

Assumptions of the Heckscher-Ohlin Model

Because the Heckscher-Ohlin (HO) model describes the economy in the long run, its assumptions differ from those in the short-run specific-factors model of Chapter 3:

Assumption 1: Both factors can move freely between the industries.

This assumption implies that if both industries are actually producing, then capital must earn the same rental R in each of them. The reason for this result is that if capital earned a higher rental in one industry than the other, then all capital would move to the industry with the higher rental and the other industry would shut down. This result differs from the specific-factors model in which capital in manufacturing and land in agriculture earned different rentals in their respective industries. But like the specific-factor model, if both industries are producing, then all labor earns the same wage W in each of them.

Our second assumption concerns how the factors are combined to make shoes and computers:

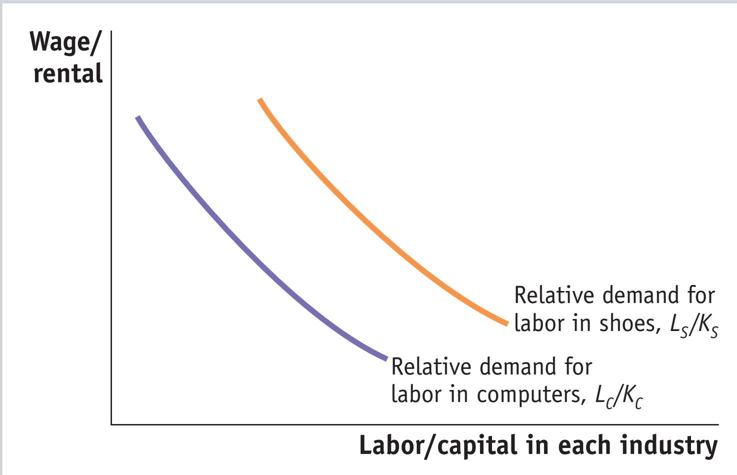
Assumption 2: Shoe production is labor-intensive; that is, it requires more labor per unit of capital to produce shoes than computers, so that $L_S/K_S > L_C/K_C$.

Another way to state this assumption is to say that computer production is capital-intensive; that is, more capital per worker is used to produce computers than to produce shoes, so that $K_C/L_C > K_S/L_S$. The idea that shoes use more labor per unit of capital, and computers use more capital per worker, matches how most of us think about the technologies used in these two industries.

In Figure 4-1, the demands for labor relative to capital in each industry (L_C/K_C and L_S/K_S) are graphed against the wage relative to the rental on capital, W/R (or the wage-rental ratio). These two curves slope down just like regular demand curves: as W/R rises, the quantity of labor demanded relative to the quantity of capital demanded falls. As we work through the HO model, remember that these are *relative* demand curves for labor; the "quantity" on the horizontal axis is the ratio of labor to capital used in production, and the "price" is the ratio of the labor wage to the capital rental. Assumption 2 says that the relative demand curve in shoes, L_S/K_S in Figure 4-1, lies to the right of the relative demand curve in computers L_C/K_C, because shoe production is more labor-intensive.

Whereas the preceding assumptions have focused on the production process within each country, the HO model requires assumptions that apply across countries as well. Our next assumption is that the amounts of labor and capital found in Home and Foreign are different:

FIGURE 4-1



Labor Intensity of Each Industry The demand for labor relative to capital is assumed to be higher in shoes than in computers, $L_S/K_S > L_C/K_C$. These two curves slope down just like regular demand curves, but in this case, they are *relative* demand curves for labor (i.e., demand for labor divided by demand for capital).

Assumption 3: Foreign is labor-abundant, by which we mean that the labor–capital ratio in Foreign exceeds that in Home, $\overline{L}^*/\overline{K}^* > \overline{L}/\overline{K}$. Equivalently, Home is capital-abundant, so that $\overline{K}/\overline{L} > \overline{K}^*/\overline{L}^*$.

There are many reasons for labor, capital, and other resources to differ across countries: countries differ in their geographic size and populations, previous waves of immigration or emigration may have changed a country's population, countries are at different stages of development and so have differing amounts of capital, and so on. If we are considering land in the HO model, Home and Foreign will have different amounts of usable land due to the shape of their borders and to differences in topography and climate. In building the HO model, we do not consider why the amounts of labor, capital, or land differ across countries but simply accept these differences as important determinants of why countries engage in international trade.

Assumption 3 focuses on a particular case, in which Foreign is labor-abundant and Home is capital-abundant. This assumption is true, for example, if Foreign has a larger workforce than Home ($\overline{L}^* > \overline{L}$) and Foreign and Home have equal amounts of capital, $\overline{K}^* = \overline{K}$. Under these circumstances, $\overline{L}^*/\overline{K}^* > \overline{L}/\overline{K}$, so Foreign is labor-abundant. Conversely, the capital–labor ratio in Home exceeds that in Foreign, $\overline{K}/\overline{L} > \overline{K}^*/\overline{L}^*$, so the Home country is capital-abundant.

Assumption 4: The final outputs, shoes and computers, can be traded freely (i.e., without any restrictions) between nations, but labor and capital do not move between countries.

In this chapter, we do not allow labor or capital to move between countries. We relax this assumption in the next chapter, in which we investigate the movement of labor between countries through immigration as well as the movement of capital between countries through foreign direct investment.

Our final two assumptions involve the technologies of firms and tastes of consumers across countries:

Assumption 5: The technologies used to produce the two goods are identical across the countries.

This assumption is the opposite of that made in the Ricardian model (Chapter 2), which assumes that technological differences across countries are the reason for trade. It is not realistic to assume that technologies are the same across countries because often the technologies used in rich versus poor countries are quite different (as described in the following application). Although assumption 5 is not very realistic, it allows us to focus on a single reason for trade: the different amounts of labor and capital found in each country. Later in this chapter, we use data to test the validity of the HO model and find that the model performs better when assumption 5 is not used.

Our final assumption is as follows:

Assumption 6: Consumer tastes are the same across countries, and preferences for computers and shoes do not vary with a country's level of income.

That is, we suppose that a poorer country will buy fewer shoes and computers, but will buy them in the same ratio as a wealthier country facing the same prices. Again, this assumption is not very realistic: consumers in poor countries do spend more of their income on shoes, clothing, and other basic goods than on computers, whereas in rich countries a higher share of income can be spent on computers and other electronic goods than on footwear and clothing. Assumption 6 is another simplifying assumption that again allows us to focus attention on the differences in resources as the sole reason for trade.

APPLICATION

Are Factor Intensities the Same Across Countries?

One of our assumptions for the Heckscher-Ohlin (HO) model is that the same good (shoes) is labor-intensive in both countries. Specifically, we assume that in both countries, shoe production has a higher labor–capital ratio than does computer production. Although it might seem obvious that this assumption holds for shoes and computers, it is not so obvious when comparing other products, say, shoes and call centers.

In principle, all countries have access to the same technologies for making footwear. In practice, however, the machines used in the United States are different from those used in Asia and elsewhere. While much of the footwear in the world is produced in developing nations, the United States retains a small number of shoe factories. New Balance, which manufactures sneakers, has five plants in the New England states, and 25% of the shoes it sells in North America are produced in the United States. One of their plants is in Norridgewock, Maine, where employees operate computerized equipment that allows one person to do the work of six.[1] This is a far cry from the plants in Asia that produce shoes for Nike, Reebok, and

AP Photo/Robert F. Bukaty

Despite its nineteenth-century exterior, this New Balance factory in Maine houses advanced shoe-manufacturing technology.

[1] This description of the New Balance plant is drawn from Aaron Bernstein, "Low-Skilled Jobs: Do They Have to Move?" *BusinessWeek*, February 26, 2001, 94–95.

other U.S. producers. Because Asian plants use older technology (such as individual sewing machines), they use more workers to operate less productive machines.

In call centers, on the other hand, technologies (and, therefore, factor intensities) are similar across countries. Each employee works with a telephone and a personal computer, so call centers in the United States and India are similar in terms of the amount of capital per worker that they require. The telephone and personal computer, costing several thousand dollars, are much less expensive than the automated manufacturing machines in the New Balance plant in the United States, which cost tens or hundreds of thousands of dollars. So the manufacture of footwear in the New Balance plant is capital-intensive as compared with a U.S. call center. In India, by contrast, the sewing machine used to produce footwear is cheaper than the computer used in the call center. So footwear production in India is labor-intensive as compared with the call center, which is the opposite of what holds in the United States. This example illustrates a **reversal of factor intensities** between the two countries.

The same reversal of factor intensities is seen when we compare the agricultural sector across countries. In the United States, agriculture is capital-intensive. Each farmer works with tens of thousands of dollars in mechanized, computerized equipment, allowing a farm to be maintained by only a handful of workers. In many developing countries, however, agriculture is labor-intensive. Farms are worked by many laborers with little or no mechanized equipment. The reason that this labor-intensive technology is used in agriculture in developing nations is that capital equipment is expensive relative to the wages earned.

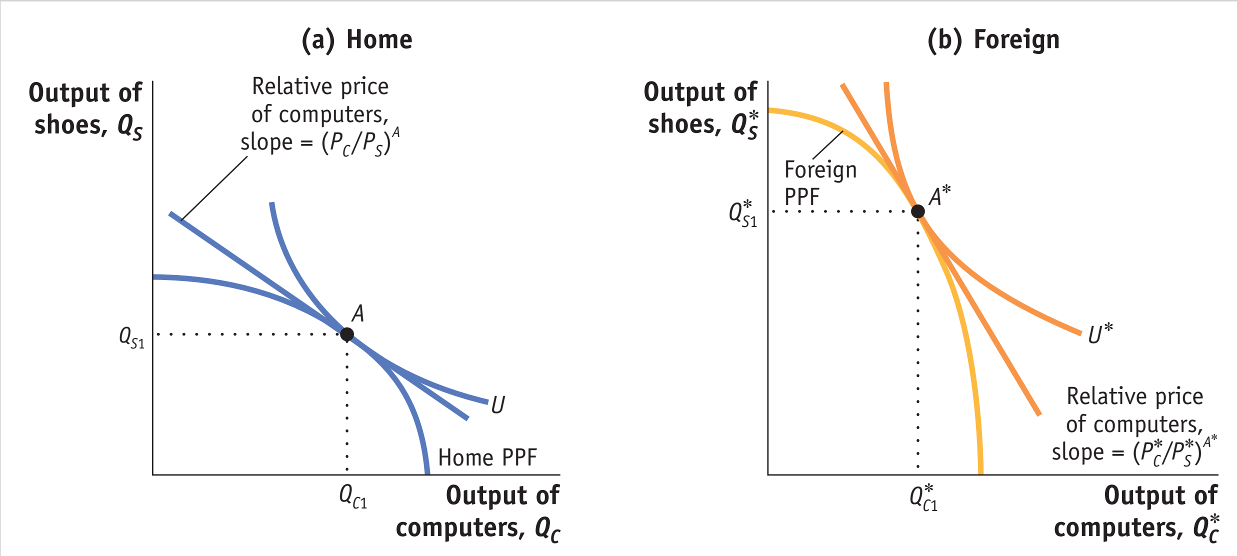
In assumption 2 and Figure 4-1, we assume that the labor–capital ratio (L/K) of one industry exceeds that of the other industry *regardless of the wage-rental ratio* (W/R). That is, whether labor is cheap (as in a developing country) or expensive (as in the United States), we are assuming that the same industry (shoes, in our example) is labor-intensive in both countries. This assumption may not be true for footwear or for agriculture, as we have just seen. In our treatment of the HO model, we ignore the possibility of factor intensity reversals. The reason for ignoring these is to get a definite prediction from the model about the pattern of trade between countries so that we can see what happens to the price of goods and the earnings of factors when countries trade with one another. ■

No-Trade Equilibrium

In assumption 3, we outlined the difference in the amount of labor and capital found at Home and in Foreign. Our goal is to use these differences in resources to predict the pattern of trade. To do this, we begin by studying the equilibrium in each country in the absence of trade.

Production Possibilities Frontiers To determine the no-trade equilibria in Home and Foreign, we start by drawing the production possibilities frontiers (PPFs) in each country as shown in Figure 4-2. Under our assumptions that Home is capital-abundant and that computer production is capital-intensive, Home is capable of producing more computers than shoes. The Home PPF drawn in panel (a) is skewed in the direction of computers to reflect Home's greater capability to produce computers. Similarly, because Foreign is labor-abundant and shoe production is labor-intensive, the Foreign PPF shown in panel (b) is skewed in the direction of shoes, reflecting Foreign's greater capability to produce shoes. These particular shapes for the PPFs are reasonable given the assumptions we have made. When we continue our study of the Heckscher-Ohlin (HO) model in Chapter 5, we prove that the PPFs must take

FIGURE 4-2



No-Trade Equilibria in Home and Foreign The Home production possibilities frontier (PPF) is shown in panel (a), and the Foreign PPF is shown in panel (b). Because Home is capital-abundant and computers are capital-intensive, the Home PPF is skewed toward computers. Home preferences are summarized by the indifference curve, *U*, and the Home no-trade (or autarky) equilibrium is at point *A*, with a low relative price of computers, as indicated by the flat slope of $(P_C/P_S)^A$. Foreign is labor-abundant and shoes are labor-intensive, so the Foreign PPF is skewed toward shoes. Foreign preferences are summarized by the indifference curve, U^*, and the Foreign no-trade equilibrium is at point A^*, with a higher relative price of computers, as indicated by the steeper slope of $(P^*_C/P^*_S)^{A*}$.

this shape.[2] For now, we accept these shapes of the PPF and use them as the starting point for our study of the HO model.

Indifference Curves Another assumption of the HO model (assumption 6) is that consumer tastes are the same across countries. As we did in the Ricardian model, we graph consumer tastes using indifference curves. Two of these curves are shown in Figure 4-2 (U and U^* for Home and Foreign, respectively); one is tangent to Home's PPF, and the other is tangent to Foreign's PPF. Notice that these indifference curves are the same shape in both countries, as required by assumption 6. They are tangent to the PPFs at different points because of the distinct shapes of the PPFs just described.

The slope of an indifference curve equals the amount that consumers are willing to pay for computers measured in terms of shoes rather than dollars. The slope of the PPF equals the opportunity cost of producing one more computer in terms of shoes given up. When the slope of an indifference curve equals the slope of a PPF, the relative price that consumers are willing to pay for computers equals the opportunity cost of producing them, so this point is the no-trade equilibrium.[3] The common slope of the indifference curve and PPF at their tangency equals the relative price of computers P_C/P_S. A steeply sloped price line implies a high relative price of computers, whereas a flat price line implies a low relative price for computers.

[2] See Problem 7 in Chapter 5.
[3] Remember that the slope of an indifference curve or PPF reflects the relative price of the good on the *horizontal* axis, which is computers in Figure 4-2.

No-Trade Equilibrium Price Given the differently shaped PPFs, the indifference curves of each country will be tangent to the PPFs at different production points, corresponding to different relative price lines across the two countries. In Home, the no-trade or autarky equilibrium is shown by point A, at which Home produces Q_{C1} of computers and Q_{S1} of shoes at the relative price of $(P_C/P_S)^A$. Because the Home PPF is skewed toward computers, the slope of the Home price line $(P_C/P_S)^A$ is quite flat, indicating a low relative price of computers. In Foreign, the no-trade or autarky equilibrium is shown by point A^* at which Foreign produces Q^*_{C1} of computers and Q^*_{S1} of shoes at the relative price of $(P^*_C/P^*_S)^{A^*}$. Because the Foreign PPF is skewed toward shoes, the slope of the Foreign price line $(P^*_C/P^*_S)^{A^*}$ is quite steep, indicating a high relative price of computers. Therefore, the result from comparing the no-trade equilibria in Figure 4-2 is that the *no-trade relative price of computers at Home is lower than in Foreign*. (Equivalently, we can say that the no-trade relative price of shoes at Home is higher than in Foreign.)

These comparisons of the no-trade prices reflect the differing amounts of labor found in the two countries: the Foreign country has abundant labor, and shoe production is labor-intensive, so the no-trade relative price of shoes is lower in Foreign than in Home. That Foreigners are willing to give up more shoes for one computer reflects the fact that Foreign resources are suited to making more shoes. The same logic applies to Home, which is relatively abundant in capital. Because computer production is capital-intensive, Home has a lower no-trade relative price of computers than Foreign. Thus, Home residents need to give up fewer shoes to obtain one computer, reflecting the fact that their resources are suited to making more computers.

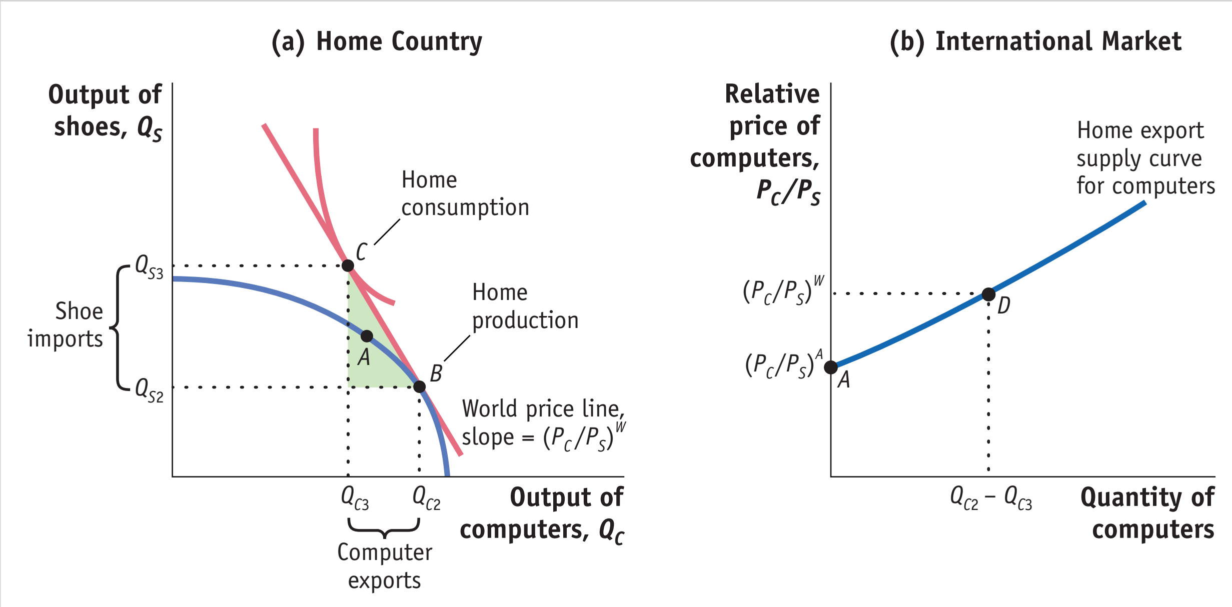
Free-Trade Equilibrium

We are now in a position to determine the pattern of trade between the countries. To do so, we proceed in several steps. First, we consider what happens when the world relative price of computers is above the no-trade relative price of computers at Home, and trace out the Home export supply of computers. Second, we consider what happens when the world relative price is *below* the no-trade relative price of computers in Foreign, and trace out the Foreign import demand for computers. Finally, we put together the Home export supply and Foreign import demand to determine the equilibrium relative price of computers with international trade.

Home Equilibrium with Free Trade The first step is displayed in Figure 4-3. We have already seen in Figure 4-2 that the no-trade relative price of computers is lower in Home than in Foreign. Under free trade, we expect the equilibrium relative price of computers to lie between the no-trade relative prices in each country (as we already found in the Ricardian model of Chapter 2). Because the no-trade relative price of computers is lower at Home, the free-trade equilibrium price will be above the no-trade price at Home. Therefore, panel (a) of Figure 4-3 shows the Home PPF with a free-trade or world relative price of computers, $(P_C/P_S)^W$, higher than the no-trade Home relative price, $(P_C/P_S)^A$, shown in panel (a) of Figure 4-2.

The no-trade equilibrium at Home, point A, has the quantities (Q_{C1}, Q_{S1}) for computers and shoes, shown in Figure 4-2. At the higher world relative price of computers, Home production moves from point A, (Q_{C1}, Q_{S1}), to point B in Figure 4-3, (Q_{C2}, Q_{S2}), with more computers and fewer shoes. Thus, with free trade, Home produces fewer shoes and specializes further in computers to take advantage of higher world relative prices of computers. Because Home can now engage in trade at the world relative price,

FIGURE 4-3



International Free-Trade Equilibrium at Home At the free-trade world relative price of computers, $(P_C/P_S)^W$, Home produces at point *B* in panel (a) and consumes at point *C*, exporting computers and importing shoes. (Point *A* is the no-trade equilibrium.) The "trade triangle" has a base equal to the Home exports of computers (the difference between the amount produced and the amount consumed with trade, $Q_{C2} - Q_{C3}$). The height of this triangle is the Home imports of shoes (the difference between the amount consumed of shoes and the amount produced with trade, $Q_{S3} - Q_{S2}$). In panel (b), we show Home exports of computers equal to zero at the no-trade relative price, $(P_C/P_S)^A$, and equal to $(Q_{C2} - Q_{C3})$ at the free-trade relative price, $(P_C/P_S)^W$.

Home's consumption can now lie on any point along the world price line through *B* with slope $(P_C/P_S)^W$. The highest Home utility is obtained at point *C*, which is tangent to the world price line $(P_C/P_S)^W$ and has the quantities consumed (Q_{C3}, Q_{S3}).

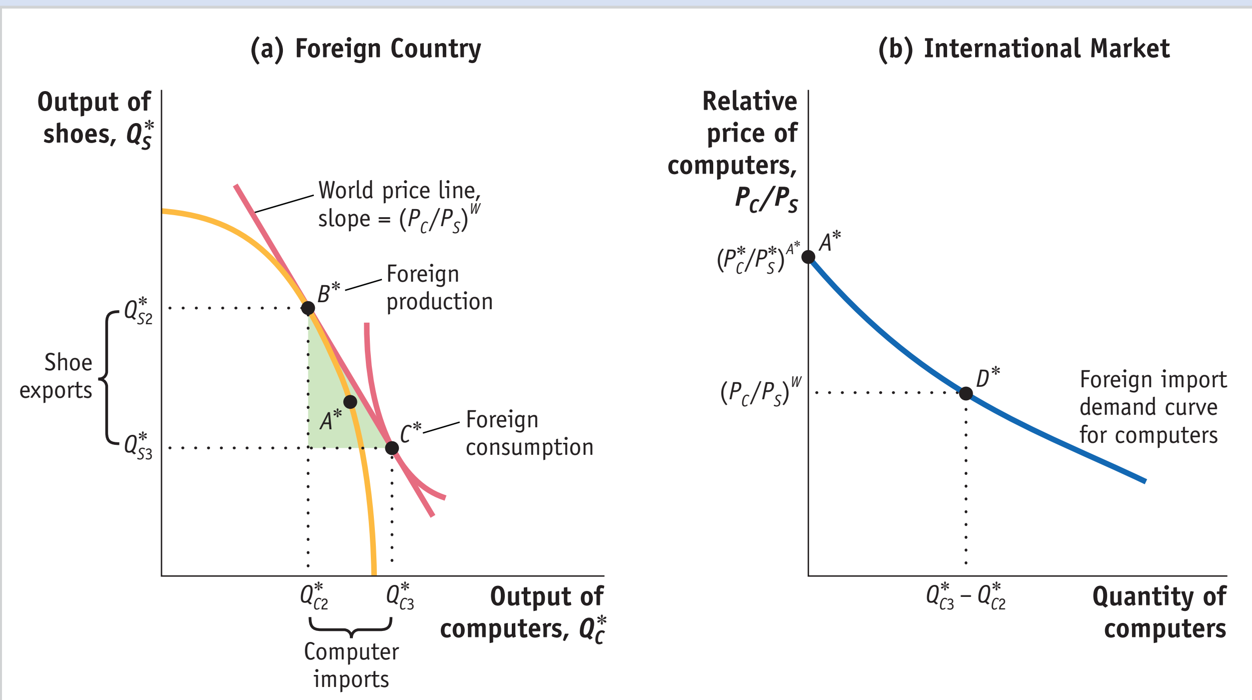
We can now define the Home "trade triangle," which is the triangle connecting points *B* and *C*, shown in panel (a) of Figure 4-3. Point *B* is where Home is producing and point *C* is where it is consuming, and the line connecting the two points represents the amount of trade at the world relative price. The base of this triangle is the Home exports of computers (the difference between the amount produced and the amount consumed with trade, or $Q_{C2} - Q_{C3}$). The height of this triangle is the Home imports of shoes (the difference between the amount consumed of shoes and the amount produced with trade, or $Q_{S3} - Q_{S2}$).

In panel (b) of Figure 4-3, we graph the Home exports of computers against their relative price. In the no-trade equilibrium, the Home relative price of computers was $(P_C/P_S)^A$, and exports of computers were zero. This no-trade equilibrium is shown by point *A* in panel (b). Under free trade, the relative price of computers is $(P_C/P_S)^W$, and exports of computers are the difference between the amount produced and amount consumed with trade, or $(Q_{C2} - Q_{C3})$. This free-trade equilibrium is shown by point *D* in panel (b). Joining up points *A* and *D*, we obtain the Home export supply curve of computers. It is upward-sloping because at higher relative prices as compared with the no-trade price, Home is willing to specialize further in computers to export more of them.

Foreign Equilibrium with Free Trade We proceed in a similar fashion for the Foreign country. In panel (a) of Figure 4-4, the Foreign no-trade equilibrium is at point A^*, with the high equilibrium relative price of computers $(P^*_C/P^*_S)^{A^*}$. Because the Foreign no-trade relative price was higher than at Home, and we expect the free-trade relative price to lie between, it follows that the free-trade or world equilibrium price of computers $(P_C/P_S)^W$ is lower than the no-trade Foreign price $(P^*_C/P^*_S)^{A^*}$.

At the world relative price, Foreign production moves from point A^*, (Q^*_{C1}, Q^*_{S1}), to point B^*, (Q^*_{C2}, Q^*_{S2}), with more shoes and fewer computers. Thus, with free trade, Foreign specializes further in shoes and produces fewer computers. Because Foreign can now engage in trade at the world relative price, Foreign's consumption can now lie on any point along the world price line through B^* with slope $(P_C/P_S)^W$. The highest Foreign utility is obtained at point C^*, which is tangent to the world price line $(P_C/P_S)^W$ and has the quantities consumed (Q^*_{C3}, Q^*_{S3}). Once again, we can connect points B^* and C^* to form a "trade triangle." The base of this triangle is Foreign imports of computers (the difference between consumption of computers and production with trade, or $Q^*_{C3} - Q^*_{C2}$), and the height is Foreign exports of shoes (the difference between production and consumption with trade, or $Q^*_{S2} - Q^*_{S3}$).

FIGURE 4-4



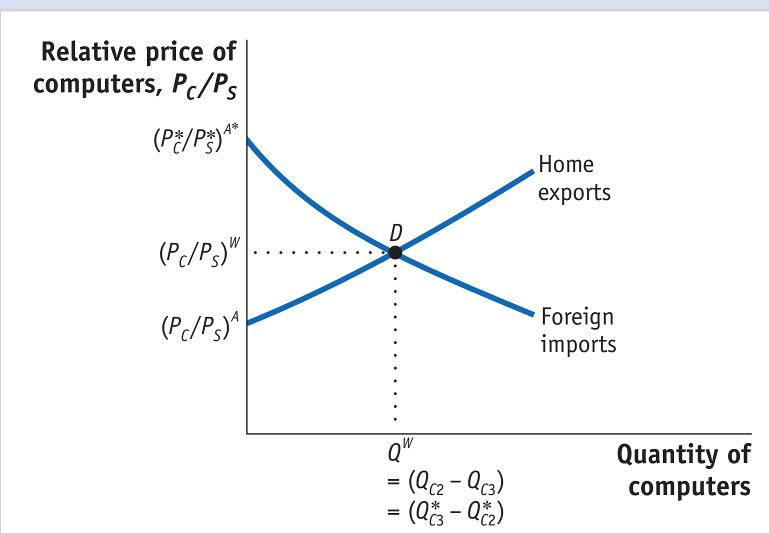
International Free-Trade Equilibrium in Foreign At the free-trade world relative price of computers, $(P_C/P_S)^W$, Foreign produces at point B^* in panel (a) and consumes at point C^*, importing computers and exporting shoes. (Point A^* is the no-trade equilibrium.) The "trade triangle" has a base equal to Foreign imports of computers (the difference between the consumption of computers and the amount produced with trade, $Q^*_{C3} - Q^*_{C2}$). The height of this triangle is Foreign exports of shoes (the difference between the production of shoes and the amount consumed with trade, $Q^*_{S2} - Q^*_{S3}$). In panel (b), we show Foreign imports of computers equal to zero at the no-trade relative price, $(P^*_C/P^*_S)^{A^*}$, and equal to $(Q^*_{C3} - Q^*_{C2})$ at the free-trade relative price, $(P_C/P_S)^W$.

In panel (b) of Figure 4-4, we graph Foreign's imports of computers against its relative price. In the no-trade equilibrium, the Foreign relative price of computers was $(P_C^*/P_S^*)^{A*}$, and imports of computers were zero. This no-trade equilibrium is shown by the point A^* in panel (b). Under free trade, the relative price of computers is $(P_C/P_S)^W$, and imports of computers are the difference between the amount produced and amount consumed with trade, or $(Q_{C3}^* - Q_{C2}^*)$. This free-trade equilibrium is shown by the point D^* in panel (b). Joining up points A^* and D^*, we obtain the Foreign import demand curve for computers. It is downward-sloping because at lower relative prices as compared with no-trade, Foreign specializes more in shoes and exports these in exchange for computers.

Equilibrium Price with Free Trade As we see in Figure 4-5, the equilibrium relative price of computers with free trade is determined by the intersection of the Home export supply and Foreign import demand curves, at point *D* (the same as point *D* in Figure 4-3 or D^* in Figure 4-4). At that relative price, the quantity of computers that the Home country wants to export equals the quantity of computers that Foreign wants to import; that is, $(Q_{C2} - Q_{C3}) = (Q_{C3}^* - Q_{C2}^*)$. Because exports equal imports, there is no reason for the relative price to change and so this is a **free-trade equilibrium.** Another way to see the equilibrium graphically is to notice that in panel (a) of Figures 4-3 and 4-4, the trade triangles of the two countries are identical in size—the quantity of computers one country wants to sell is the same as the quantity the other country wants to buy.

Pattern of Trade Using the free-trade equilibrium, we have determined the pattern of trade between the two countries. Home exports computers, the good that uses intensively the factor of production (capital) found in abundance at Home. Foreign exports shoes, the good that uses intensively the factor of production (labor) found in abundance there. This important result is called the **Heckscher-Ohlin theorem.**

FIGURE 4-5



Determination of the Free-Trade World Equilibrium Price The world relative price of computers in the free-trade equilibrium is determined at the intersection of the Home export supply and Foreign import demand, at point *D*. At this relative price, the quantity of computers that Home wants to export, $(Q_{C2} - Q_{C3})$, just equals the quantity of computers that Foreign wants to import, $(Q_{C3}^* - Q_{C2}^*)$.

Heckscher-Ohlin Theorem: With two goods and two factors, each country will export the good that uses intensively the factor of production it has in abundance and will import the other good.

It is useful to review the assumptions we made at the beginning of the chapter to see how they lead to the Heckscher-Ohlin theorem.

Assumption 1: Labor and capital flow freely between the industries.
Assumption 2: The production of shoes is labor-intensive as compared with computer production, which is capital-intensive.
Assumption 3: The amounts of labor and capital found in the two countries differ, with Foreign abundant in labor and Home abundant in capital.
Assumption 4: There is free international trade in goods.
Assumption 5: The technologies for producing shoes and computers are the same across countries.
Assumption 6: Tastes are the same across countries.

Assumptions 1 to 3 allowed us to draw the PPFs of the two countries as illustrated in Figure 4-2, and in conjunction with assumptions 5 and 6, they allowed us to determine that the no-trade relative price of computers in Home was lower than the no-trade relative price of computers in Foreign; that is, $(P_C/P_S)^A$ was less than $(P_C^*/P_S^*)^{A^*}$. This key result enabled us to determine the starting points for the Home export supply curve for computers (point A) and the Foreign import demand curve for computers (point A^*) in panel (b) of Figures 4-3 and 4-4. Using those starting points, we put together the upward-sloping Home export supply curve and downward-sloping Foreign import demand curve. We see from Figure 4-5 that the relative price of computers in the free-trade equilibrium lies between the no-trade relative prices (which confirms the expectation we had when drawing Figures 4-3 and 4-4).

Therefore, when Home opens to trade, its relative price of computers rises from the no-trade equilibrium relative price $(P_C/P_S)^A$, to the free-trade equilibrium price $(P_C/P_S)^W$, giving Home firms an incentive to export computers. That is, higher prices give Home an incentive to produce more computers than it wants to consume, and export the difference. Similarly, when Foreign opens to trade, its relative price of computers falls from the no-trade equilibrium price $(P_C^*/P_S^*)^{A^*}$, to the trade equilibrium price $(P_C/P_S)^W$, encouraging Foreign consumers to import computers from Home. That is, lower prices give Foreign an incentive to consume more computers than it wants to produce, importing the difference.

You might think that the Heckscher-Ohlin theorem is somewhat obvious. It makes sense that countries will export goods that are produced easily because the factors of production are found in abundance. It turns out, however, that this prediction does not always work in practice, as we discuss in the next section.

2 Testing the Heckscher-Ohlin Model

The first test of the Heckscher-Ohlin theorem was performed by economist Wassily Leontief in 1953, using data for the United States from 1947. We will describe his test below and show that he reached a surprising conclusion, which is called **Leontief's paradox.** After that, we will discuss more recent data for many countries that can be used to test the Heckscher-Ohlin model.

Leontief's Paradox

To test the Heckscher-Ohlin theorem, Leontief measured the amounts of labor and capital used in all industries needed to produce $1 million of U.S. exports and to produce $1 million of imports into the United States. His results are shown in Table 4-1.

TABLE 4-1

Leontief's Test Leontief used the numbers in this table to test the Heckscher-Ohlin theorem. Each column shows the amount of capital or labor needed to produce $1 million worth of exports from, or imports into, the United States in 1947. As shown in the last row, the capital–labor ratio for exports was less than the capital–labor ratio for imports, which is a paradoxical finding.

	Exports	Imports
Capital ($ millions)	2.55	3.1
Labor (person-years)	182	170
Capital/labor ($/person)	14,000	18,200

Source: Wassily Leontief, 1953, "Domestic Production and Foreign Trade: The American Capital Position Re-examined," Proceedings of the American Philosophical Society, 97, *September, 332–349. Reprinted in Richard Caves and Harry G. Johnson, eds., 1968,* Readings in International Economics *(Homewood, IL: Irwin).*

Leontief first measured the amount of capital and labor required in the production of $1 million worth of U.S. exports. To arrive at these figures, Leontief measured the labor and capital used *directly* in the production of final good exports in each industry. He also measured the labor and capital used *indirectly* in the industries that produced the intermediate inputs used in making the exports. From the first row of Table 4-1, we see that $2.55 million worth of capital was used to produce $1 million of exports. This amount of capital seems much too high, until we recognize that what is being measured is the total stock, which exceeds that part of the capital stock that was actually used to produce exports that year: the capital used that year would be measured by the depreciation on this stock. For labor, 182 person-years were used to produce the exports. Taking the ratio of these, we find that each person employed (directly or indirectly) in producing exports was working with $14,000 worth of capital.

Turning to the import side of the calculation, Leontief immediately ran into a problem—he could not measure the amount of labor and capital used to produce imports because he didn't have data on foreign technologies. To get around this difficulty, Leontief did what many researchers have done since—he simply used the data on U.S. technology to calculate estimated amounts of labor and capital used in imports from abroad. Does this approach invalidate Leontief's test of the Heckscher-Ohlin model? Not really, because the Heckscher-Ohlin model assumes that technologies are the same across countries, so Leontief is building this assumption into the calculations needed to test the theorem.

Using U.S. technology to measure the labor and capital used directly and indirectly in producing imports, Leontief arrived at the estimates in the last column of Table 4-1: $3.1 million of capital and 170 person-years were used in the production of $1 million worth of U.S. imports, so the capital–labor ratio for imports was $18,200 per worker. Notice that this amount *exceeds* the capital–labor ratio for exports of $14,000 per worker.

Leontief supposed correctly that in 1947 the United States was abundant in capital relative to the rest of the world. Thus, from the Heckscher-Ohlin theorem, Leontief expected that the United States would export capital-intensive goods and import labor-intensive goods. What Leontief actually found, however, was just the opposite: the capital–labor ratio for U.S. imports was *higher* than the capital–labor ratio found for U.S. exports! This finding contradicted the Heckscher-Ohlin theorem and came to be called Leontief's paradox.

Explanations A wide range of explanations has been offered for Leontief's paradox, including the following:

- U.S. and foreign technologies are not the same, in contrast to what the Heckscher-Ohlin theorem and Leontief assumed.

- By focusing only on labor and capital, Leontief ignored land abundance in the United States.
- Leontief should have distinguished between high-skilled and low-skilled labor (because it would not be surprising to find that U.S. exports are intensive in high-skilled labor).
- The data for 1947 may be unusual because World War II had ended just two years earlier.
- The United States was not engaged in completely free trade, as the Heckscher-Ohlin theorem assumes.

Several of the additional possible explanations for the Leontief paradox depend on having more than two factors of production. The United States is abundant in land, for example, and that might explain why in 1947 it was exporting labor-intensive products: these might have been agricultural products, which use land intensively and, in 1947, might also have used labor intensively. By ignoring land, Leontief was therefore not performing an accurate test of the Heckscher-Ohlin theorem. Alternatively, it might be that the United States was mainly exporting goods that used skilled labor. This is certainly true today, with the United States being a leading exporter of high-technology products, and was probably also true in 1947. By not distinguishing between high-skilled versus low-skilled labor, Leontief was again giving an inaccurate picture of the factors of production used in U.S. trade.

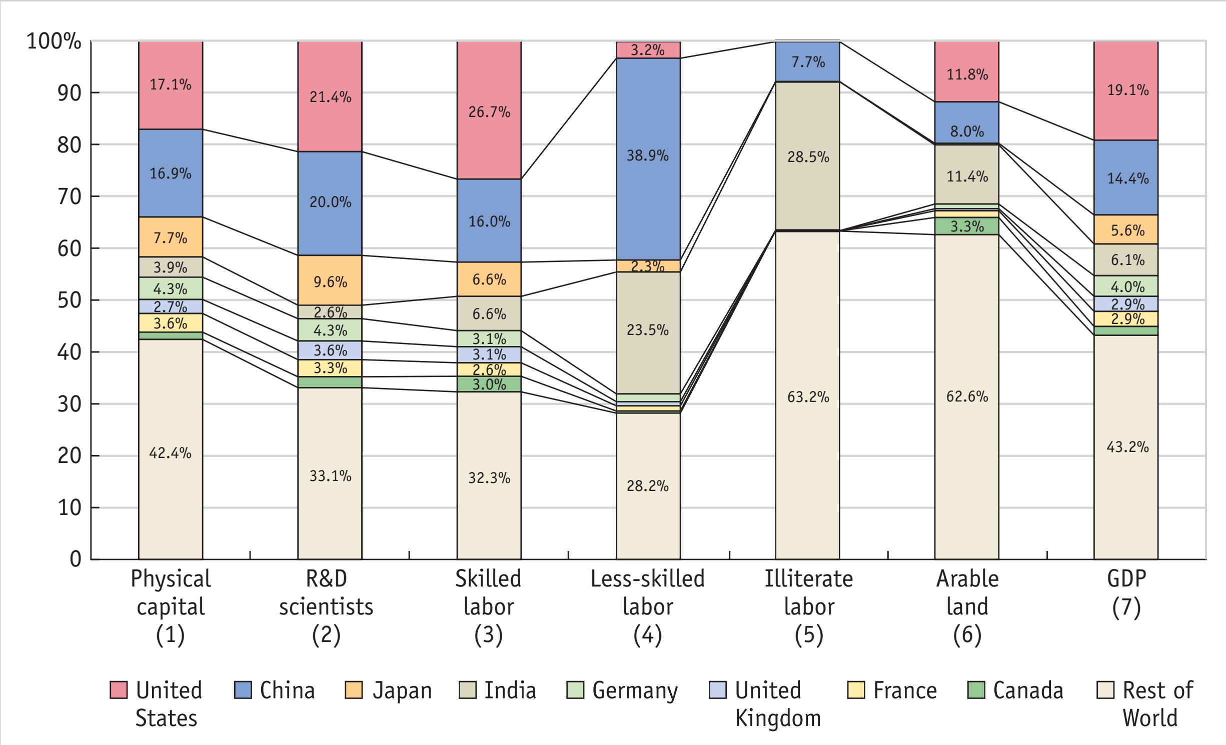
Research in later years aimed to redo the test that Leontief performed, while taking into account land, high-skilled versus low-skilled labor, checking whether the Heckscher-Ohlin theorem holds in other years, and so on. We now discuss the data that can be used to test the Heckscher-Ohlin theorem in a more recent year—2010.

Factor Endowments in 2010

In Figure 4-6, we show the country shares of six factors of production and world GDP in 2010, broken down by select countries (the United States, China, Japan, India, Germany, the United Kingdom, France, and Canada) and then the rest of the world. To determine whether a country is abundant in a certain factor, we compare the country's share of that factor with its share of world GDP. If its share of a factor exceeds its share of world GDP, then we conclude that the country is **abundant in that factor,** and if its share in a certain factor is less than its share of world GDP, then we conclude that the country is **scarce in that factor.** This definition allows us to calculate factor abundance in a setting with as many factors and countries as we want.

Capital Abundance For example, in the first bar graph of Figure 4-6, we see that in 2010, 17.1% of the world's physical capital was located in the United States, with 16.9% located in China, 7.7% in Japan, 3.9% in India, 4.3% in Germany, and so on. When we compare these numbers with the final bar in the graph, which shows each country's percentage of world GDP, we see that in 2010 the United States had 19.1% of world GDP, China had 14.4%, Japan 5.6%, India 6.1%, Germany 4.0%, and so on. Because the United States had 17.1% of the world's capital and 19.1% of world GDP, we can conclude that the United States was scarce in physical capital in 2010. China, on the other hand, is abundant in physical capital: it has 16.9% of the world's capital and produces 14.4% of the world's GDP. Indeed, it is the rapid accumulation

FIGURE 4-6



Country Factor Endowments, 2010 Shown here are country shares of six factors of production in the year 2010, for eight selected countries and the rest of the world. In the first bar graph, we see that 17.1% of the world's physical capital in 2010 was located in the United States, with 16.9% located in China, 7.7% located in Japan, and so on. In the final bar graph, we see that in 2010 the United States had 19.1% of world GDP, China had 14.4%, Japan had 5.6%, and so on. When a country's factor share is larger than its share of GDP, then the country is abundant in that factor, and when a country's factor share is less than its share of GDP, then the country is scarce in that factor.

Notes:
(1) From PWT (Penn World Trade) version 8.0 (University of Groningen and University of California, Davis).
(2) The product of R&D researchers per million and total population (World Bank, World Development Indicators).
(3) Labor force with tertiary education (World Bank, World Development Indicators).
(4) Labor force with primary and/or secondary education (World Bank, World Development Indicators).
(5) The product of one minus the adult literacy rate and the adult population (World Bank, World Development Indicators).
(6) Hectares of arable land (World Bank, World Development Indicators).
(7) Gross domestic product converted to 2010 dollars using purchasing power parity rates (PWT version 8.0, University of Groningen and University of California, Davis).

of capital in China during the past decade that has now made the United States relatively scarce in this factor (because as China accumulates more capital, the U.S. share of the world's capital falls).[4] Japan had 7.7% of the world's capital and 5.6% of world GDP in 2010, so it was also abundant in capital, as was Germany (with 4.3% of the world's capital and 4.0% of world GDP). The opposite holds for India, and the group of countries included in the rest of the world: their shares of world capital were less than their shares of GDP, so they were scarce in capital.

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[4] In 2000, China had a much smaller share of the world's physical capital—just 8.7% as compared with 16.9% in 2010. So China's share nearly doubled, while the U.S. share fell from 24.0% to 17.1%.

Labor and Land Abundance We can use a similar comparison to determine whether each country is abundant in R&D scientists, in types of labor distinguished by skill, in arable land, or any other factor of production. For example, the United States was abundant in R&D scientists in 2010 (with 21.4% of the world's total as compared with 19.1% of the world's GDP) and also skilled labor (workers with more than a high school education) but was scarce in less-skilled labor (workers with a high school education or less) and illiterate labor. India was scarce in R&D scientists (with 2.6% of the world's total as compared with 6.1% of the world's GDP) but abundant in skilled labor, semiskilled labor, and illiterate labor (with shares of the world's total that exceed its GDP share). Canada was abundant in arable land (with 3.3% of the world's total as compared with 1.7% of the world's GDP), as we would expect. But the United States was scarce in arable land (11.8% of the world's total as compared with 19.1% of the world's GDP). That is a surprising result because we often think of the United States as a major exporter of agricultural commodities, so from the Heckscher-Ohlin theorem, we would expect it to be land-abundant.

Another surprising result in Figure 4-6 is that China was abundant in R&D scientists: it had 20.0% of the world's R&D scientists, as compared with 14.4% of the world's GDP in 2010. This finding also seems to contradict the Heckscher-Ohlin theorem, because we think of China as exporting greater quantities of basic manufactured goods, not research-intensive manufactured goods. These observations regarding R&D scientists (a factor in which both the United States and China were abundant) and land (in which the United States was scarce) can cause us to question whether an R&D scientist or an acre of arable land has the same productivity in all countries. If not, then our measures of factor abundance are misleading: if an R&D scientist in the United States is more productive than his or her counterpart in China, then it does not make sense to just compare each country's share of these with each country's share of GDP; and likewise, if an acre of arable land is more productive in the United States than in other countries, then we should not compare the share of land in each country with each country's share of GDP. Instead, we need to make some adjustment for the differing productivities of R&D scientists and land across countries. In other words, we need to abandon the original Heckscher-Ohlin assumption of identical technologies across countries.

Differing Productivities Across Countries

Leontief himself suggested that we should abandon the assumption that technologies are the same across countries and instead allow for differing productivities, as in the Ricardian model. Remember that in the original formulation of the paradox, Leontief had found that the United States was exporting labor-intensive products even though it was capital-abundant at that time. One explanation for this outcome would be that labor is highly productive in the United States and less productive in the rest of the world. If that is the case, then the **effective labor force** in the United States, the labor force times its productivity (which measures how much output the labor force can produce), is much larger than it appears to be when we just count people. If this is true, perhaps the United States is abundant in *skilled* labor after all (like R&D scientists), and it should be no surprise that it is exporting labor-intensive products.

We now explore how differing productivities can be introduced into the Heckscher-Ohlin model. In addition to allowing labor to have a differing productivity across countries, we can also allow capital, land, and other factors of production to have differing productivity across countries.

Measuring Factor Abundance Once Again To allow factors of production to differ in their productivities across countries, we define the **effective factor endowment** as the actual amount of a factor found in a country times its productivity:

Effective factor endowment = Actual factor endowment • Factor productivity

The amount of an effective factor found in the world is obtained by adding up the effective factor endowments across all countries. Then to determine whether a country is abundant in a certain factor, we compare the country's share of that *effective* factor with its share of world GDP. If its share of an effective factor exceeds its share of world GDP, then we conclude that the country is **abundant in that effective factor;** if its share of an effective factor is less than its share of world GDP, then we conclude that the country is **scarce in that effective factor.** We can illustrate this approach to measuring effective factor endowments using two examples: R&D scientists and arable land.

Effective R&D Scientists The productivity of an R&D scientist depends on the laboratory equipment, computers, and other types of material with which he or she has to work. R&D scientists working in different countries will not necessarily have the same productivities because the equipment they have available to them differs. A simple way to measure the equipment they have available is to use a country's *R&D spending per scientist*. If a country has more R&D spending per scientist, then its productivity will be higher, but if there is less R&D spending per scientist, then its productivity will be lower. To measure the effective number of R&D scientists in each country, we take the total number of scientists and multiply that by the R&D spending per scientist:

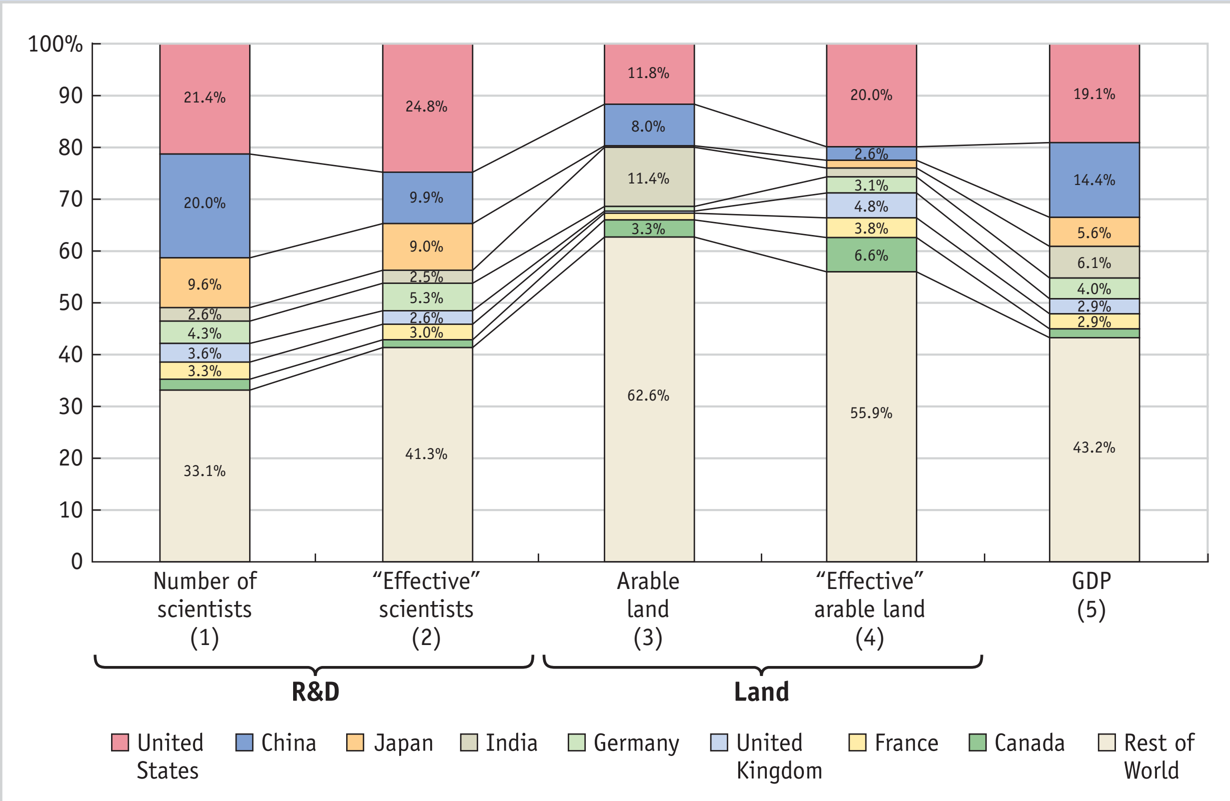
Effective R&D scientists = Actual R&D scientists • R&D spending per scientist

Using the R&D spending per scientist in this way to obtain effective R&D scientists is one method to correct for differences in the productivity of scientists across countries. It is not the only way to make such a correction because there are other measures that could be used for the productivity of scientists (e.g., we could use scientific publications available in a country, or the number of research universities). The advantage of using R&D spending per scientist is that this information is collected annually for many countries, so using this method to obtain a measure of effective R&D scientists means that we can easily compare the share of each country with the world total.[5] Those shares are shown in Figure 4-7.

In the first bar graph of Figure 4-7, we repeat from Figure 4-6 each country's share of world R&D scientists, not corrected for productivity differences. In the second bar graph, we show each country's share of effective scientists, using the R&D spending per scientist to correct for productivity. The United States had 21.4% of the world's total R&D scientists in 2010 (in the first bar) but 24.8% of the world's effective scientists (in the second bar). So the United States was more abundant in effective R&D

[5] Notice that by correcting the number of R&D scientists by the R&D spending per scientist, we end up with the total R&D spending in each country: Effective R&D scientists = Actual R&D scientists • R&D spending per scientist = Total R&D spending. So a country's share of effective R&D scientists equals its share of world R&D spending.

FIGURE 4-7



"Effective" Factor Endowments, 2010 Shown here are country shares of R&D scientists and land in 2010, using first the information from Figure 4-6, and then making an adjustment for the productivity of each factor across countries to obtain the "effective" shares. China was abundant in R&D scientists in 2010 (since it had 20.0% of the world's R&D scientists as compared with 14.4% of the world's GDP) but scarce in effective R&D scientists (because it had 9.9% of the world's effective R&D scientists as compared with 14.4% of the world's GDP). The United States was scarce in arable land when using the number of acres (since it had 11.8% of the world's land as compared with 19.1% of the world's GDP) but neither scarce nor abundant in effective land (since it had 20.0% of the world's effective land, which nearly equaled its share of the world's GDP).

Notes:
(1) The product of R&D researchers per million and total population (World Bank, World Development Indicators).
(2) R&D expenditure in units of purchasing power parity (World Bank, World Development Indicators, and PWT version 8.0, University of Groningen).
(3) Hectares of arable land (World Bank, World Development Indicators).
(4) Productivity adjustment based on agriculture TFP (Total Factor Productivity) estimation.
(5) Gross domestic product converted to 2010 dollars using purchasing power parity rates (PWT version 8.0, University of Groningen).

scientists in 2010 than it was in the number of scientists. Likewise, Germany had a greater share of effective scientists, 5.3%, as compared with its share of R&D scientists, which was 4.3%. But China's share of R&D scientists fell by half when correcting for productivity, from a 20.0% share in the number of R&D scientists to a 9.9% share in effective R&D scientists. Since China's share of world GDP was 14.4% in 2010, it became scarce in effective R&D scientists once we made this productivity correction.

China has increased its spending on R&D in recent years and now exceeds the level of R&D spending in Japan. It is also investing heavily in universities, many of which offer degrees in science and engineering. Even when compared with the United

States, China is taking the lead in some areas of R&D. An example is in research on "green" technologies, such as wind and solar power. We will discuss government subsidies in China for solar panels in a later chapter. As described in **Headlines: China Drawing High-Tech Research from U.S.,** the Silicon Valley firm Applied Materials has recently established a research laboratory in China and has many contracts to sell solar equipment there. Applied Materials was attracted to China by a combination of inexpensive land and skilled labor. For all these reasons, we should expect that China's share of effective R&D scientists will grow significantly in future years.

Effective Arable Land As we did for R&D scientists, we also need to correct arable land for its differing productivity across countries. To make this correction, we use a measure of agricultural productivity in each country. Then the effective amount of arable land found in a country is

$$\text{Effective arable land} = \text{Actual arable land} \cdot \text{Productivity in agriculture}$$

HEADLINES

China Drawing High-Tech Research from U.S.

Applied Materials, a well-known firm in Silicon Valley, recently announced plans to establish a large laboratory in Xi'an, China, as described in this article.

XI'AN, China—For years, many of China's best and brightest left for the United States, where high-tech industry was more cutting-edge. But Mark R. Pinto is moving in the opposite direction. Mr. Pinto is the first chief technology officer of a major American tech company to move to China. The company, Applied Materials, is one of Silicon Valley's most prominent firms. It supplied equipment used to perfect the first computer chips. Today, it is the world's biggest supplier of the equipment used to make semiconductors, solar panels and flat-panel displays.

In addition to moving Mr. Pinto and his family to Beijing in January, Applied Materials, whose headquarters are in Santa Clara, Calif., has just built its newest and largest research labs here. Last week, it even held its annual shareholders' meeting in Xi'an. It is hardly alone. Companies—and their engineers—are being drawn here more and more as China develops a high-tech economy that increasingly competes directly with the United States. . . .

Not just drawn by China's markets, Western companies are also attracted to China's huge reservoirs of cheap, highly skilled engineers—and the subsidies offered by many Chinese cities and regions, particularly for green energy companies. Now, Mr. Pinto said, researchers from the United States and Europe have to be ready to move to China if they want to do cutting-edge work on solar manufacturing because the new Applied Materials complex here is the only research center that can fit an entire solar panel assembly line. "If you really want to have an impact on this field, this is just such a tremendous laboratory," he said. . . .

Locally, the Xi'an city government sold a 75-year land lease to Applied Materials at a deep discount and is reimbursing the company for roughly a quarter of the lab complex's operating costs for five years, said Gang Zou, the site's general manager. The two labs, the first of their kind anywhere in the world, are each bigger than two American football fields. Applied Materials continues to develop the electronic guts of its complex machines at laboratories in the United States and Europe. But putting all the machines together and figuring out processes to make them work in unison will be done in Xi'an. The two labs, one on top of the other, will become operational once they are fully outfitted late this year. . . .

Source: Keith Bradsher, "China Drawing High-Tech Research from U.S." From The New York Times, March 18, 2010

We will not discuss here the exact method for measuring productivity in agriculture, except to say that it compares the output in each country with the inputs of labor, capital, and land: countries with higher output as compared with inputs are the more productive, and countries with lower output as compared with inputs are the less productive. The United States has very high productivity in agriculture, whereas China has lower productivity.

In the third bar graph of Figure 4-7, we repeat from Figure 4-6 each country's share of arable land, not corrected for productivity differences. In the fourth bar graph, we show each country's share of effective arable land in 2010, corrected for productivity differences. The United States had 11.8% of the world's total arable land (in the third bar), as compared with 19.1% of the world's GDP (in the final bar), so it was scarce in land in 2010 without making any productivity correction. But when measured by effective arable land, the United States had 20.0% of the world's total (in the fourth bar), as compared with 19.1% of the world's GDP (in the final bar). These two numbers are so close that we should conclude *the United States was neither abundant nor scarce in effective arable land*: its share of the world's total approximately equaled its share of the world's GDP.

How does this conclusion compare with U.S. trade in agriculture? We often think of the United States as a major exporter of agricultural goods, but this pattern is changing. In Table 4-2, we show the U.S. exports and imports of food products and total agricultural trade. This table shows that U.S. food trade has fluctuated between positive and negative net exports since 2000, which is consistent with our finding that the United States is neither abundant nor scarce in land. Total agricultural trade (including nonfood items like cotton) continues to have positive net exports, however.

TABLE 4-2

U.S. Food Trade and Total Agricultural Trade, 2000–2012 This table shows that U.S. food trade has fluctuated between positive and negative net exports since 2000, which is consistent with our finding that the United States is neither abundant nor scarce in land. Total agricultural trade (including nonfood items like cotton) has positive net exports, however.

	2000	2002	2004	2006	2008	2010	2012
U.S. food trade (billions of U.S. dollars)							
Exports	41.4	43.2	50.0	57.8	97.4	92.3	132.9
Imports	41.4	44.7	55.7	68.9	81.3	86.6	101.2
Net exports	0.0	–1.5	–5.7	–11.1	16.1	5.7	31.7
U.S. agricultural trade (billions of U.S. dollars)							
Exports	51.3	53.1	61.4	70.9	115.3	115.8	141.3
Imports	39.2	42.0	54.2	65.5	80.7	81.9	102.9
Net exports	12.1	11.1	7.2	5.5	34.6	33.9	38.4

Source: Total agricultural trade compiled by USDA using data from Census Bureau, U.S. Department of Commerce. U.S. food trade data provided by the USDA, Foreign Agricultural Service.

Leontief's Paradox Once Again

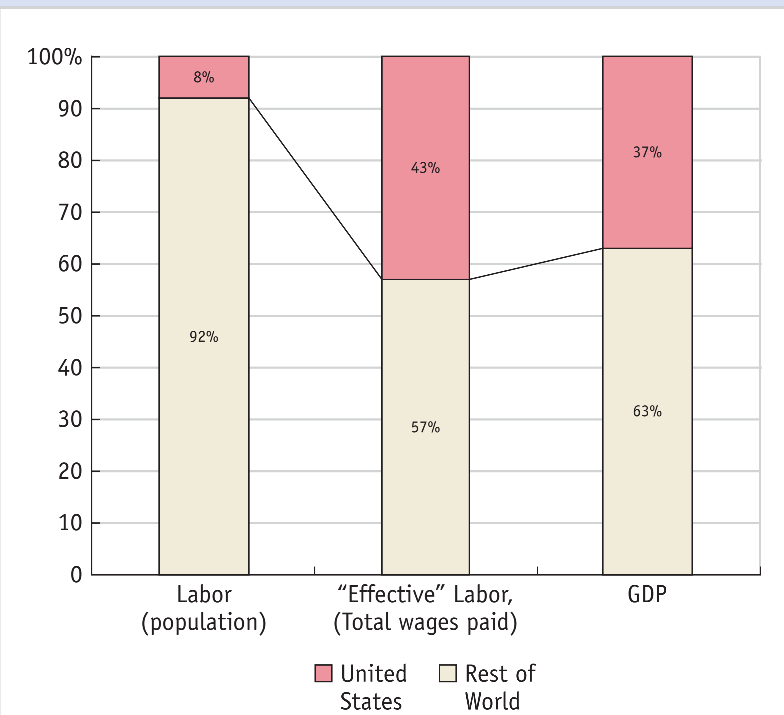
Our discussion of factor endowments in 2010 shows that it is possible for countries to be abundant in more that one factor of production: the United States and Japan are both abundant in physical capital and R&D scientists, and the United States is also abundant in skilled labor (see Figure 4-6). We have also found that it is sometimes important to correct that actual amount of a factor of production for its productivity, obtaining the effective factor endowment. Now we can apply these ideas to the United States in 1947 to reexamine the Leontief paradox.

Using a sample of 30 countries for which GDP information is available in 1947, the U.S. share of those countries' GDP was 37%. That estimate of the U.S. share of "world" GDP is shown in the last bar graph of Figure 4-8. To determine whether the United States was abundant in physical capital or labor, we need to estimate its share of the world endowments of these factors.

Capital Abundance It is hard to estimate the U.S. share of the world capital stock in the postwar years. But given the devastation of the capital stock in Europe and Japan due to World War II, we can presume that the U.S. share of world capital was more than 37%. That estimate (or really a "guesstimate") means that the U.S. share of world capital exceeds the U.S. share of world GDP, so that the United States was abundant in capital in 1947.

Labor Abundance What about the abundance of labor for the United States? If we do not correct labor for productivity differences across countries, then the population

FIGURE 4-8



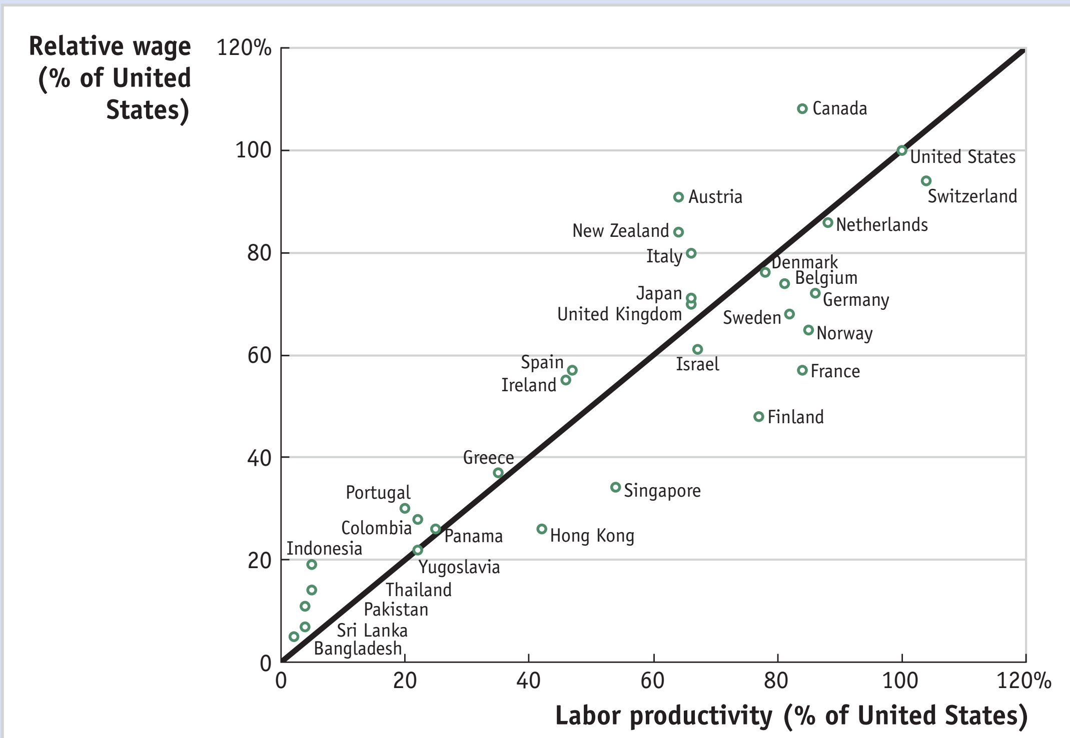
Labor Endowment and GDP for the United States and Rest of World, 1947 Shown here are the share of labor, "effective" labor, and GDP of the United States and the rest of the world (measured by 30 countries for which data are available) in 1947. The United States had only 8% of the world's population, as compared with 37% of the world's GDP, so it was very scarce in labor. But when we measure effective labor by the total wages paid in each country, then the United States had 43% of the world's effective labor as compared with 37% of GDP, so it was abundant in effective labor.

Source: Author's own calculations.

of each country is a rough measure of its labor force. The U.S. share of population for the sample of 30 countries in 1947 was very small, about 8%, which is shown in the first bar graph of Figure 4-8. This estimate of labor abundance is much less than the U.S. share of GDP, 37%. According to that comparison, the United States was scarce in labor (its share of that factor was less than its share of GDP).

Labor Productivity Using the U.S. share of population is not the right way to measure the U.S. labor endowment, however, because it does not correct for differences in the productivity of labor across countries. A good way to make that correction is to use wages paid to workers as a measure of their productivity. To illustrate why this is a good approach, in Figure 4-9 we plot the wages of workers in various countries and the estimated productivity of workers in 1990. The vertical axis in Figure 4-9 measures wages earned across a sample of 33 countries, measured relative to (i.e., as a percentage of) the United States. Only one country—Canada—has wages higher than those in the United States (probably reflecting greater union pressure in that country). All other countries have lower wages, ranging from Austria and Switzerland

FIGURE 4-9



Labor Productivity and Wages Shown here are estimated labor productivities across countries, and their wages, relative to the United States in 1990. Notice that the labor and wages were highly correlated across countries: the points roughly line up along the 45-degree line. This close connection between wages and labor productivity holds for the data in 1990, and we expect that it also held in 1947, so that we can use wages to adjust for labor productivity in explaining the Leontief paradox.

Source: Daniel Trefler, 1993, "International Factor Price Differences: Leontief was Right!" Journal of Political Economy, *101(6), December, 961–987.*

with wages that are about 95% of the U.S. wage, to Ireland, France, and Finland, with wages at about 50% of the U.S. level, to Bangladesh and Sri Lanka, with wages at about 5% of the U.S. level.

The horizontal axis in Figure 4-9 measures labor productivity in various countries relative to that in the United States. For example, labor productivity in Canada is 80% of that in the United States; labor productivity in Austria and New Zealand is about 60% of that in the United States; and labor productivity in Indonesia, Thailand, Pakistan, Sri Lanka, and Bangladesh is about 5% of that in the United States. Notice that the labor productivities (on the horizontal axis) and wages (on the vertical axis) are highly correlated across countries: the points in Figure 4-9 line up approximately along the 45-degree line. This close connection between wages and labor productivity holds for the data in 1990 and, we expect that it also held in 1947, so that we can use wages to adjust for labor productivity in explaining the Leontief Paradox.

Effective Labor Abundance As suggested by Figure 4-9, wages across countries are strongly correlated with the productivity of labor. Going back to the data for 1947, which Leontief used, we use the wages earned by labor to measure the productivity of labor in each country. Then the *effective* amount of labor found in each country equals the actual amount of labor times the wage. Multiplying the amount of labor in each country by average wages, we obtain total wages paid to labor. That information is available for 30 countries in 1947, and we have already found that the United States accounted for 37% of the GDP of these countries, as shown in the final bar in Figure 4-8. Adding up total wages paid to labor across the 30 countries and comparing it with the United States, we find that the United States accounted for 43% of wages paid to labor in these 30 countries, as shown in the bar labeled "effective" labor. By comparing this estimate with the United States share of world GDP of 37% in 1947, we see that the United States was abundant in effective labor, taking into account the differing productivity of labor across countries. So not only was the United States abundant in capital, it was also abundant in effective—or skilled—labor in 1947, just as we have also found for the year 2010!

Summary In Leontief's test of the Heckscher-Ohlin theorem, he found that the capital–labor ratio for exports from the United States in 1947 was less than the capital–labor ratio for imports. That finding seemed to contradict the Heckscher-Ohlin theorem if we think of the United States as being capital-abundant: in that case, it should be exporting capital-intensive goods (with a high capital–labor ratio). But now we have found that the United States was abundant in *both* capital *and* labor in 1947, once we correct for the productivity of labor by using its wage. Basically, the relatively low population and number of workers in the United States are boosted upward by high U.S. wages, making the effective labor force seem much larger—large enough so that the U.S. share of worldwide wages even exceeds its share of GDP.

Such a finding means the United States was *also* abundant in effective—or skilled—labor in 1947, just as it is today. Armed with this finding, it is not surprising that Leontief found exports from the United States in 1947 used relatively less capital and more labor than did imports: that pattern simply reflects the high productivity of labor in the United States and its abundance of this effective factor. As Leontief himself proposed, once we take into account differences in the productivity of factors across countries, there is no "paradox" after all, at least in the data for 1947. For more recent years, too, taking account of factor productivity differences across countries is important when testing the Heckscher-Ohlin theorem.

3 Effects of Trade on Factor Prices

In the Heckscher-Ohlin model developed in the previous sections, Home exported computers and Foreign exported shoes. Furthermore, we found in our model that the relative price of computers *rose* at Home from the no-trade equilibrium to the trade equilibrium (this higher relative price with trade is why computers are exported). Conversely, the relative price of computers *fell* in Foreign from the no-trade equilibrium to the trade equilibrium (this lower relative price with trade is why computers are imported abroad). The question we ask now is how the changes in the relative prices of goods affect the wage paid to labor in each country and the rental earned by capital. We begin by showing how the wage and rental are determined, focusing on Home.

Effect of Trade on the Wage and Rental of Home

To determine the wage and rental, we go back to Figure 4-1, which showed that the quantity of labor demanded relative to the quantity of capital demanded in each industry at Home depends on the relative wage at Home W/R. We can use these relative demands for labor in each industry to derive an economy-wide relative demand for labor, which can then be compared with the economy-wide relative supply of labor $\overline{L}/\overline{K}$. By comparing the economy-wide relative demand and supply, just as we do in any supply and demand context, we can determine Home's relative wage. Moreover, we can evaluate what happens to the relative wage when the Home relative price of computers rises after Home starts trading.

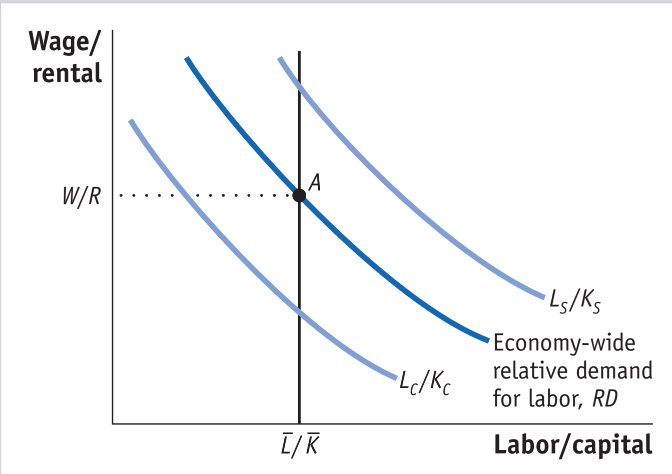
Economy-Wide Relative Demand for Labor To derive an economy-wide relative demand for labor, we use the conditions that the quantities of labor and capital used in each industry add up to the total available labor and capital: $L_C + L_S = \overline{L}$ and $K_C + K_S = \overline{K}$. We can divide total labor by total capital to get

$$\underbrace{\frac{\overline{L}}{\overline{K}}}_{\text{Relative supply}} = \frac{L_C + L_S}{\overline{K}} = \underbrace{\frac{L_C}{K_C} \cdot \left(\frac{K_C}{\overline{K}}\right) + \frac{L_S}{K_S} \cdot \left(\frac{K_S}{\overline{K}}\right)}_{\text{Relative demand}}$$

The left-hand side of this equation is the economy-wide supply of labor relative to capital, or relative supply. The right-hand side is the economy-wide demand for labor relative to capital, or relative demand. The relative demand is a weighted average of the labor–capital ratio in each industry. This weighted average is obtained by multiplying the labor–capital ratio for each industry, L_C/K_C and L_S/K_S, by the terms $K_C/\overline{K}$ and $K_S/\overline{K}$, the shares of total capital employed in each industry. These two terms must add up to 1, $(K_C/\overline{K}) + (K_S/\overline{K}) = 1$, because capital must be employed in one industry or the other.

The determination of Home's equilibrium relative wage is shown in Figure 4-10 as the intersection of the relative supply and relative demand curves. The supply of labor relative to the supply of capital, the relative supply ($\overline{L}/\overline{K}$), is shown as a vertical line because the total amounts of labor and capital do not depend on the relative wage; they are fixed by the total amount of factor resources in each country. Because the relative demand (the *RD* curve in the graph) is an average of the L_C/K_C and L_S/K_S curves from Figure 4-1, it therefore lies *between* these two curves. The point at which relative demand intersects relative supply, point *A*, tells us that the wage relative to

FIGURE 4-10

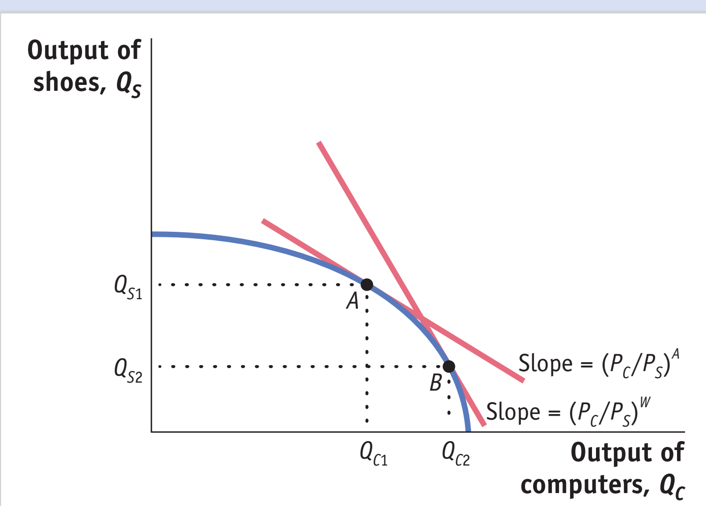


Determination of Home Wage/Rental The economy-wide relative demand for labor, *RD,* is an average of the L_C/K_C and L_S/K_S curves and lies between these curves. The relative supply, $\bar{L}/\bar{K}$, is shown by a vertical line because the total amount of resources in Home is fixed. The equilibrium point *A,* at which relative demand *RD* intersects relative supply $\bar{L}/\bar{K}$, determines the wage relative to the rental, *W/R*.

the rental is *W/R* (from the vertical axis). Point *A* describes an equilibrium in the labor and capital markets and combines these two markets into a single diagram by showing relative supply equal to relative demand.

Increase in the Relative Price of Computers When Home opens itself to trade, it faces a higher relative price of computers; that is, P_C/P_S increases at Home. We illustrate this higher relative price using Home's production possibilities frontier in Figure 4-11. At the no-trade or autarky equilibrium, point *A*, the relative price of computers is $(P_C/P_S)^A$ and the computer industry produces Q_{C1}, while the shoe

FIGURE 4-11



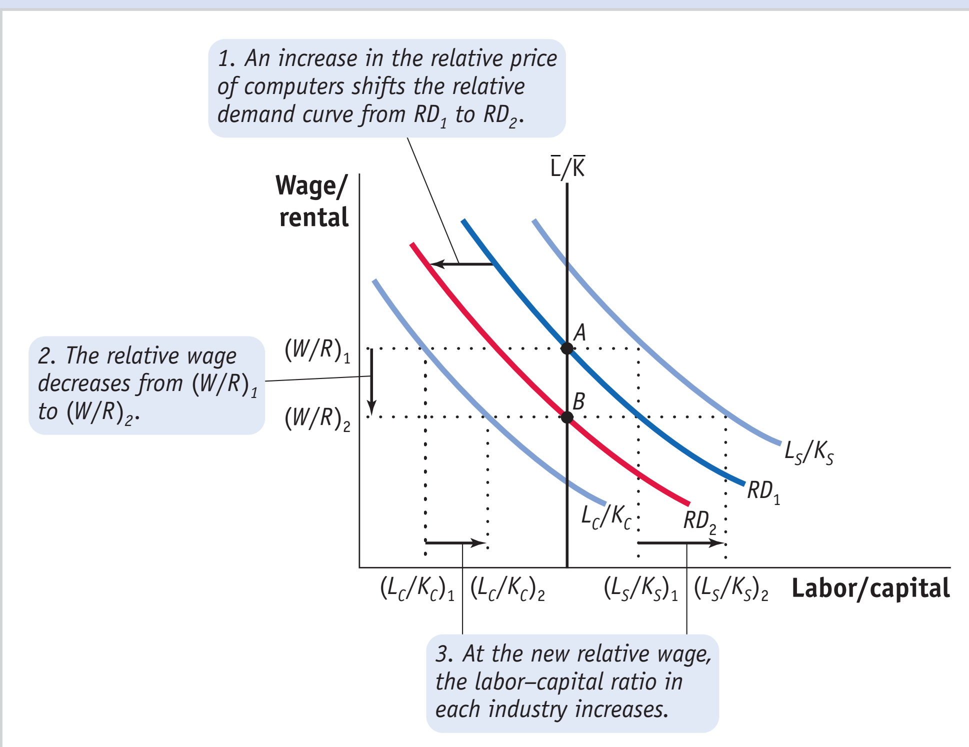
Increase in the Price of Computers Initially, Home is at a no-trade equilibrium at point *A* with a relative price of computers of $(P_C/P_S)^A$. An increase in the relative price of computers to the world price, as illustrated by the steeper world price line, $(P_C/P_S)^W$, shifts production from point *A* to *B*. At point *B,* there is a higher output of computers and a lower output of shoes, $Q_{C2} > Q_{C1}$ and $Q_{S2} < Q_{S1}$.

industry produces Q_{S1}. With a rise in the relative price of computers to $(P_C/P_S)^W$, the computer industry increases its output to Q_{C2}, and the shoe industry decreases its output to Q_{S2}. With this shift in production, labor and capital both move from shoe production to computer production. What is the effect of these resource movements on the relative supply and relative demand for labor?

The effects are shown in Figure 4-12. Relative supply $\overline{L}/\overline{K}$ is the same as before because the total amounts of labor and capital available in Home have not changed. The relative demand for labor changes, however, because capital has shifted to the computer industry. This shift affects the terms used in the weighted average: $(K_C/\overline{K})$ rises and $(K_S/\overline{K})$ falls. The relative demand for labor in the economy is now more weighted toward computers and less weighted toward the shoe industry. In Figure 4-12, the change in the weights shifts the relative demand curve from RD_1 to RD_2. The curve shifts in the direction of the relative demand curve for computers, and the equilibrium moves from point *A* to *B*.

The impacts on all the variables are as follows. First, the relative wage *W/R* falls from $(W/R)_1$ to $(W/R)_2$, reflecting the fall in the relative demand for labor as both factors move into computer production from shoe production. Second, the lower relative wage induces *both* industries to hire more workers per unit of capital (a move down along their relative demand curves). In the shoe industry, for instance, the new, lower relative wage $(W/R)_2$ intersects the relative demand curve for labor L_S/K_S at a point

FIGURE 4-12



Effect of a Higher Relative Price of Computers on Wage/Rental An increase in the relative price of computers shifts the economy-wide relative demand for labor, RD_1, toward the relative demand for labor in the computer industry, L_C/K_C. The new relative demand curve, RD_2, intersects the relative supply curve for labor at a lower relative wage $(W/R)_2$. As a result, the wage relative to the rental falls from $(W/R)_1$ to $(W/R)_2$. The lower relative wage causes both industries to increase their labor–capital ratios, as illustrated by the increase in both L_C/K_C and L_S/K_S at the new relative wage.

corresponding to a higher L/K level than the initial relative wage $(W/R)_1$. That is, $(L_S/K_S)_2 > (L_S/K_S)_1$, and the same argument holds for the computer industry. As a result, the labor–capital ratio rises in both shoes and computers.

How is it possible for the labor–capital ratio to rise in *both* industries when the amount of labor and capital available in total is fixed? The answer is that more labor per unit of capital is released from shoes than is needed to operate that capital in computers (because computers require fewer workers per machine). As the relative price of computers rises, computer output rises while shoe output falls, and labor is "freed up" to be used more in both industries. In terms of our earlier equation for relative supply and relative demand, the changes in response to the increase in the relative price of computers P_C/P_S are

$$\underbrace{\frac{\overline{L}}{\overline{K}}}_{\substack{\text{Relative supply}\\ \text{No change}}} = \underbrace{\underset{\uparrow}{\frac{L_C}{K_C}} \cdot \underset{\uparrow}{\left(\frac{K_C}{\overline{K}}\right)} + \underset{\uparrow}{\frac{L_S}{K_S}} \cdot \underset{\downarrow}{\left(\frac{K_S}{\overline{K}}\right)}}_{\substack{\text{Relative demand}\\ \text{No change in total}}}$$

The relative supply of labor has not changed, so relative demand for labor cannot change overall. Since some of the individual components of relative demand have increased, other components must decrease to keep the overall relative demand the same. After the rise in the price of computers, even more capital will be used in the computer industry ($K_C/\overline{K}$ rises while $K_S/\overline{K}$ falls) because the output of computers rises and the output of shoes falls. This shift in weights on the right-hand side pulls down the overall relative demand for labor (this is necessarily true since $L_C/K_C < L_S/K_S$ by assumption). But because the relative supply on the left-hand side doesn't change, another feature must increase the relative demand for labor: this feature is the increased labor–capital ratios in *both* industries. In this way, relative demand continues to equal relative supply at point *B*, and at the same time, the labor–capital ratios have risen in both industries.

Determination of the Real Wage and Real Rental

To summarize, we have found that an increase in the relative price of computers—which are capital-intensive—leads to a fall in the relative wage (W/R). In turn, the decrease in the relative wage leads to an increase in the labor–capital ratio used in each industry (L_C/K_C and L_S/K_S). Our goal in this section is to determine who gains and who loses from these changes. For this purpose, it is not enough to know how the *relative* wage changes; instead, we want to determine the change in the *real wage* and *real rental;* that is, the change in the quantity of shoes and computers that each factor of production can purchase. With the results we have already obtained, it will be fairly easy to determine the change in the real wage and real rental.

Change in the Real Rental Because the labor–capital ratio increases in both industries, the marginal product of capital also increases in both industries. This is because there are more people to work with each piece of capital. This result follows from our earlier argument that when a machine has more labor to work it, it will be more productive, and the marginal product of capital will go up. In both industries, the rental on capital is determined by its marginal product and by the prices of the goods:

$$R = P_C \cdot MPK_C \text{ and } R = P_S \cdot MPK_S$$

Because capital can move freely between industries in the long run, the rental on capital is equalized across them. By using the result that both marginal products of capital increase and by rearranging the previous equations, we see that

$$MPK_C = R/P_C \uparrow \text{ and } MPK_S = R/P_S \uparrow$$

Remember that R/P_C measures that quantity of computers that can be purchased with the rental, whereas R/P_S measures the quantity of shoes that can be bought with the rental. When both of these go up, the real rental on capital (in terms of either good) *increases*. Therefore, capital owners are clearly better off when the relative price of computers increases. Notice that computer manufacturing is the capital-intensive industry, so the more general result is that *an increase in the relative price of a good will benefit the factor of production used intensively in producing that good.*

Change in the Real Wage To understand what happens to the real wage when the relative price of computers rises, we again use the result that the labor–capital ratio increases in *both* industries. The law of diminishing returns tells us that the marginal product of labor must fall in both industries (since there are more workers on each machine). In both industries, the wage is determined by the marginal product of labor and the prices of the goods:

$$W = P_C \cdot MPL_C \text{ and } W = P_S \cdot MPL_S$$

Using the result that the marginal product of labor falls in both industries, we see that

$$MPL_C = W/P_C \downarrow \text{ and } MPL_S = W/P_S \downarrow$$

Therefore, the quantity of computers that can be purchased with the wage (W/P_C) and the quantity of shoes that can be purchased with the wage (W/P_S) both fall. These decreases mean that the real wage (in terms of either good) is *reduced*, and labor is clearly worse off because of the increase in the relative price of computers.

We can summarize our results with the following theorem, first derived by economists Wolfgang Stolper and Paul Samuelson.

Stolper-Samuelson Theorem: In the long run, when all factors are mobile, an increase in the relative price of a good will increase the real earnings of the factor used intensively in the production of that good and decrease the real earnings of the other factor.

For our example, the **Stolper-Samuelson theorem** predicts that when Home opens to trade and faces a higher relative price of computers, the real rental on capital in Home rises and the real wage in Home falls. In Foreign, the changes in real factor prices are just the reverse. When Foreign opens to trade and faces a lower relative price of computers, the real rental falls and the real wage rises. Remember that Foreign is abundant in labor, so our finding that labor is better off there, but worse off at Home, means that workers in the labor-abundant country gain from trade but workers in the capital-abundant country lose. In addition, capital in the capital-abundant country (Home) gains, and capital in the labor-abundant country loses. These results are sometimes summarized by saying that in the Heckscher-Ohlin model, *the abundant factor gains from trade, and the scarce factor loses from trade.*[6]

Changes in the Real Wage and Rental: A Numerical Example

To illustrate the Stolper-Samuelson theorem, we use a numerical example to show how much the real wage and rental can change in response to a change in price. Suppose that the computer and shoe industries have the following data:

Computers: Sales revenue $= P_C \cdot Q_C = 100$

Earnings of labor $= W \cdot L_C = 50$

Earnings of capital $= R \cdot K_C = 50$

Shoes: Sales revenue $= P_S \cdot Q_S = 100$

Earnings of labor $= W \cdot L_S = 60$

Earnings of capital $= R \cdot K_S = 40$

Notice that shoes are more labor-intensive than computers: the share of total revenue paid to labor in shoes (60/100 = 60%) is more than that share in computers (50/100 = 50%).

When Home and Foreign undertake trade, the relative price of computers rises. For simplicity we assume that this occurs because the price of computers P_C rises, while the price of shoes P_S does not change:

Computers: Percentage increase in price $= \Delta P_C/P_C = 10\%$

Shoes: Percentage increase in price $= \Delta P_S/P_S = 0\%$

Our goal is to see how the increase in the relative price of computers translates into long-run changes in the wage W paid to labor and the rental on capital R. Remember that the rental on capital can be calculated by taking total sales revenue in each industry, subtracting the payments to labor, and dividing by the amount of capital. This calculation gives us the following formulas for the rental in each industry:[7]

$$R = \frac{P_C \cdot Q_C - W \cdot L_C}{K_C}, \text{ for computers}$$

$$R = \frac{P_S \cdot Q_S - W \cdot L_S}{K_S}, \text{ for shoes}$$

The price of computers has risen, so $\Delta P_C > 0$, holding fixed the price of shoes, $\Delta P_S = 0$. We can trace through how this affects the rental by changing P_C and W in the previous two equations:

$$\Delta R = \frac{\Delta P_C \cdot Q_C - \Delta W \cdot L_C}{K_C}, \text{ for computers}$$

$$\Delta R = \frac{0 \cdot Q_C - \Delta W \cdot L_S}{K_S}, \text{ for shoes}$$

[6] This result follows logically from combining the Heckscher-Ohlin theorem with the Stolper-Samuelson theorem.
[7] Remember that because of factor mobility, the rental is the same in each industry, but it is helpful here to derive two separate equations for the percentage change in rental by industry.

It is convenient to work with percentage changes in the variables. For computers, $\Delta P_C/P_C$ is the percentage change in price. Similarly, $\Delta W/W$ is the percentage change in the wage, and $\Delta R/R$ is the percentage change in the rental of capital. We can introduce these terms into the preceding formulas by rewriting them as

$$\frac{\Delta R}{R} = \left(\frac{\Delta P_C}{P_C}\right)\left(\frac{P_C \cdot Q_C}{R \cdot K_C}\right) - \left(\frac{\Delta W}{W}\right)\left(\frac{W \cdot L_C}{R \cdot K_C}\right), \text{ for computers}$$

$$\frac{\Delta R}{R} = -\left(\frac{\Delta W}{W}\right)\left(\frac{W \cdot L_S}{R \cdot K_S}\right), \text{ for shoes}$$

(You should cancel terms in these equations to check that they are the same as before.)

Now we'll plug the above data for shoes and computers into these formulas:

$$\frac{\Delta R}{R} = 10\% \cdot \left(\frac{100}{50}\right) - \left(\frac{\Delta W}{W}\right)\left(\frac{50}{50}\right), \text{ for computers}$$

$$\frac{\Delta R}{R} = -\left(\frac{\Delta W}{W}\right)\left(\frac{60}{40}\right), \text{ for shoes}$$

Our goal is to find out by how much rental and wage change given changes in the relative price of the final goods, so we are trying to solve for two unknowns ($\Delta R/R$ and $\Delta W/W$) from the two equations given here. A good way to do this is to reduce the two equations with two unknowns into a single equation with one unknown. This can be done by subtracting one equation from the other, as follows:

$$\frac{\Delta R}{R} = 10\% \cdot \left(\frac{100}{50}\right) - \left(\frac{\Delta W}{W}\right)\left(\frac{50}{50}\right), \text{ for computers}$$

$$\text{Minus:} \quad \frac{\Delta R}{R} = 0 - \left(\frac{\Delta W}{W}\right)\left(\frac{60}{40}\right), \text{ for shoes}$$

$$\text{Equals:} \quad 0 = 10\% \cdot \left(\frac{100}{50}\right) + \left(\frac{\Delta W}{W}\right)\left(\frac{20}{40}\right)$$

Simplifying the last line, we get $0 = 20\% + \left(\frac{\Delta W}{W}\right)\left(\frac{1}{2}\right)$, so that

$$\left(\frac{\Delta W}{W}\right) = \left(\frac{-20\%}{\frac{1}{2}}\right) = -40\%, \text{ is the change in wages}$$

So when the price of computers increases by 10%, the wage falls by 40%. With the wage falling, labor can no longer afford to buy as many computers (W/P_C has fallen since W is falling and P_C has increased) or as many pairs of shoes (W/P_S has fallen since W is falling and P_S has not changed). In other words, the *real wage* measured in terms of either good has *fallen*, so labor is clearly worse off.

To find the change in the rental paid to capital ($\Delta R/R$), we can take our solution for $\Delta W/W = -40\%$, and plug it into the equation for the change in the rental in the shoes sector:[8]

[8] You should check that you get the same answer if instead you plug the change in the wage into the formula for the change in the rental in the computer sector.

$$\frac{\Delta R}{R} = -\left(\frac{\Delta W}{W}\right)\left(\frac{60}{40}\right) = 40\% \cdot \left(\frac{60}{40}\right) = 60\%, \text{ change in rental}$$

The rental on capital increases by 60% when the price of computers rises by 10%, so the rental increases even more (in percentage terms) than the price. Because the rental increases by more than the price of computers in percentage terms, it follows that (R/P_C) rises: owners of capital can afford to buy more computers, even though their price has gone up. In addition, they can afford to buy more shoes (R/P_S also rises, since R rises and P_S is constant). Thus, the real rental measured in terms of either good has *gone up*, and capital owners are clearly better off.

General Equation for the Long-Run Change in Factor Prices The long-run results of a change in factor prices can be summarized in the following equation:

$$\underbrace{\Delta W/W < 0}_{\text{Real wage falls}} < \underbrace{\Delta P_C/P_C < \Delta R/R}_{\text{Real rental increases}}, \text{ for an increase in } P_C$$

That is, the increase in the price of computers (10%) leads to an even larger increase in the rental on capital (60%) and a decrease in the wage (–40%). If, instead, the price of computers falls, then these inequalities are reversed, and we get

$$\underbrace{\Delta R/R < \Delta P_C/P_C}_{\text{Real rental falls}} < \underbrace{0 < \Delta W/W}_{\text{Real wage increases}}, \text{ for an decrease in } P_C$$

What happens if the relative price of shoes increases? From the Stolper-Samuelson theorem, we know that this change will benefit labor, which is used intensively in shoe production, and will harm capital. The equation summarizing the changes in factor earnings when the price of shoes increases is

$$\underbrace{\Delta R/R < 0}_{\text{Real rental falls}} < \underbrace{\Delta P_S/P_S < \Delta W/W}_{\text{Real wage increases}}, \text{ for an increase in } P_S$$

These equations relating the changes in product prices to changes in factor prices are sometimes called the "magnification effect" because they show how changes in the prices of goods have *magnified effects* on the earnings of factors: even a modest fluctuation in the relative prices of goods on world markets can lead to exaggerated changes in the long-run earnings of both factors. This result tells us that some groups—those employed intensively in export industries—can be expected to support opening an economy to trade because an increase in export prices increases their real earnings. But other groups—those employed intensively in import industries—can be expected to oppose free trade because the decrease in import prices decreases their real earnings. The following application examines the opinions that different factors of production have taken toward free trade.

APPLICATION

Opinions Toward Free Trade

Countries sometimes conduct a survey about their citizens' attitudes toward free trade. A survey conducted in the United States by the National Elections Studies (NES) in 1992 included the following question:

Some people have suggested placing new limits on foreign imports in order to protect American jobs. Others say that such limits would raise consumer prices and hurt American exports. Do you favor or oppose placing limits on imports, or haven't you thought much about this?

Respondents to the survey could either answer that they "favor" placing limits on imports, meaning that they do not support free trade, or that they "oppose" limits on imports, meaning that they support free trade. How do these answers compare with characteristics of the respondents, such as their wages, skills, or the industries in which they work?

According to the specific-factors model, in the short run we do not know whether labor will gain or lose from free trade, but we do know that the specific factor in the export sector gains, and the specific factor in the import sector loses. Think about an extension of this model, in which, in addition to their wage, labor also earns some part of the rental on the specific factor in their industry. This assumption is true for farmers, for example, who work in agriculture and may own their land; it can also be true for workers in manufacturing if their salary includes a bonus that is based on the profits earned by capital. In those situations, we would expect that workers in export industries will support free trade (since the specific factor in that industry gains), but workers in import-competing industries will be against free trade (since the specific factor in that industry loses). In the short run, then, the *industry of employment* of workers will affect their attitudes toward free trade.

In the long-run Heckscher-Ohlin (HO) model, however, the industry of employment should not matter. According to the Stolper-Samuelson theorem, an increase in the relative price of exports will benefit the factor of production used intensively in exports and harm the other factor, regardless of the industry in which these factors of production actually work (remember that each factor of production earns the same wage or rental across industries in the long run). In the United States, export industries tend to use high-skilled labor intensively for research and development and other scientific work. An increase in the relative price of exports will benefit high-skilled labor in the long run, regardless of whether these workers are employed in export-oriented industries or import-competing industries. Conversely, an increase in the relative price of exports will harm low-skilled labor, regardless of where these workers are employed. In the long run, then, the *skill level* of workers should determine their attitudes toward free trade.

In the 1992 NES survey, the industry of employment was somewhat important in explaining the respondents' attitudes toward free trade, but their skill level was much more important.[9] That is, workers in export-oriented industries are somewhat more likely to favor free trade, with those in import-competing industries favoring import restrictions, but this statistical relationship is not strong. A much more important determinant of the attitudes toward free trade is the skill level of workers, as measured by their wages or their years of education. Workers with lower wages or fewer years of education are more likely to favor import restrictions, whereas those with higher wages and more years of education favor free trade. This finding suggests that the respondents to the survey are basing their answer on their *long-run* earnings, as

[9] See Kenneth F. Scheve and Matthew J. Slaughter, 2001, "What Determines Individual Trade-Policy Preferences?" *Journal of International Economics*, 54, 267–292.

predicted by the HO model and Stolper-Samuelson theorem, rather than on their short-run industry of employment, as predicted by the specific-factors model.

There is an interesting extension to these findings, however. The survey also asked respondents whether they owned a home. It turns out that people who own homes in communities in which the local industries face a lot of import competition are much more likely to oppose free trade. Examples of this are towns in the northeastern states where people have been employed by textile mills, or in the midwestern states where people have been employed by automobile, steel, and other heavy industries. But people who own homes in communities in which the industries benefit from export opportunities, such as the high-tech areas in Boston or in Silicon Valley, California, are much more likely to support free trade. We can think of a house as a specific factor, since it cannot move locations. So the attitudes in this part of the NES survey conform to the short-run specific-factors model: people are very concerned about the asset value of their homes, just as the owners of specific factors in our model are concerned about the rental earned by the factor of production they own. ■

4 Conclusions

The Heckscher-Ohlin framework is one of the most widely used models in explaining trade patterns. It isolates the effect of different factor endowments across countries and determines the impact of these differences on trade patterns, relative prices, and factor returns. This approach is a major departure from the view that technology differences determine trade patterns as we saw in the Ricardian model and is also a departure from the short-run specific-factors model that we studied in Chapter 3.

In this chapter, we have investigated some empirical tests of the Heckscher-Ohlin theorem; that is, tests to determine whether countries actually export the goods that use their abundant factor intensively. The body of literature testing the theorem originates in Leontief's puzzling finding that U.S. exports just after World War II were relatively labor-intensive. Although the original formulation of his test did not seem to support the Heckscher-Ohlin theorem, later research has reformulated the test to measure the effective endowments of labor, capital, and other factors found in each country. Using this approach, we found that the United States was abundant in effective labor, and we also presume that it was abundant in capital. The United States had a positive factor content of net exports for both labor and capital in 1947, which is consistent with the finding of Leontief, so there was really no "paradox" after all.

By focusing on the factor intensities among goods (i.e., the relative amount of labor and capital used in production), the Heckscher-Ohlin (HO) model also provides clear guidance as to who gains and who loses from the opening of trade. In the specific-factors model, an increase in the relative price of a good leads to real gains for the specific factor used in that industry, losses for the other specific factor, and an ambiguous change in the real wage for labor. In contrast, the HO model predicts real gains for the factor used intensively in the export good, whose relative price goes up with the opening of trade, and real losses for the other factor. Having just two factors, both of which are fully mobile between the industries, leads to a very clear prediction about who gains and who loses from trade in the long run.

KEY POINTS

1. In the Heckscher-Ohlin model, we assume that the technologies are the same across countries and that countries trade because the available resources (labor, capital, and land) differ across countries.
2. The Heckscher-Ohlin model is a long-run framework, so labor, capital, and other resources can move freely between the industries.
3. With two goods, two factors, and two countries, the Heckscher-Ohlin model predicts that a country will export the good that uses its abundant factor intensively and import the other good.
4. The first test of the Heckscher-Ohlin model was made by Leontief using U.S. data for 1947. He found that U.S. exports were less capital-intensive and more labor-intensive than U.S. imports. This was a paradoxical finding because the United States was abundant in capital.
5. The assumption of identical technologies used in the Heckscher-Ohlin model does not hold in practice. Current research has extended the empirical tests of the Heckscher-Ohlin model to allow for many factors and countries, along with differing productivities of factors across countries. When we allow for different productivities of labor in 1947, we find that the United States is abundant in effective—or skilled—labor, which explains the Leontief paradox.
6. According to the Stolper-Samuelson theorem, an increase in the relative price of a good will cause the real earnings of labor and capital to move in opposite directions: the factor used intensively in the industry whose relative price goes up will find its earnings increased, and the real earnings of the other factor will fall.
7. Putting together the Heckscher-Ohlin theorem and the Stolper-Samuelson theorem, we conclude that a country's abundant factor gains from the opening of trade (because the relative price of exports goes up), and its scarce factor loses from the opening of trade.

KEY TERMS

Heckscher-Ohlin model, p. 87
reversal of factor intensities, p. 92
free-trade equilibrium, p. 97
Heckscher-Ohlin theorem, p. 97
Leontief's paradox, p. 98
abundant in that factor, p. 100
scarce in that factor, p. 100
effective labor force, p. 102
effective factor endowment, p. 103
abundant in that effective factor, p. 103
scarce in that effective factor, p. 103
Stolper-Samuelson theorem, p. 114

PROBLEMS

1. This problem uses the Heckscher-Ohlin model to predict the direction of trade. Consider the production of handmade rugs and assembly line robots in Canada and India.
   a. Which country would you expect to be relatively labor-abundant, and which is capital-abundant? Why?
   b. Which industry would you expect to be relatively labor-intensive, and which is capital-intensive? Why?
   c. Given your answers to (a) and (b), draw production possibilities frontiers for each country. Assuming that consumer preferences are the same in both countries, add indifference curves and relative price lines (without trade) to your PPF graphs. What do the slopes of the price lines tell you about the direction of trade?
   d. Allowing for trade between countries, redraw the graphs and include a "trade triangle" for each country. Identify and label the vertical and horizontal sides of the triangles as either imports or exports.
2. Leontief's paradox is an example of testing a trade model using actual data observations. If

Leontief had observed that the amount of labor needed per \$1 million of U.S. exports was 100 person-years instead of 182, would he have reached the same conclusion? Explain.

3. Suppose there are drastic technological improvements in shoe production at Home such that shoe factories can operate almost completely with computer-aided machines. Consider the following data for the Home country:

Computers: Sales revenue = $P_C Q_C = 100$

Payments to labor = $WL_C = 50$

Payments to capital = $RK_C = 50$

Percentage increase in the price = $\Delta P_C / P_C = 0\%$

Shoes: Sales revenue = $P_S Q_S = 100$

Payments to labor = $WL_S = 5$

Payments to capital = $RK_S = 95$

Percentage increase in the price = $\Delta P_S / P_S = 50\%$

a. Which industry is capital-intensive? Is this a reasonable question, given that some industries are capital-intensive in some countries and labor-intensive in others?
b. Given the percentage changes in output prices in the data provided, calculate the percentage change in the rental on capital.
c. How does the magnitude of this change compare with that of labor?
d. Which factor gains in real terms, and which factor loses? Are these results consistent with the Stolper-Samuelson theorem?

4. Using the information in the chapter, suppose Home doubles in size, while Foreign remains the same. Show that an equal proportional increase in capital and labor at Home will change the relative price of computers, wage, rental on capital, and the amount traded but not the pattern of trade.

5. Using a diagram similar to Figure 4-12, show the effect of a decrease in the relative price of computers in Foreign. What happens to the wage relative to the rental? Is there an increase in the labor–capital ratio in each industry? Explain.

6. Suppose when Russia opens to trade, it imports automobiles, a capital-intensive good.
   a. According to the Heckscher-Ohlin theorem, is Russia capital-abundant or labor-abundant? Briefly explain.
   b. What is the impact of opening trade on the real wage in Russia?
   c. What is the impact of opening trade on the real rental on capital?
   d. Which group (capital owner or labor) would support policies to limit free trade? Briefly explain.

7. In Figure 4-3, we show how the movement from the no-trade equilibrium point *A* to a trade equilibrium at a higher relative price of computers leads to an upward-sloping export supply, from points *A* to *D* in panel (b).
   a. Suppose that the relative price of computers continues to rise in panel (a), and label the production and consumption points at several higher prices.
   b. In panel (b), extend the export supply curve to show the quantity of exports at the higher relative prices of computers.
   c. What happens to the export supply curve when the price of computers is high enough? Can you explain why this happens? *Hint:* An increase in the relative price of a country's export good means that the country is richer because its terms of trade have improved. Explain how that can lead to fewer exports as their price rises.

8. On March 2, 2013, Tajikistan successfully negotiated terms to become a member of the World Trade Organization. Consequently, countries such as those in western Europe are shifting toward free trade with Tajikistan. What does the Stolper-Samuelson theorem predict about the impact of the shift on the real wage of low-skilled labor in western Europe? In Tajikistan?

9. The following are data on U.S. exports and imports in 2012 at the two-digit Harmonized Tariff Schedule (HTS) level. Which products do you think support the Heckscher-Ohlin theorem? Which products are inconsistent?

HTS Level	Product	Export ($ billions)	Import ($ billions)
22	Beverages	6.4	19.2
30	Pharmaceutical products	38.0	64.1
52	Cotton	8.2	1.1
61	Apparel	1.4	41.1
64	Footwear	0.8	23.7
72	Iron and steel	22.0	29.0
74	Copper	9.3	10.2
85	Electric machinery	105.0	289.0
87	Vehicles	122.3	240.0
88	Aircraft	95.8	24.2
94	Furniture	8.7	44.3
95	Toys	4.4	27.0

Source: International Trade Administration, U.S. Department of Commerce.

10. Following are data for soybean yield, production, and trade for 2010–2011:

    Suppose that the countries listed in the table are engaged in free trade and that soybean production is land-intensive. Answer the following:

    a. In which countries does land benefit from free trade in soybeans? Explain.
    b. In which countries does land lose from free trade in soybeans? Explain.
    c. In which countries does the move to free trade in soybeans have little or no effect on the land rental? Explain.

	Yield (metric ton/hectare)	Production (100,000 metric ton)	Export (100,000 metric ton)	Imports (100,000 metric ton)
Australia	1.71	0.29	0.025	0.007
Brazil	3.12	748.2	258	1.18
Canada	2.75	42.5	27.8	2.42
China	1.89	144	1.64	570
France	2.95	1.23	0.24	5.42
Japan	1.60	2.19	0.0006	34.6
Mexico	1.32	2.05	0.001	37.7
Russian Federation	1.48	17.6	0.008	10.7
United States	2.79	831	423	4.45

Source: Food and Agriculture Organization.

11. According to the Heckscher-Ohlin model, two countries can equalize wage differences by either engaging in international trade in goods or allowing high-skilled and low-skilled labor to freely move between the two countries. Discuss whether this is true or false, and explain why.

12. According to the standard Heckscher-Ohlin model with two factors (capital and labor) and two goods, movement of Turkish migrants to Germany would decrease the amount of capital-intensive products produced in Germany. Discuss whether this is true or false, and explain why.

NET WORK

See the New Balance plant in Skowhegan, Maine, at http://www.youtube.com/watch?v=ittvWwCS5QI. What shoes are produced there, and what is the "Super Team 33"?

Movement of Labor and Capital Between Countries

Amidst growing dissent, housing and job shortages as well as a plummeting economy, Cuban Premier Fidel Castro withdrew his guards from the Peruvian embassy in Havana on April 4, 1980. . . . Less than 48 hours after the guards were removed, throngs of Cubans crowded into the lushly landscaped gardens at the embassy, requesting asylum. . . . By mid-April, Carter issued a Presidential Memorandum allowing up to 3,500 refugees sanctuary in the U.S. . . . But the Carter Administration was taken by surprise when on April 21, refugees started arriving on Florida's shores—their numbers would eventually reach 125,000.

"Memories of Mariel, 20 Years Later"[1]

If you're a foreign student who wants to pursue a career in science or technology, or a foreign entrepreneur who wants to start a business with the backing of American investors, we should help you do that here. Because if you succeed, you'll create American businesses and American jobs. You'll help us grow our economy. You'll help us strengthen our middle class.

President Barack Obama, Del Sol High School, Las Vegas, January 29, 2013

From May to September 1980, boatloads of refugees from Cuba arrived in Miami, Florida. For political reasons, Fidel Castro had allowed them to leave freely from the port of Mariel, Cuba, during that brief period. Known as "the Mariel boat lift," this influx of about 125,000 refugees to Miami increased the city's Cuban population by 20% and its overall population by about 7%. The widespread unemployment of many of the refugees during the summer of 1980 led many people to expect that the wages of other workers in Miami would be held down by the Mariel immigrants.

Not surprisingly, the refugees were less skilled than the other workers in Miami, as is confirmed by looking at their wages: the immigrants initially earned about

[1] Judy L. Silverstein, "Memories of Mariel, 20 Years Later," *U.S. Coast Guard Reservist*, 47(3), April/May 2000, electronic edition.

one-third less than other Cubans in Miami. What is surprising, however, is that this influx of low-skilled immigrants does not appear to have pulled down the wages of other less skilled workers in Miami.[2] The wages for low-skilled workers in Miami essentially followed national trends over this period, despite the large inflow of workers from Cuba. This finding seems to contradict the prediction of basic supply and demand theory—that a higher supply of workers should bid down their wage and that restricting immigration will raise the wages for local workers. The fact that wages in Miami did not respond to the inflow of Mariel refugees calls for an explanation, which is one goal of this chapter.

A similar outcome occurred in a more recent case of sudden migration, the emigration of Russian Jews to Israel after 1989, when the Soviet Union relaxed its restrictions on such departures. From late 1989 to 1996, some 670,000 Russian Jews immigrated to Israel, which increased the population in Israel by 11% and its workforce by 14%. This wave of immigration was especially notable because the Russian immigrants were more highly skilled than the existing Israeli population. But despite this large influx of immigrants, the relative wages of high-skilled workers in Israel actually *rose* during the 1990s. Careful studies of this episode can find little or no negative impact of the Russian immigrants on the wages of other high-skilled workers.[3]

These emigrations were of different types of workers—the Cuban workers were low-skilled and the Russian emigrants high-skilled—but they share the finding that large inflows of workers need not depress wages in the areas where they settle. In other cases of large-scale migration—such as occurred from Europe to America during the 1800s and 1900s—wages did indeed fall because of the inflow of immigrants. So the Mariel boat lift and Russian immigration to Israel should be seen as special: they are cases in which the economic principles of supply and demand do not at first glance work as we would expect them to.

In this chapter, we begin our study of the movement of labor across countries by explaining the case in which immigration leads to a fall in wages, as we normally expect. The model we use is the **specific-factors model,** the short-run model introduced in Chapter 3. That model allows labor to move between industries but keeps capital and land specific to each industry. To study migration, we allow labor to move between countries as well as industries, while still keeping capital and land specific to each industry.

Next, we use the long-run Heckscher-Ohlin model, from Chapter 4, in which capital and land can also move between industries. In the long run, an increase in labor *will not* lower the wage, as illustrated by the Mariel boat lift to Miami and the Russian immigration to Israel. This outcome occurs because industries have more time to respond to the inflow of workers by adjusting their outputs. It turns out that by adjusting industry output enough, the economy can absorb the new workers without changing the wage for existing workers. The explanation for this surprising outcome relies on the assumption that industries are able to sell their outputs on international markets.

To give a brief idea of how this long-run explanation will work, think about the highly skilled scientists and engineers emigrating from Russia to Israel. The only way

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[2] See David Card, January 1990, "The Impact of the Mariel Boatlift on the Miami Labor Market," *Industrial Labor Relations Review*, 43(2), 245–257.

[3] See Neil Gandal, Gordon Hanson, and Matthew Slaughter, 2004, "Technology, Trade and Adjustment to Immigration in Israel," *European Economic Review*, 48(2), 403–428.

to employ the large number of these workers at the going wages would be to increase the number of scientific and engineering projects in which Israeli companies are engaged. Where does the demand for these new projects come from? It is unlikely this demand would be generated in Israel alone, and more likely that it would come from Israeli *exports* to the rest of the world. We see then that the ability of Israel to export products making use of the highly skilled immigrants is essential to our explanation: with international demand, it is possible for the Russian immigrants to be fully employed in export activities without lowering wages in Israel. Likewise, with the influx of low-skilled Cuban immigrants to Miami, many of whom could work in the textile and apparel industry or in agriculture, it is the ability of Florida to export those products that allows the workers to be employed at the going wages.

The effect of immigration on wages can be quite different in the short run and in the long run. In this chapter we demonstrate that difference, and discuss government policies related to immigration. Policies to restrict or to allow immigration are an important part of government regulation in every country, including the United States. As President Obama began his second term as President in 2013, one of his goals was to achieve a reform of immigration policies. We discuss why reforms are needed in the United States and what they might achieve.

After studying what happens when labor moves across countries, we study the effects of foreign direct investment (FDI), the movement of capital across countries. FDI occurs when a company from one country owns a company in another country. We conclude the chapter by discussing the gains to the source and destination countries, and to the world, from the movement of labor or capital between countries.

1 Movement of Labor Between Countries: Migration

We begin with the examples of labor migration described by the Mariel boat lift and the Russian migration to Israel. We can think of each migration as a movement of labor from the Foreign country to the Home country. What is the impact of this movement of labor on wages paid at Home? To answer this question, we make use of our work in Chapter 3, in which we studied how the wages paid to labor and the rentals paid to capital and land are determined by the prices of the goods produced. The prices of goods themselves are determined by supply and demand in world markets. In the analysis that follows, we treat the prices of goods as fixed and ask how the Home wage and the rentals paid to capital and land change as labor moves between countries.

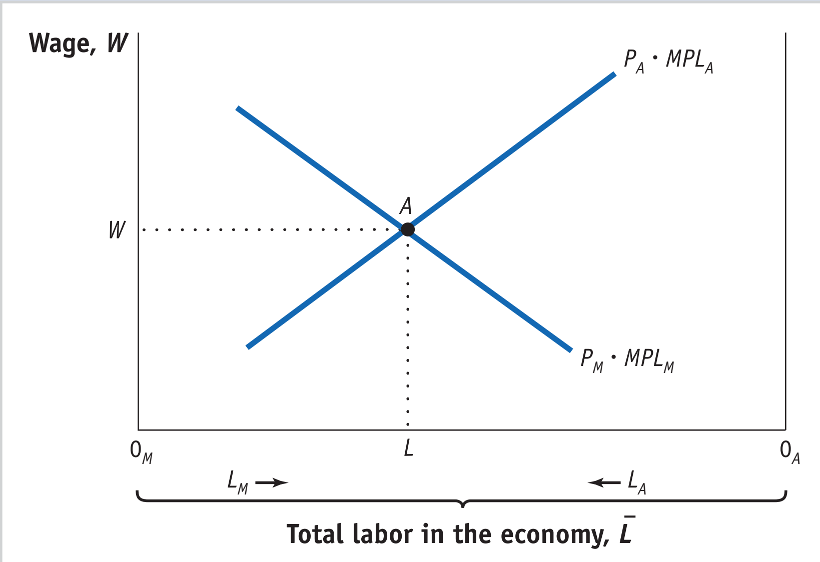
Effects of Immigration in the Short Run: Specific-Factors Model

We begin our study of the effect of factor movements between countries by using the specific-factors model we learned in Chapter 3 to analyze the short run, when labor is mobile among Home industries, but land and capital are fixed. After that, we consider the long run, when all factors are mobile among industries at Home.

Determining the Wage Figure 5-1 shows a diagram that we used in Chapter 3 to determine the equilibrium wage paid to labor. The horizontal axis measures the total amount of labor in the economy $\overline{L}$, which consists of the labor used in manufacturing L_M and the amount used in agriculture L_A:

$$L_M + L_A = \overline{L}$$

FIGURE 5-1



Home Labor Market The Home wage is determined at point A, the intersection of the marginal product of labor curves $P_M \cdot MPL_M$ and $P_A \cdot MPL_A$ in manufacturing and agriculture, respectively. The amount of labor used in manufacturing is measured from left to right, starting at the origin 0_M, and the amount of labor used in agriculture is measured from right to left, starting at the origin 0_A. At point A, 0_ML units of labor are used in manufacturing and 0_AL units of labor are used in agriculture.

In Figure 5-1, the amount of labor used in manufacturing L_M is measured from left (0_M) to right, and the amount of labor used in agriculture L_A is measured from right (0_A) to left.

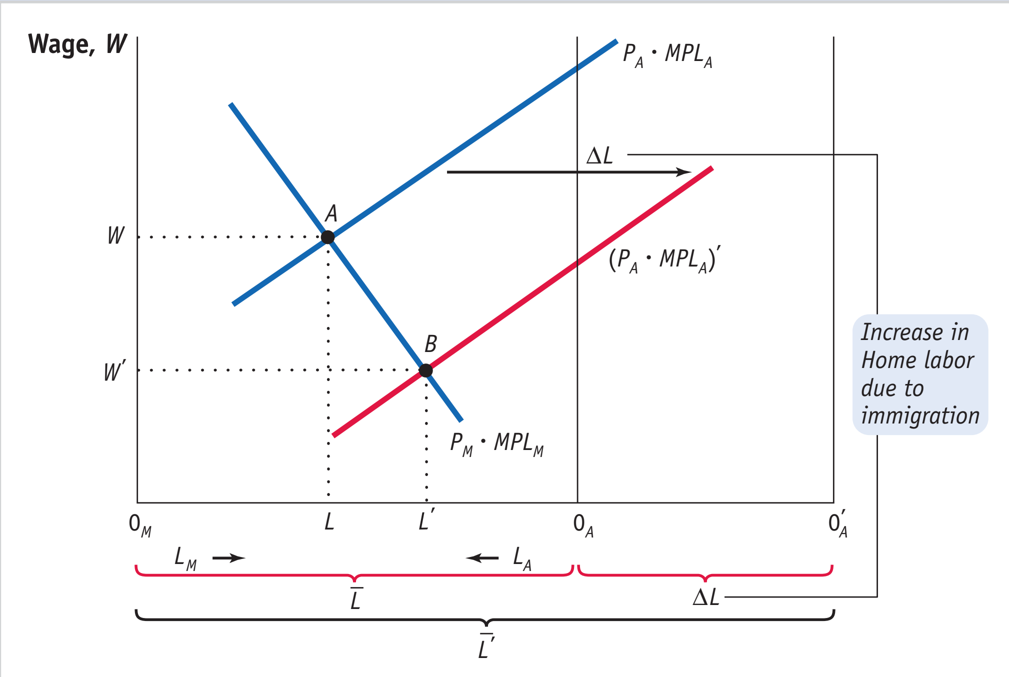
The two curves in Figure 5-1 take the marginal product of labor in each sector and multiply it by the price (P_M or P_A) in that sector. The graph of $P_M \cdot MPL_M$ is downward-sloping because as more labor is used in manufacturing, the marginal product of labor in that industry declines, and wages fall. The graph of $P_A \cdot MPL_A$ for agriculture is upward-sloping because we are measuring the labor used in agriculture L_A from *right to left* in the diagram: as more labor is used in agriculture (moving from right to left), the marginal product of labor in agriculture falls, and wages fall.

The equilibrium wage is at point A, the intersection of the marginal product curves $P_M \cdot MPL_M$ and $P_A \cdot MPL_A$ in Figure 5-1. At this point, 0_ML units of labor are used in manufacturing, and firms in that industry are willing to pay the wage $W = P_M \cdot MPL_M$. In addition, 0_AL units of labor are used in agriculture, and farmers are willing to pay the wage $W = P_A \cdot MPL_A$. Because wages are equal in the two sectors, there is no reason for labor to move between them, and the Home labor market is in equilibrium.

In the Foreign country, a similar diagram applies. We do not draw this but assume that the equilibrium wage abroad W^* is less than W in Home. This assumption would apply to the Cuban refugees, for example, who moved to Miami and to the Russian emigrants who moved to Israel to earn higher wages as well as to enjoy more freedom. As a result of this difference in wages, workers from Foreign would want to immigrate to Home and the Home workforce would increase by an amount ΔL, reflecting the number of immigrants.

Effect of Immigration on the Wage in Home The effects of immigration are shown in Figure 5-2. Because the number of workers at Home has grown by ΔL, we expand the size of the horizontal axis from $\bar{L}$ to $\bar{L}' = \bar{L} + \Delta L$. The right-most point on the horizontal axis, which is the origin 0_A for the agriculture industry, shifts to the

FIGURE 5-2



Increase in Home Labor When the amount of labor at Home increases by the amount ΔL, the origin for agriculture shifts to the right by that amount, from 0_A to $0'_A$. The marginal product of labor curve in agriculture also shifts right by the amount ΔL. Equilibrium in the Home labor market is now at point *B*: wages have fallen to *W′* and the amount of labor has increased in manufacturing (to $0_M L'$) and in agriculture (to $0'_A L'$).

right by the amount ΔL. As this origin moves rightward, it carries along with it the marginal product curve $P_A \cdot MPL_A$ for the agriculture industry (because the marginal product of labor curve is graphed relative to its origin). That curve shifts to the right by exactly the amount ΔL, the increase in the Home workforce. There is no shift in the marginal product curve $P_M \cdot MPL_M$ for the manufacturing industry because the origin 0_M for manufacturing has not changed.[4]

The new equilibrium Home wage is at point *B*, the intersection of the marginal product curves. At the new equilibrium, the wage is lower. Notice that the extra workers ΔL arriving at Home are shared between the agriculture and manufacturing industries: the number of workers employed in manufacturing is now $0_M L'$, which is higher than $0_M L$, and the number of workers employed in agriculture is $0'_A L'$, which is also higher than $0_A L$.[5] Because both industries have more workers but fixed amounts of capital and land, the wage in both industries declines due to the diminishing marginal product of labor.

We see, then, that the specific-factors model predicts that an inflow of labor will lower wages in the country in which the workers are arriving. This prediction has been confirmed in numerous episodes of large-scale immigration, as described in the applications that follow.

[4] If, instead, we had added labor to the left-hand side of the graph, the origin and marginal product curve for manufacturing would have shifted and those of agriculture would have remained the same, yielding the same final results as in Figure 5-2—the wage falls and both industries use more labor.

[5] We know that the number of workers employed in agriculture rises because the increase in workers in manufacturing, from $0_M L$ to $0_M L'$, is less than the total increase in labor ΔL.

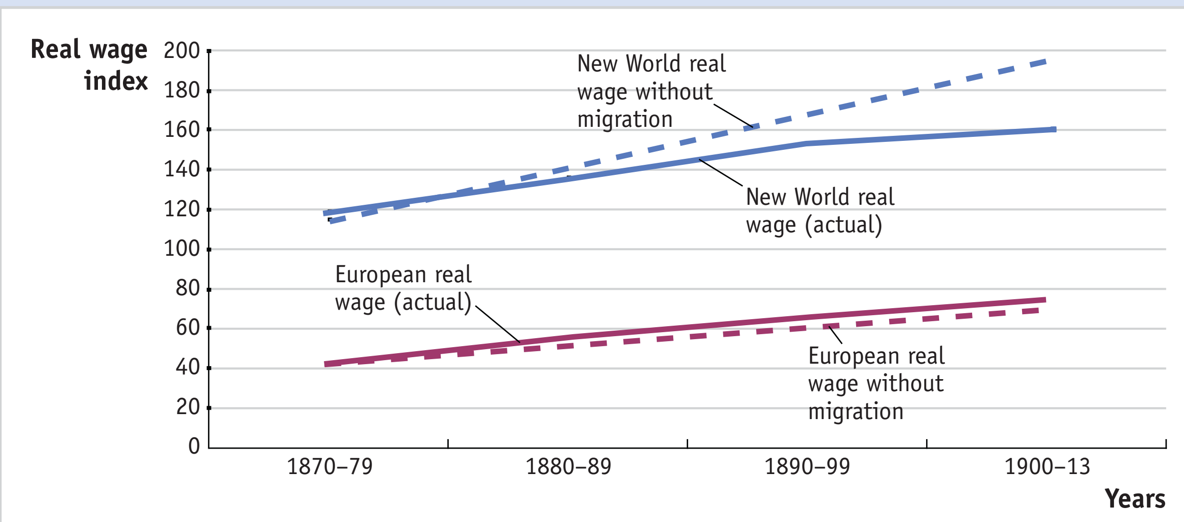
APPLICATION

Immigration to the New World

Between 1870 and 1913, some 30 million Europeans left their homes in the "Old World" to immigrate to the "New World" of North and South America and Australia. The population of Argentina rose by 60% because of immigration, and Australia and Canada gained 30% more people. The population of the United States increased by 17% as a result of immigration (and it absorbed the largest number of people, more than 15 million). The migrants left the Old World for the opportunities present in the New and, most important, for the higher real wages. In Figure 5-3, we show an index of average real wages in European countries and in the New World (an average of the United States, Canada, and Australia).[6] In 1870 real wages were nearly three times higher in the New World than in Europe—120 as compared with 40.

Real wages in both locations grew over time as capital accumulated and raised the marginal product of labor. But because of the large-scale immigration to the New World, wages grew more slowly there. By 1913, just before the onset of World War I, the wage index in the New World was at 160, so real wages had grown by (160 – 120)/120 = 33% over 43 years. In Europe, however, the wage index reached 75 by 1913, an increase of (75 – 40)/40 = 88% over 43 years. In 1870 real wages in the New World were three times as high as those in Europe, but by 1913 this wage gap was substantially reduced, and

FIGURE 5-3



Wages in Europe and the New World Large-scale migration from Europe to the New World in America and Australia closed the wage gap between the two locations. In 1870 wages in the New World were almost three times as high as wages in Europe, whereas in 1910 they were about twice as high. Migration also slowed the growth of wages in the New World relative to what they would have been without migration and allowed for slightly faster growth of wages in Europe.

Source: Alan M. Taylor and Jeffrey G. Williamson, 1997, "Convergence in the Age of Mass Migration," European Review of Economic History*, 1, April, 27–63.*

[6] From Alan M. Taylor and Jeffrey G. Williamson, 1997, "Convergence in the Age of Mass Migration," *European Review of Economic History*, 1, April, 27–63.

wages in the New World were only about twice as high as those in Europe. Large-scale migration therefore contributed to a "convergence" of real wages across the continents.

In Figure 5-3, we also show estimates of what real wages would have been if migration had not occurred. Those estimates are obtained by calculating how the marginal product of labor would have grown with capital accumulation but without the immigration. Comparing the actual real wages with the no-migration estimates, we see that the growth of wages in the New World was slowed by immigration (workers arriving), while wages in Europe grew slightly faster because of emigration (workers leaving). ■

APPLICATION

Immigration to the United States and Europe Today

The largest amount of migration is no longer from Europe to the "New World." Instead, workers from developing countries immigrate to wealthier countries in the European Union and North America, when they can. In many cases, the immigration includes a mix of low-skilled workers and high-skilled workers. During the 1960s and 1970s, some European countries actively recruited guest workers, called *gastarbeiters* in West Germany, to fill labor shortages in unskilled jobs. Many of these foreign workers have remained in Germany for years, some for generations, so they are no longer "guests" but long-term residents. At the end of 1994, about 2.1 million foreigners were employed in western Germany, with citizens of Turkey, the former Yugoslavia, Greece, and Italy representing the largest groups.

Today, the European Union has expanded to include many of the countries in Eastern Europe, and in principle there is free migration within the European Union. In practice, it can still be difficult for countries to absorb all the workers who want to enter, whether they come from inside or outside the Union. A recent example from Europe is the inflow of migrants from Northern Africa, especially from Tunisia and Libya. During 2011 and 2012, some 58,000 migrants escaped unrest in Africa and sailed on small boats to the island of Lampedusa in Italy. That inflow of migrants has created a situation not unlike the "Mariel boat lift" situation several decades ago in the United States, as discussed at the beginning of the chapter. The inflow has strained the ability of the European Union to maintain passport-free migration between countries. As described in **Headlines: Call for Return of Border Controls in Europe,** these migrants were not welcome to move freely from Italy to France, where some of them had families or friends.

Giorgio Cosulich/Getty Images

Immigrants from Tunisia, Africa arrive in Lampedusa, Italy on March 27, 2011.

In the United States, there is a widespread perception among policy makers that the current immigration system is not working and needs to be fixed. A new immigration bill was debated in the U.S. Congress in 2013. As described in **Headlines: The Economic Windfall of Immigration Reform,** there are several issues that this bill needs to address, related to both illegal and legal immigration.

It is estimated that there are about 12 million illegal immigrants in the United States, many of them from Mexico. Gaining control over U.S. borders is one goal of immigration policy, but focusing on that goal alone obscures the fact that the majority of immigrants who enter the United States each year are legal.

HEADLINES

Call for Return of Border Controls in Europe

In 2011, Nicolas Sarkozy, the French president at the time, and Silvio Berlusconi, the Italian prime minister at the time, called for limits on passport-free travel among European Union countries in response to the flood of North African immigrants entering Italy through the island of Lampedusa.

Nicolas Sarkozy and Silvio Berlusconi are expected to call on Tuesday for a partial reintroduction of national border controls across Europe, a move that would put the brakes on European integration and curb passport-free travel for more than 400 million people in 25 countries.

The French president and the Italian prime minister are meeting in Rome after weeks of tension between their two countries over how to cope with an influx of more than 25,000 immigrants fleeing revolutions in north Africa. The migrants, mostly Tunisian, reached the EU by way of Italian islands such as Lampedusa, but many hoped to get work in France where they have relatives and friends.

Earlier this month, Berlusconi's government outraged several EU governments, including France, by offering the migrants temporary residence permits which, in principle, allowed them to travel to other member states under the Schengen agreement. An Italian junior minister said on Sunday that Rome had so far issued some 8,000 permits and expected the number would rise to 11,000.

Launched in 1995, Schengen allows passport-free travel in most of the EU, Switzerland, Norway and Iceland. But the documents issued by the Italian authorities are only valid if the holders can show they have the means to support themselves, and French police have rounded up or turned back an unknown number of migrants in recent days.

On 17 April, Paris blocked trains crossing the frontier at Ventimiglia in protest at the Italian initiative. "Rarely have the two countries seemed so far apart," said Le Monde in an editorial on Monday.

Yet, with both leaders under pressure from the far right, French and Italian officials appear to have agreed a common position on amending Schengen so that national border checks can be reintroduced in "special circumstances".

Source: Excerpted from John Hooper and Ian Traynor, "Sarkozy and Berlusconi to call for return of border controls in Europe," The Guardian, *April 25 2011, electronic edition. Copyright Guardian News & Media Ltd 2011.*

Persons seeking to legally enter the United States sometimes must wait a very long time, because under current U.S. law, migrants from any one foreign country cannot number more than 7% of the total legal immigrants into the United States each year. Giovanni Peri, the author of "The Economic Windfall of Immigration Reform" article, proposes that businesses should be allowed to compete for migrants who have the skills needed for the jobs that the businesses have to offer. Firms could, for example, compete by bidding for temporary work permits in auctions. After obtaining the work permits, the firms could then sell them to other firms.[7] In this way, the permits would eventually be bought by the firms that valued them most highly, promoting efficiency in the flow of migrants.

Such an auction scheme could be used for seasonal agricultural workers, for example, some of whom legally enter the United States under the H-2A visa program. An

[7] The proposal to auction work permits is discussed at greater length in: Giovanni Peri, "Rationalizing U.S. Immigration Policy: Reforms for Simplicity, Fairness, and Economic Growth," Discussion paper 2012–01, The Hamilton Project, Washington D.C. May 2012. A video presentation is available at: http://www.hamiltonproject.org/multimedia/video/u.s._immigration_policy_-_roundtable_a_market-based_approach_to_immigr/.

HEADLINES

The Economic Windfall of Immigration Reform

Writing during the U.S. debate over immigration reform in 2013, Professor Giovanni Peri discusses three principles that reform should follow. He argues that there are large gains from increasing the supply of highly-skilled immigrants to the United States, by allowing firms to bid for temporary work permits.

After months of acrimony, it now appears that immigration reform, and a comprehensive one at that, is within reach. While most of the debates have been about the immediate consequences of any change in policy, the goal should be to promote economic growth over the next 40 years.

Much of the reform debate has centered around granting legal status to undocumented immigrants, conditional upon payment of fees and back taxes. From an economic point of view, this will likely have only a modest impact, especially in the short run. Yet the problem of undocumented immigrants is likely to come back unless we find better ways to legally accommodate new immigrants. Much larger economic gains are achievable if we reorganize the immigration system to do that, following three fundamental principles.

The first is simplification. The current visa system is the accumulation of many disconnected provisions. Some rules, set in the past—such as the 7% limit on permanent permits to any nationality—are arbitrary and produce delays, bottlenecks and inefficiencies. . . . A more rational approach would have the government set overall targets and simple rules for temporary and permanent working permits, deciding the balance between permits in "skilled" and "unskilled" jobs. But the government should not micromanage permits, rules and limits in specific occupations. Employers compete to hire immigrants, and they are best suited at selecting the individuals who will be the most productive in the jobs that are needed.

The second important principle is that the number of temporary work visas should respond to the demand for labor. Currently the limited number of these visas is set with no consideration for economic conditions. Their number is rarely revised. In periods of high demand, the economic incentives to bypass the limits and hire undocumented workers are large. . . . [W]e propose that temporary permits to hire immigrants should be made tradable and sold by the government in auctions to employers. Such a "cap and trade" system would ensure efficiency. The auction price of permits would signal the demand for immigrants and guide the upward and downward adjustment of the permit numbers over years.

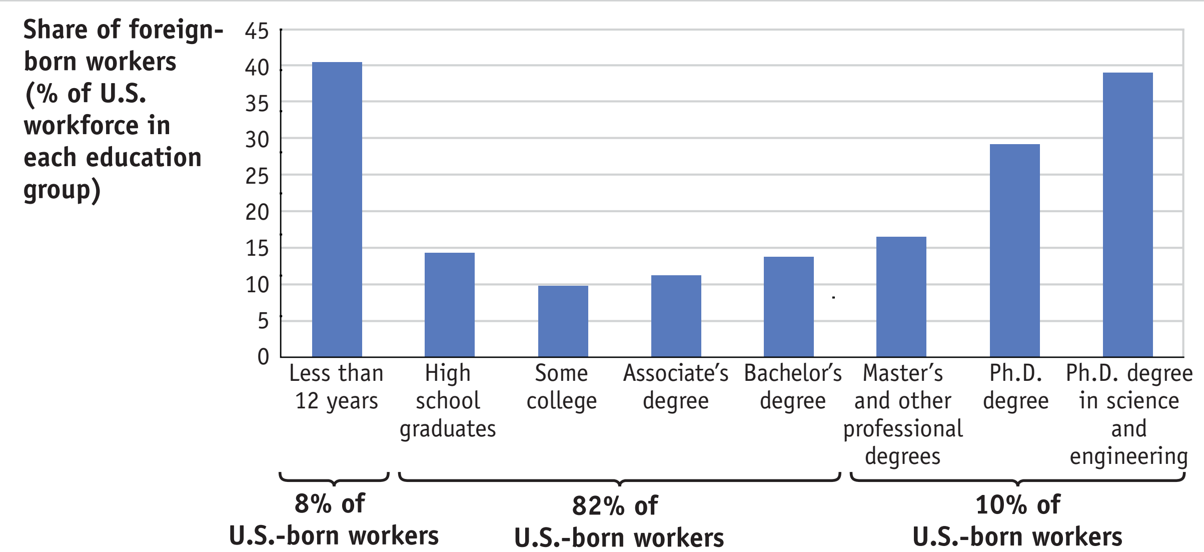
The third principle governing immigration reform is that scientists, engineers and innovators are the main drivers of productivity and of economic growth. . . . I have found in a study published in January that foreign scientists and engineers brought into this country under the H1B visa program have contributed to 10%–20% of the yearly productivity growth in the U.S. during the period 1990–2010. This allowed the GDP per capita to be 4% higher that it would have been without them—that's an aggregate increase of output of $615 billion as of 2010.

Source: Excerpted from Giovanni Peri, "The Economic Windfall of Immigration Reform," The Wall Street Journal*, February 13th 2013. p. A15. Reprinted with permission of The Wall Street Journal, Copyright © (2013) Dow Jones & Company, Inc. All Rights Reserved Worldwide.*

auction could also expand the existing H-1B visa program for engineers, scientists, and other skilled workers needed in high-technology industries. The H-1B program was established during the Clinton administration to attract highly skilled immigrants to the United States, and it continues today. According to this article, the inflow of highly skilled immigrants on H-1B visas can explain 10% to 20% of the yearly productivity growth in the United States, as discussed later in the chapter.

The potential competition that immigrants create for U.S. workers with the same educational level is illustrated in Figure 5-4. On the vertical axis we show the share of immigrants (legal and illegal) as a percentage of the total workforce in the United States with that educational level. For example, from the first bar we see that immigrants account for 40% of the total number of workers in the United States that do not have a high-school education (the remaining 60% are U.S. born). Many of those

FIGURE 5-4



Share of Foreign-Born Workers in U.S. Workforce, 2010 This figure shows the share of foreign-born workers in the U.S. workforce, categorized by educational level. For example, among workers with 0 to 11 years of education, about 40% were foreign-born. At the other end of the spectrum, the foreign-born make up 16% of workers with Master's and professional degrees, almost 30% of those with Ph.D.'s, and almost 40% of those with Ph.D.'s in science and engineering. In the middle educational levels (high school and college graduates), there are much smaller shares of foreign-born workers, ranging from 10% to 15%. On the horizontal axis, we show the share of U.S.-born workers in each educational group. Only about 8% to 10% of U.S.-born workers are categorized in each of the low-education and high-education groups; most U.S.-born workers are either high school graduates or college graduates.

Source: 2010 American Community Survey, U.S. Census Bureau.

immigrants without a high-school education are illegal, but we do not know the exact number. We know, however, that the share of high-school dropouts in the U.S.-born workforce is quite small: only 8% of workers born in the United States do not have a high-school education. That percentage is shown on the horizontal axis of Figure 5-4. So, even though illegal immigrants attract much attention in the U.S. debate over immigration, those immigrants with less than high-school education are competing with a small share of U.S.-born workers.

As we move to the next bars in Figure 5-4, the story changes. A large portion of U.S.-born workers—82% as shown on the horizontal axis—have completed high school education, may have started college, or graduated with an Associate's or Bachelor's degree. The shares of these educational groups that are composed of immigrants are quite small, ranging between 10% and 15% (the remainder being U.S.-born workers). So in these middle levels of education, immigrants are not numerous enough to create a significant amount of competition with U.S.-born workers for jobs.

At the other end of the spectrum, 10% of U.S.-born workers have Master's degrees or Ph.D.'s. Within this high-education group, foreign-born Master's-degree holders make up 16% of the U.S. workforce, and foreign-born Ph.D.'s make up nearly 30%, of the U.S. workforce. Furthermore, an even higher fraction of foreign-born immigrants, close to 40%, have Ph.D.'s in science and engineering fields (with slightly more than 60% being U.S. born). To summarize, Figure 5-4 shows that immigrants into the United States compete primarily with workers at the lowest and highest ends of the educational levels and much less with the majority of U.S.-born workers with mid-levels of education.

If we extend the specific-factors model to allow for several types of labor distinguished by educational level but continue to treat capital and land as fixed, then the greatest negative impact of immigration on wages would be for the lowest- and highest-educated U.S. workers. That prediction is supported by estimates of the effect of immigration on U.S. wages: from 1990 to 2006, immigration led to a fall in wages of 7.8% for high school dropouts and 4.7% for college graduates. But the impact of immigration on the wages of the majority of U.S. workers (those with mid-levels of education) is much less: wages of high school graduates decreased by 2.2% from 1990 to 2006, and wages of individuals with less than four years of college decreased by less than 1%. The negative impact of immigration on wages is thus fairly modest for most workers and is offset when capital moves between industries, as discussed later in the chapter. ■

Other Effects of Immigration in the Short Run

The United States and Europe have both welcomed foreign workers into specific industries, such as agriculture and the high-tech industry, even though these workers compete with domestic workers in those industries. This observation suggests that there must be benefits to the industries involved. We can measure the potential benefits by the payments to capital and land, which we refer to as "rentals." We saw in Chapter 3 that there are two ways to compute the rentals: either as the earnings left over in the industry after paying labor or as the marginal product of capital or land times the price of the good produced in each industry. Under either method, the owners of capital and land benefit from the reduction in wages due to immigration.

Rentals on Capital and Land Under the first method for computing the rentals, we take the revenue earned in either manufacturing or agriculture and subtract the payments to labor. If wages fall, then there is more left over as earnings of capital and land, so these rentals are higher. Under the second method for computing rentals, capital and land earn their marginal product in each industry times the price of the industry's good. As more labor is hired in each industry (because wages are lower), the marginal products of capital and land both increase. The increase in the marginal product occurs because each machine or acre of land has more workers available to it, and that machine or acre of land is therefore more productive. So under the second method, too, the marginal products of capital and land rise and so do their rentals.

From this line of reasoning, we should not be surprised that owners of capital and land often support more open borders, which provide them with foreign workers who can be employed in their industries. The restriction on immigration in a country should therefore be seen as a compromise between entrepreneurs and landowners who might welcome the foreign labor; local unions and workers who view migrants as a potential source of competition leading to lower wages; and the immigrant groups themselves, who if they are large enough (such as the Cuban population in Miami) might also have the ability to influence the political outcome on immigration policy.

Effect of Immigration on Industry Output One final effect of labor immigration is its effect on the output of the industries. In Figure 5-2, the increase in the labor force due to immigration led to more workers being employed in each of the industries: employment increased from 0_ML to $0_ML'$ in manufacturing and from 0_AL to

$0'_A L'$ in agriculture. With more workers and the same amount of capital or land, the output of both industries rises. This outcome is shown in Figure 5-5—immigration leads to an outward shift in the production possibilities frontier (PPF). With constant prices of goods (as we assumed earlier, because prices are determined by world supply and demand), the output of the industries rises from point *A* to point *B*.

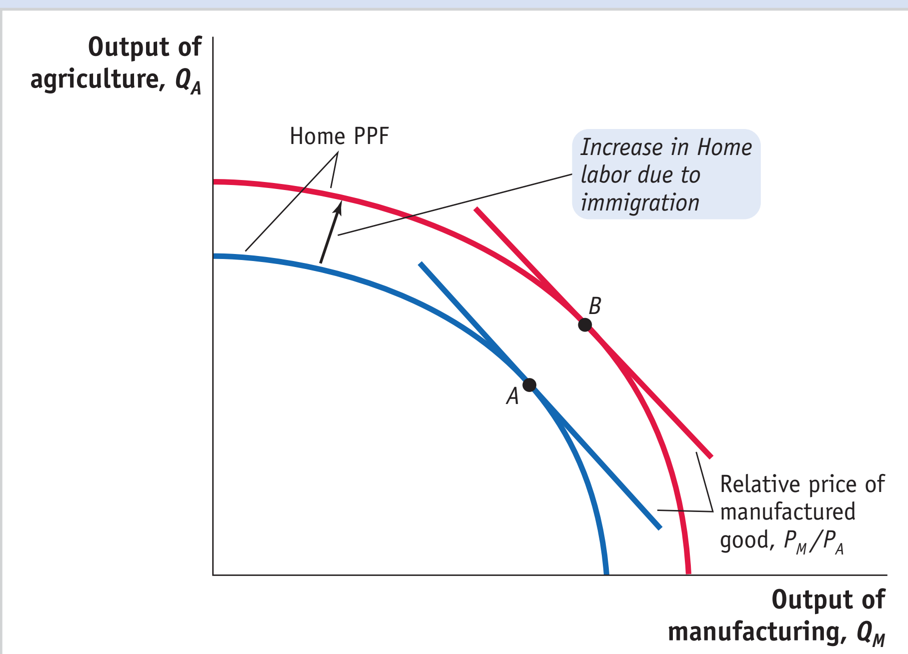
Although it may seem obvious that having more labor in an economy will increase the output of both industries, it turns out that this result depends on the short-run nature of the specific-factors model, when capital and land in each industry are fixed. If instead these resources can move between the industries, as would occur in the long run, then the output of one industry will increase but that of the other industry will decline, as we explain in the next section.

Effects of Immigration in the Long Run

We turn now to the long run, in which all factors are free to move between industries. Because it is complicated to analyze a model with three factors of production—capital, land, and labor—all of which are fully mobile between industries, we will ignore land and assume that only labor and capital are used to produce two goods: computers and shoes. The long-run model is just like the Heckscher-Ohlin model studied in the previous chapter except that we now allow labor to move between countries. (Later in the chapter, we allow capital to move between the countries.)

The amount of capital used in computers is K_C, and the amount of capital used in shoe production is K_S. These quantities add up to the total capital available in the economy: $K_C + K_S = \overline{K}$. Because capital is fully mobile between the two sectors in the

FIGURE 5-5



Shift in Home Production Possibilities Curve With the increase in labor at Home from immigration, the production possibilities frontier shifts outward and the output of both industries increases, from point *A* to point *B*. Output in both industries increases because of the short-run nature of the specific-factors model; in the short run, land and capital do not move between the industries, and the extra labor in the economy is shared between both industries.

long run, it must earn the same rental R in each. The amount of labor used to manufacture computers is L_C, and the labor used in shoe production is L_S. These amounts add up to the total labor in the economy, $L_C + L_S = \overline{L}$, and all labor earns the same wage of W in both sectors.

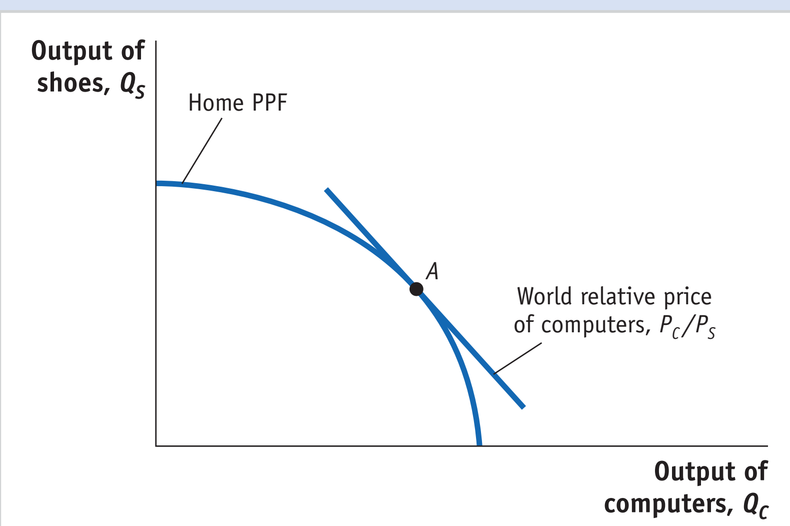
In our analysis, we make the realistic assumption that more labor per machine is used in shoe production than in computer production. That assumption means that shoe production is labor-intensive compared with computer production, so the labor–capital ratio in shoes is higher than it is in computers: $L_S/K_S > L_C/K_C$. Computer production, then, is capital-intensive compared with shoes, and the capital–labor ratio is higher in computers: $K_C/L_C > K_S/L_S$.

The PPF for an economy producing shoes and computers is shown in Figure 5-6. Given the prices of both goods (determined by supply and demand in world markets), the equilibrium outputs are shown at point A, at the tangency of the PPF and world relative price line. Our goal in this section is to see how the equilibrium is affected by having an inflow of labor into Home as a result of immigration.

"You seem familiar, yet somehow strange—are you by any chance Canadian?"

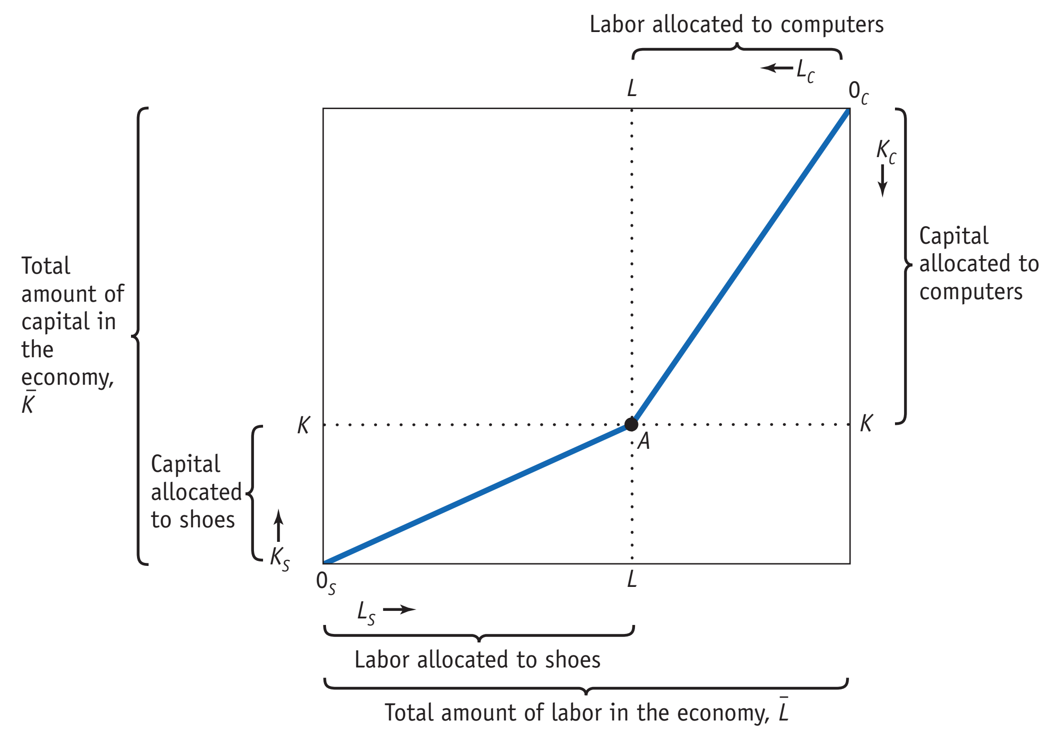
Box Diagram To analyze the effect of immigration, it is useful to develop a new diagram to keep track of the amount of labor and capital used in each industry. Shown as a "box diagram" in Figure 5-7, the length of the top and bottom horizontal axes is the total amount of labor $\overline{L}$ at Home, and the length of the right and left vertical axes is the total amount of capital $\overline{K}$ at Home. A point like point A in the diagram indicates that 0_SL units of labor and 0_SK units of capital are used in shoes, while 0_CL units of labor and 0_CK units of capital are used in computers. Another way to express this is that the line 0_SA shows the amount of labor and capital used in shoes and the line 0_CA shows the amount of labor and capital used in computers.

FIGURE 5-6



Production Possibilities Frontier Shown here is the production possibilities frontier (PPF) between two manufactured goods, computers and shoes, with initial equilibrium at point A. Domestic production takes place at point A, which is the point of tangency between the world price line and the PPF.

FIGURE 5-7



Allocation of Labor and Capital in a Box Diagram The top and bottom axes of the box diagram measure the amount of labor, $\bar{L}$, in the economy, and the side axes measure the amount of capital, $\bar{K}$. At point A, 0_SL units of labor and 0_SK units of capital are used in shoe production, and 0_CL units of labor and 0_CK units of capital are used in computers. The K/L ratios in the two industries are measured by the slopes of 0_SA and 0_CA, respectively.

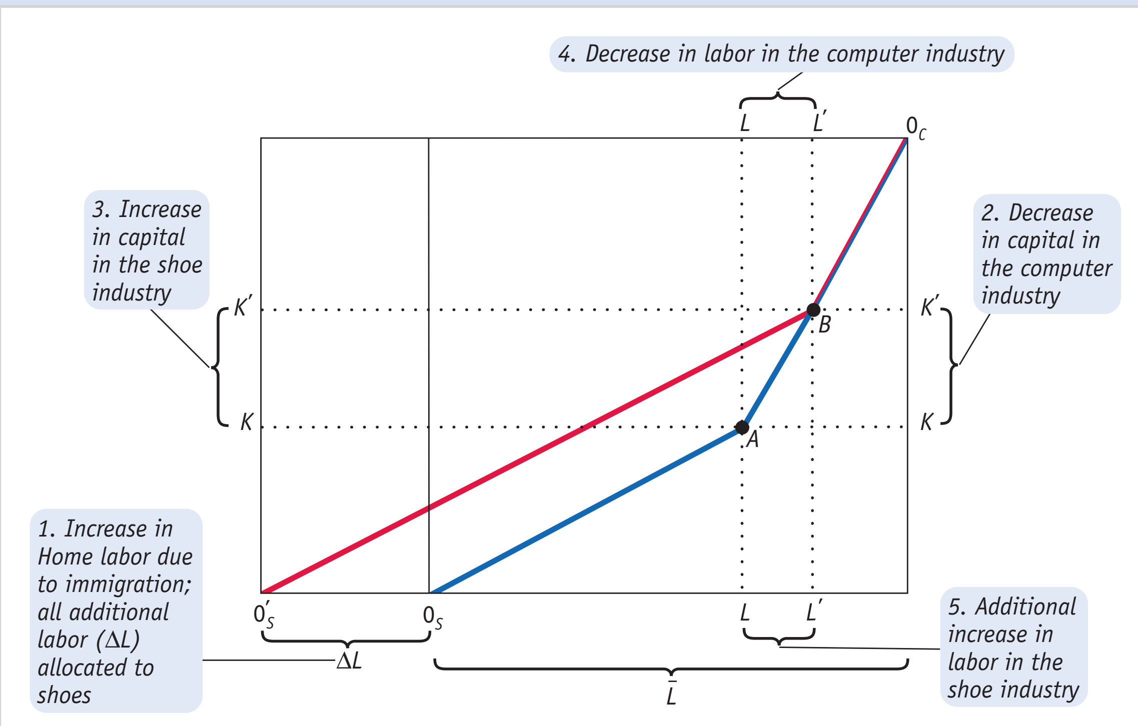
Notice that the line 0_SA for shoes is flatter than the line 0_CA for computers. We can calculate the slopes of these lines by dividing the vertical distance by the horizontal distance (the rise over the run). The slope of 0_SA is $0_SK/0_SL$, the capital–labor ratio used in the shoe industry. Likewise, the slope of 0_CA is $0_CK/0_CL$, the capital–labor ratio for computers. The line 0_SA is flatter than 0_CA, so the capital–labor ratio in the shoe industry is less than that in computers; that is, there are fewer units of capital per worker in the shoe industry. This is precisely the assumption that we made earlier. It is a realistic assumption given that the manufacture of computer components such as semiconductors requires highly precise and expensive equipment, which is operated by a small number of workers. Shoe production, on the other hand, requires more workers and a smaller amount of capital.

Determination of the Real Wage and Real Rental In addition to determining the amount of labor and capital used in each industry in the long run, we also need to determine the wage and rental in the economy. To do so, we use the logic introduced in Chapter 3: the wage and rental are determined by the marginal products of labor and capital, which are in turn determined by the capital–labor ratio in either industry. If there is a higher capital–labor ratio (i.e., if there are more machines per worker), then by the law of diminishing returns, the marginal product of capital and the real rental must be lower. Having more machines per worker means that the marginal product of labor (and hence the real wage) is higher because each worker is more productive. On the other hand, if there is a higher labor–capital ratio (more workers per machine), then the marginal product of labor must be lower because of diminishing returns, and hence the real wage is lower, too. In addition, having more workers per machine means that the marginal product of capital and the real rental are both higher.

The important point to remember is that each amount of labor and capital used in Figure 5-7 along line $0_S A$ corresponds to a particular capital–labor ratio for shoe manufacture and therefore a particular real wage and real rental. We now consider how the labor and capital used in each industry will change due to immigration at Home. Although the total amount of labor and capital used in each industry changes, we will show that the capital–labor ratios are unaffected by immigration, which means that the immigrants can be absorbed with no change at all in the real wage and real rental.

Increase in the Amount of Home Labor Suppose that because of immigration, the amount of labor at Home increases from $\overline{L}$ to $\overline{L}' = \overline{L} + \Delta L$. This increase expands the labor axes in the box diagram, as shown in Figure 5-8. Rather than allocating $\overline{L}$ labor and $\overline{K}$ capital between the two industries, we must now allocate $\overline{L}'$ labor and

FIGURE 5-8



Increase in Home Labor With an increase in Home labor from $\overline{L}$ to $\overline{L} + \Delta L$, the origin for the shoe industry shifts from 0_S to $0'_S$. At point B, $0'_S L'$ units of labor and $0'_S K'$ units of capital are used in shoes, whereas $0_C L'$ units of labor and $0_C K'$ units of capital are used in computers. In the long run, industry outputs adjust so that the capital–labor ratios in each industry at point B (the slopes of $0'_S B$ and $0_C B$) are unchanged from the initial equilibrium at point A (the slopes of $0_S A$ and $0_C A$). To achieve this outcome, all new labor resulting from immigration is allocated to the shoe industry, and capital and *additional* labor are transferred from computers to shoes, keeping the capital–labor ratio in both industries unchanged.

$\overline{K}$ capital. The question is how much labor and capital will be used in each industry so that the total amount of both factors is fully employed?

You might think that the only way to employ the extra labor is to allocate more of it to both industries (as occurred in the short-run specific-factors model). This outcome would tend to lower the marginal product of labor in both industries and therefore lower the wage. But it turns out that such an outcome will not occur in the long-run model because when capital is also able to move between the industries, industry outputs will adjust to keep the capital–labor ratios in each industry constant. Instead of allocating the extra labor to both industries, all the extra labor (ΔL) will be allocated to shoes, the *labor*-intensive industry. Moreover, along with that extra labor, some capital is withdrawn from computers and allocated to shoes. To maintain the capital–labor ratio in the computer industry, some labor will also leave the computer industry, along with the capital, and go to the shoe industry. Because all the new workers in the shoe industry (immigrants plus former computer workers) have the same amount of capital to work with as the shoe workers prior to immigration, the capital–labor ratio in the shoe industry stays the same. *In this way, the capital–labor ratio in each industry is unchanged and the additional labor in the economy is fully employed.*

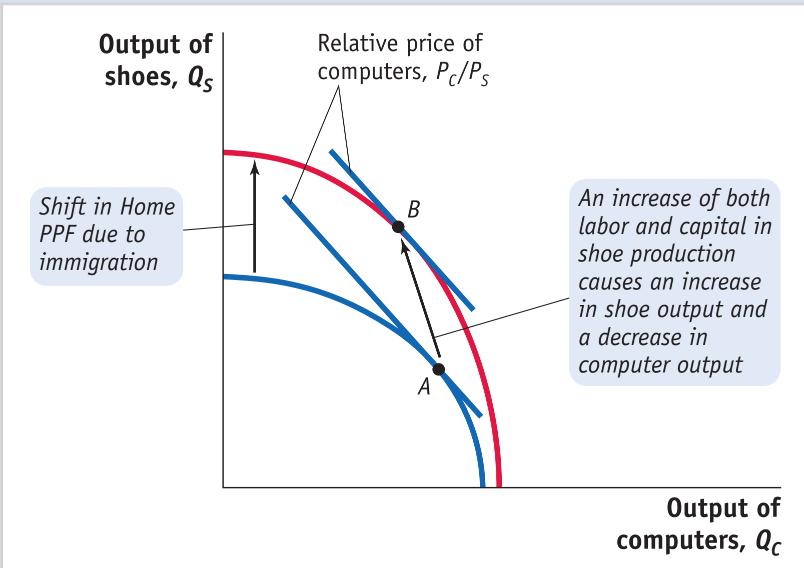
This outcome is illustrated in Figure 5-8, where the initial equilibrium is at point A. With the inflow of labor due to immigration, the labor axis expands from $\overline{L}$ to $\overline{L} + \Delta L$, from 0_S to $0'_S$. and the origin for the shoe industry shifts from 0_S to $0'_S$. Consider point B as a possible new equilibrium. At this point, $0'_S L'$ units of labor and $0'_S K'$ units of capital are used in shoes, while $0_C L'$ units of labor and $0_C K'$ units of capital are used in computers. Notice that the lines $0_S A$ and $0'_S B$ are parallel and have the same slope, and similarly, the lines $0_C A$ and $0_C B$ have the same slope. The extra labor has been employed by *expanding* the amount of labor and capital used in shoes (the line $0'_S B$ is longer than $0_S A$) and *contracting* the amount of labor and capital used in computers (the line $0_C B$ is smaller than $0_C A$). That the lines have the same slope means that the capital–labor ratio used in each industry is exactly the same before and after the inflow of labor.

What has happened to the wage and rentals in the economy? Because the capital–labor ratios are unchanged in both industries, the marginal products of labor and capital are also unchanged. Therefore, the wage and rental do not change at all because of the immigration of labor! This result is very different from what happens in the short-run specific-factors model, which showed that immigration depressed the wage and raised the rental on capital and land. In the long-run model, when capital can move between industries, an inflow of labor has no impact on the wage and rental. Instead, the extra labor is employed in shoes, by combining it with capital and additional labor that has shifted out of computers. In that way, the capital–labor ratios in both industries are unchanged, as are the wage and rental.

Effect of Immigration on Industry Outputs What is the effect of immigration on the output of each industry? We have already seen from Figure 5-8 that more labor and capital are used in the labor-intensive industry (shoes), whereas less labor and capital are used in the capital-intensive industry (computers). Because the factors of production both increase or both decrease, it follows that the output of shoes expands and the output of computers contracts.

This outcome is shown in Figure 5-9, which shows the outward shift of the PPF due to the increase in the labor endowment at Home. Given the prices of computers and shoes, the initial equilibrium was at point A. At this point, the slope of the PPF equals the relative price of computers, as shown by the slope of the line tangent to the

FIGURE 5-9



The Long-Run Effect on Industry Outputs of an Increase in Home Labor With an increase in the amount of labor at Home, the PPF shifts outward. The output of shoes increases, while the output of computers declines as the equilibrium moves from point *A* to *B*. The prices of goods have not changed, so the slopes of the PPFs at points *A* and *B* (i.e., the relative price of computers) are equal.

PPF. With unchanged prices for the goods, and more labor in the economy, the equilibrium moves to point *B*, with greater output of shoes but reduced output of computers. Notice that the slope of the PPFs at points *A* and *B* is identical because the relative price of computers is unchanged. As suggested by the diagram, the expansion in the amount of labor leads to an uneven outward shift of the PPF—it shifts out more in the direction of shoes (the labor-intensive industry) than in the direction of computers. This asymmetric shift illustrates that the new labor is employed in shoes and that this additional labor pulls capital and additional labor out of computers in the long run, to establish the new equilibrium at point *B*. *The finding that an increase in labor will expand one industry but contract the other holds only in the long run; in the short run, as we saw in Figure 5-5, both industries will expand.* This finding, called the **Rybczynski theorem,** shows how much the long-run model differs from the short-run model. The long-run result is named after the economist T. N. Rybczynski, who first discovered it.

Rybczynski Theorem

The formal statement of the Rybczynski theorem is as follows: in the Heckscher-Ohlin model with two goods and two factors, an increase in the amount of a factor found in an economy will increase the output of the industry using that factor intensively and decrease the output of the other industry.

We have proved the Rybczynski theorem for the case of immigration, in which labor in the economy grows. As we find later in the chapter, the same theorem holds when capital in the economy grows: in this case, the industry using capital intensively expands and the other industry contracts.[8]

[8] Furthermore, the Rybczynski theorem can be used to compare the output of the same industry across two countries, where the two countries have identical technologies but differing factor endowments as in the Heckscher-Ohlin model. See Problem 7 at the end of the chapter.

Effect of Immigration on Factor Prices The Rybczynski theorem, which applies to the long-run Heckscher-Ohlin model with two goods and two factors of production, states that an increase in labor will expand output in one industry but contract output in the other industry. Notice that the change in outputs in the Rybczynski theorem goes hand in hand with the previous finding that the wage and rental will not change due to an increase in labor (or capital). The reason that factor prices do not need to change is that the economy can absorb the extra amount of a factor by increasing the output of the industry using that factor intensively and reducing the output of the other industry. The finding that factor prices do not change is sometimes called the **factor price insensitivity** result.

Factor Price Insensitivity Theorem

The factor price insensitivity theorem states that: in the Heckscher-Ohlin model with two goods and two factors, an increase in the amount of a factor found in an economy can be absorbed by changing the outputs of the industries, without any change in the factor prices.

The applications that follow offer evidence of changes in output that absorb new additions to the labor force, as predicted by the Rybczynski theorem, without requiring large changes in factor prices, as predicted by the factor price insensitivity result.

APPLICATION

The Effects of the Mariel Boat Lift on Industry Output in Miami

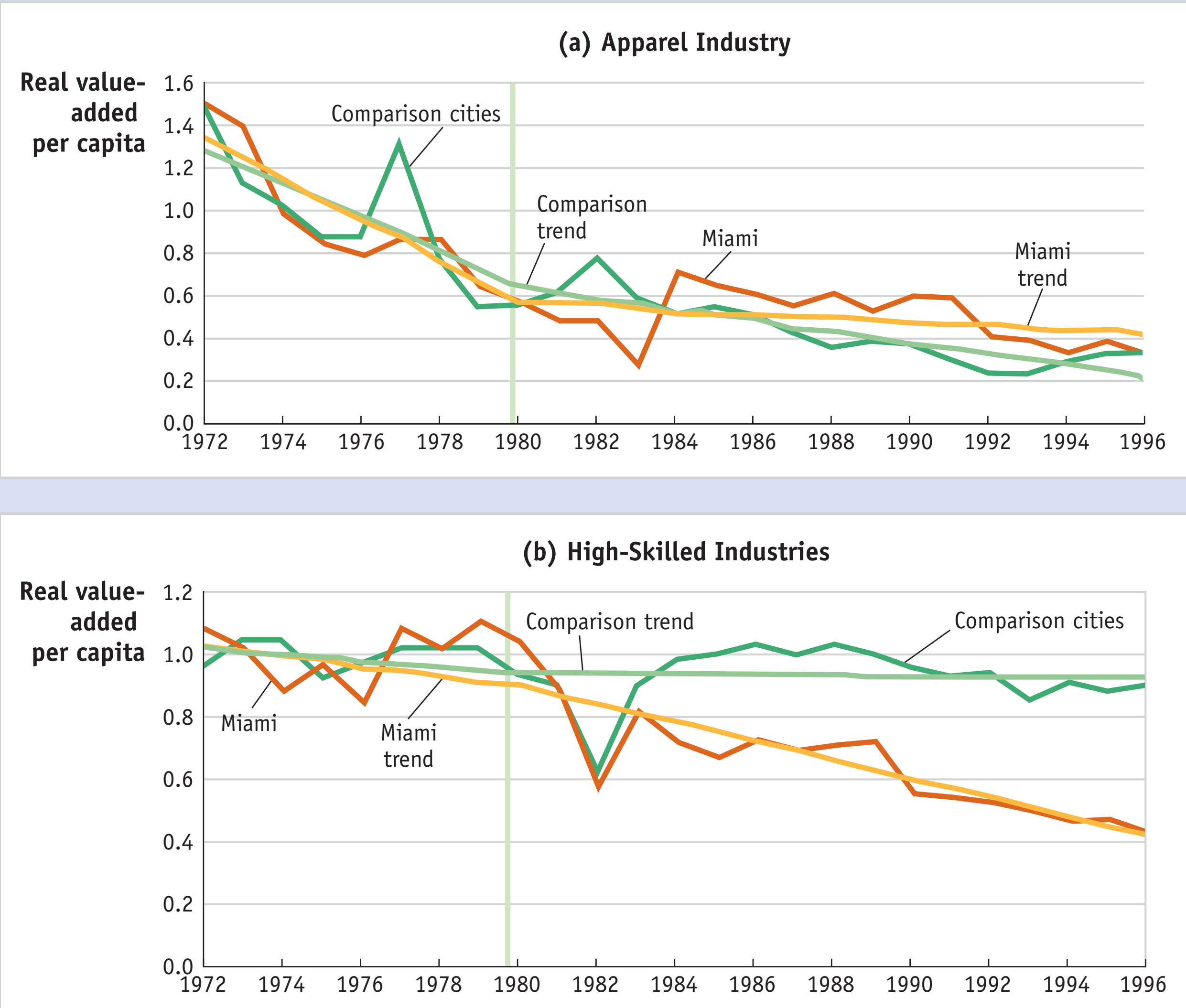
Now that we have a better understanding of long-run adjustments due to changes in factor endowments, let us return to the case of the Mariel boat lift to Miami in 1980. We know that the Cuban refugees were less skilled than the average labor force in Miami. According to the Rybczynski theorem, then, we expect some unskilled-labor–intensive industry, such as footwear or apparel, to expand. In addition, we expect that some skill-intensive industry, such as the high-tech industry, will contract. Figure 5-10 shows how this prediction lines up with the evidence from Miami and some comparison cities.[9]

Panel (a) of Figure 5-10 shows real value-added in the apparel industry for Miami and for an average of comparison cities. **Real value-added** measures the payments to labor and capital in an industry corrected for inflation. Thus, real value-added is a way to measure the output of the industry. We divide output by the population of the city to obtain real value-added per capita, which measures the output of the industry adjusted for the city size.

Panel (a) shows that the apparel industry was declining in Miami and the comparison cities before 1980. After the boat lift, the industry continued to decline but at a slower rate in Miami; the trend of output per capita for Miami has a smaller slope (and hence a smaller rate of decline in output) than that of the trend for comparison cities from 1980 onward. Notice that there is an increase in industry output in Miami from 1983 to 1984 (which may be due to new data collected that year), but even when averaging this out as the trend lines do, the industry decline in Miami is slightly

[9] Figure 5-10 and the material in this application are drawn from Ethan Lewis, 2004, "How Did the Miami Labor Market Absorb the Mariel Immigrants?" Federal Reserve Bank of Philadelphia Working Paper No. 04-3.

FIGURE 5-10



Industry Value-Added in Miami Shown here are real value-added in the apparel industry and in high-skilled industries (measured relative to the city population), for Miami and an average of comparison cities. In panel (a), with the inflow of refugees from Cuba in 1980, real value-added in the apparel industry in Miami rose from 1983 to 1984, and the trend decline of this industry in Miami was slower (i.e., value-added did not fall as fast) after 1980 than in the comparison cities. In panel (b), real value-added in Miami in high-skilled industries fell faster after 1980 than in the comparison cities. Both these findings are consistent with the Rybczynski theorem.

Source: Ethan Lewis, 2004, "How Did the Miami Labor Market Absorb the Mariel Immigrants?" Federal Reserve Bank of Philadelphia Working Paper No. 04–3.

slower than in the comparison cities after 1980. This graph provides some evidence of the Rybczynski theorem at work: the reduction in the apparel industry in Miami was slower than it would have been without the inflow of immigrants.

What about the second prediction of the Rybczynski theorem: Did the output of any other industry in Miami fall because of the immigration? Panel (b) of Figure 5-10 shows that the output of a group of skill-intensive industries (including motor vehicles, electronic equipment, and aircraft) fell more rapidly in Miami after 1980. These data may also provide some evidence in favor of the Rybczynski theorem. However, it also happened that with the influx of refugees, there was a flight of homeowners away from Miami, and some of these were probably high-skilled workers. So the decline in the group of skill-intensive industries, shown in panel (b), could instead be due to this population decline. The change in industry outputs in Miami provides some evidence in favor of the Rybczynski theorem. Do these changes in industry outputs in Miami also provide an adequate explanation for why wages of unskilled workers did not decline, or is there some other explanation? An alternative explanation for the finding that wages did not change comes from comparing the use of computers in Miami with national trends. Beginning in the early 1980s, computers became increasingly used in the workplace. The adoption of computers is called a "skill-biased technological change." That is, computers led to an increase in the demand for high-skilled workers and reduced the hiring of low-skilled workers. This trend occurred across the United States and in other countries.

In Miami, however, computers were adopted somewhat more slowly than in cities with similar industry mix and ethnic populations. One explanation for this finding is that firms in many industries, not just apparel, employed the Mariel refugees and other low-skilled workers rather than switching to computer technologies. Evidence to support this finding is that the Mariel refugees were, in fact, employed in many industries. Only about 20% worked in manufacturing (5% in apparel), and the remainder worked in service industries. The idea that the firms may have slowed the adoption of new technologies to employ the Mariel emigrants is hard to prove conclusively, however. We suggest it here as an alternative to the Rybczynski theorem to explain how the refugees could be absorbed across many industries rather than just in the industries using unskilled labor, such as apparel. ■

APPLICATION

Immigration and U.S. Wages, 1990–2006

In 1980, the year of the Mariel boat lift, the percentage of foreign-born people in the U.S. population was 6.2%. The percentage grew to 9.1% in 1990 and then to 13.0% in 2005, so there was slightly more than a doubling of foreign-born people in 25 years.[10] That period saw the greatest recent increase in foreign-born people in the United States, and by 2010 the percentage had grown only slightly more, to 13.5%. How did the wave of immigration prior to 2006 affect U.S. wages?

Part A of Table 5-1 reports the estimated impact of the immigration from 1990 to 2006 on the wages of various workers, distinguished by their educational level. The first row in part A summarizes the estimates from the specific-factors model, when capital and land are kept fixed within all industries. As we discussed in an earlier application, the greatest negative impact of immigration is on native-born workers with less than 12 years of education, followed by college graduates, and then followed by high school graduates and those with some college. Overall, the average impact of immigration on U.S. wages over the period of 1990–2006 was –3.0%. That is, wages fell by 3.0%, consistent with the specific-factors model.

[10] This information on foreign-born people is available from the United Nations, at http://www.esa.un.org/migration.

TABLE 5-1

Immigration and Wages in the United States This table shows the estimated effect of immigration on the wages of workers, depending on their educational level, from 1990–2006. Short-run estimates hold capital and land fixed, while long-run estimates allow capital to adjust so that the capital/labor ratio and real rental are constant in the economy. Part A shows the impact of immigration assuming that U.S.-born and foreign-born workers are perfect substitutes. Immigration has the greatest impact on workers with very low or high levels of education and only a small impact on those workers with middle levels of education (12 to 15 years). The impact is even smaller in the long run, when capital adjusts to keep the real rental on capital fixed. Part B shows long-run estimates when U.S.-born and foreign-born workers in the U.S. are imperfect substitutes. In this case, immigrants compete especially strongly with other foreign-born workers by lowering their wages, and can potentially complement the activities of U.S.-born workers.

	PERCENTAGE CHANGE IN THE WAGE OF WORKERS WITH EDUCATIONAL LEVEL				
	Less Than 12 Years	**High School Graduate**	**Some College**	**College Graduates**	**Overall Average**
Part A: Effect of Immigration on All U.S. Workers					
Method:					
Short run	−7.8	−2.2	−0.9	−4.7	−3.0
Long run	−4.7	0.9	2.2	−1.7	0.1
Part B: Long-Run Effect of Immigration, by Type of Worker					
Type of Worker:					
U.S. born	0.3	0.4	0.9	0.5	0.6
Foreign born	−4.9	−7.0	−4.0	−8.1	−6.4

Sources: Gianmarco I. P. Ottaviano and Giovanni Peri, 2012, "Rethinking The Effect Of Immigration On Wages," Journal of the European Economic Association, European Economic Association, *vol. 10(1), 152–197; and Gianmarco I.P. Ottaviano and Giovanni Peri, 2008, "Immigration and National Wages: Clarifying the Theory and the Empirics." National Bureau of Economic Research working paper no. 14188, Tables 7–8.*

A different story emerges, however, if instead of keeping capital fixed, we hold constant the capital–labor ratio in the economy and the real rental on capital. Under this approach, we allow capital to grow to accommodate the inflow of immigrants, so that there is no change in the real rental. This approach is similar to the long-run model we have discussed, except that we now distinguish several types of labor by their education levels. In the second row of part A, we see that total U.S. immigration had a negative impact on workers with the lowest and highest levels of education and a *positive* impact on the other workers (due to the growth in capital). With these new assumptions, we see that the average U.S. wage rose by 0.1% because of immigration (combined with capital growth), rather than falling by 3.0%.

The finding that the average U.S. wage is nearly constant in the long run (rising by just 0.1%) is similar to our long-run model in which wages do not change because of immigration. However, the finding that some workers gain (wages rise for the middle education levels) and others lose (wages fall for the lowest and the highest education levels) is different from our long-run model. There are two reasons for this outcome. First, as we already noted, Table 5-1 categorizes workers by different education levels. Even when the *overall* capital–labor ratio is fixed, and the real rental on capital is fixed, it is still possible for the wages of workers with certain education levels to change. Second, we can refer back to the U-shaped pattern of immigration shown in

Figure 5-4, where the fraction of immigrants in the U.S. workforce is largest for the lowest and highest education levels. It is not surprising, then, that these two groups face the greatest loss in wages due to an inflow of immigrants.

We can dig a little deeper to better understand the long-run wage changes in part A. In part A, we assumed that U.S.-born workers and foreign-born workers in each education level are perfect substitutes, that is, they do the same types of jobs and have the same abilities. In reality, evidence shows that U.S. workers and immigrants often end up doing different types of jobs, even when they have similar education. In part B of Table 5-1, we build in this realistic feature by treating U.S.-born workers and foreign-born workers in each education level as imperfect substitutes. Just as the prices of goods that are imperfect substitutes (for example, different types of cell phones) can differ, the wages of U.S.-born and foreign-born workers with the same education can also differ. This modification to our assumptions leads to a substantial change in the results.

In part B of Table 5-1, we find that immigration now raises the wages of all U.S.-born workers in the long run, by 0.6% on average. That slight rise occurs because the U.S-born and foreign-born workers are doing different jobs that can complement one another. For example, on a construction site, an immigrant worker with limited language skills can focus on physical tasks, while a U.S. worker can focus on tasks involving personal interaction. Part B shows another interesting outcome: the 1990–2006 immigration had the greatest impact on the wages of all other foreign-born workers, whose wages fell by an average of 6.4% in the long run. When we allow for imperfect substitution between U.S.-born and foreign-born workers, immigrants compete especially strongly with other foreign-born workers, and can potentially complement the activities of U.S.-born workers. Contrary to popular belief, immigrants don't necessarily lower the wages for U.S. workers with similar educational backgrounds. Instead, immigrants can raise wages for U.S. workers if the two groups are doing jobs that are complementary. ■

2 Movement of Capital Between Countries: Foreign Direct Investment

To continue our examination of what happens to wages and rentals when factors can move across borders, we turn now to look at how capital can move from one country to another through **foreign direct investment (FDI),** which occurs when a firm from one country owns a company in another country. How much does the company have to own for foreign direct investment to occur? Definitions vary, but the Department of Commerce in the United States uses 10%: if a foreign company acquires 10% or more of a U.S. firm, then that is counted as an FDI inflow to the United States, and if a U.S. company acquires 10% or more of a foreign firm, then that is counted as an FDI outflow from the United States.

When a company builds a plant in a foreign country, it is sometimes called "greenfield FDI" (because we imagine the site for the plant starting with grass on it). When a firm buys an existing foreign plant, it is called "acquisition FDI" (or sometimes "brownfield FDI"). Having capital move from high-wage to low-wage countries to earn a higher rental is the traditional view of FDI, and the viewpoint we take in this chapter.[11]

[11] As discussed in Chapter 1, there are many instances of FDI that do not fit with this traditional view.

Greenfield Investment

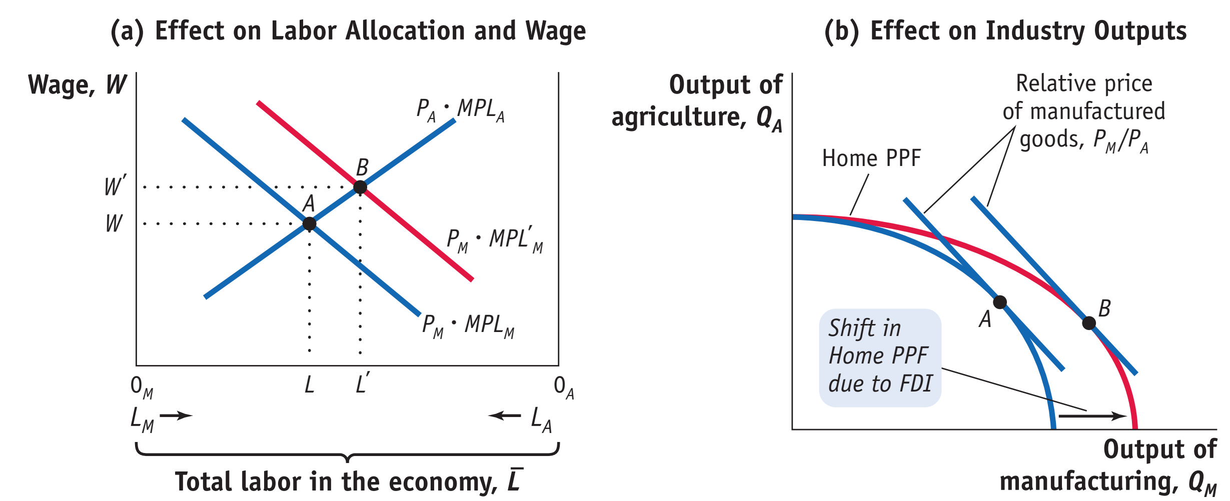
Our focus in this section will be on greenfield investment; that is, the building of new plants abroad. We model FDI as a movement of capital between countries, just as we modeled the movement of labor between countries. The key question we ask is: How does the movement of capital into a country affect the earnings of labor and capital there? This question is similar to the one we asked for immigration, so the earlier graphs that we developed can be modified to address FDI.

FDI in the Short Run: Specific-Factors Model

We begin by modeling FDI in the short run, using the specific-factors model. In that model, the manufacturing industry uses capital and labor and the agriculture industry uses land and labor, so as capital flows into the economy, it will be used in manufacturing. The additional capital will raise the marginal product of labor in manufacturing because workers there have more machines with which to work. Therefore, as capital flows into the economy, it will shift out the curve $P_M \cdot MPL_M$ for the manufacturing industry as shown in panel (a) of Figure 5-11.

Effect of FDI on the Wage As a result of this shift, the equilibrium wage increases, from W to W'. More workers are drawn into the manufacturing industry, and the labor used there increases from 0_ML to $0_ML'$. Because these workers are pulled out of agriculture, the labor used there shrinks from 0_AL to $0_AL'$ (measuring from right to left).

FIGURE 5-11



Increase in the Capital Stock in the Short Run In panel (a), an inflow of capital into the manufacturing sector shifts out the marginal product of labor curve in that sector. The equilibrium in the labor market moves from point A to B, and the wage increases from W to W'. Labor used in the manufacturing industry increases from 0_ML to $0_ML'$. These workers are pulled out of agriculture, so the labor used there shrinks from 0_AL to $0_AL'$.

In panel (b), with the inflow of capital into manufacturing, and the extra labor used in that sector, the output of manufacturing increases. Because labor has been drawn out of agriculture, the output of that sector falls. These changes in outputs are shown by the outward shift of the PPF (due to the increase in capital) and the movement from point A to point B.

Effect of FDI on the Industry Outputs It is easy to determine the effect of an inflow of FDI on industry outputs. Because workers are pulled out of agriculture, and there is no change in the amount of land used there, output of the agriculture industry must fall. With an increase in the number of workers used in manufacturing and an increase in capital used there, the output of the manufacturing industry must rise. These changes in output are shown in panel (b) of Figure 5-11 by the outward shift of the production possibilities frontier. At constant prices for goods (i.e., the relative price lines have the same slope before and after the increase in capital), the equilibrium outputs shift from point *A* to point *B*, with more manufacturing output and less agricultural output.

Effect of FDI on the Rentals Finally, we can determine the impact of the inflow of capital on the rental earned by capital and the rental earned by land. It is easiest to start with the agriculture industry. Because fewer workers are employed there, each acre of land cannot be cultivated as intensively as before, and the marginal product of land must fall. One way to measure the rental on land T is by the value of its marginal product, $R_T = P_A \cdot MPT_A$. With the fall in the marginal product of land (MPT_A), and no change in the price of agricultural goods, the rental on land falls.

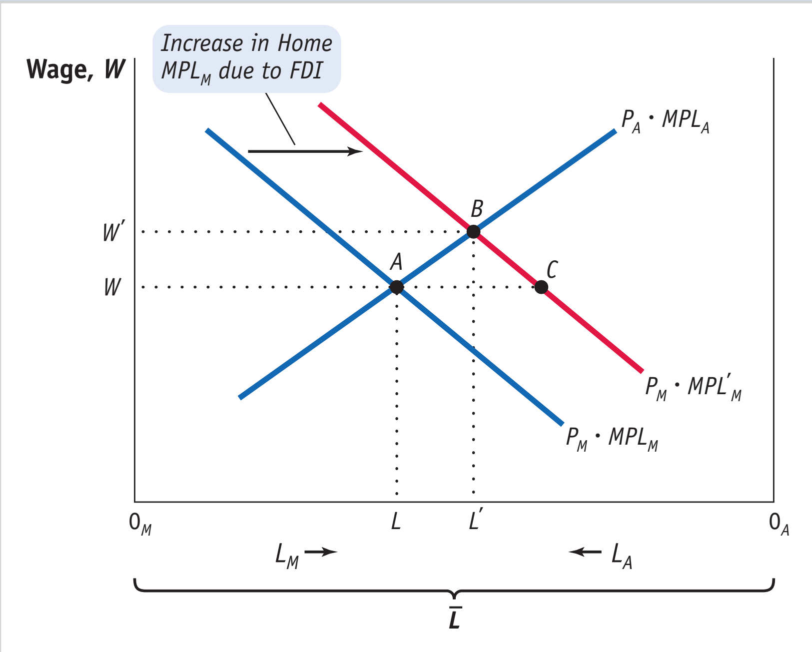
Now let us consider manufacturing, which uses more capital and more labor than before. One way to measure the rental on capital is by the value of the marginal product of capital, or $R_K = P_M \cdot MPK_M$. Using this method, however, it is difficult to determine how the rental on capital changes. As capital flows into manufacturing, the marginal product of capital falls because of diminishing returns. That effect reduces the rental on capital. But as labor is drawn into manufacturing, the marginal product of capital tends to rise. So we do not know at first glance how the rental on capital changes overall.

Fortunately, we can resolve this difficulty by using another method to measure the rental on capital. We take the revenue earned in manufacturing and subtract the payments to labor. If wages are higher, and everything else is the same, then there must be a reduced amount of funds left over as earnings of capital, so the rental is lower.

Let us apply this line of reasoning more carefully to see how the inflow of FDI affects the rental on capital. In Figure 5-12, we begin at point *A* and then assume the capital stock expands because of FDI. Suppose we hold the wage constant, and let the labor used in manufacturing expand up to point *C*. Because the wage is the same at points *A* and *C*, the marginal product of labor in manufacturing must also be the same (since the wage is $W = P_M \cdot MPL_M$). The only way that the marginal product of labor can remain constant is for each worker to have the same amount of capital to work with as he or she had before the capital inflow. In other words, the capital–labor ratio in manufacturing L_M/K_M must be the same at points *A* and *C*: the expansion of capital in manufacturing is just matched by a proportional expansion of labor into manufacturing. But if the capital–labor ratio in manufacturing is identical at points *A* and *C*, then the marginal product of capital must also be equal at these two points (because each machine has the same number of people working on it). Therefore, the rental on capital, $R_K = P_M \cdot MPK_M$, is also equal at points *A* and *C*.

Now let's see what happens as the manufacturing wage increases while holding constant the amount of capital used in that sector. The increase in the wage will move us up the curve $P_M \cdot MPL'_M$ from point *C* to point *B*. As the wage rises, less labor is used in manufacturing. With less labor used on each machine in manufacturing, the marginal product of capital and the rental on capital must fall. This result confirms

FIGURE 5-12



The Effect of an Increase in Capital Stock on the Rental on Capital By carefully tracing through how the capital–labor ratio in manufacturing is affected by the movement from *A* to *C* (where wages and hence the capital–labor ratio do not change), and then the movement from *C* to *B* (where wages and the capital–labor ratio both increase), we conclude that the rental on capital is lower at point *B* than at point *A*. Therefore, the rental on capital declines when the capital stock increases through FDI.

our earlier reasoning: when wages are higher and the amount of capital used in manufacturing is the same, then the earnings of capital (i.e., its rental) must be lower. Because the rental on capital is the same at points *A* and *C* but is lower at point *B* than *C*, the overall effect of the FDI inflow is to reduce the rental on capital. We learned previously that the FDI inflow also reduces the rental on land, so both rentals fall.

FDI in the Long Run

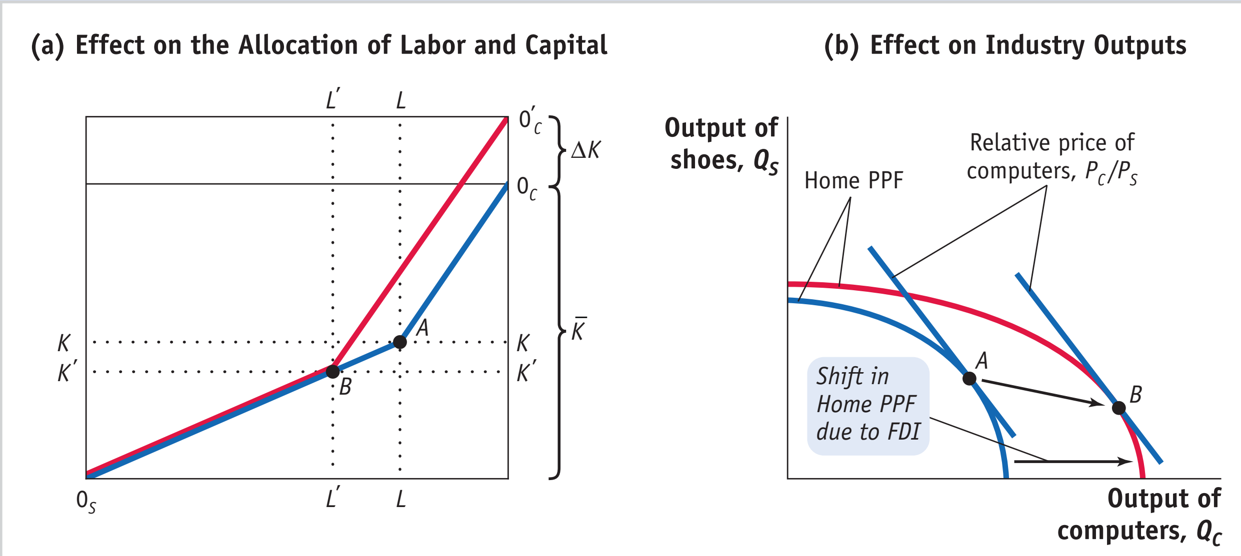
The results of FDI in the long run, when capital and labor can move between industries, differ from those we saw in the short-run specific-factors model. To model FDI in the long run, we assume again that there are two industries—computers and shoes—both of which use two factors of production: labor and capital. Computers are capital-intensive as compared with shoes, meaning that K_C/L_C exceeds K_S/L_S.

In panel (a) of Figure 5-13, we show the initial allocation of labor and capital between the two industries at point *A*. The labor and capital used in the shoe industry are $0_S L$ and $0_S K$, so this combination is measured by the line $0_S A$. The labor and capital used in computers are $0_C L$ and $0_C K$, so this combination is measured by the line $0_C A$. That amount of labor and capital used in each industry produces the output of shoes and computers shown by point *A* on the PPF in panel (b).

Effect of FDI on Outputs and Factor Prices

An inflow of FDI causes the amount of capital in the economy to increase. That increase expands the right and left sides of the box in panel (a) of Figure 5-13 and shifts the origin up to $0'_C$. The new allocation of factors between the industries is shown at point *B*. Now the labor and capital used in the shoe industry are measured by $0_S B$, which is shorter than the line $0_S A$. Therefore, less labor and less capital are used in the production of footwear, and shoe

FIGURE 5-13



Increase in the Capital Stock in the Long Run In panel (a), the top and bottom axes of the box diagram measure the amount of labor in the economy, and the right and left axes measure the amount of capital. The initial equilibrium is at point *A*. When there is an inflow of capital, the equilibrium moves to point *B*. Similar to the box diagram for immigration (Figure 5-8), the *K/L* ratios remain unchanged by allocating the new capital, as well as additional capital and labor from shoes, to computers. In panel (b), with the increase in the amount of capital at Home from increased FDI, the PPF shifts outward. The output of computers increases while the output of shoes declines as the equilibrium moves from point *A* to *B*. Because the prices of goods have not changed, the slopes of the PPFs at points *A* and *B* are equal.

output falls. The labor and capital used in computers are measured by $0'_C B$, which is longer than the line $0_C A$. Therefore, more labor and more capital are used in computers, and the output of that industry rises.

The change in outputs of shoes and computers is shown by the shift from point *A* to point *B* in panel (b) of Figure 5-13. In accordance with the Rybczynski theorem, the increase in capital through FDI has increased the output of the capital-intensive industry (computers) and reduced the output of the labor-intensive industry (shoes). Furthermore, this change in outputs is achieved *with no change* in the capital–labor ratios in either industry: the lines $0'_C B$ and $0_S B$ have the same slopes as $0_C A$ and $0_S A$, respectively.

Because the capital–labor ratios are unchanged in the two industries, the wage and the rental on capital are also unchanged. Each person has the same amount of capital to work with in his or her industry, and each machine has the same number of workers. The marginal products of labor and capital are unchanged in the two industries, as are the factor prices. This outcome is basically the same as that for immigration in the long run: in the long-run model, an inflow of *either* factor of production will leave factor prices unchanged.

When discussing immigration, we found cases in which wages were reduced (the short-run prediction) and other cases in which wages have been constant (the long-run prediction). What about for foreign direct investment? Does it tend to lower rentals or leave them unchanged? There are fewer studies of this question, but we next consider an important application for Singapore.

APPLICATION

The Effect of FDI on Rentals and Wages in Singapore

For many years, Singapore has encouraged foreign firms to establish subsidiaries within its borders, especially in the electronics industry. For example, many hard disks are manufactured in Singapore by foreign companies. In 2005 Singapore had the fourth largest amount of FDI in the world (measured by stock of foreign capital found there), following China, Mexico, and Brazil, even though it is much smaller than those economies.[12] As capital in Singapore has grown, what has happened to the rental and to the wage?

One way to answer this question is to estimate the marginal product of capital in Singapore, using a production function that applies to the entire economy. The overall capital–labor ratio in Singapore has grown by about 5% per year from 1970 to 1990. Because of diminishing returns, it follows that the marginal product of capital (equal to the real rental) has fallen, by an average of 3.4% per year as shown in part A of Table 5-2. At the same time, each worker has more capital to work with, so the marginal product of labor (equal to the real wage) has grown by an average of

TABLE 5-2

Real Rental and Wages in Singapore This table shows the growth rate in the real rental and real wages in Singapore, depending on the method used to construct these factor prices. In part A, a production function approach is used to construct the factor prices, and the real rental falls over time because of the growth in capital. As a result, implied productivity growth is negative. In part B, the rental and wages are constructed from data on payments to capital and labor in Singapore, and real wages grow over time, while the real rental either grows or falls slightly. As a result, implied productivity growth is positive.

	ANNUAL GROWTH RATE (%)		
	Real Rental	**Real Wages**	**Implied Productivity**
Part A: Using Production Function and Marginal Products			
Period:			
1970–1980	−5.0	2.6	−1.5
1980–1990	−1.9	0.5	−0.7
1970–1990	−3.4	1.6	−1.1
Part B: Using Calculated Rental and Actual Wages			
Interest Rate Used and Period:			
Bank lending rate (1968–1990)	1.6	2.7	2.2
Return on equity (1971–1990)	−0.2	3.2	1.5
Earnings-price ratio (1973–1990)	−0.5	3.6	1.6

Sources: Part A from Alwyn Young, 1995, "The Tyranny of Numbers: Confronting the Statistical Realities of the East Asian Growth Experience," Quarterly Journal of Economics, *110(3), August, 641–680.*

Part B from Chang-Tai Hsieh, 2002, "What Explains the Industrial Revolution in East Asia? Evidence from the Factor Markets," American Economic Review, *92(3), 502–526.*

[12] In 2005, China had $318 billion in foreign capital, with another $533 billion in Hong Kong; Mexico had $210 billion; Brazil $202 billion; and Singapore $189 billion, which was 7% of the total foreign capital in developing countries.

1.6% per year, as also shown in part A. These estimates of the falling rental and rising wage are consistent with the short-run specific-factors model.

But there is a second way to calculate a rental on capital besides using the marginal product. Under this second approach, we start with the price P_K of some capital equipment. If that equipment were rented rather than purchased, what would its rental be? Let us suppose that the rental agency needs to make the same rate of return on renting the capital equipment that it would make if it invested its money in some financial asset, such as a savings account in a bank or the stock market. If it invested P_K and the asset had the interest rate of i, then it could expect to earn $P_K \cdot i$ from that asset. On the other hand, if it rents out the equipment, then that machinery also suffers wear and tear, and the rental agency needs to recover that cost, too. If d is the rate of depreciation of the capital equipment (the fraction of it that is used up each year), then to earn the same return on a financial asset as from renting out the equipment, the rental agency must receive $P_K \cdot (i + d)$. This formula is an estimate of R, the rental on capital. Dividing by an overall price index P, the real rental is

$$\frac{R}{P} = \frac{P_K}{P} \cdot (i + d)$$

In part B of Table 5-2, we show the growth rate in the real rental, computed from this formula, which depends on the interest rate used. In the first row, we use the bank lending rate for i, and the computed real rental grows by 1.6% per year. In the next rows, we use two interest rates from the stock market: the return on equity (what you would earn from investing in stocks) and the earnings–price ratio (the profits that each firm earns divided by the value of its outstanding stocks). In both these latter cases, the calculated real rental falls slightly over time, by 0.2% and 0.5% per year, much less than the fall in the real rental in part A. According to the calculated real rentals in part B, there is little evidence of a downward fall in the rentals over time.

In part B, we also show the real wage, computed from actual wages paid in Singapore. Real wages grow substantially over time—between 2.7% and 3.6% per year, depending on the exact interest rate and period used. This is not what we predicted from our long-run model, in which factor prices would be unchanged by an inflow of capital, because the capital–labor ratios are constant (so the marginal product of labor would not change). That real wages are growing in Singapore, with little change in the real rental, is an indication that there is *productivity growth* in the economy, which leads to an increase in the marginal product of labor *and* in the real wage.

We will not discuss how productivity growth is actually measured[13] but just report the findings from the studies in Table 5-2: in part B, productivity growth is between 1.5% and 2.2% per year, depending on the period, but in part A, productivity growth is negative! The reason that productivity growth is so much higher in part B is because the average of the growth in the real wage and real rental is rising, which indicates that productivity growth has occurred. In contrast, in part A the average of the growth in the real wage and real rental is zero or negative, indicating that no productivity growth has occurred.

The idea that Singapore might have zero productivity growth contradicts what many people believe about its economy and the economies of other fast-growing Asian countries, which were thought to exhibit "miraculous" growth during this period. If productivity growth is zero or negative, then all growth is due only to capital accumulation,

[13] The calculation of productivity growth is discussed in Problem 10.

and FDI has no spillover benefits to the local economy. Positive productivity growth, as shown in part B, indicates that the free-market policies pursued by Singapore stimulated innovations in the manufacture of goods that have resulted in higher productivity and lower costs. This is what many economists and policy makers believe happened in Singapore, but this belief is challenged by the productivity calculations in part A. Which scenario is correct—zero or positive productivity growth for Singapore—is a source of ongoing debate in economics. Read the item **Headlines: The Myth of Asia's Miracle** for one interpretation of the growth in Singapore and elsewhere in Asia. ■

3 Gains from Labor and Capital Flows

Foreign investment and immigration are both controversial policy issues. Most countries impose limits on FDI at some time in their development but later become open to foreign investment. Nearly all countries impose limits on the inflow of people. In

HEADLINES

The Myth of Asia's Miracle

A CAUTIONARY FABLE: Once upon a time, Western opinion leaders found themselves both impressed and frightened by the extraordinary growth rates achieved by a set of Eastern economies. Although those economies were still substantially poorer and smaller than those of the West, the speed with which they had transformed themselves from peasant societies into industrial powerhouses, their continuing ability to achieve growth rates several times higher than the advanced nations, and their increasing ability to challenge or even surpass American and European technology in certain areas seemed to call into question the dominance not only of Western power but of Western ideology. The leaders of those nations did not share our faith in free markets or unlimited civil liberties. They asserted with increasing self-confidence that their system was superior: societies that accepted strong, even authoritarian governments and were willing to limit individual liberties in the interest of the common good, take charge of their economics, and sacrifice short-run consumer interests for the sake of long-run growth would eventually outperform the increasingly chaotic societies of the West. And a growing minority of Western intellectuals agreed.

The gap between Western and Eastern economic performance eventually became a political issue. The Democrats recaptured the White House under the leadership of a young, energetic new president who pledged to "get the country moving again"—a pledge that, to him and his closest advisers, meant accelerating America's economic growth to meet the Eastern challenge.

The time, of course, was the early 1960s. The dynamic young president was John F. Kennedy. The technological feats that so alarmed the West were the launch of Sputnik and the early Soviet lead in space. And the rapidly growing Eastern economies were those of the Soviet Union and its satellite nations.

Were you tricked by this fable? Did you think that the "Eastern economies" that the author, Paul Krugman, referred to in the beginning were the Asian economies? Krugman is using this rhetorical trick to suggest that the high growth of the Asian economies is not too different from the growth of the Soviet Union in the 1950s and 1960s, which was due to capital accumulation but without much productivity growth. Other economists disagree and believe that Asian growth is due in significant part to improved productivity, in addition to capital accumulation.

Source: Excerpted from Paul Krugman, 1994, "The Myth of Asia's Miracle," Foreign Affairs*, November/December, 63–79. Reprinted by permission of FOREIGN AFFAIRS, November/December. Copyright 1994 by the Council on Foreign Relations, Inc. www.ForeignAffairs.com.*

the United States, controls on immigration were first established by the Quota Law of 1921, which limited the number of people arriving annually from each country of origin. The Immigration and Nationality Act Amendments of 1965 revised the country-specific limits and allowed immigration on a first-come, first-served basis, up to an annual limit, with special allowances for family members and people in certain occupations. Subsequent revisions to the immigration laws in the United States have established penalties for employers who knowingly hire illegal immigrants, have allowed some illegal immigrants to gain citizenship, or have tightened border controls and deported other illegal immigrants.

Why is immigration so controversial? A glance at articles in the newspaper or on the Internet will show that some groups oppose the spending of public funds on immigrants, such as for schooling, medical care, or welfare. Other groups fear the competition for jobs created by the inflow of foreign workers. We have already seen that immigration creates gains and losses for different groups, often lowering the wage for workers in similar jobs but providing benefits to firms hiring these workers.

This finding raises the important question: Does immigration provide an overall gain to the host country, not including the gains to the immigrants themselves? We presume that the immigrants are better off from higher wages in the country to which they move.[14] But what about the other workers and owners of capital and land in the host country? In the short run, we learned that workers in the host country face competition from the immigrants and receive lower wages, while owners of capital and land benefit from immigration. When we add up these various gains and losses, are there "overall gains" to the destination country, in the same way as we have found overall gains from trade? Fortunately, this answer turns out to be yes.

Immigration benefits the host country in the specific-factors model, not including the income of the immigrants themselves. If we include the immigrant earnings with Foreign income, then we find that emigration benefits the Foreign country, too. The same argument can be made for FDI. An inflow of capital benefits the host country, not including the extra earnings of foreign capital. By counting those extra earnings in Foreign income, then FDI also benefits the source country of the capital. After showing these theoretical results, we discuss how large the overall gains from immigration or FDI flows might be in practice.

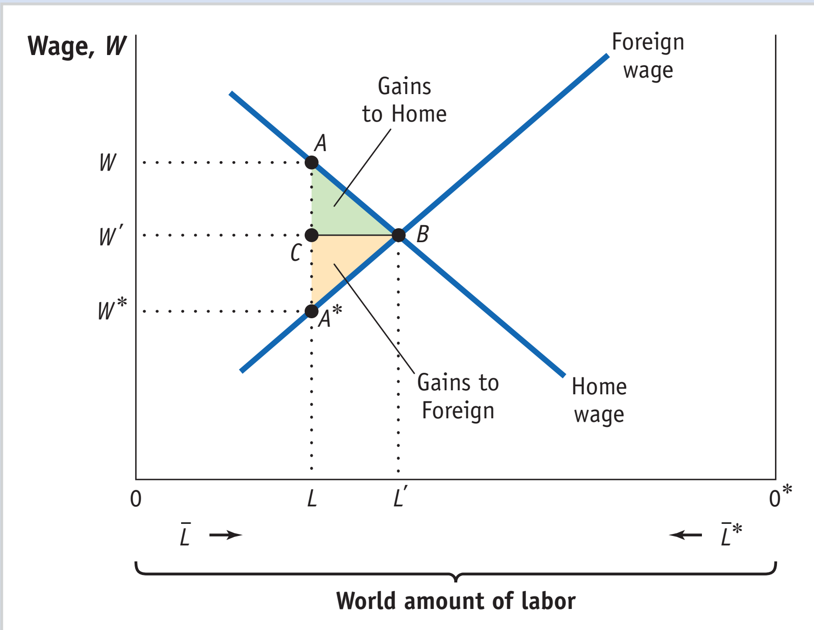
Gains from Immigration

To measure the gains from immigration, we will use the specific-factors model. In Figure 5-14, we measure the *world* amount of labor on the horizontal axis, which equals $\overline{L} + \overline{L}^*$. The number of workers in the Home country $\overline{L}$ is measured from left (the origin 0) to right. The number of workers in Foreign $\overline{L}^*$ is measured from right (0^*) to left. Each point on the horizontal axis indicates how many workers are located in the two countries. For example, point L indicates that $0L$ workers are located in Home, and 0^*L workers are located in the Foreign country.

Wages at Home and Abroad We already know from our discussion earlier in the chapter that as immigrants enter the Home country, the wage is reduced. In Figure 5-14, we graph this relationship as a downward-sloping line labeled "Home

[14] This ignores cases in which the immigrants regret the decision to move because of hardship in making the passage or discrimination once they arrive.

FIGURE 5-14



World Labor Market Initially, Home has $0L$ workers and Foreign has 0^*L workers. The Home wage is W, as determined at point A, which is higher than the Foreign wage W^* at A^*. Workers will move from Foreign to Home to receive higher wages. The equilibrium with full migration is at point B, where wages are equalized at W'. The gain to Home from migration is measured by triangle ABC, and triangle A^*BC represents the gains to Foreign.

wage." With Home workers of $0L$ before immigration, the wage is W at point A. If Foreign workers enter and the Home labor force grows to $0L'$, then the Home wage is reduced to W' at point B. The downward-sloping "Home wage" line illustrates the inverse relationship between the number of Home workers and their wage. You can think of this line as a labor demand curve, not for a single industry, but for the economy as a whole.

Similarly, in the Foreign country, there is an inverse relationship between the numbers of workers and their wage. Before any emigration, the labor force in Foreign is 0^*L, and we show the wage at W^* at point A^*. That is lower than the Home wage of W, so some workers will want to migrate from Foreign to Home. Remembering that we measure the Foreign workers from right (0^*) to left, when the labor force abroad shrinks from 0^*L to $0^*L'$, the Foreign wages rise from W^* to W' at point B. We see that as Foreign workers leave, it benefits those left behind by raising their wages.

We will refer to point B as the **equilibrium with full migration.** At this point, the wages earned at Home and abroad are equalized at W'. It would certainly take a long time for migration to lead to complete wage equality across countries. In our discussion of emigration from the Old World to the New, we saw in Figure 5-3 that real wages in the New World were still twice as high as wages in Europe even after 40 years of large-scale migration. So the equilibrium with full migration is reached only in the very long run. The question we want to answer is whether this migration has benefited the workers (not including the immigrants), labor, and capital in the Home country. In addition, we want to know whether migration has benefited the Foreign country, including the migrants.

Gains for the Home Country To determine whether there are overall gains for Home, we need to measure the contribution of each Foreign worker to the output of one good or the other in that country. This measurement is easy to do. The marginal product of labor in either industry (multiplied by the price of shoes or computers) equals the Home wage. So the first Foreign worker to migrate has a marginal product equal to the Home wage, which is W at point A. As more Foreign workers migrate, the marginal product of labor in both Home industries falls due to diminishing returns. We can measure the immigrants' marginal product by the wage that is paid at Home, which falls from W to W' as we move down the Home wage curve from point A to B.

At the equilibrium with full migration, point B, *all* Foreign immigrants are paid the Home wage of W'. But all Foreign workers except the last one to enter had a marginal product of labor that is above W': the first Foreign worker had a marginal product of W, and the later Foreign immigrants have lower marginal products, ranging from W to W'. Therefore, their contribution to the output of goods in the Home economy *exceeds* the wage that they are paid. The first Foreign immigrant had a marginal product of W but receives the wage W', so the gain to the Home economy from having that worker is $(W - W')$. Likewise, each immigrant to come later has a marginal product between W and W' but is still paid the wage W', so the difference between their marginal products and wages is a gain for the Home economy.

Adding the gains to the Home economy from the Foreign workers, we end up with the triangle ABC, which represents the Home gains as a result of full immigration. The reason for these gains is the law of diminishing returns: as more Foreign immigrants enter the Home workforce, their marginal products fall, and because the wage equals the marginal product of the last worker, it must be less than the marginal products of the earlier immigrants. This economic logic guarantees gains to the Home country from migration.

Gains for the Foreign Country Now consider the Foreign country. To assess the overall gains from emigration, we include the wages received by the migrants who left in calculating Foreign income. These wages are often returned to their families (see **Side Bar: Immigrants and Their Remittances**), but even if they are not, we still incorporate the wages earned by the immigrants in our measure of Foreign income because that is from where the migrants originally came.

In the absence of any emigration, the Foreign wage is W^*, the marginal product of labor in either industry abroad (multiplied by the price of that product in Foreign). As Foreign workers emigrate, the marginal product of labor remaining in Foreign rises, and the Foreign wage rises from W^* to W' (or from points A^* to B in Figure 5-14). Each of these higher marginal products or wages—between W^* and W'—equals the drop in Foreign output (of either good) from having workers leave.

Under full migration, all Foreign migrants earn the wage W' in the Home country. Notice that this wage is *higher* than their Foreign marginal products of labor, which are between W^* and W'. The difference between the wage earned by the migrants and their Foreign marginal products equals the gain to Foreign. Adding up the gains over all Foreign emigrants, we obtain the triangle A^*BC. This gain represents the earnings of the emigrants over and above the drop in output that occurs when they leave Foreign.

World Gains from Migration Combining the gains to the Home and Foreign countries, we obtain the triangular region ABA^*, the world gains from immigration. This magnitude is not too difficult to measure in practice. Turning the triangle on its side, its base equals $(W - W^*)$, the difference in the Home and Foreign wage in the

SIDE BAR

Immigrants and Their Remittances

Immigrants often send a substantial portion of their earnings back home, which we refer to as "remittances." According to estimates from the World Bank, remittances to developing countries were $406 billion in 2012, up from $372 billion in 2011. In 2011, official aid to foreign governments was $156 billion, less than half the amount of remittances from immigrants back to their home countries. The countries receiving the largest amount of remittances in 2011 were India ($64 billion), China ($62 billion), Mexico ($24 billion), and the Philippines ($23 billion). As a share of GDP, however, remittances are highest in smaller and lower-income countries, including Tajikistan (31%), Lesotho (29%), Samoa (23%), Kyrgyz Republic (21%), and Nepal and Tonga (20% each). In 2011, there were about 215 million immigrant workers in the world, so the remittances of $372 billion translate into each immigrant worker sending home approximately $1,800.

In Table 5-3, we show the remittances received by some developing countries in 2010, as compared with their net foreign aid. For all countries except Sudan, the income sent home by emigrants is a larger source of income than official aid. Sudan was experiencing a humanitarian crisis in 2010 so official aid was high. Remittances and official aid are especially important in other African countries, too.

The fact that emigrants return some of their income back home may not be enough to compensate their home countries for the loss of their labor. To calculate any gain to the home countries from the emigration of their workers, we need to include *all the earnings* of the emigrants in their home countries' income. In reality, however, emigrants do not send all of their income home, so the countries they leave can lose from their outflow. Consider, for example, the case of highly educated migrants. In 2000 there were 1 million Indian-born people with college educations living in the 30 wealthy countries of the Organisation for Economic Co-operation and Development (OECD). That amounts to 4.3% of India's large number of college graduates. In 2008, 53% of Indian-born migrants living in the OECD had a postsecondary education. For Asia as a whole, 38% of migrants living in the OECD had a postsecondary education. But for some individual countries, the outflow is much larger. Almost 47% of Ghana's college-educated labor force lives in OECD countries, and for Guyana, the percentage is 89%.[15] Unless these migrants return most of their earnings back home, those countries lose from the outflow of these highly educated workers.

To address this concern, Jagdish Bhagwati, an Indian-born economist now at Columbia University in New York, has proposed that countries impose a "brain-drain tax" on the outflow of educated workers. The idea is to tax the earnings of people living outside the countries in which they were born and, through an organization such as the United Nations, return the proceeds from the tax to the countries that lose the most workers. In that way, countries with an outflow of educated workers would be compensated, at least in part, for the outflow. A brain-drain tax has been widely debated, but so far it has not been used in practice.

TABLE 5-3

Workers' Remittances and Net Foreign Aid, 2010 Shown here are the remittances received by various countries from their citizens working abroad. In many cases, these remittances are larger than the official aid received by the countries. An exception was Sudan, which was experiencing a humanitarian crisis in 2010 so aid was high.

Country	Remittances Received ($ millions)	Net Aid Received ($ millions)
Albania	924	305
Bangladesh	10,836	1,415
Brazil	2,076	661
Colombia	4,023	901
Croatia	342	151
Dominican Republic	2,998	175
India	53,043	2,806
Mexico	21,303	471
Morocco	6,423	993
Sudan	1,291	2,076
Vietnam	8,000	2,940

Source: World Development Indicators, The World Bank.

15 These percentages are obtained from "Fruit that falls far from the tree," *The Economist*, November 3, 2005, which draws on a World Bank study, and from the 2008 OECD Migration Outlook.

absence of any migration. The height of the triangle is $(L' - L)$, the number of foreign workers that would emigrate in the equilibrium with full migration. So the area of the triangle is $\frac{1}{2}(W - W^*) \cdot (L' - L)$. To solve for the area, we need to know the difference in wages before any migration and the number of people who would emigrate.

One way to think about the world gains from migration is that they equal the *increase in world GDP due to immigration*. To understand why this is so, think about the first person to migrate from Foreign to Home. That person earns the wage W^* in Foreign, which equals his or her marginal product times the price in the industry in which he or she works. When this individual leaves Foreign, GDP in that country falls by W^*. Once he or she moves to Home, he or she earns W, which again reflects the marginal product times the industry price. So W equals the increase in Home GDP when the immigrant begins working. The difference between the Home and Foreign wages therefore equals the net increase in world GDP due to migration. By adding up this amount across all migrants, we obtain the triangular region ABA^*, the increase in world GDP and the world gains due to migration.

In practice, however, there are other costs that immigrants bear that would make the gains from immigration less than the increase in world GDP. Immigrants often face sizable moving costs, including the psychological costs of missing their families and home countries as well as monetary payments to traffickers of illegal immigrants. These costs should be subtracted from the increase in GDP to obtain the net gains. Because all the moving costs are hard to quantify, however, in the next application we measure the net gains from immigration by the increase in Home or world GDP.

APPLICATION

Gains from Migration

How large are the gains from immigration? For the United States, a study by the economist George Borjas puts the net gain from immigration at about 0.1% of GDP (one-tenth of 1% of GDP). That value is obtained by using a stock of immigrants equal to 10% of the workforce in the United States and assuming that the immigrants compete for the same jobs as U.S. workers. If instead we assume the immigrants are lower-skilled on average than the U.S. population, then the low-skilled immigrants can complement the higher-skilled U.S. population, and the gains from immigration in the United States are somewhat higher, up to 0.4% of GDP. These estimates are shown in the first row of Table 5-4. The net gains to the United States in this case equal the increase in U.S. GDP.

Borjas's estimates for the U.S. gains from immigration may seem small, but lying behind these numbers is a larger shift in income from labor to capital and landowners. Labor loses from immigration, while capital and landowners gain, and the net effect of all these changes in real income is the gain in GDP that Borjas estimates. For the net gain of 0.1% of U.S. GDP due to immigration, Borjas estimates that capital would gain 2% and domestic labor would lose 1.9% of GDP. These figures lead him to conclude, "The relatively small size of the immigration surplus [that is, the gain in GDP]—particularly when compared to the very large wealth transfers caused by immigration [that is, the shift in income from labor to capital]—probably explains why the debate over immigration policy has usually focused on the potentially harmful labor market impacts rather than the overall increase in native income."

TABLE 5-4

Gains from Immigration The results from several studies of immigration are shown in this table. The second column shows the amount of immigration (as a percentage of the Home labor force), and the third column shows the increase in Home GDP or the increase in GDP of the region.

	AMOUNT OF IMMIGRATION	
	Percent of Home labor	**Increase in GDP (%)**
Part A: Calculation of Home Gains		
Study used:		
Borjas (1995, 1999), U.S. gains	10	0.1–0.4
Kremer and Watt (2006), Household workers	7	1.2–1.4
Peri, Shih, and Sparber (2013)	(24% of STEM workers*)	4.0
Part B: Calculation of Regional Gains		
Study used:		
Walmsley and Winters (2005),		
From developed to developing countries	3	0.6
Klein and Ventura (2009),		
Enlargement of the European Union†		
After 10 years	0.8–1.8	0.2–0.7
After 25 years	2.5–5.0	0.6–1.8
After 50 years	4.8–8.8	1.7–4.5
Common Labor Market in NAFTA†		
After 10 years	1.0–2.4	0.1–0.4
After 25 years	2.8–5.5	0.4–1.0
After 50 years	4.4–9.1	1.3–3.0

*STEM workers: scientists, technology professionals, engineers, and mathematicians

† All numbers are an estimated range.

Sources: George Borjas, 1995, "The Economic Benefits from Immigration," Journal of Economic Perspectives, *9(2), 3–22.*

George Borjas, 1999, "The Economic Analysis of Immigration." In Orley Ashenfelter and David Card, eds., Handbook of Labor Economics, *Vol. 3A (Amsterdam: North Holland), pp. 1697–1760. Paul Klein and Gustavo Ventura, 2009, "Productivity Differences and the Dynamic Effects of Labour Movements,"* Journal of Monetary Economics, *56(8), November, 1059–1073.*

Michael Kremer and Stanley Watt, 2006, "The Globalization of Household Production," Harvard University.

Giovanni Peri, Kevin Shih, and Chad Sparber, 2013, "STEM Workers, H1B Visa and productivity in U.S. Cities," University of California, Davis.

Terrie Louise Walmsley and L. Alan Winters, 2005, "Relaxing the Restrictions on the Temporary Movement of Natural Persons: A Simulation Analysis," Journal of Economic Integration, *20(4), December, 688–726.*

Other calculations suggest that the overall gains from immigration could be larger than Borjas's estimates. In the second row of Table 5-4, we report figures from a study by Kremer and Watt that focuses on just one type of immigrant: household workers. Foreign household workers, who are primarily female, make up 10% or more of the labor force in Bahrain, Kuwait, and Saudi Arabia, and about 7% of the labor force in Hong Kong and Singapore. The presence of these household workers often allows another member of that household—typically, a highly educated woman—to seek employment in her Home country. Thus, the immigration of low-skilled household workers allows for an increase in the high-skilled supply of individuals at Home, generating higher Home GDP as a result. It is estimated that this type of immigration, if it accounts for 7% of the workforce as in some countries, would increase Home GDP by approximately 1.2% to 1.4%.

Another larger estimate of the gains from immigration was obtained in a study by Giovanni Peri, who wrote **Headlines: The Economic Windfall of Immigration Reform,** seen earlier in the chapter. Peri and his co-authors measured the inflow of foreign workers to the United States who are scientists, technology professionals, engineers, or mathematicians—or STEM workers, for short. The H-1B visa program has allowed between 50,000 and 150,000 of these immigrants to enter the United States annually since 1991. Many have remained in the country as permanent residents. By 2010, foreign-born STEM workers accounted for 1.1% of the population in major cities in the United States, and accounted for 24% of the total STEM workers (foreign or U.S.-born) found in these cities. Peri and his co-authors measured the productivity gains to these cities from having this inflow of foreign talent, and they found that the gains were substantial: as mentioned in the earlier Headlines article, they found that 10% to 20% of the productivity growth in these cities can be explained by the presence of the foreign STEM workers. These productivity gains can come from new start-up technology companies, patents for new inventions, and so on. Adding up these productivity gains over time, the presence of the foreign STEM workers accounted for a 4% increase in GDP in the United States by 2010.

In part B of Table 5-4, we report results from estimates of gains due to migration for several regions of the world. The first study, by Walmsley and Winters, found that an increase in labor supply to developed countries of 3%, as a result of immigration from the developing countries, would create world gains of 0.6% of world GDP. This calculation is similar to the triangle of gains ABA^* shown in Figure 5-14. The next study, by Klein and Ventura, obtains larger estimates of the world gains by modeling the differences in technology across countries. Under this approach, wealthier regions have higher productivity, so an immigrant moving there will be more productive than at home. This productivity increase is offset somewhat by a skill loss for the immigrant (since the immigrant may not find the job for which he or she is best suited, at least initially). Nevertheless, the assumed skill loss is less than the productivity difference between countries, so immigrants are always more productive in the country to which they move.

In their study, Klein and Ventura considered the recent enlargement of the European Union (EU) from 15 countries to 25.[16] Workers from the newly added Eastern European countries are, in principle, permitted to work anywhere in the EU. Klein and Ventura assumed that the original 15 EU countries are twice as productive as the newly added countries. During the first 10 years, they found that the population of those 15 EU countries increased by an estimated 0.8% to 1.8%, and the combined GDP in the EU increased by 0.2% to 0.7%. The range of these estimates comes from different assumptions about the skill losses of immigrants when they move, and from the psychological costs of their moving, which slow down the extent of migration. As time passed, however, more people flowed from Eastern to Western Europe, and GDP continued to rise. Klein and Ventura estimated that in 25 years the combined GDP of the EU will increase by 0.6% to 1.8%, and that over 50 years, the increase in GDP would be 1.7% to 4.5%.

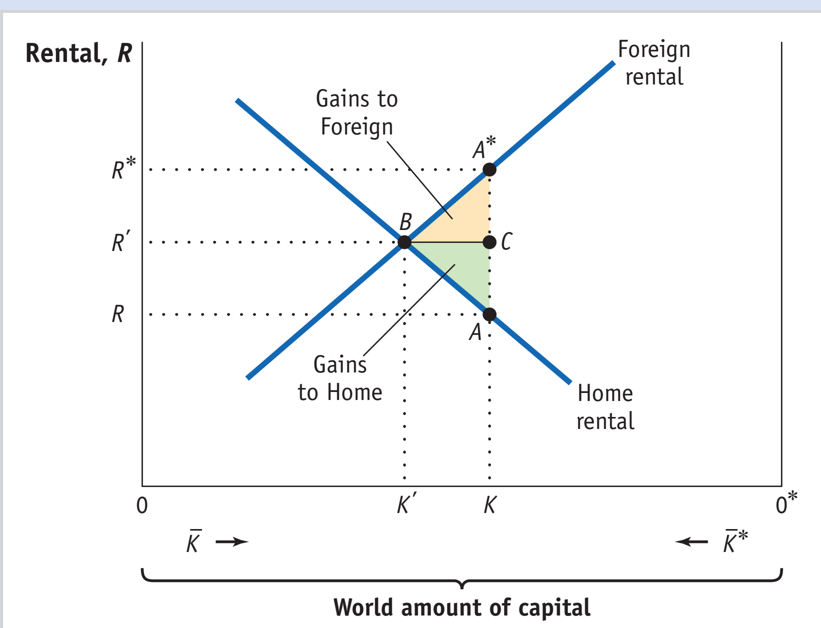
[16] Prior to 2004, the European Union consisted of 15 countries: Belgium, France, Germany, Italy, Luxembourg, and the Netherlands (founding members in 1952); Denmark, Ireland, and the United Kingdom (added in 1973); Greece (added in 1981); Portugal and Spain (added in 1986); and Austria, Finland, and Sweden (added in 1995). On May 1, 2004, 10 more countries were added: Cyprus, the Czech Republic, Estonia, Hungary, Lithuania, Latvia, Malta, Poland, Slovakia, and Slovenia.

Next, Klein and Ventura considered a common labor market within the North American Free Trade Area (NAFTA), established in 1994, which consists of Canada, Mexico, and the United States. Although NAFTA allows for free international trade between these countries, labor mobility is not free. So the experiment that Klein and Ventura considered allowed workers from Mexico to migrate freely to the United States and Canada, which are assumed to have workers who are 1.7 times as productive as those from Mexico. During the first 10 years, they predicted that the population of the United States and Canada would increase by an estimated 1.0% to 2.4% due to the immigration from Mexico, and the combined GDP in the NAFTA region would increase by 0.1% to 0.4%. After 25 years, they estimated that the combined GDP of the region would increase by 0.4% to 1.0%, and over 50 years, the increase in GDP would be 1.3% to 3.0%. These estimates are hypothetical because they assume free mobility of labor within the NAFTA countries, which did not occur. In the next chapter we will discuss some other estimates of the gains due to NAFTA, based on the actual experience of the countries involved with free international trade, but without free labor mobility.

Gains from Foreign Direct Investment

A diagram very similar to Figure 5-14 can be used to measure the gains from FDI. In Figure 5-15, we show the world amount of capital on the horizontal axis, which equals $\overline{K} + \overline{K}^*$. The rental earned in each country is on the vertical axis. With $0K$ units of capital employed at Home (measured from left to right), the Home rental is R, determined at point A. The remaining capital 0^*K (measured from right to left) is in Foreign, and the Foreign rental is R^*, determined at point A^*.

FIGURE 5-15



World Capital Market With $0K$ units of capital at Home, the Home rental is R at point A. The remaining capital 0^*K is in Foreign, and the Foreign rental is R^* at point A^*. Capital will move from Home to Foreign to receive a higher rental. The equilibrium with full capital flows is at point B, where rentals are equalized at R'. Triangle ABC measures the gains to Home from the capital outflow, and triangle A^*BC measures the gains to Foreign.

Because the Foreign rental is higher than that at Home, capital will flow from Home to Foreign. As it enters Foreign, the additional capital will reduce the marginal product of capital and bid down the rental. Likewise, as capital leaves Home, the marginal product of capital will increase, and the Home rental will be bid up. The equilibrium with full capital flows is at point *B*, where rentals are equalized at R'. Similar to what we found in the case of immigration, the gains to Home from the capital outflow is the triangle *ABC*, while the gains to Foreign is the triangle A^*BC, and the world gains are A^*BA. ■

4 Conclusions

Immigration, the movement of workers between countries, potentially affects the wages in the host country in which the workers arrive. In the short-run specific-factor model, a larger supply of workers due to immigration will lower wages. Most immigrants into the United States have either the lowest or the highest amounts of education. As a result, after an inflow of labor from other countries, the wages of these two groups of workers fall in the short run. The majority of U.S. workers, those with mid-levels of education, are not affected that much by immigration. Moreover, the arrival of immigrants is beneficial to owners of capital and land in the specific-factors model. As wages are reduced in the short run, the rentals on capital and land will rise. This result helps to explain why landowners lobby for programs to allow agricultural workers to immigrate at least temporarily, and why other industries support increased immigration, such as H1-B visas for workers in the high-technology and other professional industries.

In a long-run framework, when capital can move between industries, the fall in wages will not occur. Instead, the industries that use labor intensively can expand and other industries contract, so that the immigrants become employed without any fall in wages. This change in industry outputs is the main finding of the Rybczynski theorem. The evidence from the Mariel boat lift in 1980 suggests that a readjustment of industry outputs along these lines occurred in Miami after the arrival of immigrants from Cuba: the output of the apparel industry fell by less than predicted from other cities, whereas the output of some skill-intensive industries fell by more than predicted.

The movement of capital between countries is referred to as foreign direct investment (FDI) and has effects analogous to immigration. In the short run, the entry of foreign capital into a country will lower the rental on capital, raise wages, and lower the rental on land. But in the long run, when capital and land can move between industries, these changes in the wage and rentals need not occur. Instead, industry outputs can adjust according to the Rybczynski theorem so that the extra capital is fully employed without any change in the wage or rentals. Evidence from Singapore suggests that foreign capital can be absorbed without a large decline in the rental or the marginal product of capital, though this is an area of ongoing debate in economics.

Both immigration and FDI create world gains as labor and capital move from countries with low marginal products to countries with high marginal products. Gains for the host country are created because the inflow of labor and capital is paid an amount that is less than its full contribution to GDP in the host country. At the same time, there are also gains to the labor and capital in the country they leave, provided that the income earned by the emigrants or capital is included in that country's welfare.

KEY POINTS

1. Holding the amount of capital and land fixed in both industries, as in the specific-factors model, immigration leads to a fall in wages. This was the case, for example, with the mass migration to the New World in the nineteenth century.
2. As wages fall because of immigration, the marginal products of the specific factors (capital and land) rise, and therefore their rentals also increase.
3. Fixing the amount of capital and land in a country is a reasonable assumption in the short run, but in the longer run, firms will move capital between industries, which will change the effect of immigration on wages and rentals.
4. In a long-run model with two goods and two factors, both of which are perfectly mobile between the industries, additional labor from immigration will be absorbed entirely by the labor-intensive industry. Furthermore, the labor-intensive industry will also absorb additional capital and labor from the capital-intensive industry, so its capital–labor ratio does not change in the long run. Because the capital–labor ratio in each industry does not change, the wage and rentals remain the same as well. This results in what is known as factor price insensitivity.
5. According to the Rybczynski theorem, immigration will lead to an increase in output in the labor-intensive industry and a decrease in the output of the capital-intensive industry. This result is different from that of the short-run specific-factors model, in which immigration leads to increased output in both industries.
6. Besides trade in goods and the movement of labor, another way that countries interact with one another is through investment. When a company owns property, plant, or equipment in another country, it is called foreign direct investment, or FDI.
7. In the short run, FDI lowers the rentals on capital and land and raises wages. In the long run, the extra capital can be absorbed in the capital-intensive industry without any change in the wage or rental.
8. According to the Rybczynski theorem, FDI will lead to an increase in the output of the capital-intensive industry and a decrease in the output of the labor-intensive industry.
9. The movement of capital and labor generates overall gains for both the source and host countries, provided that the income of the emigrants is included in the source country's welfare. Hence, there are global gains from immigration and FDI.

KEY TERMS

specific-factors model, p. 124
Rybczynski theorem, p. 139
factor price insensitivity, p. 140
real value-added, p. 140
foreign direct investment (FDI), p. 144
equilibrium with full migration, p. 153

PROBLEMS

1. In the short-run specific-factors model, examine the impact on a small country following a natural disaster that decreases it population. Assume that land is specific to agriculture and capital is specific to manufacturing, whereas labor is free to move between the two sectors.
   a. In a diagram similar to Figure 5-2, determine the impact of the decrease in the workforce on the output of each industry and the equilibrium wage.
   b. What happens to the rentals on capital and land?
2. How would your answer to Problem 1 change if instead we use the long-run model, with shoes and computers produced using labor and capital?

3. Consider an increase in the supply of labor due to immigration, and use the long-run model. Figure 5-8 shows the box diagram and the leftward shift of the origin for the shoe industry. Redraw this diagram but instead shift to the right the origin for computers. That is, expand the labor axis by the amount ΔL but shift it to the right rather than to the left. With the new diagram, show how the amount of labor and capital in shoes and computers is determined, without any change in factor prices. Carefully explain what has happened to the amount of labor and capital used in each industry and to the output of each industry.

4. In the short-run specific-factors model, consider a decrease in the stock of land. For example, suppose a natural disaster decreases the quantity of arable land used for planting crops.

   a. Redraw panel (a) of Figure 5-11 starting from the initial equilibrium at point A.
   b. What is the effect of this change in land on the quantity of labor in each industry and on the equilibrium wage?
   c. What is the effect on the rental on land and the rental on capital?
   d. Now suppose that the international community wants to help the country struck by the natural disaster and decides to do so by increasing its level of FDI. So the rest of the world increases its investment in physical capital in the stricken country. Illustrate the effect of this policy on the equilibrium wage and rentals.

5. According to part A of Table 5-1, what education level loses most (i.e., has the greatest decrease in wage) from immigration to the United States? Does this result depend on keeping the rental on capital constant? Explain why or why not.

6. Suppose that computers use 2 units of capital for each worker, so that $K_C = 2 \cdot L_C$, whereas shoes use 0.5 unit of capital for each worker, so that $K_S = 0.5 \cdot L_S$. There are 100 workers and 100 units of capital in the economy.

   a. Solve for the amount of labor and capital used in each industry.

   Hint: The box diagram shown in Figure 5-7 means that the amount of labor and capital used in each industry must add up to the total for the economy, so that

   $$K_C + K_S = 100 \text{ and } L_C + L_S = 100$$

   Use the facts that $K_C = 2 \cdot L_C$ and $K_S = 0.5 \cdot L_S$ to rewrite these equations as

   $$2 \cdot L_C + 0.5 \cdot L_S = 100 \text{ and } L_C + L_S = 100$$

   Use these two equations to solve for L_C and L_S, and then calculate the amount of capital used in each industry using $K_C = 2 \cdot L_C$ and $K_S = 0.5 \cdot L_S$.

   b. Suppose that the number of workers increases to 125 due to immigration, keeping total capital fixed at 100. Again, solve for the amount of labor and capital used in each industry. *Hint:* Redo the calculations from part (a), but using $L_C + L_S = 125$.
   c. Suppose instead that the amount of capital increases to 125 due to FDI, keeping the total number of workers fixed at 100. Again solve for the amount of labor and capital used in each industry. *Hint:* Redo the calculations from part (a), using $K_C + K_S = 125$.
   d. Explain how your results in parts (b) and (c) are related to the Rybczynski theorem.

Questions 7 and 8 explore the implications of the Rybczynski theorem and the factor price insensitivity result for the Heckscher-Ohlin model from Chapter 4.

7. In this question, we use the Rybczynski theorem to review the derivation of the Heckscher-Ohlin theorem.

   a. Start at the no-trade equilibrium point A on the Home PPF in Figure 4-2, panel (a). Suppose that through immigration, the amount of labor in Home grows. Draw the new PPF, and label the point *B* where production would occur with the same prices for goods. *Hint:* You can refer to Figure 5-9 to see the effect of immigration on the PPF.
   b. Suppose that the only difference between Foreign and Home is that Foreign has more labor. Otherwise, the technologies used to produce each good are the same across

countries. Then how does the Foreign PPF compare with the new Home PPF (including immigration) that you drew in part (a)? Is point *B* the no-trade equilibrium in Foreign? Explain why or why not.

c. Illustrate a new point A^* that is the no-trade equilibrium in Foreign. How do the relative no-trade prices of computers compare in Home and Foreign? Therefore, what will be the pattern of trade between the countries, and why?

8. Continuing from Problem 7, we now use the factor price insensitivity result to compare factor prices across countries in the Heckscher-Ohlin model.

   a. Illustrate the international trade equilibrium on the Home and Foreign production possibilities frontiers. *Hint:* You can refer to Figure 4-3 to see the international trade equilibrium.
   b. Suppose that the only difference between Foreign and Home is that Foreign has more labor. Otherwise, the technologies used to produce each good are the same across countries. Then, according to the factor price insensitivity result, how will the wage and rental compare in the two countries?
   c. Call the result in part (b) "factor price equalization." Is this a realistic result? *Hint:* You can refer to Figure 4-9 to see wages across countries.
   d. Based on our extension of the Heckscher-Ohlin model at the end of Chapter 4, what is one reason why the factor price equalization result does not hold in reality?

9. Recall the formula from the application "The Effect of FDI on Rentals and Wages in Singapore." Give an intuitive explanation for this formula for the rental rate. *Hint:* Describe one side of the equation as a marginal benefit and the other as a marginal cost.

10. In Table 5-2, we show the growth in the real rental and real wages in Singapore, along with the implied productivity growth. One way to calculate the productivity growth is to take the average of the growth in the real rental and real wage. The idea is that firms can afford to pay more to labor and capital if there is productivity growth, so in that case real factor prices should be growing. But if there is no productivity growth, then the average of the growth in the real rental and real wage should be close to zero.

    To calculate the average of the growth in the real factor prices, we use the shares of GDP going to capital and labor. Specifically, we multiply the growth in the real rental by the capital share of GDP and add the growth in the real wage multiplied by the labor share of GDP. Then answer the following:

    a. For a capital-rich country like Singapore, the share of capital in GDP is about one-half and the share of labor is also one-half. Using these shares, calculate the average of the growth in the real rental and real wage shown in each row of Table 5-2. How do your answers compare with the productivity growth shown in the last column of Table 5-2?
    b. For an industrialized country like the United States, the share of capital in GDP is about one-third and the share of labor in GDP is about two-thirds. Using these shares, calculate the average of the growth in the real rental and real wage shown in each row of Table 5-2. How do your answers now compare with the productivity growth shown in the last column?

11. Figure 5-14 is a supply and demand diagram for the world labor market. Starting at points *A* and A^*, consider a situation in which some Foreign workers migrate to Home but not enough to reach the equilibrium with full migration (point *B*). As a result of the migration, the Home wage decreases from W to $W'' > W'$, and the Foreign wage increases from W^* to $W^{**} < W'$.

    a. Are there gains that accrue to the Home country? If so, redraw the graph and identify the magnitude of the gains for each country. If not, say why not.
    b. Are there gains that accrue to the Foreign country? If so, again show the magnitude of these gains in the diagram and also show the world gains.

12. A housekeeper from the Philippines is contemplating immigrating to Singapore in search of higher wages. Suppose the housekeeper earns approximately $2,000 annually and expects to find a job in Singapore worth approximately $5,000 annually for a period of three years. Furthermore, assume that the cost of living in Singapore is $500 more per year than at home.
    a. What can we say about the productivity of housekeepers in Singapore versus the Philippines? Explain.
    b. What is the total gain to the housekeeper from migrating?
    c. Is there a corresponding gain for the employer in Singapore? Explain.

NET WORK

Immigration is frequently debated in the United States and other countries. Find a recent news report dealing with immigration policy in the United States, and briefly summarize the issues discussed.