Chapter

4

The Heckscher–Ohlin Model

Topics to Be Covered

The HO Model: Basic Assumptions
The HO Theorem
Equilibrium in the HO Model
Some New HO Theorems
Some Final Observations

Key Words

Factor endowments
Labor intensive
Capital intensive
Labor abundant
Capital abundant
Incomplete specialization
Factor price equalization (FPE)

Economists, like all other scientists, are not happy until they think they have things right. As we showed in the preceding chapter, the classical theory of international trade has a number of serious defects. In particular, it offers several extreme predictions that are not borne out in real-world trade patterns. This inconsistency between reality and theoretical predictions provided economists in the nineteenth and twentieth centuries with the motivation to explore further the causes and consequences of international trade.

At first, economists sought to increase their understanding of international trade by relaxing some of the strict assumptions of the classical model. For instance, the assumption of constant opportunity costs was abandoned, and, instead, economists assumed that production was characterized by increasing opportunity costs. This modification removed from the theory the stark and often-violated prediction that trade would lead countries to abandon completely the production of import-competing goods. But problems with the classical theory remained. It was built on the notion that trade arose due to differences in productivity levels between countries, yet it was incapable of explaining why these differences might exist. Furthermore, contrary to the theory's

prediction, trade seemed to prosper between the nations of Europe and between Europe and the United States, countries with similar levels of economic development and technology.

Some economists chose to abandon the classical theory altogether in search of an alternative explanation of comparative advantage. In the early twentieth century an important new theory of international trade emerged. The Heckscher–Ohlin (HO) model of the patterns and determinants of international trade was developed by two Swedish economists, Eli Heckscher and Bertil Ohlin. Heckscher laid out the basic fundamentals of the model in a paper first published in 1919. This paper, however, was written in Swedish and was not translated into English for almost 30 years.* Consequently, the model received little attention. Heckscher's pupil, Ohlin, elaborated on these ideas in his 1924 doctoral dissertation (also in Swedish) and later in a book published in English by Harvard University in 1933.†

Heckscher and Ohlin built their theory around two basic characteristics of countries and products. Countries differ from each other according to the factors of production they possess. Goods differ from each other according to the factors that are required in their production. Given these features of the world, Heckscher and Ohlin argued that a country will be able to produce at lower cost (and therefore have comparative advantage in) those products whose production requires relatively large amounts of the factors of production (also known as **factor endowments**; e.g., labor, land, capital, natural resources) with which that country is relatively well endowed. For instance, countries with large amounts of land relative to other factors (e.g., Australia) will have a comparative advantage in producing goods that require relatively large amounts of land for efficient production (e.g., wheat).

Factor endowments

The quantities of factors of production (e.g., labor and machines) possessed by a country.

Following the publication of Ohlin's book, the ideas of Heckscher and Ohlin quickly gained adherents among economists around the world. The appeal of the model was its fundamental simplicity, its logical completeness, and the ease with which it could be manipulated to understand the causes and effects of international trade. As economists studied the model, they found that it was capable of providing important insights into such issues as the effect of international trade on wages and other factor prices, and the impact of economic growth on the pattern of international trade. It also provides an explanation for the political behavior of various interest groups in an economy.

In the remainder of this chapter, we examine the HO model. We begin, as we have in the previous two chapters, by spelling out the assumptions behind the model. Then, we turn our attention to a number of important extensions to the model. Throughout, we compare and contrast the structure and predictions of the classical and HO theories.

THE HO MODEL: BASIC ASSUMPTIONS

By now, you should be familiar with the way economists construct a theory. First, they establish its framework by spelling out a series of assumptions. Then, once the assumptions are in place, the model can be solved, and experiments can be performed with it. That is the approach we shall take here. To demonstrate the workings of the HO model, we retain the first ten assumptions described in Chapters 2 and 3. We *drop* the assumptions that labor is the only relevant factor of production (Assumption 11) and that the technology in each country can be completely described with knowledge of unit labor inputs (Assumption 12). These last two assumptions pertain only to the classical model. Instead, we add five new assumptions.

Assumption 13

There are two factors of production: labor (L) and capital (K). Furthermore, owners of capital are paid a rental payment (R) for the services of their assets. Labor receives a wage payment (W).

* An English translation of this paper, entitled "The Effect of Foreign Trade on the Distribution of Income," appears in Howard S. Ellis and Lloyd A. Metzler, eds., *Readings in International Trade* (Philadelphia: The Blakiston Co., 1949).

† Ohlin's book is titled *Interregional and International Trade* (Boston: Harvard University Press, 1933).

This assumption relaxes one of the strict assumptions of the classical model. Recall from the preceding chapter that we had assumed that the only relevant factor of production was labor. This was done because labor was assumed to *always* use the same (fixed) amount of machinery in the production process of either good. In the HO model the number of machines that workers use in production becomes an important factor in determining trade patterns and may change with changes in relative factor prices.

Assumption 14

The technology sets available to each country are identical.

This assumption is one of the most crucial in the HO model. It says that for any good (say, textiles), producers in both countries have ready access to the same choices of production techniques. That is, various methods exist for the production of most goods; these methods typically involve the use of various quantities of labor vs. capital inputs. The actual choice of production technique made by producers in each country will depend upon factor prices in those countries. That is, if labor is relatively cheap compared with capital in *A* vs. *B*, then textile producers in *A* will tend to use more labor-intensive technologies than textile producers in *B*. *However, if factor prices are identical in the two countries, then exactly the same production processes for any given industry will be employed in both.* Note that the effect of this assumption is to *rule out the classical basis for international trade.* Thus, the HO model represents a clear departure from classical theorizing.

Assumption 15

In both countries, the production of textiles (good *T*) always requires more labor per machine than the production of soybeans (good *S*). The production of both goods in both countries is subject to constant returns to scale.

The first part of this assumption simply says that *T* is more **labor intensive** than *S*, or, equivalently, that *S* is more **capital intensive** than *T*. Thus, for any level of production and in either country, the amount of labor used per machine is higher in the *T* industry than in the *S* industry. Mathematically, the following relationship always holds true:

Labor (capital) intensive

A good is labor (capital) intensive relative to another good if its production requires more (less) labor per machine than the other good requires in its production.

$$L_T/K_T > L_S/K_S$$

or, equivalently,

$$K_T/L_T < K_S/L_S$$

where L_j is the amount of labor employed in the j industry ($j = S$ or T), and K_j is the amount of capital employed in the j industry.

The reader should keep two things in mind when thinking about this assumption. First, the choice of *T* as the relatively labor-intensive commodity is purely arbitrary. Second, in defining labor (or, equivalently, capital) intensity, we emphasize the notion of *relative* labor intensity. That is, what is crucial here is that one of the two goods must utilize more workers *per machine* than the other and not simply more workers. Thus, an industry does not become labor intensive simply by being larger than another industry and therefore employing more labor. Differences in the capital/labor ratio K_j/L_j determine relative factor intensities. That such differences exist in the real world would seem to be rather obvious. However, to confirm the general validity of this assumption, Global Insights 4.1 provides detail on the capital/labor ratios in various U.S. industries.

The second part of Assumption 15 says that proportionate changes in the use of capital and labor lead to equiproportionate changes in output. For example, one way to double the current output of textiles would be to double the amount of labor and capital employed in the textile industry.

Global Insights 4.1

Capital/Labor Ratios of Selected U.S. Industries

One of the crucial elements of the Heckscher–Ohlin theory is that different goods display different factor intensities in their production. In this feature, we illustrate some examples of factor intensities for a variety of U.S. industries. Consider the following table. A number of interesting points emerge as we study the results in the table. First, there is considerable variation in the capital/labor ratio across industries. In 1960, values for this ratio ranged from a low in the apparel industry of $1,500 of capital per worker to a high in the petroleum- and coal-products industry of $93,800 of capital per worker. In 2000, these industries also represented the extremes in capital per worker, with the ratio in the apparel industry being $8,300 and the petroleum- and coal-products ratio being $266,700 per worker.

A second thing to note is that, over time, the capital/labor ratio has risen in all industries. This result reflects the fact that, for many years, the capital stock of the United States has risen more rapidly than the labor force. Third, the ranking by industry has shown no dramatic changes over the 40-year period shown in the study.

CAPITAL/LABOR RATIOS: U.S. INDUSTRIES, SELECTED YEARS (THOUSANDS OF 1972 DOLLARS)

Industry	1960	1980	2000
Apparel	1.5	3.2	8.3
Chemicals	30.4	58.9	85.9
Electrical machines	6.4	13.0	35.3
Fabricated metals	8.7	13.2	22.1
Food and kindred products	12.2	22.5	36.8
Furniture	4.6	7.6	10.4
Instruments and related products	6.5	13.3	27.2
Leather products	2.3	4.3	14.6
Miscellaneous manufacturing	4.1	9.7	14.6
Nonelectrical machines	9.0	14.6	25.9
Paper products	20.2	38.4	58.9
Petroleum and coal	93.8	1612	266.7
Primary metals	26.5	37.1	71.0
Printing and publishing	10.2	11.9	16.9
Rubber and plastics	10.3	18.8	24.7
Stone, clay, glass products	16.2	26.7	35.6
Textiles	8.4	14.3	27.3
Tobacco manufactures	9.0	31.9	100.1
Transportation equipment	10.5	20.3	21.3
AVERAGE	15.3	27.4	47.6

Source: "Energy Price Shocks and Productivity Growth: A Survey" by E. R. Berndt and D. O. Wood. Copyright © 1985 MIT. Reprinted by permission.

Assumption 16

Countries differ in their endowments of factors of production, L and K. In our presentation we will assume that A is relatively capital abundant, while B is relatively labor abundant.

What does it mean for a country to be relatively **labor** (or **capital**) **abundant**? The definition we will use says that a country is relatively labor abundant if the total workforce relative to the total capital stock is greater there than in the other country.* Mathematically, then, country A would be relatively capital abundant if

Labor (capital) abundant
A country is labor (capital) abundant relative to another country if it has more (fewer) workers per machine than the other country.

$$K_A/L_A > K_B/L_B$$

where L_k is the size of the total workforce in country $K(k = A \text{ or } B)$, while K_k is the total amount of machines available in country K. As with the discussion of factor intensity in the production of the two goods, relative differences matter here.† Thus, a country cannot be labor abundant simply by having a larger population. The size of that country's capital stock must also be taken into account. More simply, ratios are important, not levels. In addition, we will assume that countries that are labor abundant (i.e., that have labor forces that are large relative to their capital stocks) will have low wages relative to rental payments, and vice versa for capital-abundant countries.‡

Combining the implications of Assumptions 15 and 16 allows us to develop graphically the shapes of the production possibility frontiers (PPFs) for the two countries. First, because the two goods differ in factor intensity in both countries, the PPFs of each country will exhibit increasing opportunity costs. To understand this point better, consider the following experiment: Suppose that in country B we begin with all of B's capital and labor working in the S industry. This would establish one point on B's PPF, the point on the S axis. (See point Z on Figure 4.1.) Now, imagine that the managers of the S industry are asked to cut back their production by one unit of output. The S industry now has excess factors of production, which can be used to produce some of good T.

How likely is S to contract its output? It would seem that the industry would try to retain as much capital as possible, since the production of S requires relatively more capital. Thus, as it reduces output, this industry is likely to release, at first, mostly labor, since S requires relatively less of that factor. So initially, at least, it is likely that as S contracts, relatively more labor than capital is laid off and therefore becomes available to industry T. But, T uses relatively more labor than capital in its production. Consequently, the release of factors by S to T occurs in precisely the fashion required for T to expand most readily. Hence, initially, as we move away from point Z in the figure, the output of T increases greatly, while the output of S contracts only a little.

Why does B's PPF become flatter as we near point Y? Think again about the process of expansion and contraction of the two industries. As we near point Y, the output of S is nearing zero. We would expect that, as output has fallen, the S industry has tried to retain as much capital per remaining worker as possible. However, it should be clear that the closer output S comes to zero, the greater are the amounts of capital being idled by that industry. When the T industry absorbs greater and

* The definition of factor abundance we employ is known as the quantity definition. There is an alternative (and not necessarily consistent) definition. The price definition of relative factor abundance says that a country is relatively labor abundant if the wage-to-rental payment in its country is lower than the wage-to-rental payment in the other country. Thus, according to Assumption 16 and the price definition, the following relationship exists:

$$W_A/R_A > W_B/R_B$$

where W_k is the wage rate in country $K(k = A \text{ or } B)$ and R_k is the rental rate in country K. In the text we assume that both definitions hold simultaneously. However, there is no law in economics that guarantees this to be true.

† The astute reader will note that in describing the technology of producing goods we refer to T as the labor-intensive product, while in referring to countries we describe B as the labor-abundant country. It has become common practice in the literature on the HO model to refer to the factor intensity of production and the factor abundance of countries. We will continue to employ this terminology throughout.

‡ This is known as Samuelson's strong factor abundance assumption.

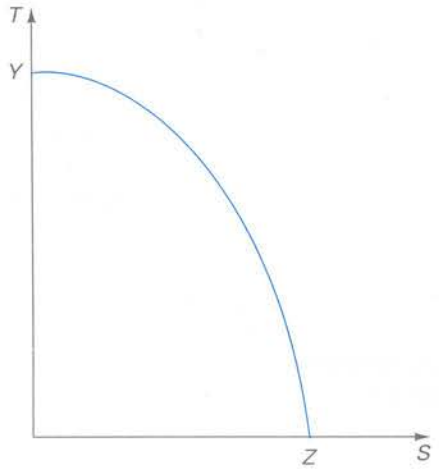

FIGURE 4.1 Country *B*'s Production Possibility Frontier

greater amounts of capital relative to labor, it is able to expand by smaller and smaller amounts. This again is due to our assumptions about the underlying technology required to produce *T*.

Thus, we have established that country *B* has a PPF that exhibits increasing opportunity costs. Because technology is identical in the two countries, *A* will also have a PPF that exhibits increasing opportunity costs. Although both PPFs will be nonlinear, they will not have the same shapes. Because country *B* is assumed to be relatively labor abundant and good *T* is assumed to be relatively labor intensive, we would expect *B*'s PPF to lie primarily along the *T* axis (see Figure 4.1). That is, given its resources and the technology for making the two goods, country *B* should be able to make relatively more *T* than *S*. By identical reasoning, we would expect *A*'s PPF to lie mainly along the *S* axis.

We have now laid out the supply side of the economies of both countries. We turn now to demand.

Assumption 17

Tastes in the two countries are identical.

This assumption simply states that the community indifference curves (CICs) for the two countries are identical. Consequently, if faced with the same relative price ratio and the same level of GDP, each country would consume exactly the same amounts of the two goods. As we shall establish in more detail in the next section, the purpose of this assumption is to guarantee that comparative advantage, and therefore the direction of trade, is determined by supply conditions in the two economies rather than demand factors.

THE HO THEOREM

The HO model holds that the direction of international trade flows between two countries is determined by the endowment of productive factors in the two countries and the factor content of the goods involved. In the two-good case, the theory can be stated more precisely in the form of a theorem known as the HO theorem.

The HO Theorem

A country will have comparative advantage in, and therefore will export, that good whose production is relatively intensive in the factor with which that country is relatively well endowed.

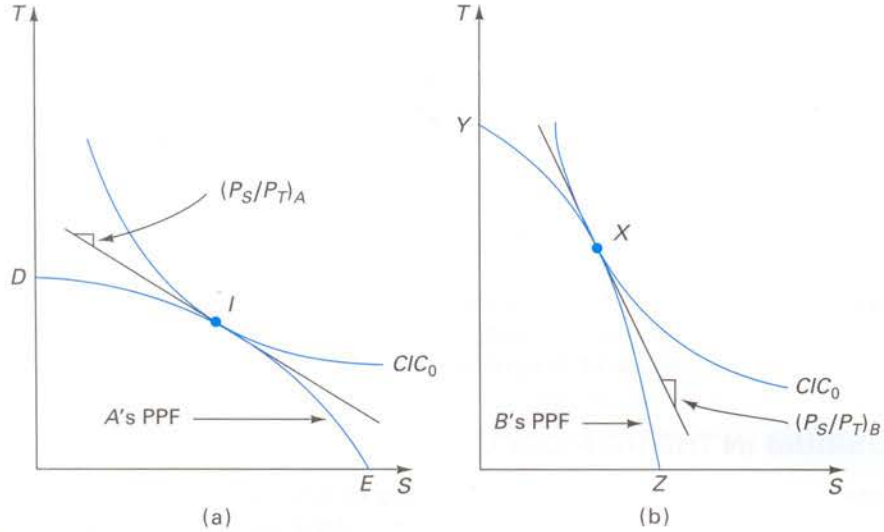

FIGURE 4.2 Proof of the HO Theorem

Put more simply, the theorem states that the country that is relatively capital abundant compared with the other country will have a comparative advantage in the good that requires more capital per worker to produce. With regard to our assumptions, we would expect that country B (A) will have a comparative advantage in textiles (soybeans), since we have assumed that B (A) is relatively labor (capital) abundant and that textile (soybean) production is relatively labor (capital) intensive.

Let's try to prove the HO theorem graphically.* Consider Figure 4.2. In discussing the assumptions of the model, we have already determined that the PPFs of the two countries will exhibit increasing opportunity costs and will have different shapes. This is illustrated in panels (a) and (b) in Figure 4.2, where we show country A and B, respectively. Our goal is to find the autarky (pretrade) price ratios for the two countries to determine the direction of comparative advantage. To do that, we need to bring demand factors into the story. Recall that we have assumed that tastes in the two countries are identical. In terms of our diagrams, this means that the CICs for the two countries should have the same shape and should lie in the same general location in the two graphs. The CICs we have drawn have this property and, to emphasize the point that they represent the same preferences, are both labeled CIC_0.† Consider now the autarky equilibrium production and consumption points for the two countries. These occur at point I for A and point X for B.

As we learned in Chapter 2, the slope of the PPFs at the production point defines the price ratio for that country. Consequently, we have drawn in the price lines tangent to the PPFs at the production points and labeled them $(P_S/P_T)_A$ and $(P_S/P_T)_B$. From the diagram, it is clear that

$$(P_S/P_T)_A < (P_S/P_T)_B$$

* This proof is based essentially on the quantity definition of factor abundance. In Appendix 4.1 we sketch out a proof of the theorem using the price definition of abundance.

† Note carefully that even though both CICs have the same label, this does not mean that the two countries experience equal levels of satisfaction (or real GDP) in autarky. If the two countries are not at the same levels of satisfaction, we must also assume that the CICs are sufficiently well behaved so that their shape does not change radically as one moves to lower or higher levels of community satisfaction. A sufficient condition for our proof to hold is that as real GDP grows at constant relative prices, consumers continue to buy more of both goods in the same proportions.

This establishes that country A (B) has a comparative advantage in the production of good S (T).* Now, let's go back to our assumptions. Recall that S was assumed to be the capital-intensive good and that A was assumed to be the capital-abundant country. This proves the theorem. Before you read on, however, you should convince yourself that we haven't only proved the theorem for country A, but we have established that it is true for country as well.

So far, we have shown how comparative advantage is determined in the HO model. How do we know that trade will flow in the direction of comparative advantage? The answer to this question is the same as that found in Chapter 3. Namely, in a competitive environment, trade flows are determined by profit-seeking activities of economic agents. If a product is relatively cheap in one country, it will tend to be exported to those places where it is relatively expensive. Consequently, we would expect to see country A export good S. Likewise, exporters in B should want to export T to A, where it is (at first) relatively more expensive.

EQUILIBRIUM IN THE HO MODEL†

Let us now consider the effect of the introduction of international trade on the production and consumption decisions of a single country. After we analyze this effect, we turn to an examination of the world trade equilibrium in the HO model. Again, we know from previous chapters that once trade is allowed between two countries, differences in relative prices will not persist. Consequently, the price of S will begin to rise in A (where it was initially low) and fall in B (where it was initially high). For the time being, let's focus our attention on country A.

Consider Figure 4.3. Once trade begins, the price of S will start to rise in A. This is illustrated by the terms of trade lines $(P_S/P_T)_0$, $(P_S/P_T)_1$, and $(P_S/P_T)_2$. The flattest price line, $(P_S/P_T)_0$, is tangent to A's PPF at the autarky point $X_0(= C_0)$. As the terms of trade rise to $(P_S/P_T)_1$, the production of T declines, and factors are released to the S industry, allowing A's production point to move to point X_1. At that point, the supply of S exceeds the local demand for it, and some can be exported to country B in exchange for T. This allows consumption to move off A's PPF to

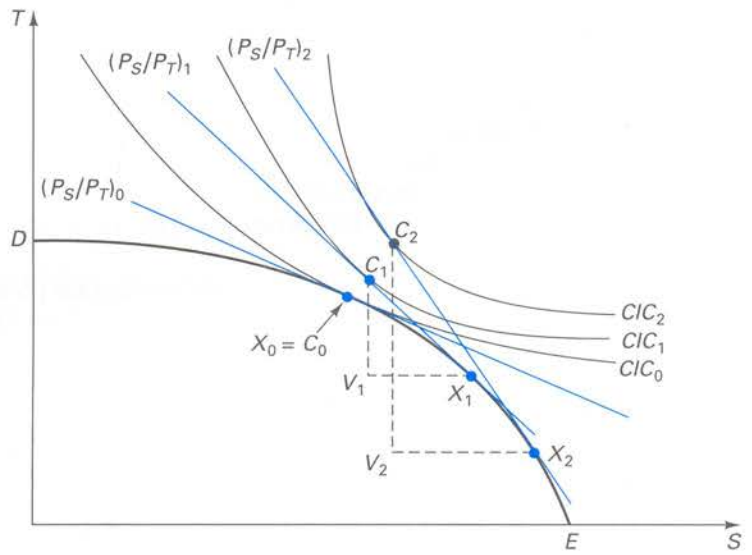

FIGURE 4.3 The Effect of Rising World Prices of Good S on Country A's Trade

* Recall that a country has a comparative advantage in a good if the good has a lower autarky relative price in that country.

† This section may be skipped without loss of continuity.

point C_1. How much is traded at price $(P_S/P_T)_1$? This is given in the figure by the triangle $V_1C_1X_1$. Triangle $V_1C_1X_1$ is A's trade triangle when the price is $(P_S/P_T)_1$. The base of the triangle, V_1X_1, represents exports, while the side, V_1C_1, is A's desired imports.

If the terms of trade were to continue to rise, say to $(P_S/P_T)_2$, then the production point would continue to move down A's PPF, this time to X_2. At this point, A is almost completely specialized in the production of soybeans. Country A's consumption point moves from C_1 to C_2. Thus, it relies more and more on country B for the textiles it consumes. As the figure clearly shows, A's trade triangle has grown in size to $V_2C_2X_2$.

The figure we have just been discussing is slightly misleading. The reader should note carefully that at any point in time, only one price will prevail in the market. What will be that price, and how is it determined? Again, the answer is the same as with the Ricardian model. The terms of trade that will prevail once trade begins are determined by international forces of demand and supply known as *reciprocal demand.** These forces seek a price that can prevail simultaneously in *both* countries so that desired trade flows are balanced. After all, if desired trade flows are not balanced, then, by definition, one country wants to trade more than the other, and this will cause the terms of trade to change.

Diagrammatically, the condition for international equilibrium is that the trade triangles of the two countries be congruent. This is the same equilibrium condition as before. Recall that the sides of these triangles represent desired trade amounts for a given international price, which, in turn, is represented in the trade triangles by the slope of the hypotenuse.

An example of an international trade equilibrium is given in Figure 4.4. In panel (a), we illustrate country A's trade triangle. In particular, after trade begins and equilibrium is reached, production in A occurs at point X_A, while consumption occurs at point C_A. Country A's exports are given by the distance V_AX_A, and its imports are given by the distance V_AC_A. Panel (b) illustrates equilibrium for B. There, production occurs at point X_B, and consumption occurs at C_B. Country B's exports are denoted by the distance X_BV_B, and its imports by V_BC_B.

How do we know that this diagram illustrates an international trade *equilibrium*? The answer is that the trade triangles of the two countries have the congruency property just described. That is, the distance V_AX_A—country A's desired exports when the international price

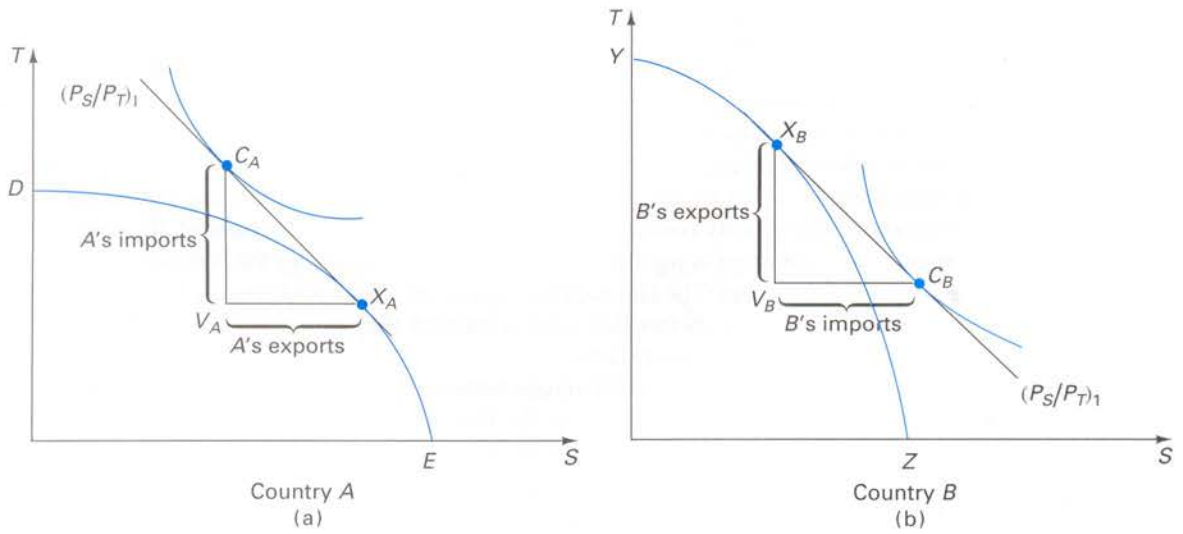

FIGURE 4.4 Trade Equilibrium in the HO Model

* Recall that we defined and discussed the concept of reciprocal demand in Chapter 3.

is $(P_S/P_T)_1$—is equal in quantity terms to country B's desired imports—denoted by the distance V_BC_B—at the same international price. In terms of simple geometry, the bases of the two triangles have the same length. And, as we have seen several times now, if the international market is in equilibrium for product S, we know that it is also in equilibrium for product T. Hence, we know that the sides of the two triangles are also equal in length.

What are some of the other characteristics of this equilibrium, and how do they compare with those we have studied in our analysis of the classical model? Note first that neither country completely specializes in the production of its comparative-advantage good. **Incomplete specialization** in production is a straightforward result of the presence of increasing opportunity costs. That is, as the introduction of international trade leads to an increase in the relative price of a country's exportable good, there is an incentive to produce more of that good. Production will continue to expand so long as the relative cost of expanding production is less than or just equal to the relative price. However, as production expands in this model, so do relative costs. Consequently, there will tend to be a point beyond which relative costs exceed the relative price. This point represents the barrier to further expansion of production, unless the price were to rise still more.

Incomplete specialization

A country is incompletely specialized in production if, after trade begins, it continues to produce some of the good it imports.

Is complete specialization likely in the HO model? No, but it can't be ruled out. As we noted earlier, the production point depends upon the relative price of exports. It remains a possibility that the price could rise so much that all of the economy's resources could be attracted to the export industry. A second factor that would make complete specialization more likely would be if the two goods were relatively similar in their use of factor inputs. The more similar are the techniques used in producing the two goods, the less additional output of one good is lost as factors are increasingly attracted to the other industry. In other words, as goods become more similar in production, the less bowed out are the PPFs, and the PPFs begin to look more like the straight-line, constant-cost PPFs found in the classical model—where complete specialization always tends to occur.

A second and closely related difference between the HO model and the classical model has to do with the manner in which the process of reciprocal demand leads to an equilibrium terms of trade. Recall that in the classical model, once trade begins, the production point is fixed at the point of complete specialization. This means that equilibrium levels of exports and imports are achieved solely through changes in demand in the two countries. In the HO model, reciprocal demand leads to an equilibrium price by inducing changes in *both* demand and supply. This point is established in Figure 4.5.

In the top part of the figure, we present the national demand and supply curves that are implied by the assumptions of the classical model. In the bottom part of the diagram, we illustrate the national demand and supply curves for the two countries under HO assumptions. The major difference between these two diagrams is the shape of the national supply curves. The classical national supply curves are horizontal up to a certain point, reflecting the underlying assumption of constant opportunity costs. Afterward, these curves become vertical, illustrating that once complete specialization is reached, no more can be produced in the economy regardless of how high the price becomes. The HO national supply curves are also vertical at the point of complete specialization. However, before that point is reached, they are upward sloping, reflecting the existence of increasing opportunity costs.

Let us now consider the differences between the two models in the process of reciprocal demand. For ease of exposition, we let the Greek letter ρ (rho) denote the relative price P_S/P_T. Consider first the situation under the classical model. Figure 4.5a and 4.5b show how the autarky prices of S are determined in the two countries. These prices are, respectively, ρ_A and ρ_B. At these prices the autarky production levels are Q_{AA} and Q_{BA}, respectively.

Because ρ_A is less than ρ_B, country A has a comparative advantage in S and will export it to B. We know that once international trade begins, there can be only one world price. Suppose that price is ρ_0. In country A, the production of S will rise to Q_M units, while consumption

of S will fall to Q_0 units. The difference between these two amounts reflects A's desired exports to B.

In country B, if the price falls from ρ_B to ρ_0, local production will fall to zero, while consumption rises to Q_{B0}. The difference between these two amounts represents B's desired imports of S. Casual inspection of the diagram indicates that at ρ_0, B's desired imports exceeds A's desired exports. In other words, there is excess demand in the market for traded goods; to close this imbalance, the world price must rise above ρ_0. As the price rises, the excess demand begins to fall, but in a special way. Note from the diagram that total world supply remains constant at Q_M units, the amount produced in country A. On the other hand, as the price rises, consumption of S in *both* countries falls (note the pattern of the arrows in the diagram). Finally, as ρ rises, total world consumption falls enough so that world markets are in equilibrium. In the diagram this occurs at ρ_1.

The lower part of Figure 4.5 illustrates the mechanism of reciprocal demand using HO assumptions. As before, the autarky prices and outputs for the two countries are given by ρ_A, ρ_B, Q_{AA}, and Q_{BA}, respectively. Again, we are assuming that A has the lower autarky price of S and therefore has comparative advantage in that good. Once trade opens, the

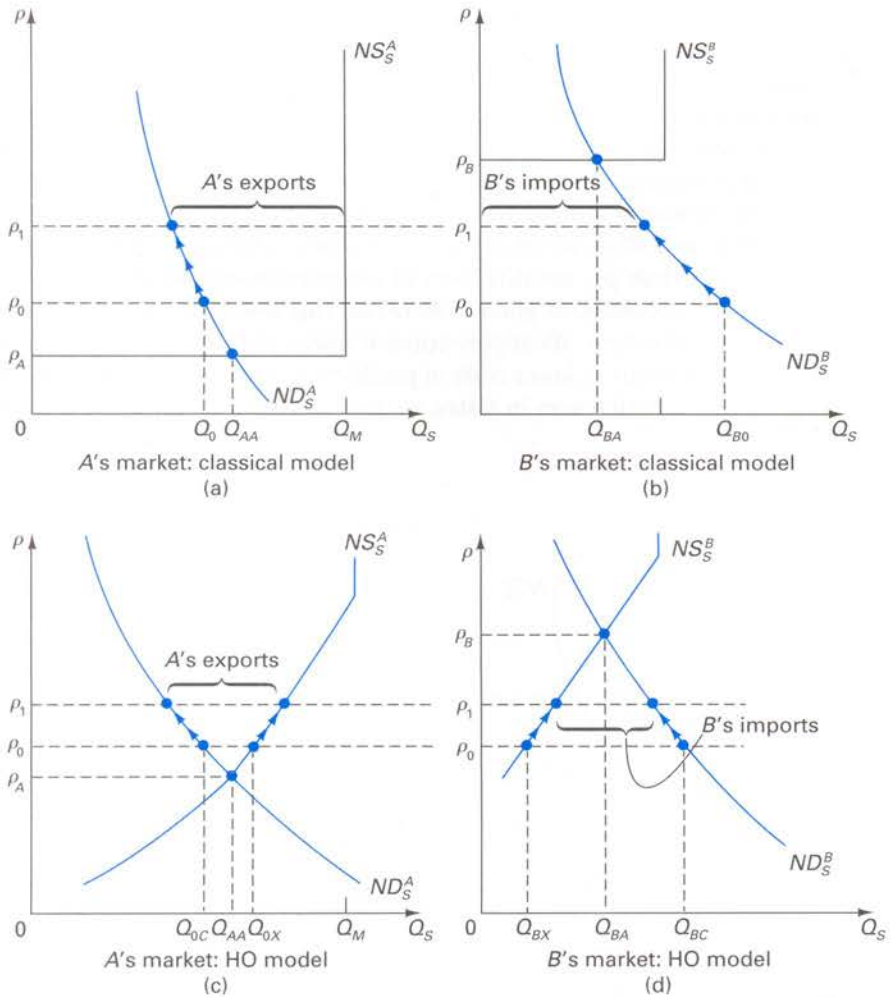

FIGURE 4.5 Reciprocal Demand in the Classical and HO Models

price of S will rise in A and fall in B, generating an incentive for S to flow from A to B. If the price settles first at ρ_0, then A's desired exports would be the difference between the amount produced and consumed at that price, $Q_{0X} - Q_{0C}$. Country B's desired imports at price ρ_0 would be given by the amount $Q_{BC} - Q_{BX}$. Again, by inspection we can see that there is initially an excess demand. How is this excess demand eliminated? The price must rise. But note the difference in this model. As ρ rises, consumption falls in both countries (as was the case before), but supply also rises in both countries. In other words, the higher the world price in the exporting country, the more that country exports—for two reasons. First, its own citizens will demand less; and second, its producers will want to produce more. In the importing country, the higher the world price, the less it imports, for precisely the same reasons: Its consumers purchase less, and its domestic producers produce more.

A third major difference between the HO model and the classical model has to do with the importance of assumptions made about demand. The classical model places no restrictions on assumptions about consumer tastes in the two countries, except that consumers be sufficiently cosmopolitan so that some of both goods be consumed before and after trade opens. The reason so little attention is paid to demand is that the autarky prices in that model are determined solely by supply conditions (see again the top part of Figure 4.5). On the other hand, the HO model assumes that tastes be identical. Why is this assumption made?

In Figure 4.6 we replicate the demand and supply curves from the lower part of Figure 4.5. Consider the following thought experiment: Suppose that instead of the demand and supply curves as they are drawn, we change the assumptions of the model so that tastes in each country are very different. In particular, suppose that citizens of country A strongly prefer good S, while citizens of country B abhor this product. Under these alternative conditions, the supply curves would not change, but the demand curves would shift from those initially drawn to $ND_S^{A'}$ and $ND_S^{B'}$, respectively. Autarky prices would be given by ρ_A' and ρ_B', and because ρ_B' is lower than ρ_A', the direction of comparative advantage shifts so that B would have comparative advantage in good S. Note that this would be true even though, for any corresponding level of output, A's supply curve is lower, indicating that A has a natural comparative advantage in terms of lower costs of production. Thus, we see the importance of assumptions. By ruling out differences in tastes, we prevent tastes from overturning the predictions of the HO model.

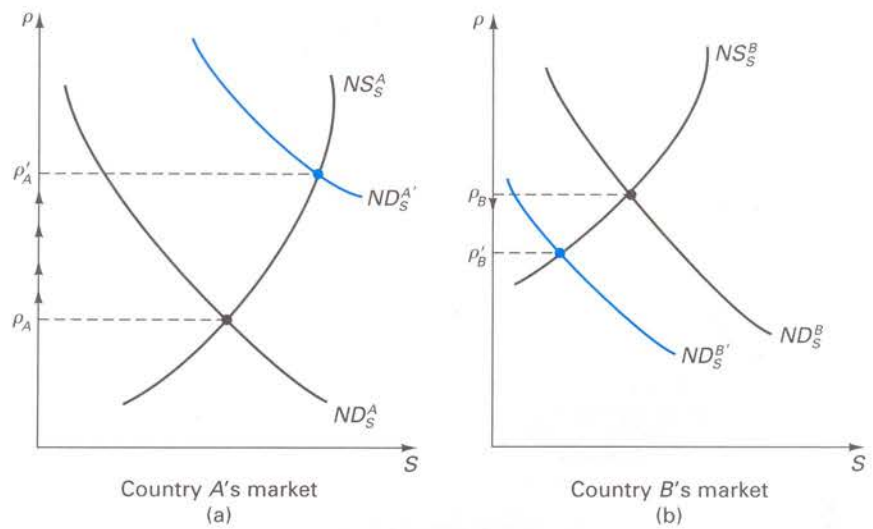

FIGURE 4.6 The Importance of Assuming Identical Tastes

SOME NEW HO THEOREMS

In addition to the HO theorem, which predicts the direction of comparative advantage, the HO model offers several other important theorems about economic behavior in an economy engaged in international trade. These theorems refer to issues such as the effect of economic growth on trade and the impact trade has on the distribution of income in a society. The first of these is known as the Rybczynski theorem.*

The Rybczynski Theorem

At constant world prices, if a country experiences an increase in the supply of one factor, it will produce more of the product whose production is intensive in that factor and less of the other product.

Accordingly, if country A were to increase its capital stock above its initial endowment, everything else held constant, it would produce more S than before and less T. This example is illustrated in Figure 4.7. Growth in A's capital stock leads to an outward shift in its PPF. Most of this shift occurs along the S axis, because S is in the capital-intensive industry. The new production point (after growth has occurred) is given by point X_1, the point on the new PPF where its slope is equal to the (fixed) world price ρ.

Because S is A's export good, an increase in the size of A's capital stock would lead producers in A to try to expand their exports. Conversely, if A's labor force were to increase, holding all other things constant, including world prices and the size of A's capital stock, A would want to produce more T relative to S and trade less.

A proof of the Rybczynski theorem is left for Appendix 4.1. However, the intuition behind this theorem is straightforward. It basically says that the way in which a country grows has an impact on the production and trade mixes of that country. Countries with low savings rates that invest little in new plants and equipment will tend to produce and trade goods with high labor content. Countries with high savings and investment rates will tend to produce and trade more capital-intensive goods. (See Chapter 10 for an expanded discussion of the relationship between economic growth and international trade.)

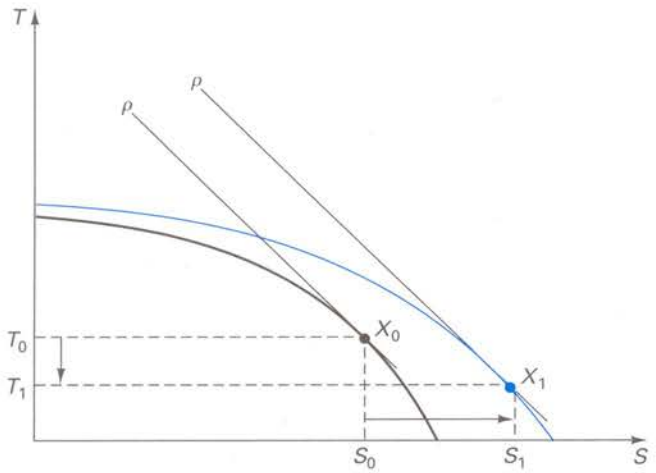

FIGURE 4.7 The Effect of an Increase in A's Capital Stock

* This theorem was originally developed in T. M. Rybczynski, "Factor Endowments and Relative Commodity Prices," *Economica* (1955).

Factor price equalization (FPE)

Factor price equalization occurs if all individual factor prices (e.g., wages, rental payments) are identical when measured in the same currency.

Perhaps the most controversial theorem of the HO model is concerned with the effect of international trade on factor prices. This theorem is known as the **factor price equalization (FPE)** theorem.*

The Factor Price Equalization Theorem

Given all the assumptions of the HO model, free international trade will lead to the international equalization of individual factor prices.

In other words, in countries that have high wages before trade begins, there will be a tendency for wages to fall. In countries with initially low wages, trade will produce a tendency for wages to rise. Under the strict assumptions of the HO model, these tendencies will continue until the equalization of wages is achieved. The same will be true for rental rates on capital.

To understand this theorem better, let's try to prove that it is true. Recall our assumptions. Country *A* is assumed to be abundant in capital and scarce in labor. This would suggest that, initially, wages are high in *A*, while rents are low. In *B*, where capital is scarce and labor plentiful, we would expect just the opposite situation initially. Now, let trade occur. In *A* there will be a tendency for the output of *S* to increase and for the output of *T* to contract. The *S* industry employs relatively more capital per worker than the *T* industry does. Consequently, there will be an initial mismatch between industry *S*'s increased demand for factors and the factors that actually become available to the *S* industry as the *T* industry contracts. In particular, we would expect that *T* would keep idle more labor and less capital than *S* initially desires. Hence, in the factor markets there are an excess supply of labor at the initial wage and an excess demand for capital at the existing rental rate. For equilibrium to return, we would expect that wages would fall in *A*, while rents would rise.

In country *B*, trade leads to an expansion in the output of *T*. The resources required to facilitate this expansion must come from *S*. Industry *S* uses relatively more capital per worker than *T*; hence, as it cuts back production, industry *S* releases to *T* relatively more capital per worker than *T* would like to hire at the existing factor prices. What is required for equilibrium here? Rents must fall and wages must rise.

We see from this discussion that there is a tendency for wages (rents) to fall when they are initially high and to rise when they are initially low. How do we know that they will equalize? The answer is simple. International trade leads to a common (product) price worldwide. We have assumed that markets are competitive and that technology is identical. Since each country will continue to produce some of both goods, and these goods will be produced at the same price using the same technology, it is straightforward to conclude that factor prices will equalize.

It is important to note how strict the conditions are for factor price equalization to occur. In particular, all of the assumptions of the HO model must hold perfectly. Two of the most important of these are the assumptions of no barriers to trade and of access to identical technology. If workers everywhere have the same productivity, then free trade guarantees that they will earn the same wage. However, if there are restrictions on the ability to trade, then some workers may earn more than their equally productive foreign counterparts. Since neither assumption is perfectly satisfied in the real world, we should not expect complete factor price equalization.

There is some support, however, for the main predictions of the theorem. A study by Dan Ben-David has examined how lowering trade barriers between countries has affected income levels in different countries.* His analysis focused on the effect of lowering trade barriers in Western Europe following the formation of the European Union. He shows in his study that trade liberalization leads to a marked reduction in the dispersion of incomes across countries. Since the technologies available to each of the countries in the study are quite similar, Ben-David's findings are in line with the model.

* See Dan Ben-David, "Equalizing Exchange: A Study of the Effects of Trade Liberalization," *Quarterly Journal of Economics* (1993).

The factor price equalization theorem predicts that some factor payments will rise and others fall with the introduction of trade. The next HO theorem spells out in more detail the winners and losers from trade.

The Stolper–Samuelson Theorem

Free international trade benefits the abundant factor and harms the scarce factor.*

To understand the implications of this theorem, let's return to our proof of the FPE theorem. There, we showed that wages fall in *A*, the labor-scarce country, and rise in *B*, the labor-abundant country. Also, we concluded that rents will rise in *A*, the capital-abundant country, and fall in *B*, the capital-scarce country. This, in fact, proves the theorem.†

The abundant factor enjoys an increase in its payment for productive efforts, while the scarce factor loses. The intuition behind this result is straightforward. Wages initially high in *A* because labor is relatively scarce and hence can exploit its scarcity power in the factor markets. The introduction of international trade means that manufacturers using scarce labor in *A* must now compete with manufacturers using more abundant labor in *B*. International competitive pressures tend to force down wages in *A*. Thus, even though labor is immobile between countries, its price is equalized through competitive bidding for its services, embodied in the production of goods.

What are the implications of the Stolper–Samuelson theorem? First, we now have established a reason for some groups in a society to oppose international trade. In the classical model, international trade benefits everyone. This is true because no adjustment in wages is required to guarantee full employment as workers are displaced from import-competing industries toward expanding export industries. In the HO model, scarce factors must agree to a cut in their compensation to remain employed (in either industry). Global Insights 4.2 discusses several studies of the U.S. economy that explore various implications of the HO model, including the Stolper–Samuelson theorem.

The Stolper–Samuelson theorem provides insights into why governments may impose barriers to trade. Clearly, workers who expect their wages to fall because of trade should be opposed to trade. Similarly, so should capitalists in capital-scarce countries. Consequently, we would expect that scarce factors lobby their respective governments for measures to restrict the amount of international trade that could occur. On the other hand, abundant factors are apt to lobby for free-trade policies.‡

Finally, it is important to remember that even though some in society lose from international trade, the country overall gains from international trade relative to autarky. To convince yourself of this fact, re-examine Figure 4.4. Clearly, after trade is established, each country consumes a bundle of goods that would have been unattainable in autarky. This implies a higher standard of living for each economy as a whole. Put more simply, the gainers gain from trade more than the losers lose.** This is an interesting result that has a potential policy implication. It should be possible for a system of taxation and transfers to be developed that could compensate the losers for their loss while leaving the gainers better off than

* This theorem was first spelled out in Wolfgang Stolper and Paul Samuelson, "Protection and Real Wages," *Review of Economic Studies* (1941).

† A more formal proof of this theorem is provided in Appendix 4.1.

‡ In an interesting and highly readable paper, Stephen Magee tests this proposition. He finds that in nineteen of twenty cases, industry and labor groups take identical positions with respect to protectionist policies. One explanation of these findings is that in the short run, capital is not mobile between sectors. For more on this point, see Appendix 4.2. The reference is Stephen Magee, "Three Simple Tests of the Stolper–Samuelson Theorem," in *Current Issues in World Trade and Payments*, ed. P. Oppenheimer (London: Routledge & Kegan Paul, 1980), 138–153.

** An elegant proof of this statement can be found in Avinash Dixit and Victor Norman, *Theory of International Trade* (Cambridge, England: Cambridge University Press, 1980).

they would be in autarky. Such a system has never been implemented, but attempts at such programs (albeit highly imperfect) have been made in the United States and elsewhere. In Chapter 8 we briefly discuss the U.S. program known as trade adjustment assistance, put into place after World War II.

Global Insights 4.2

Trade, Wages, and Jobs in the U.S. Economy

Over the past three decades there has been a remarkable shift in the distribution of income across various segments of the U.S. economy. Real wages paid to blue-collar workers have grown only slightly.* For much of this period, real wages paid to college graduates have risen significantly, leading to a significant widening in the gap between the wages paid to the two groups of workers. At the same time, the real earnings of the richest in America were rapidly rising to record levels. In 2006, the share of corporate profits in national income rose to nearly the highest it had been in the past 60 years. As these income and income shares have changed so too has the nature of the American economy. There has been a sharp reduction in employment in manufacturing, especially in low-skill sectors such as textiles and footwear and a large expansion of service sector employment. Many politicians, union leaders, and commentators have deplored these changes, often pointing to international trade as being responsible. They argue that trade with low-wage countries is destroying the U.S. manufacturing base, and the process of factor price equalization predicted by the HO model is causing low-skilled wages to fall toward wage rates paid in developing countries.

One of the features of the international trade experience of the United States over the past several decades and especially since the early 1990s is the rising importance of imports of manufactured goods from Asian and certain Latin American countries. Most prominent among these are China and the Asian NICs (Hong Kong, the Republic of Korea, Singapore, and Taiwan) as well as Brazil, Malaysia, Mexico, and Thailand.† Various economists have looked at the data to try to determine if this increased trade has led to the widening American income gap. In the mid-1990s, a series of studies concluded that rapid technological change had caused firms to reduce their demand for low-skilled workers, leading to reduced wages and employment levels, and that international trade played at most only a small role in expanding the earnings gap.‡

As the gap has continued to widen, several economists have returned to study the question and now find themselves taking opposing positions. Robert Lawrence continues to argue that trade is not responsible, pointing to the fact that the growth in the earnings gap has slowed even as Chinese imports have expanded. He also contends that America no longer makes many of the low-skilled, labor-intensive goods it imports. And, even if it does make goods that are also imported from developing countries, the production process used in the United States is much more capital intensive than that used overseas. Thus, he sees little direct industrial competition from developing countries and little reason to blame trade for the income gap.**

In a recent paper, Paul Krugman also re-examines the issue. He argues that trade is increasingly responsible for expanding the income gap. This is because of the growing practice of international vertical specialization in production. Lower technological components of high-tech goods are made or assembled in developing countries. In the process, American demand for lower-skilled workers previously used to perform these duties falls, causing wages for these workers to decline. Despite Krugman's conclusion that the effect of rapid trade growth on wage inequality may be significant, he acknowledges that the statistical evidence in support of his argument is fragmentary.††

Thus, at this point, the impact of trade on U.S. wages and the earnings gap between skilled and unskilled workers remains unclear. What is certain, however, is that trade is not the only factor that may have played a role. Technological change, the decline in unionism, and many other factors have also contributed to the earnings gap. In addition, the gap itself may be mis-measured in that non-wage benefits provided to workers typically are not included in the calculations.

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* Blue-collar workers include precision production craft and repair workers, machine operators, transportation handlers, and laborers.

† These nine countries accounted for 80 percent of the increase in U.S trade with all developing countries between 1980 and 2004.

‡ See, for instance, Paul Krugman and Robert Z. Lawrence, "Trade, Jobs and Wages," *Scientific American* (1994); and Gary Burtless, "International Trade and the Rise of Earnings Inequality," *Journal of Economic Literature* (1995).

** See Robert Z. Lawrence, "Blue-Collar Blues: Is Trade to Blame for Rising U.S. Income Inequality?" Peterson Institute for International Economics, Washington, D.C., 2008.

†† See Paul Krugman, "Trade and Wages: Reconsidered," *Brookings Papers on Economic Activity* (Spring 2008).

SOME FINAL OBSERVATIONS

This chapter has sought to spell out the simple Heckscher–Ohlin model of the commodity composition of international trade. For about 20 years, from about 1933 to 1953, this model was perhaps the most revered general equilibrium theory in all of economics. Economists marveled at its logical tightness, its seeming explanation for many of the phenomena found in real-world trade patterns, and the degree to which the model could be manipulated to study issues such as the effect of trade on the distribution of income. For these reasons, even today most trade economists prefer to work with this model.

As we shall see in the next chapter, problems have emerged with the model. Much as with the problems encountered with the classical model, these revolve around difficulties economists have had in squaring the many predictions of the model with reality. This, in turn, has led some economists to try to expand the model, most notably by adding *more* factors and goods to the analysis. These efforts require the use of mathematical tools, such as linear algebra, to illustrate and are generally not amenable to geometry. Consequently, we forgo their discussion in this text. Suffice it to say, however, that some of the more interesting and clear-cut predictions of the simple HO model, such as factor price equalization, hold less well under more general specifications of the model.*

Other economists, prompted by the apparent shortcomings of the HO model, have sought to develop new theories of international trade patterns. Several of these new theories are discussed in the next chapter. However, none of these theories is as complete in its structure as the HO model. Thus, despite its shortcomings, the HO model is likely to retain an important place in international trade theory for some time to come.

Summary

1. The Heckscher–Ohlin (HO) model of comparative advantage is a complete model of the workings of an economy as it engages in international trade. This model holds that comparative advantage is determined by the underlying factor endowments of a country relative to endowments in the rest of the world.
2. The HO theorem states that a country has a comparative advantage in those goods whose production is intensive in the factors with which that country is relatively well endowed.
3. Unlike the classical model, the HO model predicts that in equilibrium each country will continue to produce some of both goods.
4. Also unlike the classical model, the HO model requires that strict assumptions be made about the nature of tastes in each country, or else the predictions of the theory could be overturned.
5. The HO theory also includes several other important theorems: the Rybczynski theorem, the factor price equalization theorem, and the Stolper–Samuelson theorem.
6. The Rybczynski theorem predicts that if a country's endowment of a factor increases (at constant prices), there will be a tendency for that country to produce more of the product whose production is intensive in the growing factor and less of the other.

* A clear and concise presentation of the HO model with many goods and factors can be found in Edward Leamer, *Sources of Comparative Advantage: Theory and Evidence* (Boston: MIT Press, 1984). See especially Chapter 1, which also contains a very interesting discussion of the effects on the predictions of the model when its various underlying assumptions are violated. Other contributions to the literature on the multi-factor, multi-good HO model include Alan Deardorff, "Weak Links in the Law of Comparative Advantage," *Journal of International Economics* (1979); Wilfred Ethier, "Some of the Theorems of International Trade with Many Goods and Factors," *Journal of International Economics* (1974); Ronald Jones and José Scheinkman, "The Relevance of the Two-Sector Production Model in Trade Theory," *Journal of Political Economy* (1977); Jaroslav Vanek, "The Factor Proportions Theory: The *N*-Factor Case," *Kyklos* (1968); and James Williams, "The Factor Proportions Theorem: The Case of *M* Commodities and *N* Factors," *Canadian Journal of Economics* (1977). These and many other important papers on this topic are surveyed in Wilfred Ethier, "Higher Dimensional Issues in Trade Theory," in *Handbook of International Economics*, vol. 1, ed. Ronald Jones and Peter Kenen (Amsterdam: North-Holland, 1984).

7. The factor price equalization theorem predicts that under the strict assumptions of the HO model, free trade will lead to an international equalization of individual factor payments.
8. The Stolper–Samuelson theorem predicts that trade benefits the abundant factors of a country and harms the scarce factors. This result differs from the classical model, which predicts that all individuals gain from international trade.
9. Despite the implications of the Stolper–Samuelson theorem, it is still true that trade benefits both countries, because the gainers outweigh the losers.

Exercises

1. Use a general equilibrium depiction of trade equilibrium in the HO model (e.g., either graph Figure 4.4) to prove that complete specialization in the production of exports will, in general, lower the standard of living of an economy relative to incomplete specialization.
2. Some have argued that the factor price equalization theorem implies that U.S. wages must fall to the level of those found in the least developed countries of the world. Comment on the validity of this statement.
3. Consider the following data on the factor endowments of two countries, *A* and *B*:

	Countries	
Factor Endowments	***A***	***B***
Labor force (millions of workers)	36	18
Capital stock (thousands of machines)	12	9

   a. Which country is relatively capital abundant?
   b. Which country is relatively labor abundant?
   c. Suppose that good *S* is capital intensive relative to good *T*. Which country will have comparative advantage in the production of *S*? Explain.
4. Compare and contrast the classical and HO theories of the commodity composition of trade. Discuss differences in assumptions, posttrade production points, and the effects of trade on the distribution of income.
5. Australia is land abundant, and India is labor abundant. Wheat is land intensive relative to textiles. Graphically demonstrate the pretrade and posttrade equilibria between these two countries. Find and label the trade triangles for each. Which factors gain and which factors lose when trade arises between these two countries? Explain carefully.
6. One of the important changes in the world economy over the past three decades has been the rapid increase in capital investment in the countries of the Pacific Basin (notably Japan and Korea). What are the implications of this investment for the commodity patterns of trade of these two countries, say, with respect to the United States? Explain carefully. (Hint: Think about the Rybczynski theorem.)
7. Explain carefully why the assumption of identical technology worldwide eliminates the classical basis for international trade.
8. Use the Rybczynski theorem to prove that the more dissimilar countries become in their factor endowments, the more likely it is for complete specialization to occur once trade begins.
9. Answer the questions in Exercise 3 using the following data on factor endowments of countries *C* and *D*:

	Countries	
Factor Endowments	***C***	***D***
Labor force (in millions of workers)	6	20
Capital stock (in thousands of machines)	24	40

10. Suppose that country *A* is capital abundant. It can produce two goods, *X* and *Y*. Good *Y* is labor intensive relative to good *X*. Derive *A*'s PPF and determine the pretrade relative price of *Y* in terms of *X*. Now, suppose that there is technological innovation that makes labor more productive in the *Y* industry, but not in making *X*. In a separate diagram, illustrate what would happen to *A*'s PPF and explain your result. Show as well what would happen to the pretrade relative price of *Y* in *A*. How might this affect *A*'s trade patterns? Explain.
11. The assumption (in the HO model) that the technology sets available to both the countries are identical implies that if factor prices are identical in the two countries, then exactly the same production processes for any given industry will be employed in both. True or false? Explain.

Please visit our Web site at **www.pearsoninternationaleditions.com/husted** for more exercises and readings.

APPENDIX 4.1

Alternate Proofs of Selected HO Theorems

In this appendix we provide rigorous proofs of the HO theorem and some of its basic corollaries. The principal geometric tool we use is the *production isoquant*. A production isoquant describes the various combinations of labor and capital required to produce a fixed quantity of a given product. For example, suppose good S is produced using labor (L) and capital (K). Figure A4.1 illustrates a possible isoquant map for that industry. On the axes we are measuring units of factor inputs, K and L. Along each of the curves the level of S output is constant. This is illustrated on the diagram by output levels S_0, S_1, and S_2. Note, in particular, that output increases as the isoquants lie farther and farther from the origin. This reflects the fact that more input leads to more output.

The curvature of the isoquants represents the ease with which labor can be substituted for capital and still maintain constant production. While this figure shows isoquants as they are most frequently drawn, economic theory does not limit them to having this shape. In particular, they may take the form of right angles. If this is the underlying technology, then factors are said not to be substitutable for each other. They are always used in fixed proportion, with additional amounts of any one factor useless toward the production of more output. At the other extreme, isoquants could be straight (negatively sloped) lines, indicating that factors are perfect substitutes for each other. Let us demonstrate how knowledge of these isoquants can be used to prove the various theorems.

THE HECKSCHER–OHLIN THEOREM (PRICE DEFINITION)

The HO theorem states that a country that is relatively abundant in a certain factor will have a comparative advantage in producing the good whose production is relatively intensive in that factor. How do we translate this theorem about factor endowments and intensities into a diagram?

In our example from the main part of this chapter, we illustrated the theorem by assuming that country A (B) was relatively abundant in K (L), and that good S (T) was relatively K (L) intensive in its production. Therefore, A (B) should have a comparative advantage in the production of good S (T).

Consider Figure A4.2. There, we superimpose a single isoquant from the isoquant maps for good S and good T onto a single diagram. Each isoquant represents the various technologies required to produce *exactly 1 unit* of the relevant product.

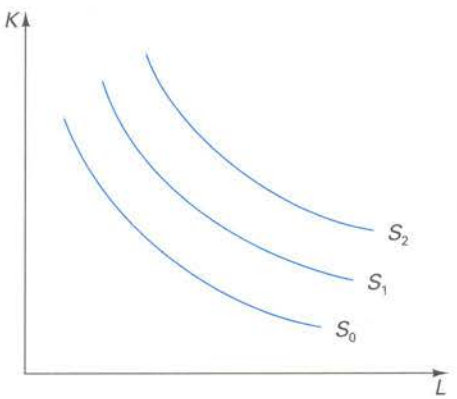

FIGURE A4.1 Isoquant Map for the S Industry

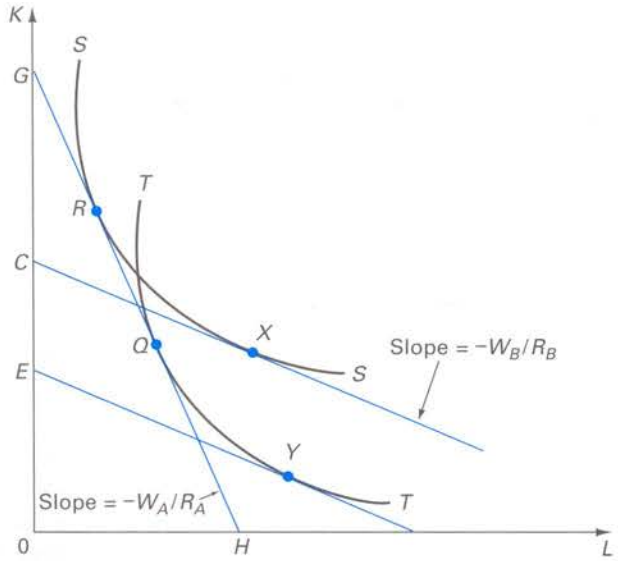

FIGURE A4.2 Proof of the HO Theorem (Price Definition)

Before proceeding with the proof, let us note several things about the diagram. First, the *S* isoquant is shown as being closer (than the *T* isoquant is) to the *K* axis. This reflects our underlying assumption that *S* is more capital intensive than *T*. Second, we have illustrated only one isoquant for each product. The assumption of constant returns to scale production functions in each industry means that isoquants are regularly spaced and identical with each other as output levels increase. Thus, if we can establish that a particular theorem holds for one combination of output levels, it will apply to all levels, since to increase or decrease output requires only to increase or decrease factors by equiproportionate changes. The assumption of constant returns to scale (and no fixed costs) also implies that average cost and marginal cost are constant and equal to each other for all levels of production.

Third, the assumption of identical technology in both countries means that these isoquants apply equally well to the production situations faced in country *A* or *B*. Hence, we can use one diagram to compare costs between countries. Finally, recall that a firm chooses its input combinations by finding the least costly input combination that will allow it to produce a desired level of output. In the diagram, such a combination occurs at the tangency of an *isocost* line (such as *GH*) with the isoquant, such as point *R* for industry *S* or point *Q* for industry *T*.

We turn now to a proof about comparative advantage. What is it that we want to show? In particular, we would like to demonstrate that when the autarky wage/rental ratio is higher in *A* than in *B*, the autarky relative price of *T* (*S*) is higher in *A* (*B*) than in *B* (*A*). Suppose that the autarky price of *S*, P_S/P_T, in *A* equals 1; that is, in money terms, *S* and *T* have the same price. If that is so, then the line segment *GH* must refer to the pretrade cost constraint facing *A*'s firms. Why? Since this line is tangent to both the *S* and *T* isoquants, the cost of producing 1 unit of each must be identical. This follows directly from the fact that *GH* is an isocost line; that is, it represents all of the combinations of *K* and *L* that can be hired with a given amount of money for the going rental and wage rates. Relying on the facts that (1) the total cost of producing 1 unit is also the marginal cost of that unit and (2) in perfect competition, price is set equal to marginal cost (*MC*), point *G* can also be described by the following ratio:

$$(MC_{SA} = P_{SA} = MC_{TA} = P_{TA})/R_A$$

By analogy, point H can be described by the ratio

$$(MC_{SA} = P_{SA} = MC_{TA} = P_{TA})/W_A$$

This implies, of course, that the slope of the line connecting points G and H is, in absolute value, equal to W_A/R_A, the autarky wage/rental ratio in A.

Let's turn our attention to country B. Because B is assumed to be more labor abundant than A, its wage/rental ratio must be lower than A's. Hence, by construction, the line segment GH *cannot apply* to country B. Instead, it must be the case that two separate but parallel isocost lines are required to illustrate B's optimal input choices for 1 unit of each good. These combinations are illustrated by points X and Y in Figure A4.2. Now, note that because the isocost line to produce 1 unit of S in B is higher than the isocost line to produce 1 unit of T in B, it must be the case that the marginal cost of a unit of S in B is greater than the marginal cost of a unit of T. That is, $MC_{SB} > MC_{TB}$. But, again, since price equals marginal cost, the condition above implies that $P_{SB} > P_{TB}$. This is exactly what we wanted to show. Since the relative price of S equals 1 in A but is greater than 1 in B, we have shown that A has a comparative advantage in S, while B has a comparative advantage in T.

THE RYBCZYNSKI THEOREM

The Rybczynski theorem states that if a country experiences an increase in its endowment of any one factor (say, labor), then, holding all other things constant (including factor and product prices), the output of the good that uses the factor intensively will rise, and the output of the other good will fall. To prove this theorem, we again rely on the isoquant map.

Consider Figure A4.3. There, we show two isoquants, one each for S and T. The isoquants we illustrate refer to an output of \$1 worth of each good. Suppose that the relative price of S is equal to 1. As we have seen from the preceding discussion, this must imply that there is an isocost line that is just tangent to the two isoquants, just as drawn in the diagram. Furthermore, we know that the vertical and horizontal intercepts of this isocost line must equal $+1/R$ and $+1/W$, respectively. The tangency points F and D determine the optimal input combinations to produce \$1 of S output and \$1 of T output. And, if wages and rental rates are held fixed, the assumption

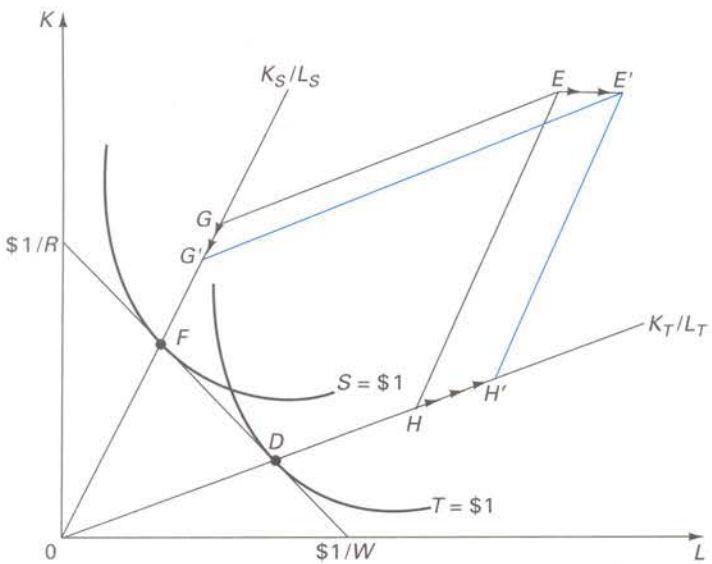

FIGURE A4.3 Proof of the Rybczynski Theorem

of constant returns to scale guarantees that the slope of the rays from the origin passing through points F and D determines the optimal capital/labor use ratios for the two industries, given those factor prices.

How does the economy divide its output between the two products? This depends upon the overall supply of available factors of production. Suppose that the economy is initially endowed with a set of factors defined by point E. To find the optimal production of S and T, complete the parallelogram from point E to the two rays emanating from the origin. This defines points G and H on the two rays. These points represent optimal production levels of S and T, given the prices prevailing in the economy. How do we know that this is true? First, we know that output must occur on the rays. Second, we want to use all available resources. If, for instance, we add the factor combination represented by the line $0G$ to point H, we reach the total endowment level E. Similarly, if we add $0H$ to G, we also reach point E.

Now we are in position to prove the theorem. Suppose that the country's endowment of labor rises, but capital and prices do not change. This pulls the country's endowment point horizontally away from E to, say, E'. By completing the parallelogram with points E' and 0 at the corners, we see that the optimal production levels of S and T have changed from their old levels. In particular, the output of S has fallen (to G'), while that of T has risen (to H'). This proves the theorem.

THE STOLPER–SAMUELSON THEOREM

The Stolper–Samuelson theorem states that the factor that is used intensively in the product whose relative price has risen gains from this price rise, while the other factor loses. In the context of the HO model, this theorem translates into the simple statement that the abundant factor gains from trade, while the scarce factor loses. To see that this is true, consider Figure A4.4.

As in the preceding discussion, we illustrate two isoquants representing \$1 of output of both S and T. Let the economy produce some of both goods. At initial prices and values of W and R, the optimal input allocation for \$1 of output of each good is given by points F and D. Now, let the price of T rise, say, due to the opening of international trade. At a higher price for T, \$1 worth of this product would lie on a lower isoquant (remember that isoquants refer to physical units).

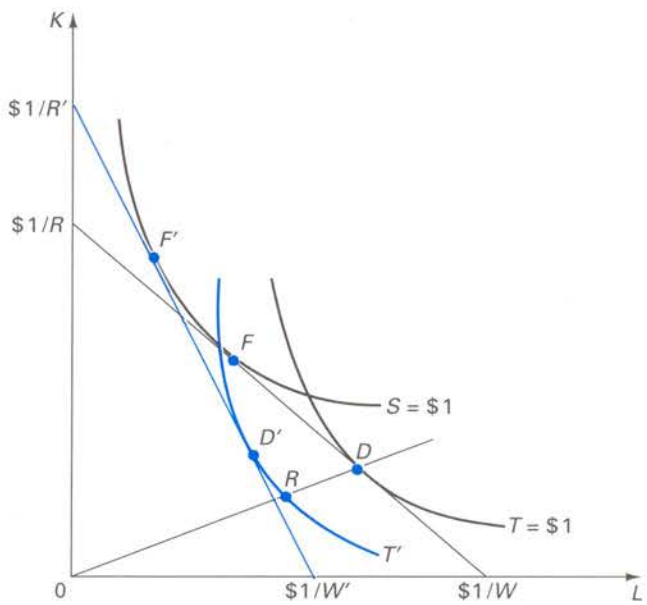

FIGURE A4.4 Proof of the Stolper–Samuelson Theorem

Thus, the $T = \$1$ isoquant would become the isoquant labeled T'. If some of both goods are still to be produced, the \$1 isocost line must rotate to maintain tangency with the two isoquants S and T'. How can this be accomplished? Wages and rents must change. The new isocost line has intercepts $\$1/R'$ and $+ 1/W'$. Since the numerators of these fractions are the same as before, we can deduce what has happened to rents and wages by simply comparing $1/R$ with $1/R'$ and $1/W$ with $1/W'$. In the first case, the fraction has risen. This could occur only if $R' < R$, that is, if rents have fallen. On the other hand, a comparison of horizontal intercepts shows that W has risen.

These changes in W and R are nominal changes. What has happened to the purchasing power of capitalists and labor? For capitalists, the answer is straightforward. We have assumed that the price of S has stayed fixed while the price of T has risen. A fall in R, therefore, means that capitalists have lost purchasing power in terms of either product—they are definitely worse off when the price of the labor-intensive good T rises relative to the price of the capital-intensive good S.

What about labor? The rise in W definitely means that labor can afford to purchase more S, because its price has been assumed to remain constant. However, the price of T has risen. Can labor buy more or less of this product? The answer is more. How do we know? Graphically, the increase in wages can be found by comparing the proportion $(1/W)/(1/W')$. This increase is greater than the proportionate increase in the price of T, which can be found by the ratio of the line segments $0D/0R$. This proves the theorem.

APPENDIX 4.2

The Specific Factors Model

The Heckscher–Ohlin model takes a long-run view of the world. By that we mean that in comparing one equilibrium point to another, enough time is assumed to have elapsed to allow capital equipment to be shifted from one industry to another. In the real world, machines tend to have very specific uses, and shifting capital resources across industries can take considerable time. As it turns out, if factors cannot move quickly between sectors, then the short-run impacts of international trade may be somewhat different than the long-run impacts. In this appendix, we present a brief discussion of the specific factors (Ricardo–Viner) model. This model is very useful in helping us to understand the short-run impact of international trade on an economy.

The specific factors model maintains all of the assumptions and structure of the HO model with one exception: In this model, one of the factors is immobile between industries. Here we will assume that the immobile factor is capital, so that the machinery used in the S industry is distinct from the machinery used in the T industry. Moreover, these two types of machines cannot be substituted for each other in the production process. Since the two types of machines are completely distinct, there is no guarantee that the owners of these machines receive the same rental payments. On the other hand, labor is assumed to be perfectly mobile, ensuring that the wage rate is the same in both industries.

Figure A4.5 shows the pretrade equilibrium situation in country A's labor market. The figure is somewhat different than others we have presented, so some explanation is required. The length of the horizontal axis measures the total amount of labor in A, with units of labor in the S industry measured off to the right from point O_S and labor in T measured to the left from O_T. The two vertical axes both measure the wage rate in A. The VMP_S curve represents the S industry's demand for labor. The height of this demand curve at a particular level of employment equals the value marginal product of labor, $P_S \times MP_{LS}$. This amount of money is the revenue that firms in S receive by selling what the last worker hired has produced. Clearly, firms will want to hire workers only so long as the cost of the last worker hired does not exceed the value of that worker's marginal product. In other words, the S industry will hire workers until $W = P_S \times MP_{LS}$.

The VMP_T curve is the T industry's demand for labor. It points in the opposite direction because we measure labor working in T starting at point O_T and increasing as we move

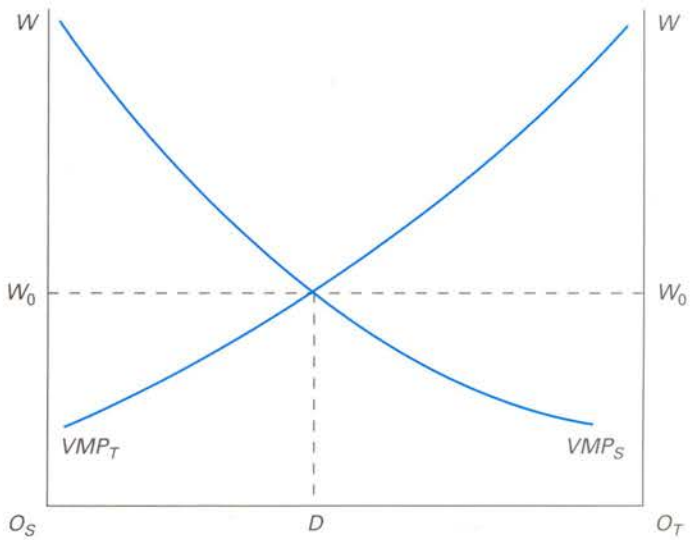

FIGURE A4.5 Equilibrium in the Specific Factors Model

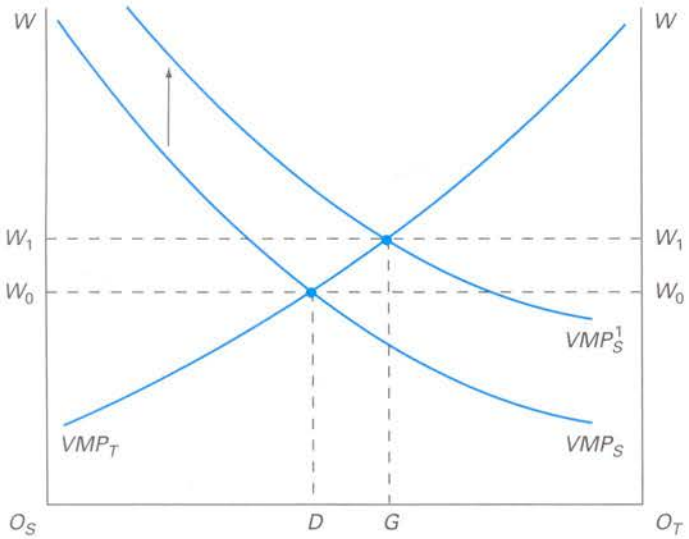

FIGURE A4.6 Effects of an Increase in P_S

left in the figure. As was the case with industry S, the T industry will also hire workers until $W = P_T \times MP_{LT}$.

Labor market equilibrium occurs at the intersection of the two curves. The height of the intersection point determines the wage paid workers, no matter where they are employed. At that point, and at no other in the diagram, $W = P_S \times MP_{LS}$ and $W = P_T \times MP_{LT}$. In equilibrium, O_SD workers are employed in the S industry and DO_T workers in industry T. The wage paid workers in both industries is W_0.

Let's use the specific factors model to consider the effect on wages and rental rates if country A opens up to international trade. We have already established that A has comparative advantage in good S and that once trade opens P_S/P_T will rise in A. It is easiest to illustrate what will happen in A's labor market if we suppose that the relative price rises because P_S rises while P_T remains constant. Under this assumption, the demand for labor will rise in industry S by the amount of the increase in P_S while the demand for labor in industry T will remain constant. We show this in Figure A4.6.

How have things changed in the new equilibrium? Employment has risen in S, from O_SD workers to O_SG workers, while employment in T has fallen by the same amount. As the diagram illustrates, international trade causes a redistribution of jobs. In this case, the money wage paid to all workers rises, from W_0 to W_1. Are workers better off? Not necessarily, because the price of S has gone up too and by more than the rise in W. If workers consume large amounts of S and only little T, they are worse off.

What about owners of capital? In industry S, capital owners are better off in real terms. The same number of machines produce more because there are more workers and the goods are sold at a higher price. Thus, rental payments must rise. In contrast, owners of capital used in T must be worse off. Their machines produce less, because employment has declined and the price of T has not changed. Thus, rental payments earned in T must fall. Given this, it is easy to imagine why capital and labor in certain industries might oppose the expansion of international trade.