Factor Endowments and the Heckscher–Ohlin Theory

chapter 5

LEARNING GOALS:

After reading this chapter, you should be able to:

- **Explain how comparative advantage is based on differences in factor endowments across nations**
- **Explain how trade affects relative factor prices within and across nations**
- **Explain why trade is likely to be only a small reason for higher skilled–unskilled wage inequalities**

5.1 Introduction

In this chapter, we extend our trade model in two important directions. First, we explain the basis of (i.e., what determines) comparative advantage. We have seen in previous chapters that the difference in relative commodity prices between two nations is evidence of their comparative advantage and forms the basis for mutually beneficial trade. We now go one step further and explain the reason, or cause, for the difference in relative commodity prices and comparative advantage between the two nations. The second way we extend our trade model is to analyze the effect that international trade has on the earnings of factors of production in the two trading nations. That is, we want to examine the effect of international trade on the earnings of labor as well as on international differences in earnings.

These two important questions were left largely unanswered by Smith, Ricardo, and Mill. According to classical economists, comparative advantage was based on the difference in the *productivity of labor* (the only factor of production they explicitly considered) among nations, but they provided no explanation for such a difference in productivity, except for possible differences in climate. The Heckscher–Ohlin theory goes much beyond that by extending the trade model of the previous two chapters to examine the basis for comparative advantage and the effect that trade has on factor earnings in the two nations.

Section 5.2 deals with the assumptions of the theory. Section 5.3 clarifies the meaning of factor intensity and factor abundance, and explains how the latter is related to factor prices and the shape of the production frontier in each nation.

Section 5.4 presents the Heckscher–Ohlin model proper and illustrates it graphically. The effect of international trade on factor earnings and income distribution in the two nations is examined in Section 5.5. The chapter concludes with Section 5.6, which reviews empirical tests of the Heckscher–Ohlin trade model. The appendix presents the formal derivation of the factor–price equalization theorem and introduces more advanced tools for empirically testing the Heckscher–Ohlin trade model.

5.2 Assumptions of the Theory

The Heckscher–Ohlin theory is based on a number of simplifying assumptions (some made only implicitly by Heckscher and Ohlin). Rather than note these assumptions along the way as they are needed in the analysis, it is both logical and convenient to present them together and explain their meaning at this point. This will not only allow us to view the theory to be presented in a better perspective but will also make the presentation smoother and more direct. To make the theory more realistic, we will relax these assumptions in the next chapter and examine the effect that such relaxation has on the conclusions reached in this chapter.

5.2A The Assumptions

The Heckscher–Ohlin theory is based on the following assumptions:

1. There are two nations (Nation 1 and Nation 2), two commodities (commodity X and commodity Y), and two factors of production (labor and capital).
2. Both nations use the same technology in production.
3. Commodity X is labor intensive, and commodity Y is capital intensive in both nations.
4. Both commodities are produced under constant returns to scale in both nations.
5. There is incomplete specialization in production in both nations.
6. Tastes are equal in both nations.
7. There is perfect competition in both commodities and factor markets in both nations.
8. There is perfect factor mobility within each nation but no international factor mobility.
9. There are no transportation costs, tariffs, or other obstructions to the free flow of international trade.
10. All resources are fully employed in both nations.
11. International trade between the two nations is balanced.

5.2B Meaning of the Assumptions

The meaning of assumption 1 (two nations, two commodities, and two factors) is clear, and it is made in order to be able to illustrate the theory with a two-dimensional figure. This assumption is made with the knowledge (discussed in the next chapter) that its relaxation (so as to deal with the more realistic case of more than two nations, more than two commodities, and more than two factors) will leave the conclusions of the theory basically unchanged.

Assumption 2 (that both nations use the *same technology*) means that both nations have access to and use the same general production techniques. Thus, if factor prices were the same in both nations, producers in both nations would use exactly the same amount of labor and capital in the production of each commodity. Since factor prices usually differ, producers in each nation will use more of the relatively cheaper factor in the nation to minimize their costs of production.

Assumption 3 (that commodity X is labor intensive and commodity Y is capital intensive) means that commodity X requires relatively more labor to produce than commodity Y in both nations. In a more technical and precise way, this means that the labor–capital ratio (L/K) is higher for commodity X than for commodity Y in both nations at the same relative factor prices. This is equivalent to saying that the capital–labor ratio (K/L) is *lower for X than for Y*. But it does not mean that the K/L ratio for X is the same in Nation 1 and Nation 2, only that K/L is lower for X than for Y in both nations. This point is so important that we will use Section 5.3A to clarify it.

Assumption 4 (constant returns to scale in the production of both commodities in both nations) means that increasing the amount of labor and capital used in the production of any commodity will increase output of that commodity in the same proportion. For example, if Nation 1 increases by 10 percent both the amount of labor and the amount of capital that it uses in the production of commodity X, its output of commodity X will also increase by 10 percent. If it doubles the amount of both labor and capital used, its output of X will also double. The same is true for commodity Y and in Nation 2.

Assumption 5 (incomplete specialization in production in both nations) means that even with free trade both nations continue to produce both commodities. This implies that neither of the two nations is "very small."

Assumption 6 (equal tastes in both nations) means that demand preferences, as reflected in the shape and location of indifference curves, are identical in both nations. Thus, when relative commodity prices are equal in the two nations (as, for example, with free trade), both nations will consume X and Y in the same proportion. This is illustrated in Section 5.4C.

Assumption 7 (perfect competition in both commodities and factor markets) means that producers, consumers, and traders of commodity X and commodity Y in both nations are each too small to affect the price of these commodities. The same is true for each user and supplier of labor time and capital. Perfect competition also means that, in the long run, commodity prices equal their costs of production, leaving no (economic) profit after all costs (including implicit costs) are taken into account. Finally, perfect competition means that all producers, consumers, and owners of factors of production have perfect knowledge of commodity prices and factor earnings in all parts of the nation and in all industries.

Assumption 8 (perfect internal factor mobility but no international factor mobility) means that labor and capital are free to move, and indeed do move quickly, from areas and industries of lower earnings to areas and industries of higher earnings until earnings for the same type of labor and capital are the same in all areas, uses, and industries of the nation. On the other hand, there is zero international factor mobility (i.e., no mobility of factors among nations), so that international differences in factor earnings would persist indefinitely in the absence of international trade.

Assumption 9 (no transportation costs, tariffs, or other obstructions to the free flow of international trade) means that specialization in production proceeds until relative (and absolute) commodity prices are the same in both nations with trade. If we allowed for transportation costs and tariffs, specialization would proceed only until relative (and absolute) commodity prices differed by no more than the costs of transportation and the tariff on each unit of the commodity traded.

Assumption 10 (all resources are fully employed in both nations) means that there are no unemployed resources or factors of production in either nation.

Assumption 11 (international trade between the two nations is balanced) means that the total value of each nation's exports equals the total value of the nation's imports.

5.3 Factor Intensity, Factor Abundance, and the Shape of the Production Frontier

Since the Heckscher–Ohlin theory to be presented in Section 5.4 is expressed in terms of factor intensity and factor abundance, it is crucial that the meaning of these terms be very clear and precise. Hence, the meaning of factor intensity is explained and illustrated in Section 5.3A. In Section 5.3B, we examine the meaning of factor abundance and its relationship to factor prices. Finally, in Section 5.3C, we focus on the relationship between factor abundance and the shape of the production frontier of each nation.

5.3A Factor Intensity

In a world of two commodities (X and Y) and two factors (labor and capital), we say that commodity Y is *capital intensive* if the capital–labor ratio (K/L) used in the production of Y is greater than K/L used in the production of X.

For example, if two units of capital ($2K$) and two units of labor ($2L$) are required to produce one unit of commodity Y, the capital–labor ratio is one. That is, $2/2$ in the production of Y. If at the same time $1K$ and $4L$ are required to produce one unit of X, $K/L = 1/4$ for commodity X. Since $K/L = 1$ for Y and $K/L = 1/4$ for X, we say that Y is K intensive and X is L intensive.

Note that it is not the *absolute* amount of capital and labor used in the production of commodities X and Y that is important in measuring the capital and labor intensity of the two commodities, but the amount of capital *per unit of labor* (i.e., K/L). For example, suppose that $3K$ and $12L$ (instead of $1K$ and $4L$) are required to produce 1X, while to produce 1Y requires $2K$ and $2L$ (as indicated earlier). Even though to produce 1X requires $3K$, while to produce 1Y requires only $2K$, commodity Y would still be the K-intensive commodity because K/L is higher for Y than for X. That is, $K/L = 2/2$ for Y, but $K/L = 3/12 = 1/4$ for X.

If we plotted capital (K) along the vertical axis of a graph and labor (L) along the horizontal axis, and production took place along a straight-line ray from the origin, the slope of the line would measure the capital–labor ratio (K/L) in the production of the commodity. This is shown in Figure 5.1.

Figure 5.1 shows that Nation 1 can produce 1Y with $2K$ and $2L$. With $4K$ and $4L$, Nation 1 can produce 2Y because of constant returns to scale (assumption 4). Thus, $K/L = 2/2 = 4/4 = 1$ for Y. This is given by the slope of 1 for the ray from the origin for commodity Y in Nation 1 (see the figure). On the other hand, $1K$ and $4L$ are required to produce 1X, and $2K$ and $8L$ to produce 2X, in Nation 1. Thus, $K/L = 1/4$ for X in Nation 1. This is given by the slope of $1/4$ for the ray from the origin for commodity X in Nation 1. Since K/L, or the slope of the ray from the origin, is higher for commodity Y than for commodity X, we say that commodity Y is K intensive and commodity X is L intensive in Nation 1.

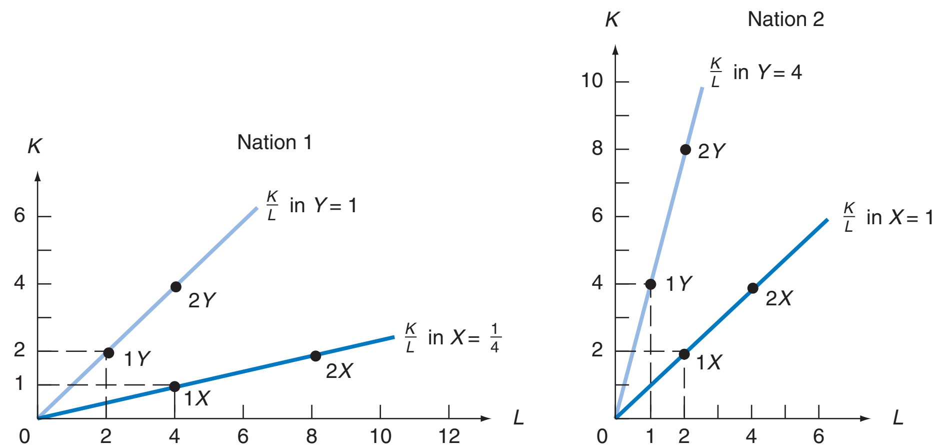


FIGURE 5.1. Factor Intensities for Commodities X and Y in Nations 1 and 2.
In Nation 1, the capital–labor ratio (K/L) equals 1 for commodity Y and $K/L = \frac{1}{4}$ for commodity X. These are given by the slope of the ray from the origin for each commodity in Nation 1. Thus, commodity Y is the K-intensive commodity in Nation 1. In Nation 2, $K/L = 4$ for Y and $K/L = 1$ for X. Thus, commodity Y is the K-intensive commodity, and commodity X is the L-intensive commodity in both nations. Nation 2 uses a higher K/L than Nation 1 in the production of both commodities because the relative price of capital (r/w) is lower in Nation 2. If r/w declined, producers would substitute K for L in the production of both commodities to minimize their costs of production. As a result, K/L would rise for both commodities.

In Nation 2, K/L (or the slope of the ray) is 4 for Y and 1 for X (see Figure 5.1). Therefore, Y is the K-intensive commodity, and X is the L-intensive commodity in Nation 2 also. This is illustrated by the fact that the ray from the origin for commodity Y is steeper (i.e., has a greater slope) than the ray for commodity X in both nations.

Even though commodity Y is K intensive in relation to commodity X in both nations, *Nation 2 uses a higher K/L* in producing both Y and X than Nation 1. For Y, $K/L = 4$ in Nation 2 but $K/L = 1$ in Nation 1. For X, $K/L = 1$ in Nation 2 but $K/L = \frac{1}{4}$ in Nation 1. The obvious question is: Why does Nation 2 use more K-intensive production techniques in both commodities than Nation 1? The answer is that capital must be relatively cheaper in Nation 2 than in Nation 1, so that producers in Nation 2 use relatively more capital in the production of both commodities to minimize their costs of production. But why is capital relatively cheaper in Nation 2? To answer this question, we must define factor abundance and examine its relationship to factor prices.

Before doing this, however, we must settle one other related point of crucial importance. This refers to what happens if, for whatever reason, the relative price of capital falls. Producers would substitute capital for labor in the production of both commodities to minimize their costs of production. As a result, both commodities would become more K intensive. However, only if K/L in the production of commodity Y exceeds K/L in the production of commodity X *at all possible relative factor prices* can we say *unequivocally* that commodity Y is the K-intensive commodity. This is basically an empirical question and will be explored in Section 5.6. For now, we will assume that this is true (i.e., that commodity Y remains the K-intensive commodity at all possible relative factor prices).

To summarize, we say that commodity Y is unequivocally the K-intensive commodity if K/L is higher for commodity Y than for commodity X at all possible relative factor prices.

Nation 2 uses a higher K/L in the production of both commodities because the relative price of capital is lower in Nation 2 than in Nation 1. If the relative price of capital declines, producers will substitute K for L in the production of both commodities to minimize their costs of production. Thus, K/L will rise for both commodities, but Y continues to be the K-intensive commodity.

5.3B Factor Abundance

There are two ways to define factor abundance. One way is in terms of physical *units* (i.e., in terms of the overall amount of capital and labor available to each nation). Another way to define factor abundance is in terms of relative factor prices (i.e., in terms of the rental price of capital and the price of labor time in each nation).

According to the definition in terms of physical units, Nation 2 is capital abundant if the ratio of the total amount of capital to the total amount of labor (*TK/TL*) available in Nation 2 is *greater* than that in Nation 1 (i.e., if *TK/TL* for Nation 2 exceeds *TK/TL* for Nation 1). Note that it is not the absolute amount of capital and labor available in each nation that is important but the *ratio* of the total amount of capital to the total amount of labor. Thus, Nation 2 can have less capital than Nation 1 and still be the capital-abundant nation if *TK/TL* in Nation 2 exceeds *TK/TL* in Nation 1.

According to the definition in terms of factor prices, Nation 2 is capital abundant if the ratio of the rental price of capital to the price of labor time (P_K/P_L) is *lower* in Nation 2 than in Nation 1 (i.e., if P_K/P_L in Nation 2 is smaller than P_K/P_L in Nation 1). Since the rental price of capital is usually taken to be the interest rate (r) while the price of labor time is the wage rate (w), $P_K/P_L = r/w$. Once again, it is not the absolute level of r that determines whether or not a nation is the K-abundant nation, but r/w. For example, r may be higher in Nation 2 than in Nation 1, but Nation 2 will still be the K-abundant nation if r/w is lower there than in Nation 1.

The relationship between the two definitions of factor abundance is clear. The definition of factor abundance in terms of physical units considers only the supply of factors. The definition in terms of relative factor prices considers both demand and supply (since we know from principles of economics that the price of a commodity or factor is determined by both demand and supply considerations under perfect competition). Also from principles of economics, we know that the demand for a factor of production is a derived demand—derived from the demand for the final commodity that requires the factor in its production.

Since we have assumed that tastes, or demand preferences, are the same in both nations, the two definitions of factor abundance give the same conclusions in our case. That is, with *TK/TL* larger in Nation 2 than in Nation 1 in the face of equal demand conditions (and technology), P_K/P_L will be smaller in Nation 2. Thus, Nation 2 is the K-abundant nation in terms of both definitions.

This is not always the case. For example, it is conceivable that the demand for commodity Y (the K-intensive commodity), and therefore the demand for capital, could be so much higher in Nation 2 than in Nation 1 that the relative price of capital would be higher in Nation 2 than in Nation 1 (despite the relatively greater supply of capital in Nation 2). In that case, Nation 2 would be considered K abundant according to the definition in physical terms and L abundant according to the definition in terms of relative factor prices.

In such situations, it is the definition in terms of relative factor prices that should be used. That is, a nation is K abundant if the relative price of capital is lower in it than in the other nation. In our case, there is no such contradiction between the two definitions. Nation 2 is K abundant and Nation 1 is L abundant in terms of both definitions. We will assume this to be the case throughout the rest of the chapter, unless otherwise explicitly indicated.

5.3c Factor Abundance and the Shape of the Production Frontier

Since Nation 2 is the K-abundant nation and commodity Y is the K-intensive commodity, Nation 2 can produce *relatively* more of commodity Y than Nation 1. On the other hand, since Nation 1 is the L-abundant nation and commodity X is the L-intensive commodity, Nation 1 can produce relatively more of commodity X than Nation 2. This gives a production frontier for Nation 1 that is relatively flatter and wider than the production frontier of Nation 2 (if we measure X along the horizontal axis).

In Figure 5.2, we have plotted the production frontiers of Nation 1 and Nation 2 on the same set of axes. (These are the same production frontiers introduced with Figure 3.1 and used throughout Chapters 3 and 4.) Since Nation 1 is the L-abundant nation and commodity X is the L-intensive commodity, Nation 1's production frontier is skewed toward the horizontal axis, which measures commodity X. On the other hand, since Nation 2 is the K-abundant nation and commodity Y is the K-intensive commodity, Nation 2's production frontier is skewed toward the vertical axis measuring commodity Y. The production frontiers are plotted on the same set of axes so that the difference in their shape is more clearly evident and because this will facilitate the illustration of the Heckscher–Ohlin model in

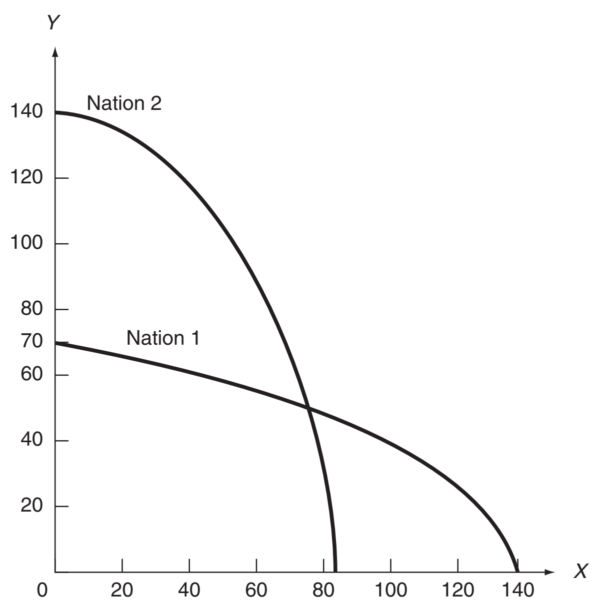


FIGURE 5.2. The Shape of the Production Frontiers of Nation 1 and Nation 2.
The production frontier of Nation 1 is flatter and wider than the production frontier of Nation 2, indicating that Nation 1 can produce relatively more of commodity X than Nation 2. The reason for this is that Nation 1 is the L-abundant nation and commodity X is the L-intensive commodity.

Section 5.4C. Case Study 5-1 presents the relative resource endowments of various countries, and Case Study 5-2 gives the capital stock per worker for a number of leading developed and developing countries.

CASE STUDY 5-1 Relative Resource Endowments of Various Countries

Table 5.1 gives the share of the world's resource endowments of (1) land, (2) physical capital, (3) research and development (R&D) scientists, (4) highly skilled labor, (5) medium-skilled labor, and (6) unskilled labor, as well as the share of world GDP, for most of the leading developed and developing countries in 2006 (more recent data were not available for all resource endowments). Arable land is the general resource to produce agricultural products; physical capital refers to machinery, factories, and other nonhuman means of production; R&D scientists refers to the most highly skilled labor with more than tertiary (college) education and used to produce the most highly technological products; highly skilled labor is labor that has completed tertiary or college education; unskilled labor is labor that has no education beyond primary education. A nation is broadly defined as having a relative abundance of those factors for which its share of the world availability of that factor exceeds the nation's share of world output (GDP in terms of purchasing power).

The table shows that the U.S. share of the world availability of R&D scientists and highly skilled labor exceeds its share of world GDP; it is about the same as its share of world output for the availability of physical capital, and smaller than its share of world GDP for arable land and

TABLE 5.1. Factor Endowments of Various Countries as a Percentage of the World Total in 2006

Country	(1) Arable Land	(2) Physical Capital	(3) R&D Scientists	(4) Highly Skilled Labor	(5) Medium-Skilled Labor	(6) Unskilled Labor	(7) GDP
United States	12.2%	22.0%	24.1%	22.2%	7.5%	0.4%	21.9%
Japan	0.3	14.1	12.3	10.3	4.2	0.2	7.0
Germany	0.8	6.8	4.9	4.4	3.3	0.5	4.5
United Kingdom	0.4	2.8	3.2	3.4	2.2	0.1	3.4
France	1.3	4.4	3.5	3.1	1.9	0.1	3.3
Italy	0.5	3.5	1.4	1.5	2.3	0.3	2.8
Canada	3.2	3.0	2.2	3.1	0.9	0.1	2.0
China	10.1	11.1	21.1	5.9	25.6	24.9	10.2
India	11.2	4.9	1.6	5.9	9.2	21.7	4.5
Russia	8.5	2.3	8.1	2.8	6.6	0.1	3.0
Brazil	4.2	2.9	1.5	2.6	3.2	2.9	2.7
Korea	0.1	3.3	3.5	2.6	1.7	1.3	1.7
Mexico	1.8	2.0	0.8	3.2	1.5	0.2	2.1
Rest of the World	45.4	16.7	11.7	29.0	28.4	47.2	30.7
World	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: Author's calculations on data from: World Bank, OECD, and United Nations Data Bank.

(continued)

CASE STUDY 5-1 Continued

medium-skilled and unskilled labor. Thus, we would expect the United States to have a net export surplus or comparative advantage in the most highly technological goods that are intensive in R&D scientists and highly skilled labor, to be more or less neutral in capital-intensive goods, and to have a comparative disadvantage in agricultural and other land and natural resource-intensive products, as well as in all types of goods produced with medium-skilled and unskilled labor.

Japan has a relative abundance (and we expect it to have a comparative advantage) in capital-intensive products and in products requiring intensive use of R&D scientists and highly skilled labor; the United Kingdom does not seem to have any relative abundance in broadly defined factors (in fact, the United Kingdom has a relative abundance of highly skilled financial labor). Germany and France have a relative abundance of physical capital and R&D scientists; Italy has a relative abundance in physical capital; and Canada is relatively abundant in arable land, physical capital, R&D scientists, and highly skilled labor.

China has a relative abundance of physical capital but especially of R&D scientists, medium-skilled labor, and unskilled labor; India has a relative abundance of arable land, physical capital, highly skilled, medium-skilled, and unskilled labor; Russia is relatively abundant in arable land, R&D scientists, and medium-skilled labor; Brazil has a relative abundance in all but R&D scientists and highly skilled labor; Korea has a relative abundance in physical capital, R&D scientists, and highly skilled labor; and Mexico is relatively abundant in highly skilled labor.

CASE STUDY 5-2 Capital–Labor Ratios of Selected Countries

Table 5.2 gives the capital stock per worker of a number of developed and developing countries in 2006. Capital stocks are measured in 1990 international dollar prices to reflect the actual purchasing power of the dollar in each country, thus allowing meaningful international comparisons. The table shows that the United States has a lower capital stock per worker than many other industrial or developed countries (the left-hand part of the table) but a much higher capital stock per worker than developing countries (the right-hand part of the table). From Table 5.2, we can thus infer that the United States has a comparative advantage in capital-intensive products with respect to developing countries but not with respect to many other developed or industrial countries. This is broadly consistent with the data presented in Table 5.1.

TABLE 5.2. Capital Stock per Worker of Selected Countries in 2006 (in 1990 International Dollar Prices)

Developed Country	Capital Stock per Worker	Developing Country	Capital Stock per Worker
Japan	$111, 615	Korea	$45, 235
Canada	89, 652	Mexico	23, 921
Germany	87, 400	Turkey	20, 478
France	85, 097	Brazil	16, 650
Italy	73, 966	Russia	16, 131
United States	73, 282	Thailand	11, 688
Spain	51, 814	China	7, 485
United Kingdom	44, 545	India	5, 870

Source: Author's calculations on UN data.

Having clarified the meaning of factor intensity and factor abundance, we are now ready to present the Heckscher–Ohlin theory.

5.4 Factor Endowments and the Heckscher–Ohlin Theory

In 1919, *Eli Heckscher*, a Swedish economist, published an article titled "The Effect of Foreign Trade on the Distribution of Income," in which he presented the outline of what was to become the "modern theory of international trade." The article went largely unnoticed for over ten years until *Bertil Ohlin*, another Swedish economist and former student of Heckscher, picked it up, built on it, clarified it, and in 1933 published his famous book *Interregional and International Trade*.

We will discuss only Ohlin's work, since it incorporates all that Heckscher had said in his article and much more. However, since the essence of the model was first introduced by Heckscher, due credit is given to him by calling the theory the Heckscher–Ohlin theory. Ohlin, for his part, shared (with James Meade) the 1977 Nobel prize in economics for his work in international trade.

The Heckscher–Ohlin (H–O) theory can be presented in a nutshell in the form of two theorems: the so-called *H–O theorem* (which deals with and predicts the pattern of trade) and the *factor–price equalization theorem* (which deals with the effect of international trade on factor prices). The factor–price equalization theorem will be discussed in Section 5.5. In this section, we present and discuss the H–O theorem. We begin with a statement of the theorem and briefly explain its meaning. Then we examine the general equilibrium nature of the H–O theory, and finally we give a geometrical interpretation of the model.

5.4A The Heckscher–Ohlin Theorem

Starting with the assumptions presented in Section 5.2, we can state the Heckscher–Ohlin theorem as follows: *A nation will export the commodity whose production requires the intensive use of the nation's relatively abundant and cheap factor and import the commodity whose production requires the intensive use of the nation's relatively scarce and expensive factor*. In short, the relatively labor-rich nation exports the relatively labor-intensive commodity and imports the relatively capital-intensive commodity.

In terms of our previous discussion, this means that Nation 1 exports commodity X because commodity X is the L-intensive commodity and L is the relatively abundant and cheap factor in Nation 1. Conversely, Nation 2 exports commodity Y because commodity Y is the K-intensive commodity and K is the relatively abundant and cheap factor in Nation 2 (i.e., r/w is lower in Nation 2 than in Nation 1).

Of all the possible reasons for differences in relative commodity prices and comparative advantage among nations, the H–O theorem isolates the difference in relative factor abundance, or *factor endowments*, among nations as the basic cause or determinant of comparative advantage and international trade. For this reason, the H–O model is often referred to as the factor-proportions or factor-endowment theory. That is, each nation specializes in the production and export of the commodity intensive in its relatively abundant and cheap factor and imports the commodity intensive in its relatively scarce and expensive factor.

Thus, the H–O theorem *explains* comparative advantage rather than assuming it (as was the case for classical economists). In other words, the H–O theorem postulates that the difference in relative factor abundance and prices is the *cause* of the pretrade difference in relative commodity prices between two nations. This difference in *relative* factor and *relative* commodity prices is then translated into a difference in *absolute* factor and commodity prices between the two nations (as outlined in Section 2.4D). It is this difference in absolute commodity prices in the two nations that is the *immediate* cause of trade.

5.4B General Equilibrium Framework of the Heckscher–Ohlin Theory

The general equilibrium nature of the H–O theory can be visualized and summarized with the use of Figure 5.3. Starting at the lower right-hand corner of the diagram, we see that tastes and the distribution in the ownership of factors of production (i.e., the distribution of income) together determine the demand for commodities. The demand for commodities determines the derived demand for the factors required to produce them. The demand for factors of production, together with the supply of the factors, determines the price of factors of production under perfect competition. The price of factors of production, together with technology, determines the price of final commodities. The difference in relative commodity prices between nations determines comparative advantage and the pattern of trade (i.e., which nation exports which commodity).

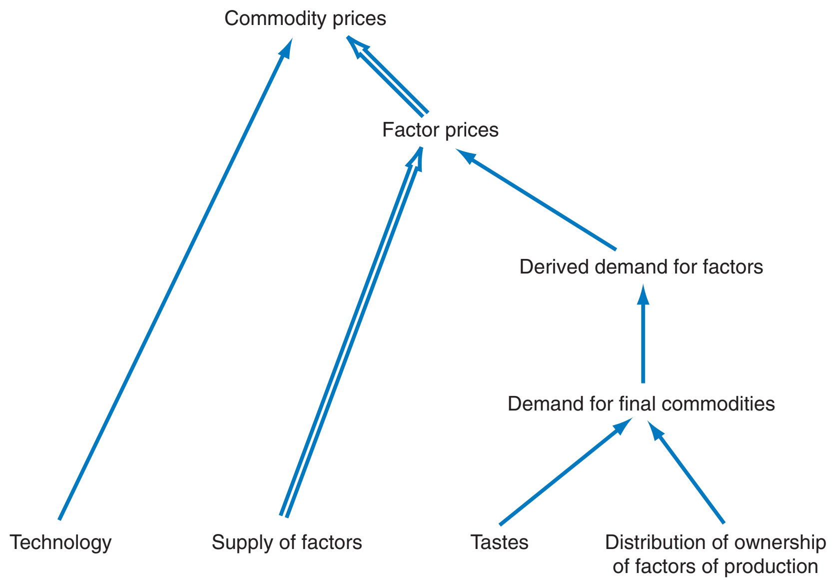


FIGURE 5.3. General Equilibrium Framework of the Heckscher–Ohlin Theory.
Beginning at the lower right-hand corner of the diagram, we see that the distribution of ownership of factors of production or income and tastes determines the demand for commodities. The demand for factors of production is then derived from the demand for final commodities. The demand for and supply of factors determine the price of factors. The price of factors and technology determine the price of final commodities. The difference in relative commodity prices among nations then determines comparative advantage and the pattern of trade.

Figure 5.3 shows clearly how all economic forces jointly determine the price of final commodities. This is what is meant when we say that the H–O model is a general equilibrium model.

However, out of all these forces working together, the H–O theorem isolates the difference in the *physical* availability or supply of factors of production among nations (in the face of equal tastes and technology) to explain the difference in relative commodity prices and trade among nations. Specifically, Ohlin assumed equal tastes (and income distribution) among nations. This gave rise to similar demands for final commodities and factors of production in different nations. Thus, it is the difference in the supply of the various factors of production in different nations that is the cause of different relative factor prices in different nations. Finally, the same technology but different factor prices lead to different relative commodity prices and trade among nations. Thus, the difference in the relative supply of factors leading to the difference in relative factor prices and commodity prices is shown by the double lines in Figure 5.3.

Note that the H–O model does not require that tastes, distribution of income, and technology be exactly the same in the two nations for these results to follow. It requires only that they be broadly similar. The assumptions of equal tastes, distribution of income, and technology do simplify the exposition and graphical illustration of the theory. They will be relaxed in Section 6.2.

5.4c Illustration of the Heckscher–Ohlin Theory

The H–O theory is illustrated in Figure 5.4. The left panel of the figure shows the production frontiers of Nation 1 and Nation 2, as in Figure 5.2. As indicated in Section 5.3c, Nation 1's production frontier is skewed along the X-axis because commodity X is the *L*-intensive

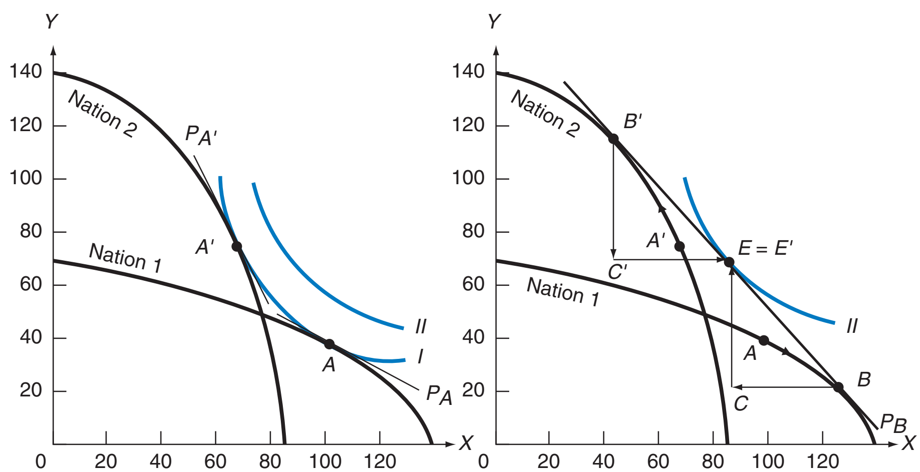


FIGURE 5.4. The Heckscher—Ohlin Model.
Indifference curve *I* is common to both nations because of the assumption of equal tastes. Indifference curve *I* is tangent to the production frontier of Nation 1 at point *A* and tangent to the production frontier of Nation 2 at *A′*. This defines the no-trade equilibrium-relative commodity price of P_A in Nation 1 and $P_{A'}$ in Nation 2 (see the left panel). Since $P_A < P_{A'}$, Nation 1 has a comparative advantage in commodity X and Nation 2 in commodity Y. With trade (see the right panel) Nation 1 produces at point *B* and by exchanging X for Y reaches point *E* in consumption (see trade triangle *BCE*). Nation 2 produces at *B′* and by exchanging Y for X reaches point *E′* (which coincides with *E*). Both nations gain from trade because they consume on higher indifference curve *II*.

commodity, Nation 1 is the L-abundant nation, and both nations use the same technology. Furthermore, since the two nations have equal tastes, they face the same indifference map. Indifference curve I (which is common for both nations) is tangent to Nation 1's production frontier at point A and to Nation 2's production frontier at A'. Indifference curve I is the highest indifference curve that Nation 1 and Nation 2 can reach in isolation, and points A and A' represent their equilibrium points of production and consumption in the absence of trade. Note that although we assume that the two nations have identical tastes (indifference map), the two nations need not be on the *same* indifference curve in isolation and end up on the same indifference map with trade. We only did so in order to simplify the figure.

The tangency of indifference curve I at points A and A' defines the no-trade, or autarky, equilibrium-relative commodity prices of P_A in Nation 1 and $P_{A'}$ in Nation 2 (see the figure). Since $P_A < P_{A'}$, Nation 1 has a comparative advantage in commodity X, and Nation 2 has a comparative advantage in commodity Y.

The right panel shows that with trade Nation 1 specializes in the production of commodity X, and Nation 2 specializes in the production of commodity Y (see the direction of the arrows on the production frontiers of the two nations). Specialization in production proceeds until Nation 1 has reached point B and Nation 2 has reached point B', where the transformation curves of the two nations are tangent to the common relative price line P_B. Nation 1 will then export commodity X in exchange for commodity Y and consume at point E on indifference curve II (see trade triangle BCE). On the contrary, Nation 2 will export Y for X and consume at point E', which coincides with point E (see trade triangle $B'C'E'$).

Note that Nation 1's exports of commodity X equal Nation 2's imports of commodity X (i.e., $BC = C'E'$). Similarly, Nation 2's exports of commodity Y equal Nation 1's imports of commodity Y (i.e., $B'C' = CE$). At $P_X/P_Y > P_B$, Nation 1 wants to export more of commodity X than Nation 2 wants to import at this high relative price of X, and P_X/P_Y falls toward P_B. On the contrary, at $P_X/P_Y < P_B$, Nation 1 wants to export less of commodity X than Nation 2 wants to import at this low relative price of X, and P_X/P_Y rises toward P_B. This tendency of P_X/P_Y could also be explained in terms of commodity Y.

Also to be noted is that point E involves more of Y but less of X than point A. Nevertheless, Nation 1 gains from trade because point E is on higher indifference curve II. Similarly, even though point E' involves more X but less Y than point A', Nation 2 is also better off because point E' is on higher indifference curve II. This pattern of specialization in production and trade and consumption will remain the same until there is a change in the underlying demand or supply conditions in commodity and factor markets in either or both nations.

It is now instructive briefly to compare Figure 5.4 with Figure 3.4. In Figure 3.4, the difference in the production frontiers of the two nations is reinforced by their difference in tastes, thus making the autarky-relative commodity prices in the two nations differ even more than in Figure 5.4. On the other hand, the tastes of the two nations could be different in such a way as to make mutually beneficial trade impossible. This would occur if the different indifference curves in the two nations were tangent to their respective and different production frontiers in such a way as to result in equal autarky-relative commodity prices in the two nations. This is assigned as end-of-chapter Problem 4, with the answer on the website.

Note also that the H–O theory does not require identical tastes (i.e., equal indifference curves) in the two nations. It only requires that if tastes differ, they do not differ sufficiently to neutralize the tendency of different factor endowments and production possibility curves from leading to different relative commodity prices and comparative advantage in the two nations.

Thus, in a sense, Figure 3.4 can be regarded as a more general illustration of the H–O model than Figure 5.4. Case Study 5-3 identifies the factor intensity of various industries and then Case Study 5-4 examines whether the patterns of trade of some of the leading developed and developing countries conforms to their factor endowments, as predicted by the H–O theory.

CASE STUDY 5-3 Classification of Major Product Categories in Terms of Factor Intensity

Table 5.3 gives the approximate factor intensity of the major product categories entering into international trade. It must be pointed out, however, that in this age of globalization and outsourcing of parts and components from abroad, the overall average factor intensity of a product may be different from that of some of its parts and components.

TABLE 5.3. Factor Intensity of Major Product Categories

Arable Land and Other Natural Resource-Intensive Products:
Agricultural products (food and raw materials)
Fuels and mining products (ores and other minerals, fuels, and nonferrous metals)

Capital-Intensive Products:
Iron and steel
Agricultural chemicals
Automotive products (automotive vehicles, parts, and engines)

R&D Scientists and Other Highly Skilled Labor-Intensive Products:
Chemicals (pharmaceuticals and other chemicals, excluding agricultural)
Office and telecommunications equipment
Civilian aircraft, engines, and parts
Machinery (power generating, nonelectrical, and electrical machinery)
Scientific and controlling instruments

Unskilled Labor-Intensive Products
Textiles
Clothing and footwear
Personal and household goods

Source: World Trade Organizations, *International Trade Statistics*, (Geneva: WTO, 2008); and J. Romalis, ''Factor Proportions and the Structure Commodity of Trade,'' *American Economic Review*, March 2004, pp. 67–97.

CASE STUDY 5-4 The Factor Intensity of Trade of Various Countries

We now look at trade data for the year 2006 to determine the factor intensities of the net exports of the various countries examined in Case Study 5-1 to see if their trade broadly corresponded to their relative factor endowments.

United States: In 2006, the United States had a net export surplus in products intensive in R&D and other highly skilled labor (such as chemicals other than pharmaceuticals, aircrafts, integrated circuits, power-generating machinery, and scientific and controlling instruments), and a net import surplus in some natural resource products (such as fuels) and products intensive in unskilled labor (such as textiles, clothing, and personal and household goods). These correspond to the broad relative factor endowments of the

(continued)

CASE STUDY 5-4 Continued

United States and conform to the predictions of the H–O theory. On the other hand, the United States had a net trade deficit in other products intensive in R&D and highly skilled labor, such as pharmaceuticals, machinery (other than power generating machinery), and office and telecommunications equipment, and a net exporter of agricultural products, when we would have expected the opposite. The United States was also a large net importer of some capital-intensive products (such as iron and steel, and automotive products), in which we would have expected its trade to be more or less balanced.

Japan: Japan had a large net export surplus in capital-intensive products and products intensive in R&D and other highly skilled labor, and a very large net import surplus in products intensive in natural resources and unskilled labor—as expected from Japan's relative factor endowments. Japan also had large net imports surplus of commercial aircrafts.

European Union: As predicted by its relative factor abundance, the European Union (EU-27) had a net export surplus in capital-intensive products and in products intensive in R&D and other highly skilled labor, and a net import surplus in agricultural products, fuels and mining products, textiles and clothing, and personal and household goods. But the EU had also a large net import surplus in office and telecom equipment, which is not in conformity with its relative abundance of R&D and other highly skilled labor.

Canada: Canada's trade was dominated by a very large net export surplus in agricultural products and fuels and mining products, and a large net import surplus of products intensive in unskilled labor as predicted by its relative factor endowments. Contrary to its relative abundance, however, Canada had a net import surplus in almost all other capital and skill-intensive products, except for automotive products (which was mostly in balance).

China: As predicted by its relative factor endowments, China had a large import surplus in agricultural, fuel, and mining products, and a large export surplus in iron and steel, in transport equipment other than automotive, and in office and telecom equipment, electrical machinery, textiles, clothing, and personal and household goods. Contrary to its relative factor endowments, however, China had net import surplus in chemicals other than pharmaceuticals, integrated circuits, automotive products, and power-generating and nonelectrical machinery.

Other Countries: As for the other countries, the trade of India, Russia, Brazil, Korea, and Mexico reflected to a large extent their relative factor endowments, but with some major exceptions.

In summary, we can say that a great deal of the trade of most of the largest developed and developing countries took place as predicted by the factor endowment (H–O) theory, but there were some important exceptions. More rigorous tests of the H–O theory are discussed in Section 5.6. Changes in comparative advantage over time are examined in Chapter 7.

Source: World Trade Organization, *International Trade Statistics*, Geneva, 2008.

5.5 Factor–Price Equalization and Income Distribution

In this section, we examine the *factor–price equalization theorem*, which is really a corollary, since it follows directly from the H–O theorem and holds only if the H–O theorem holds. It was *Paul Samuelson* (1970 Nobel prize in economics) who rigorously proved this factor–price equalization theorem (corollary). For this reason, it is sometimes referred to as the Heckscher–Ohlin–Samuelson theorem (H–O–S theorem, for short).

In Section 5.5A, we state the theorem and explain its meaning. Section 5.5B presents an intuitive proof of the factor–price equalization theorem. In Section 5.5C, we examine the related question of the effect of international trade on the distribution of income within each trading nation. Section 5.5D extends the analysis to the case where one or more factors of production are not mobile but specific to an industry. Finally, in Section 5.5E, we briefly consider the empirical relevance of the factor–price equalization theorem. The rigorous proof of the factor–price equalization theorem and of the specific-factors model are presented in the appendix to this chapter and requires the tools of analysis of intermediate microeconomic theory reviewed in the appendix to Chapter 3.

5.5A The Factor–Price Equalization Theorem

Starting with the assumptions given in Section 5.2A, we can state the factor–price equalization (H–O–S) theorem as follows: *International trade will bring about equalization in the relative and absolute returns to homogeneous factors across nations*. As such, international trade is a substitute for the international mobility of factors.

What this means is that international trade will cause the wages of homogeneous labor (i.e., labor with the same level of training, skills, and productivity) to be the same in all trading nations (if all of the assumptions of Section 5.2A hold). Similarly, international trade will cause the return to homogeneous capital (i.e., capital of the same productivity and risk) to be the same in all trading nations. That is, international trade will make w the same in Nation 1 and Nation 2; similarly, it will cause r to be the same in both nations. Both relative and absolute factor prices will be equalized.

From Section 5.4, we know that in the absence of trade the relative price of commodity X is lower in Nation 1 than in Nation 2 because the relative price of labor, or the wage rate, is lower in Nation 1. As Nation 1 specializes in the production of commodity X (the L-intensive commodity) and reduces its production of commodity Y (the K-intensive commodity), the relative demand for labor rises, causing wages (w) to rise, while the relative demand for capital falls, causing the interest rate (r) to fall. The exact opposite occurs in Nation 2. That is, as Nation 2 specializes in the production of Y and reduces its production of X with trade, its demand for L falls, causing w to fall, while its demand for K rises, causing r to rise.

To summarize, international trade causes w to rise in Nation 1 (the low-wage nation) and to fall in Nation 2 (the high-wage nation). Thus, international trade reduces the pretrade difference in w between the two nations. Similarly, international trade causes r to fall in Nation 1 (the K-expensive nation) and to rise in Nation 2 (the K-cheap nation), thus reducing the pretrade difference in r between the two nations. This proves that international trade *tends to reduce* the pretrade difference in w and r between the two nations.

We can go further and demonstrate that international trade not only tends to reduce the international difference in the returns to homogeneous factors, but would in fact bring about complete equalization in relative factor prices when all of the assumptions made hold. This is so because as long as relative factor prices differ, relative commodity prices differ and trade continues to expand. But the expansion of trade reduces the difference in factor prices between nations. Thus, international trade keeps expanding until relative commodity prices are completely equalized, which means that relative factor prices have also become equal in the two nations.

5.5B Relative and Absolute Factor–Price Equalization

We can show graphically that relative factor prices are equalized by trade in the two nations (if all the assumptions of Section 5.2A hold). In Figure 5.5, the relative price of labor (w/r) is measured along the horizontal axis, and the relative price of commodity X (P_X/P_Y) is measured along the vertical axis. Since each nation operates under perfect competition and uses the same technology, there is a one-to-one relationship between w/r and P_X/P_Y. That is, each w/r ratio is associated with a specific P_X/P_Y ratio.

Before trade, Nation 1 is at point A, with $w/r = (w/r)_1$ and $P_X/P_Y = P_A$, while Nation 2 is at point A', with $w/r = (w/r)_2$ and $P_X/P_Y = P_{A'}$. With w/r lower in Nation 1 than in Nation 2 in the absence of trade, P_A is lower than $P_{A'}$ so that Nation 1 has a comparative advantage in commodity X.

As Nation 1 (the relatively L-abundant nation) specializes in the production of commodity X (the L-intensive commodity) and reduces the production of commodity Y, the demand for labor increases relative to the demand for capital and w/r rises in Nation 1. This causes P_X/P_Y to rise in Nation 1. On the other hand, as Nation 2 (the K-abundant nation) specializes in the production of commodity Y (the K-intensive commodity), its relative demand for capital increases and r/w rises (i.e., w/r falls). This causes P_Y/P_X to rise (i.e., P_X/P_Y to fall) in Nation 2. The process will continue until point $B = B'$, at which $P_B = P_{B'}$ and $w/r = (w/r)^*$ in both nations (see Figure 5.5). Note that $P_B = P_{B'}$ *only if* w/r is identical in the two nations, since both nations operate under perfect competition and use the same technology (by assumption). Note also that $P_B = P_{B'}$ lies between P_A and $P_{A'}$, and

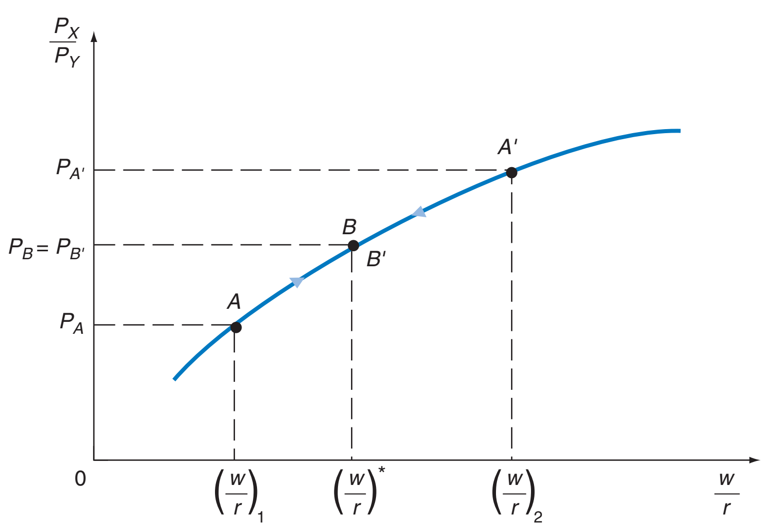


FIGURE 5.5. Relative Factor–Price Equalization.
The horizontal axis measures w/r and the vertical axis P_X/P_Y. Before trade, Nation 1 is at point A, with $w/r = (w/r)_1$ and $P_X/P_Y = P_A$ while Nation 2 is at point A', with $w/r = (w/r)_2$ and $P_X/P_Y = P_{A'}$. Since w/r is lower in Nation 1 than in Nation 2, P_A is lower than $P_{A'}$ so that Nation 1 has a comparative advantage in commodity X. As Nation 1 specializes in the production of commodity X with trade and increases the demand for labor relative to capital, w/r rises. As Nation 2 specializes in the production of commodity Y and increases its relative demand for capital, r/w rises (i.e., w/r falls). This will continue until point $B = B'$, at which $P_B = P_{B'}$ and $w/r = (w/r)^*$ in both nations.

$(w/r)^*$ lies between $(w/r)_1$ and $(w/r)_2$. To summarize, P_X/P_Y will become equal as a result of trade, and this will occur only when w/r has also become equal in the two nations (as long as both nations continue to produce both commodities). A more rigorous and difficult proof of the relative factor–price equalization theorem is given in the appendix.

The preceding paragraph shows the process by which *relative, not absolute*, factor prices are equalized. Equalization of *absolute* factor prices means that free international trade also equalizes the real wages for the same type of labor in the two nations and the real rate of interest for the same type of capital in the two nations. However, given that trade equalizes relative factor prices, that perfect competition exists in all commodity and factor markets, and that both nations use the same technology and face constant returns to scale in the production of both commodities, it follows that trade also equalizes the absolute returns to homogeneous factors. A rigorous and difficult proof of absolute factor–price equalization is presented in the appendix to this chapter, following the proof of relative factor–price equalization.

Note that trade acts as a substitute for the international mobility of factors of production in its effect on factor prices. With perfect mobility (i.e., with complete information and no legal restrictions or transportation costs), labor would migrate from the low-wage nation to the high-wage nation until wages in the two nations became equal. Similarly, capital would move from the low-interest to the high-interest nation until the rate of interest was equalized in the two nations. *While trade operates on the demand for factors, factor mobility operates on the supply of factors*. In either case, the result is complete equalization in the absolute returns of homogeneous factors. With some (rather than perfect) international mobility of factors, a smaller volume of trade would be required to bring about equality in factor returns between the two nations.

5.5c Effect of Trade on the Distribution of Income

In the previous section we examined the effect of international trade on the difference in factor prices *between nations*, but in this section we analyze the effect of international trade on relative factor prices and income *within each nation*. These two questions are certainly related, but they are not the same.

Specifically, we have seen in Section 5.5A that international trade tends to equalize w in the two nations and also to equalize r in the two nations. We now want to examine how international trade affects real wages and the real income of labor in relation to real interest rates and the real income of owners of capital *within* each nation. Do the real wages and income of labor rise or fall in relation to the real interest rates and earnings of owners of capital in the same nation as a result of international trade?

From our discussion in Section 5.5A, we know that trade increases the price of the nation's abundant and cheap factor and reduces the price of its scarce and expensive factor. In terms of our example, w rises and r falls in Nation 1, while w falls and r rises in Nation 2. Since labor and capital are assumed to remain fully employed before and after trade, the real income of labor and the real income of owners of capital move in the same direction as the movement in factor prices. Thus, trade causes the real income of labor to rise and the real income of owners of capital to fall in Nation 1 (the nation with cheap labor and expensive capital). On the other hand, international trade causes the real income of labor to fall and the real income of owners of capital to rise in Nation 2 (the nation with expensive labor and cheap capital). This is the conclusion of the *Stolper–Samuelson theorem*, which is examined in detail in Section 8.4C.

Since in developed nations (e.g., the United States, Germany, Japan, France, Britain, Italy, Canada) capital is the relatively abundant factor (as in our Nation 2), international trade tends to reduce the real income of labor and increase the real income of owners of capital. This is why labor unions in developed nations generally favor trade restrictions. In less developed nations (e.g., India, Egypt, Korea, Mexico), however, labor is the relatively abundant factor, and international trade will increase the real income of labor and reduce the real income of owners of capital.

Since, according to the Heckscher–Ohlin theory, international trade causes real wages and the real income of labor to fall in a capital-abundant and labor-scarce nation such as the United States, shouldn't the U.S. government restrict trade? The answer is almost invariably no. The reason is that the loss that trade causes to labor (particularly unskilled labor; see Case Study 5-5) is less than the gain received by owners of capital. With an appropriate redistribution policy of taxes on owners of capital and subsidies to labor, both broad classes of factors of production can benefit from international trade. Such a redistribution policy can take not only the form of retraining labor displaced by imports but also the form of tax relief for labor and provision of some social services. We return to this important question in our discussion of trade restrictions in Chapters 8 and 9.

CASE STUDY 5-5 Has International Trade Increased U.S. Wage Inequalities?

Has international trade increased wage inequalities between skilled and unskilled workers in the United States and other industrial countries during the past two decades? The answer is yes, but it was probably not a major cause. First, some facts. Between 1979 and 1993, average real wages declined by more than 20 percent for U.S. high school graduates but rose by 11 percent for college graduates, resulting in a large increase in skilled–unskilled workers' real wage inequalities. According to another study, the real wage differential between college and high school graduates in the United States increased by 63 percent between 1973 and 1996. The question is how much did international trade contribute to this increase?

Here there are wide disagreements. Some economists, such as *Wood* (1994, 1995, 1998), *Borjas and Ramey* (1994), *Sachs and Shatz* (1994, 1996), *Rodrik* (1997), and *Feenstra and Hanson* (2009) argue that the growth of manufactured exports from newly industrializing economies (NIEs) was the major cause of the increased wage inequalities in the United States and unemployment in Western Europe between 1980 and 2000. Other economists, such as *Krugman and Lawrence* (1994), *Bhagwati and Kosters* (1994), *Krugman* (1995, 2000), *Slaughter and Wagel* (1997), *Cline* (1997), and *OECD* (1998), however, point out that industrial countries' nonpetroleum imports from low-wage countries are only about 3 percent of their GDP and, hence, it could not possibly have been the major cause of the large fall in the real wages of unskilled workers in the United States and large increase in unemployment (because of more rigid wages) in Western Europe. They acknowledge that international trade certainly contributed to the unskilled workers' problems in industrial countries, but that it played only a minor role in (i.e., it may have been responsible for no more than 10 to 15 percent) the increase in U.S. skilled–unskilled real wage inequalities. Most of the increase in unskilled–skilled real wage inequalities was probably due to technological changes, such as automation and the computerization of many jobs,

(continued)

CASE STUDY 5-5 Continued

which sharply reduced the demand for unskilled workers in the United States and Europe.

The weight of evidence seems to be with this latter view—international trade seems to have had only a small *direct* impact (about 10%) on the demand and wages of unskilled labor in industrial nations from 1980 to 2000. Most of the increase in wage inequality was due to other factors (see Table 5.4). Despite the sharp increase in international trade and off-shoring during the past two decades, *Lawrence* (2008) and *Krugman* (2008) agree with that conclusion, and so does *Lippoldt* (2012). To the extent, however, that international trade and off-shoring led to more rapid technological change, *Ebenstein et al.* (2009) found that their effect on wage inequalities in the United States was much greater and comparable to that of technological change. Also refer to Case Studies 1-3, 3-3, and 3-4.

TABLE 5.4. Sources of Wage Inequalities in the United States

Source of Wage Inequality	Contribution (in percent)
Technological change	37.7
Trade	10.1
Stagnant minimum wage	7.2
Decline of unions	4.4
Immigration	2.9
Unexplained	37.7

Source: "At the Heart of the Trade Debate: Inequity," *The Wall Street Journal*, October 31, 1997, p. A2.

5.5D The Specific-Factors Model

The effect of international trade on the distribution of income discussed in the previous section is based on the assumption that factors are perfectly mobile among the nation's industries or sectors. Although this is likely to be true in the long run, it may not be true in the short run, when some factors (say, capital) may be immobile or specific to some industry or sector. In this case, the conclusions of the Heckscher–Ohlin model on the effects of international trade on distribution need to be modified as explained by the specific-factors model.

In order to examine the specific-factors model, suppose that a nation that is relatively labor-abundant produces two commodities: commodity X, which is L intensive, and commodity Y, which is K intensive. Both commodities are produced with labor and capital, but labor is mobile between the two industries while capital is specific to each industry. That is, the capital used in the production of X (say, food) cannot be used in the production of Y (say, cloth), and vice versa. This is like having three factors of production: labor (which is used in and is mobile between the production of X and Y), natural resources (arable land), which are used only in the production of X, and capital, which is used only in the production of Y.

With the opening of trade, the nation will specialize in the production of and will export commodity X (the labor-intensive commodity) and import commodity Y (the specific capital-intensive commodity). This will increase the relative price of X (i.e., P_X/P_Y) and the demand and nominal wage rate of labor in the nation. Some labor will move from the production of Y to the production of X. Since labor is mobile between the two industries, industry Y will have to pay the higher going nominal wage rate for labor even while facing a reduction in P_Y/P_X and the transfer of some its labor to the production of X.

The effect of this on the *real* wage rate of labor in the nation is ambiguous. The reason is that the increase in P_X/P_Y and in the derived demand for labor will be greater than the increase in the nominal wage rate (since the supply of labor is not vertical—this is explained and shown in Figure 5.9 in the appendix), and so the real wage rate of labor falls in terms of commodity X. On the contrary, since the nominal wage rate increased but the price of commodity Y (the import-competing commodity) declined in the nation, the real wage rate increased in terms of commodity Y. Thus, the real wage rate in the nation falls in terms of X but rises in terms of Y. The effect on the real wage of labor is, therefore, ambiguous. The real wage and income will fall for those workers who consume mainly commodity X and will increase for those workers who consume mainly commodity Y.

The result for specific capital is not ambiguous. Since capital is specific to each industry, opening trade does not lead to any transfer of capital from the production of commodity Y to the production of commodity X in the nation. With more labor used with the given specific capital in the production of X (the nation's export commodity), the real return on capital in the production of X rises. On the contrary, with less labor used with the same amount of specific capital in the production of Y (the nation's import-competing commodity), the real return on the specific capital used in the production of Y falls.

The conclusion reached by the specific-factors model is that trade will have an ambiguous effect on the nation's mobile factors, benefit the immobile factors specific to the nation's export commodities or sectors, and harm the immobile factors specific to the nation's import-competing commodities or sectors. In the previously mentioned example, the opening of trade will have an ambiguous effect on the real wage and income of labor (the nation's mobile factor), will increase the real return on the specific capital used in the production of X (the nation's export commodity), and will reduce the real return on the other specific factor used in the production of commodity Y (the nation's import-competing commodity). If the specific factor used in the production of X was natural resources, then opening of trade would increase the real return or rent on land, reduce the real return on capital used in the production of Y, and have an ambiguous effect on labor. (See Appendix A5.4 for the rigorous proof of this theorem.)

5.5E Empirical Relevance

Has international trade equalized the returns to homogeneous factors in different nations in the real world? Even casual observation clearly indicates that it has not. Thus, wages are much higher for doctors, engineers, technicians, mechanics, secretaries, and laborers in the United States and Germany than in Korea and Mexico.

The reason for this is that many of the simplifying assumptions on which the H–O–S theory rests do not hold in the real world. For example, nations do not use exactly the same technology, and transportation costs and trade barriers prevent the equalization of relative commodity prices in different nations. Furthermore, many industries operate under conditions of imperfect competition and nonconstant returns to scale. It should not be surprising,

CASE STUDY 5-6 Convergence of Real Wages among Industrial Countries

Table 5.5 shows that real hourly wages in manufacturing in the leading industrial countries have converged in U.S. wages over time. Specifically, average wages abroad rose from 27 percent of U.S. wages in 1959 to 43 percent in 1983, 96 percent in 1997, and 103 percent in 2010. Although the rapid expansion of international trade over this period is likely to have been an important reason for the wage convergence, other important forces were also at work, such as the reduction of the technological gap between the United States and the other leading industrial countries, the smaller growth of the labor force in the latter group of countries than in the United States, and increased international labor mobility.

TABLE 5.5. Real Hourly Wage in Manufacturing in the Leading Industrial Countries as a Percentage of the U.S. Wage

Country	1959	1983	1997	2007
Japan	11	24	97	92
Italy	23	42	85	96
France	27	41	108	117
United Kingdom	29	35	80	85
Germany	29	56	126	126
Canada	42	57	82	103
Unweighted average	27	43	96	103
United States	100	100	100	100

Source: U.S. Bureau of Labor Statistics, *Bulletins*. December 2011.

therefore, that international trade has not equalized wages and interest rates for homogeneous factors in different nations.

Under these circumstances, it is more realistic to say that international trade has *reduced*, rather than completely eliminated, the international difference in the returns to homogeneous factors. Although international trade seems to have reduced differences in real wages in manufacturing among the leading industrial countries (see Case Study 5-6), this cannot be regarded as "proof" of the theory, and it is even more difficult to give a clear-cut answer for other countries and other factors.

The reason for this is that, even if international trade has operated to reduce absolute differences in factor returns among nations, many other forces were operating at the same time, preventing any such relationship from becoming clearly evident. For example, while international trade may have tended to reduce the difference in real wages and incomes for the same type of labor between the United States and Egypt, technological advances occurred more rapidly in the United States than in Egypt, so that the difference in earnings has in fact increased. This seems indeed to have been the case between developed nations as a group and most developing nations since World War II.

Once again, this does not disprove the factor–price equalization theorem, since in the absence of trade these international differences might have been much greater than they are now. In any event, the factor–price equalization theorem is useful because it identifies crucial forces affecting factor prices and provides important insights into the general equilibrium nature of our trade model and of economics in general.

One thing the factor–price equalization theorem *does not say* is that international trade will eliminate or reduce international differences in *per capita incomes*. It only predicts that international trade will eliminate or reduce international differences in the returns to *homogeneous factors*. Even if real wages were to be equalized among nations, their per capita incomes could still remain widely different. Per capita income depends on many other forces not directly related to the factor–price equalization theorem. These other forces include the ratio of skilled to unskilled labor, the participation rate in the labor force, the dependency rate, the type of effort made by workers, and so on. For example, Japan has a higher ratio of skilled to unskilled labor than India, a higher participation rate and lower dependency rate, and Japanese workers seem to thrive on work and precision. Thus, even if wages for the same type of labor were exactly the same in Japan and India, Japan would end up with a much higher per capita income than India.

5.6 Empirical Tests of the Heckscher–Ohlin Model

This section presents and evaluates the results of empirical tests of the Heckscher–Ohlin model. A model must be successfully tested empirically before it is accepted as a theory. If a model is contradicted by empirical evidence, it must be rejected and an alternative model drawn up.

In Section 5.6A, we present the results of the original empirical test of the Heckscher–Ohlin model, conducted by *Wassily Leontief*. Since these results seemed to conflict with the model, many attempts were made to reconcile them with the model; in the process numerous other empirical tests were undertaken. These are discussed in Section 5.6B. In Section 5.6C, we look at the situation called *factor-intensity reversal*, which, if very prevalent, would also lead to rejection of the H–O model. Empirical tests, however, indicate that this is not a very frequent occurrence in the real world.

5.6A Empirical Results—The Leontief Paradox

The first empirical test of the Heckscher–Ohlin model was conducted by *Wassily Leontief* in 1951 using U.S. data for the year 1947. Since the United States was the most K-abundant nation in the world, Leontief expected to find that it exported K-intensive commodities and imported L-intensive commodities.

For this test, Leontief utilized the input–output table of the U.S. economy to calculate the amount of labor and capital in a "representative bundle" of $1 million worth of U.S. exports and import substitutes for the year 1947. (The input–output table is a table showing the origin and destination of each product in the economy. Leontief himself had contributed importantly to the development of this new technique of analysis and received the Nobel prize in 1973 for his contributions.)

To be noted is that Leontief estimated K/L for U.S. import substitutes rather than for imports. Import substitutes are commodities, such as automobiles, that the United States produces at home but also imports from abroad (because of incomplete specialization in production). Leontief was forced to use U.S. data on import substitutes because *foreign* production data on actual U.S. imports were not available. However, Leontief correctly reasoned that even though U.S. import substitutes would be more K intensive than actual imports (because K was relatively cheaper in the United States than abroad), they should still be less K intensive than U.S. exports if the H–O model held true. Of course, the use of U.S. data on import substitutes, instead of foreign data on actual U.S. imports, also eliminated from the calculations commodities, such as coffee and bananas, not produced at all in the United States.

The results of Leontief's test were startling. U.S. import substitutes were about 30 percent more K intensive than U.S. exports. That is, the United States seemed to export L-intensive commodities and import K-intensive commodities. This was the opposite of what the H–O model predicted, and it became known as the Leontief paradox (see Case Study 5-7).

CASE STUDY 5-7 Capital and Labor Requirements in U.S. Trade

Table 5.6 gives the capital and labor requirements per million dollars of U.S. exports and import substitutes, as well as the capital/worker-year for imports relative to exports. For example, dividing the capital/worker-year of $18,180 for U.S. import substitutes by the capital/worker-year of $14,010 for exports using 1947 data (see the third row of the table), Leontief obtained the capital/worker-year for imports relative to exports of 1.30. Since the United States is a relatively capital-abundant nation and U.S. import substitutes are more capital intensive than U.S. exports, we have a paradox. Using 1951 trade data, the K/L ratio for imports/exports fell to 1.06, and, excluding natural resource industries, the ratio fell to 0.88 (thus eliminating the paradox). Using 1958 input requirements and 1962 trade data, Baldwin obtained the K/L ratio for imports/exports of 1.27. When natural resource industries were excluded, the ratio fell to 1.04, and when human capital was included, it fell to 0.92 (once again, eliminating the paradox).

TABLE 5.6. Capital and Labor Requirements per Million Dollars of U.S. Exports and Import Substitutes

	Exports	Import Substitutes	Imports/Exports
Leontief			
(1947 input requirements, 1947 trade):			
Capital	$2,550,780	$3,091,339	
Labor (worker-years)	182	170	
Capital/worker-year	$14,010	$18,180	1.30
Leontief			
(1947 input requirements, 1951 trade):			
Capital	$2,256,800	$2,303,400	
Labor (worker-years)	174	168	
Capital/worker-year	$12,977	$13,726	1.06
Capital/worker-year, excluding natural resources			0.88
Baldwin			
(1958 input requirements, 1962 trade):			
Capital	$1,876,000	$2,132,000	
Labor (worker-years)	131	119	
Capital/worker-year	$14,200	$18,000	1.27
Capital/worker-year, excluding natural resources			1.04
Capital/worker-year, excluding natural resources and including human capital			0.92

Sources: Leontief (1951, 1956) and Baldwin (1971). See the Selected Bibliography at the end of the chapter.

In the same study, Leontief tried to rationalize his results rather than reject the H–O model. He argued that what we had here was an optical illusion: Since in 1947 U.S. labor was about three times as productive as foreign labor, the United States was really an *L*-abundant nation if we multiplied the U.S. labor force by 3 and compared this figure to the availability of capital in the nation. Therefore, it was only appropriate that U.S. exports should be *L* intensive in relation to U.S. import substitutes. This explanation is not acceptable, and Leontief himself subsequently withdrew it. The reason is that while U.S. labor was definitely more productive than foreign labor (though the multiple of 3 used by Leontief was largely arbitrary), so was U.S. capital. Therefore, both U.S. labor *and* U.S. capital should be multiplied by a similar multiple, leaving the relative abundance of capital in the United States more or less unaffected.

Similarly invalid is another explanation that postulated that U.S. tastes were biased so strongly in favor of *K*-intensive commodities as to result in higher relative prices for these commodities in the United States. Therefore, the United States would export relatively *L*-intensive commodities. The reason this explanation is not acceptable is that tastes are known to be similar across nations. A study by *Houthakker* in 1957 on household consumption patterns in many countries found that the income elasticity of demand for food, clothing, housing, and other classes of goods was remarkably similar across nations. As a result, this explanation of the Leontief paradox based on a difference in tastes is also unacceptable.

5.6B Explanations of the Leontief Paradox and Other Empirical Tests of the H–O Model

One possible explanation of the paradox is that the year 1947, which Leontief used for the test, was too close to World War II to be representative. Leontief himself answered this criticism by repeating his study in 1956 using the 1947 input–output table of the U.S. economy but 1951 trade data. (The year 1951 is usually taken to mark the completion of postwar reconstruction.) This analysis showed that U.S. exports were only 6 percent more *L* intensive than U.S. import substitutes. Leontief had reduced the paradox but had not eliminated it (see Case Study 5-7).

A more general source of bias is that Leontief used a two-factor model (*L* and *K*), thus abstracting from other factors such as natural resources (soil, climate, mineral deposits, forests, etc.). However, a commodity might be intensive in natural resources so that classifying it as either *K* or *L* intensive (with a two-factor model) would clearly be inappropriate. Furthermore, many production processes using natural resources—such as coal mining, steel production, and farming—also require large amounts of physical capital. The U.S. dependence on imports of many natural resources, therefore, might help explain the large capital intensity of U.S. import-competing industries.

U.S. tariff policy was another source of bias in the Leontief study. A tariff is nothing else than a tax on imports. As such, it reduces imports and stimulates the domestic production of import substitutes. In a 1956 study, *Kravis* found that the most heavily protected industries in the United States were the *L*-intensive industries. This biased the pattern of trade and reduced the labor intensity of U.S. import substitutes, thus contributing to the existence of the Leontief paradox.

Perhaps the most important source of bias was the fact that Leontief included in his measure of capital only physical capital (such as machinery, other equipment, buildings, and so on) and completely ignored human capital. Human capital refers to the education, job training, and health embodied in workers, which increase their productivity. The implication is that since U.S. labor embodies more human capital than foreign labor, adding the human capital component to physical capital would make U.S. exports more K intensive relative to U.S. import substitutes. (In fairness to Leontief, it must be said that the analysis of human capital became fully developed and fashionable only following the work of *Schultz* in 1961 and *Becker* in 1964.)

Somewhat related to human capital is the influence of research and development (R&D) on U.S. exports. The "knowledge" capital resulting from R&D leads to an increase in the value of output derived from a given stock of material and human resources. Even casual observation shows that most U.S. exports are R&D and skill intensive. Thus, human and knowledge capital are important considerations in determining the pattern of U.S. trade. These were not considered by Leontief in his study.

The most important of the numerous empirical studies following a human capital approach were undertaken by Kravis, Keesing, Kenen, and Baldwin. In two studies published in 1956, *Kravis* found that wages in U.S. exports industries in both 1947 and 1951 were about 15 percent higher than wages in U.S. import-competing industries. Kravis correctly argued that the higher wages in U.S. exports industries were a reflection of the greater productivity and human capital embodied in U.S. exports than in U.S. import substitutes.

In a 1966 study, *Keesing* found that U.S. exports were more skill intensive than the exports of nine other industrial nations for the year 1957. This reflected the fact that the United States had the most highly trained labor force, embodying more human capital than other nations.

It remained for *Kenen*, in a 1965 study, to actually estimate the human capital embodied in U.S. exports and import-competing goods, add these estimates to the physical capital requirements, and then recompute K/L for U.S. exports and U.S. import substitutes. Using 1947 data and without excluding products with an important natural resource content (as in the original Leontief study), Kenen succeeded in eliminating the Leontief paradox.

In a 1971 study, *Baldwin* updated Leontief's study by using the 1958 U.S. input–output table and U.S. trade data for 1962. Baldwin found that excluding natural resource industries was not sufficient to eliminate the paradox unless human capital was included (see Case Study 5-7). The paradox remained, however, for developing nations and for Canada. Similar paradoxical results arose by using other countries' data. A 1977 study by *Branson and Monoyios* also raised some questions on the appropriateness of combining human and physical capital into a single measure for the purpose of testing the H–O trade model.

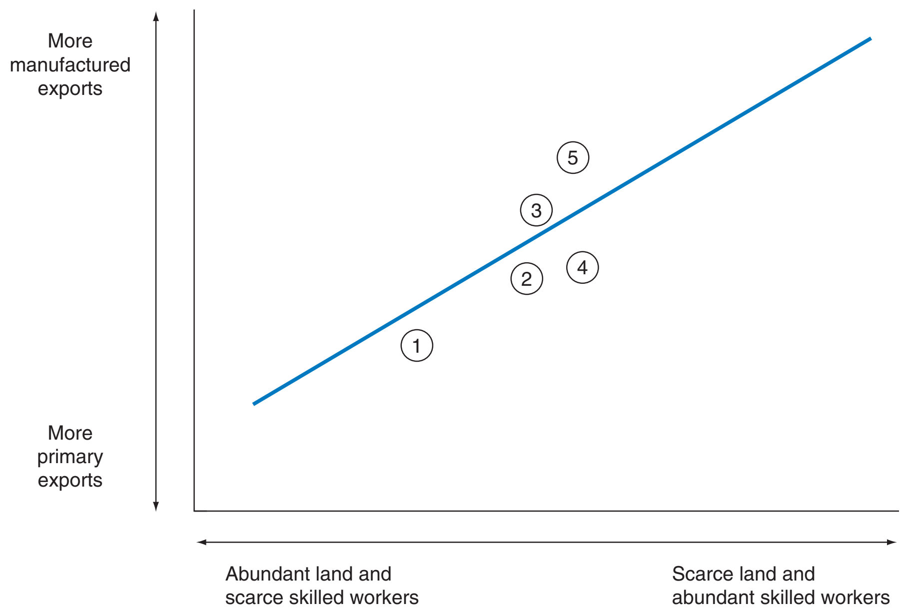
In 1980 and 1984 publications, *Leamer* argued that in a multifactor world we should compare the K/L ratio in production versus consumption rather than in exports versus imports. Taking this approach to Leontief's 1947 data, *Leamer* (1984) found that the K/L ratio embodied in U.S. production was indeed greater than that embodied in U.S. consumption, so that the paradox disappeared. This was confirmed in a 1981 study by *Stern and Maskus* for the year 1972 and in a 1990 study by *Salvatore and Barazesh* for each year from 1958 to 1981 when natural resource industries were excluded.

In a 1987 study, however, *Bowen, Leamer, and Sveikauskas*, using more complete 1967 cross-sectional data on trade, factor-input requirements, and factor endowments for 27 countries, 12 factors (resources), and many commodities, found that the H–O trade model was supported only about half of the time. This seemed to inflict a devastating blow on the validity of the H–O model. Subsequent research, however, does provide support for some restricted form of the H–O trade model. In a 1993 study, *Brecher and*

Choudhri found production evidence in support of the H–O model for U.S.–Canadian trade; a 1994 study by *Wood* provided support for the H–O model for trade between developed and developing countries based on differences in their relative availability of skills and land, and so did a 1995 study by the World Bank (see Case Study 5-8).

CASE STUDY 5-8 The H–O Model with Skills and Land

Figure 5.6 shows that Africa (1) with relatively more abundant land and fewer skilled workers exports more primary commodities, whereas industrial market economies (5) with relatively more skilled workers export more manufactured goods. Between Africa and industrial countries lie Latin America (2), South Asia (3), and East Asia (4), which have relatively less land and more skilled workers than Africa and export relatively more manufactured goods than Africa but fewer than industrial countries. The straight line in the figure is the regression line showing the general relationship between relative factor endowments and type of exports. It was estimated for the year 1985 from 126 data points (not shown in the figure), each referring to a country, and it shows a clear positive relationship between skill availability and exports of manufactures. The numbered circles in the figure show regional averages.



Legend:
(1) Sub-Saharan Africa; (2) Latin America and the Caribbean; (3) South Asia; (4) East Asia and the Pacific; (5) Industrial market economies

FIGURE 5.6. Comparative Advantage with Skills and Land.
The regression line shows that Africa with relatively more land and fewer skilled workers than other regions exports more primary commodities and fewer manufactured goods than other regions.
Source: World Bank, *World Development Report,* Washington, D.C., 1995, p. 59.

Additional evidence in support of the H–O model for trade in manufactured goods among the largest industrial countries was also provided in 1996 by *James and Elmslie*, and more broadly, but still qualified, by *Leamer* (1993), *Leamer and Levinsohn* (1995), and *Wood* (1997).

More convincing evidence validating a qualified or restricted form of the H–O theory comes from more recent research. Using data on a large sample of developed and developing countries over the 1970–1992 period and allowing for differences in technology among nations, *Harrigan and Zakrajsek* (2000) show that factor endowments do explain comparative advantage. *Schott* (2003, p. 686) provides "strong support for H–O specialization" by utilizing more disaggregated data, which shows that countries specialize in the particular subset of goods most suited to their specific factor endowments (showing, for example, that considering all electrical machinery as hi-tech, as done in previous studies, was wrong because electrical machinery also includes portable radios assembled by hand).

Additional evidence is provided by *Davis and Weinstein* (2001). They utilized the trade data of ten countries (the United States, Japan, Germany, France, the United Kingdom, Italy, Canada, Australia, Denmark, and the Netherlands) with the rest of the world. For 34 sectors, over the 1970–1995 period, and allowing for different technologies and factor prices across countries, the existence of nontraded goods, and transportation costs, *Davis and Weinstein* show that countries export commodities intensive in their relatively abundant and cheap factors of production and they do so in the predicted magnitudes.

More evidence is provided by *Romalis* (2004). By using a many-country version of the Heckscher–Ohlin model with differentiated products and transportation costs, and detailed bilateral trade data, *Romalis* (p. 67) conclude, "Countries capture larger shares of world production and trade in commodities that more intensively use their abundant factor. Countries that rapidly accumulate a factor see their production and export structures systematically shift towards industries that intensively use that factor."

Some support for the Heckscher–Ohlin model was also provided by Morrow (2010) using panel data across 20 developed and developing countries over the 1985–1995 period by considering also relative labor productivity differences across 24 manufacturing industries (besides differences in factor endowments across nations). *Chor* (2010) provided additional evidence by including relative institutional strengths of different countries. *Trefler and Zhu* (2010) showed more support by using "the correct" (i.e., a better) definition of factor content and input–output tables for 41 developed and developing countries for 24 industries for the year 1997.

Thus, it seems (see Baldwin, 2008, pp. 174–175) that we can retain the traditional Hecksher–Ohlin model for explaining trade between developed and developing countries (often referred to as North–South trade) and a qualified or restricted version of the H–O model for the much larger volume of trade among developed countries (i.e., North–North trade) if the model is extended to allow for different technologies and factor prices across countries, as well as the existence of nontraded goods, economies of scale, product differentiation, and transportation costs. But then some would argue that not much is left from the original H–O model and that all we have is a general factor-endowments trade model. The next chapter will examine economies of scale, product differentiation, and technological differences as additional or complementary factors determining comparative advantage and international trade.

5.6c Factor-Intensity Reversal

Factor-intensity reversal refers to the situation where a given commodity is the L-intensive commodity in the L-abundant nation and the K-intensive commodity in the K-abundant nation. For example, factor-intensity reversal is present if commodity X is the L-intensive commodity in Nation 1 (the low-wage nation), and, at the same time, it is the K-intensive commodity in Nation 2 (the high-wage nation).

To determine when and why factor-intensity reversal occurs, we use the concept of the elasticity of substitution of factors in production. The elasticity of substitution measures the degree or ease with which one factor can be substituted for another in production as the relative price of the factor declines. For example, suppose that the elasticity of substitution of L for K is much greater in the production of commodity X than in the production of commodity Y. This means that it is much easier to substitute L for K (or vice versa) in the production of commodity X than in the production of commodity Y.

Factor-intensity reversal is more likely to occur the greater is the *difference* in the elasticity of substitution of L for K in the production of the two commodities. With a large elasticity of substitution of L for K in the production of commodity X, Nation 1 will produce commodity X with L-intensive techniques because its wages are low. On the other hand, Nation 2 will produce commodity X with K-intensive techniques because its wages are high. If at the same time the elasticity of substitution of L for K is very low in the production of commodity Y, the two nations will be forced to use similar techniques in producing commodity Y even though their relative factor prices may differ greatly. As a result, commodity X will be the L-intensive commodity in Nation 1 and the K-intensive commodity in Nation 2, and we have a case of factor-intensity reversal.

When factor-intensity reversal is present, neither the H–O theorem nor the factor–price equalization theorem holds. The H–O model fails because it would predict that Nation 1 (the L-abundant nation) would export commodity X (its L-intensive commodity) and that Nation 2 (the K-abundant nation) would also export commodity X (its K-intensive commodity). Since the two nations cannot possibly export the same *homogeneous* commodity to each other, the H–O model no longer predicts the pattern of trade.

With factor-intensity reversal, the factor–price equalization theorem also fails to hold. The reason for this is that as Nation 1 specializes in the production of commodity X and demands more L, the relative and the absolute wage rate will rise in Nation 1 (the low-wage nation). Conversely, since Nation 2 cannot export commodity X to Nation 1, it will have to specialize in the production of and export commodity Y. Since commodity Y is the L-intensive commodity in Nation 2, the demand for L and thus wages will also rise in Nation 2. What happens to the *difference* in relative and absolute wages between Nation 1 and Nation 2 depends on how fast wages rise in each nation. The difference in relative and absolute wages between the two nations could decline, increase, or remain unchanged as a result of international trade, so that the factor–price equalization theorem no longer holds.

That factor-intensity reversal does occur in the real world is beyond doubt. The question is how prevalent it is. If factor reversal is very prevalent, the entire H–O theory must be rejected. If it occurs but rarely, we can retain the H–O model and treat factor reversal as an exception. The frequency of factor reversal in the real world is an empirical question.

The first empirical research on this topic was a study conducted by *Minhas* in 1962, in which he found factor reversal to be fairly prevalent, occurring in about one-third of the cases that he studied. However, by correcting an important source of bias in the Minhas study, Leontief showed in 1964 that factor reversal occurred in only about 8 percent of the cases studied, and that if two industries with an important natural resource content were excluded, factor reversal occurred in only 1 percent of the cases.

A study by *Ball*, published in 1966 and testing another aspect of Minhas's results, confirmed Leontief's conclusion that factor-intensity reversal seems to be a rather rare occurrence in the real world. As a result, the assumption that one commodity is L intensive and the other commodity is K intensive (assumption 3 in Section 5.2) at all *relevant* relative factor prices generally holds, so that the H–O model can be retained.

SUMMARY

1. The Heckscher–Ohlin theory presented in this chapter extends our trade model of previous chapters to explain the basis of (i.e., what determines) comparative advantage and to examine the effect of international trade on the earnings of factors of production. These two important questions were left largely unanswered by classical economists.

2. The Heckscher–Ohlin theory is based on a number of simplifying assumptions (some made only implicitly by Heckscher and Ohlin). These are (1) two nations, two commodities, and two factors of production; (2) both nations use the same technology; (3) the same commodity is labor intensive in both nations; (4) constant returns to scale; (5) incomplete specialization in production; (6) equal tastes in both nations; (7) perfect competition in both commodities and factor markets; (8) perfect internal but no international mobility of factors; (9) no transportation costs, tariffs, or other obstructions to the free flow of international trade; (10) all resources are fully employed; and (11) trade is balanced. These assumptions will be relaxed in Chapter 6.

3. In a world of two nations (Nation 1 and Nation 2), two commodities (X and Y), and two factors (labor and capital), we say that commodity Y is capital intensive if the capital–labor ratio (K/L) used in the production of Y is greater than K/L for X in both nations. We also say that Nation 2 is the K-abundant nation if the relative price of capital (r/w) is *lower* there than in Nation 1. Thus, Nation 2's production frontier is skewed toward the Y-axis and Nation 1's is skewed toward the X-axis. Since the relative price of capital is lower in Nation 2, producers there will use more K-intensive techniques in the production of both commodities in relation to Nation 1. Producers would also substitute K for L (causing K/L to rise) in the production of both commodities if the relative price of capital declined. Commodity Y is *unequivocally* the K-intensive commodity if K/L remains higher for Y than for X in both nations at all relative factor prices.

4. The Heckscher–Ohlin, or factor-endowment, theory can be expressed in terms of two theorems. According to the H–O theorem, a nation will export the commodity intensive in its relatively abundant and cheap factor and import the commodity intensive in its relatively scarce and expensive factor. According to the factor–price equalization (H–O–S) theorem, international trade will bring about equalization of relative and absolute returns to homogeneous factors across nations. If some factors are specific (i.e., can only be used in some industries), the specific-factors model postulates that trade will have an ambiguous effect on the nation's mobile factors: It will benefit the immobile factors that are specific to the nation's export commodities or sectors, and harm the immobile factors that are specific to the nation's import-competing commodities or sectors.

5. Out of all the possible forces that could cause a difference in pretrade-relative commodity prices between nations, Heckscher and Ohlin isolate the difference in factor endowments (in the face of equal technology and tastes) as the basic determinant or cause of comparative advantage. International trade can also be a substitute for the international mobility of factors in equalizing relative and absolute returns to homogeneous factors across nations. The general equilibrium

nature of the H–O theory arises from the fact that all commodity and factor markets are components of an overall unified system so that a change in any part affects every other part.

6. The first empirical test of the H–O model was conducted by Leontief using 1947 U.S. data. Leontief found that U.S. import substitutes were about 30 percent more K intensive than U.S. exports. Since the United States is the most K-abundant nation, this result was the opposite of what the H–O model predicted; this became known as the Leontief paradox. Empirical results seem to show that the traditional Heckscher–Ohlin model can explain trade between developed and developing countries (often referred to as North–South trade) and a highly qualified or restricted version of the H–O can model the much larger trade among developed countries (i.e., North–North trade).

7. Factor-intensity reversal refers to the situation where a commodity is L intensive in the L-abundant nation and K intensive in the K-abundant nation. This may occur when the elasticity of substitution of factors in production varies greatly for the two commodities. With factor reversal, both the H–O theorem and the factor–price equalization theorem fail. Minhas conducted a test in 1962 that showed that factor reversal was fairly prevalent. Leontief and Ball demonstrated, however, that Minhas's results were biased and that factor reversal was a rather rare occurrence.

A LOOK AHEAD

In Chapter 6, we relax the assumptions of the Heckscher–Ohlin model and examine complementary trade theories that base international trade on economies of scale and imperfect competition, and we evaluate their relative importance as explanations of international trade today. We will also look at the effect of transportation costs and environmental standards on international trade and the relationship between transportation costs and environmental standards on the location of industry.

KEY TERMS

Capital-intensive commodity, p. 111
Capital–labor ratio (K/L), p. 111
Cobb–Douglas production function, p. 151
Constant elasticity of substitution (CES) production function, p. 151
Constant returns to scale, p. 111
Derived demand, p. 114
Elasticity of substitution, p. 137
Euler's theorem, p. 145
Factor abundance, p. 114
Factor-intensity reversal, p. 137
Factor–price equalization (H–O–S) theorem, p. 124
Factor-proportions or factor-endowment theory, p. 118
Heckscher–Ohlin (H–O) theorem, p. 118
Heckscher–Ohlin (H–O) theory, p. 118
Human capital, p. 134
Import substitutes, p. 131
Input–output table, p. 131
Internal factor mobility, p. 111
International factor mobility, p. 111
Labor–capital ratio (L/K), p. 111
Labor-intensive commodity, p. 111
Leontief paradox, p. 132
Perfect competition, p. 111
Relative factor prices, p. 114
Specific-factors model, p. 128

QUESTIONS FOR REVIEW

1. In what ways does the Heckscher–Ohlin theory represent an extension of the trade model presented in the previous chapters? What did classical economists say on these matters?

2. State the assumptions of the Heckscher–Ohlin theory. What is the meaning and importance of each of these assumptions?

3. What is meant by labor-intensive commodity? Capital-intensive commodity? Capital–labor ratio?

4. What is meant by capital-abundant nation? What determines the shape of the production frontier of each nation?

5. What determines the capital–labor ratio in the production of each commodity in both nations? Which of the two nations would you expect to use a higher capital–labor ratio in the production of both commodities? Why? Under what circumstance would the capital–labor ratio be the same in the production of both commodities in each nation?

6. If labor and capital can be substituted for each other in the production of both commodities, when can we say that one commodity is capital intensive and the other labor intensive?

7. What does the Heckscher–Ohlin theory postulate? Which force do Heckscher and Ohlin identify as the basic determinant of comparative advantage and trade?

8. What does the factor–price equalization theorem postulate? What is its relationship to the international mobility of factors of production?

9. Explain why the Heckscher–Ohlin theory is a general equilibrium model.

10. What is meant by the Leontief paradox? What are some possible explanations of the paradox? How can human capital contribute to the explanation of the paradox?

11. What were the results of empirical tests on the relationship between human capital and international trade? Natural resources and international trade? What is the status of the H–O theory today?

12. What is meant by factor-intensity reversal? How is this related to the elasticity of substitution of factors in production? Why would the prevalence of factor reversal lead to rejection of the H–O theorem and the factor–price equalization theorem? What were the results of empirical tests on the prevalence of factor reversal in the real world?

13. Did more recent research confirm or reject the H–O model?

PROBLEMS

1. Draw two sets of axes, one for Nation 1 and the other for Nation 2, measuring labor along the horizontal axis and capital along the vertical axis.

(a) Show by straight lines through the origin that K/L is higher for commodity Y than for commodity X in both nations in the absence of trade and that K/L is higher in Nation 2 than in Nation 1 for both commodities.

(b) What happens to the slope of the lines measuring K/L of each commodity in Nation 2 if r/w rises in Nation 2 as a result of international trade?

(c) What happens to the slope of the lines measuring K/L in Nation 1 if r/w falls in Nation 1 as a result of international trade?

(d) Given the results of parts b and c, does international trade increase or reduce the difference in the K/L in the production of each commodity in the two nations as compared with the pretrade situation?

2. Without looking at the text,

(a) Sketch a figure similar to Figure 5.4 showing the autarky equilibrium point in each nation and the point of production and consumption in each nation with trade.

(b) With reference to your figure in part a, explain what determines the comparative advantage of each nation.

(c) Why do the two nations consume different amounts of the two commodities in the absence of trade but the same amount with trade?

3. Starting with the production frontiers for Nation 1 and Nation 2 shown in Figure 5.4, show graphically that even with a small difference in tastes in the two nations, Nation 1 would continue to have a comparative advantage in commodity X.

***4.** Starting with the production frontiers for Nation 1 and Nation 2 shown in Figure 5.4, show graphically that sufficiently different tastes in the two nations could conceivably neutralize the difference in their factor endowments and lead to equal relative commodity prices in the two nations in the absence of trade.

5. Starting with the production frontiers for Nation 1 and Nation 2 shown in Figure 5.4, show that with an even greater difference in tastes in the two nations, Nation 1 could end up exporting the capital-intensive commodity.

6. A difference in factor endowments will cause the production frontiers of two nations to be shaped differently.

(a) What else could cause their production frontiers to have different shapes?

(b) What assumption made by Heckscher and Ohlin prevented this in the Heckscher–Ohlin model?

(c) What are other possible causes of a difference in relative commodity prices between the two nations in the absence of trade?

***7.** Draw a figure similar to Figure 5.4 but showing that the Heckscher–Ohlin model holds, even with some difference in tastes between Nation 1 and Nation 2.

8. If you have traveled to poor developing countries, you will have noticed that people there consume very different goods and services than U.S. consumers. Does this mean that tastes in developing countries are very different from U.S. tastes? Explain.

9. Starting from the pretrade equilibrium point in Figure 5.4, assume that tastes in Nation 1 change in favor of the commodity of its comparative *disadvantage* (i.e., in favor of commodity Y).

(a) What is the effect of this change in tastes on P_X/P_Y in Nation 1? How did you reach such a conclusion?

(b) What is the effect of this change in tastes on r/w in Nation 1?

(c) What is the effect of this on the volume of trade and on the trade partner?

10. Comment on the following quotation: "The assumptions necessary to bring about complete equality in the returns to homogeneous factors among nations are so restrictive and unrepresentative of actual reality that the theory can be said to prove the opposite of what it seems to say—namely, that there is no chance whatsoever that factor prices will ever be equalized by free commodity trade."

11. In what way can international trade be said to have contributed to increased wage inequalities in the United States during the past 20 years?

12. **(a)** Discuss the meaning and importance of the Leontief paradox.

(b) Summarize the empirical results of Kravis, Keesing, Kenen, and Baldwin on the importance of human capital in helping to resolve the paradox.

(c) How was the paradox seemingly resolved by Leamer, Stern, Maskus, and Salvatore and Barazesh?

(d) What is the status of the controversy today?

***13.** **(a)** Draw a figure similar to Figure 5.1 showing factor-intensity reversal.

(b) With reference to your figure, explain how factor reversal could take place.

(c) Summarize the empirical results of Minhas, Leontief, and Ball on the prevalence of factor reversal in the real world.

14. Explain why, with factor-intensity reversal, international differences in the price of capital can decrease, increase, or remain unchanged with international trade.

15. **(a)** Explain how more recent research tried to verify the H–O model.

(b) Explain the results of these more recent empirical tests.

(c) What general conclusion can be reached with respect to the utility and acceptance of the H–O model?

*= Answer provided at www.wiley.com/college/salvatore.

APPENDIX

This appendix presents the formal proof of the factor–price equalization theorem and examines factor-intensity reversal. Section A5.1 repeats (with some modifications to fit our present aim) the Edgeworth box diagrams of Nation 1 and Nation 2 from Figures 3.9 and 3.10. Section A5.2 then examines how international trade brings about equality in *relative* factor prices in the two nations. Section A5.3 shows that *absolute* factor prices are also equalized across nations as a result of international trade. Section A5.4 examines the effect of trade on the short-run distribution of income with the specific-factors model.

Sections A5.5 to A5.7 then feature factor-intensity reversal, utilizing the more advanced analytical tools reviewed in the appendix to Chapter 3. Section A5.5 gives a diagrammatic presentation of factor-intensity reversal. Section A5.6 presents the formula to measure the elasticity of substitution of L for K in production and examines its relationship to factor-intensity reversal. Section A5.7 discusses the method used to conduct empirical tests to determine the prevalence of factor-intensity reversal in the real world.

A5.1 The Edgeworth Box Diagram for Nation 1 and Nation 2

Figure 5.7 shows the Edgeworth box diagram of Nation 2 superimposed on the box diagram of Nation 1 in such a way that their origins for commodity X coincide. The origins for commodity Y differ because Nation 1 has a relative abundance of labor, whereas Nation 2 has a relative abundance of capital. The box diagrams are superimposed on each other to facilitate the analysis to follow.

Because both nations use the same *technology*, the isoquants for commodity X in the two nations are identical (and are measured from the common origin O_X). Similarly, the isoquants for commodity Y in the two nations are also identical (but are measured from origin O_Y for Nation 1 and from origin $O_{Y'}$ for Nation 2). X-isoquants farther from O_X refer to progressively higher outputs of X, while Y-isoquants farther from O_Y or $O_{Y'}$ refer to greater outputs of Y.

By joining all points where an X-isoquant is tangent to a Y-isoquant in each nation, we obtain the nation's production contract curve. Points A, F, and B on Nation 1's production contract curve in Figure 5.7 refer to corresponding points on Nation 1's production frontier (see Figure 3.9). Similarly, points A', F', and B' on Nation 2's production contract curve refer to corresponding points on Nation 2's production frontier. Note that the contract curves of both nations bulge toward the lower right-hand corner because commodity X is the L-intensive commodity in both nations.

A5.2 Relative Factor–Price Equalization

Figure 5.8 repeats Figure 5.7 but omits (to keep the figure simple) all isoquants as well as points F and F' (which are not needed in the subsequent analysis). The no-trade equilibrium point is A in Nation 1 and A' in Nation 2 (as in Figures 3.3 and 3.4). The K/L ratio in the production of commodity X is smaller in Nation 1 than in Nation 2. This is given by the lesser slope of the line (not shown) from origin O_X to point A as opposed to point A'. Similarly, the K/L ratio in the production of commodity Y is also smaller in Nation 1 than

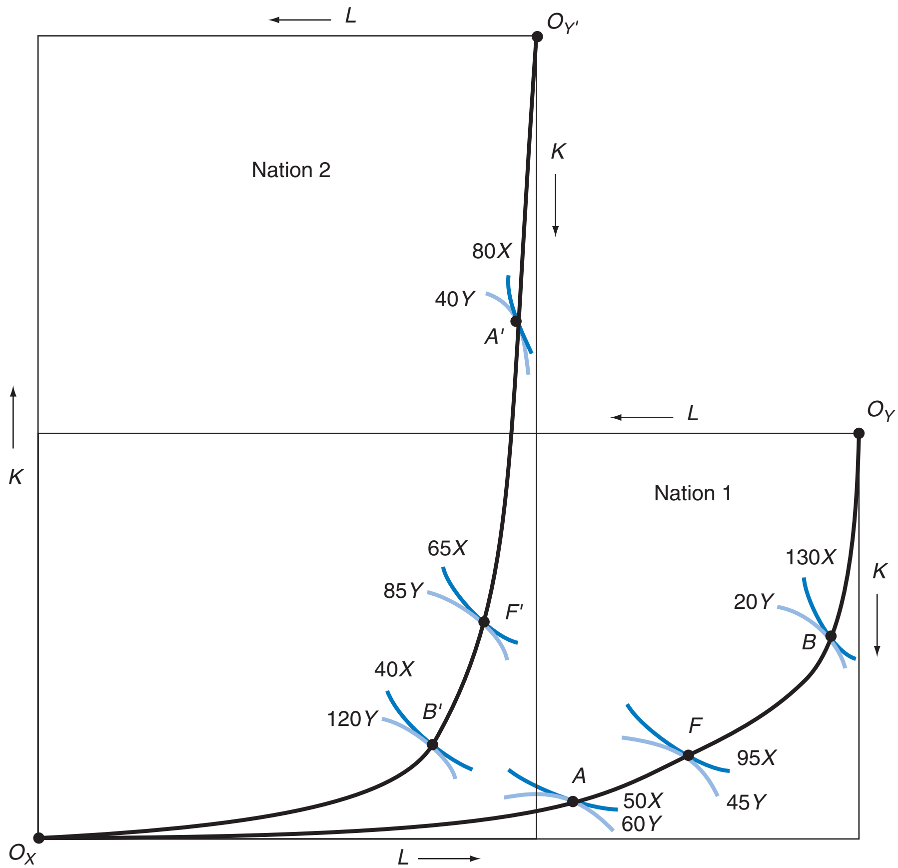


FIGURE 5.7. The Edgeworth Box Diagram for Nation 1 and Nation 2—Once Again. The Edgeworth box diagram of Nation 2 from Figure 3.10 is superimposed on the box diagram for Nation 1 from Figure 3.9 in such a way that their origins for commodity X coincide. Because both nations use the same technology, the isoquants of commodity X are identical in the two nations. The same is true for the Y-isoquants. The points on each nation's production contract curve refer to corresponding points on the nation's production frontier. The contract curves of both nations bulge toward the lower right-hand corner because commodity X is the *L*-intensive commodity in both nations.

in Nation 2. This is given by the smaller slope of the line (not shown) from O_Y to point A as opposed to the slope of the line (also not shown) from $O_{Y'}$ to point A'.

Since Nation 1 uses a smaller amount of capital per unit of labor (K/L) in the production of both commodities with respect to Nation 2, the productivity of labor and therefore the wage rate (w) are lower, while the productivity of capital and therefore the rate of interest (r) are higher, in Nation 1 than in Nation 2. This is always the case when both nations use a production function that is homogeneous of degree one, showing constant returns to scale (as assumed throughout).

With a lower w and a higher r, w/r is lower in Nation 1 than in Nation 2. This is consistent with the relative physical abundance of labor in Nation 1 and capital in Nation 2. The lower w/r in Nation 1 at autarky point A is reflected in the smaller (absolute) slope

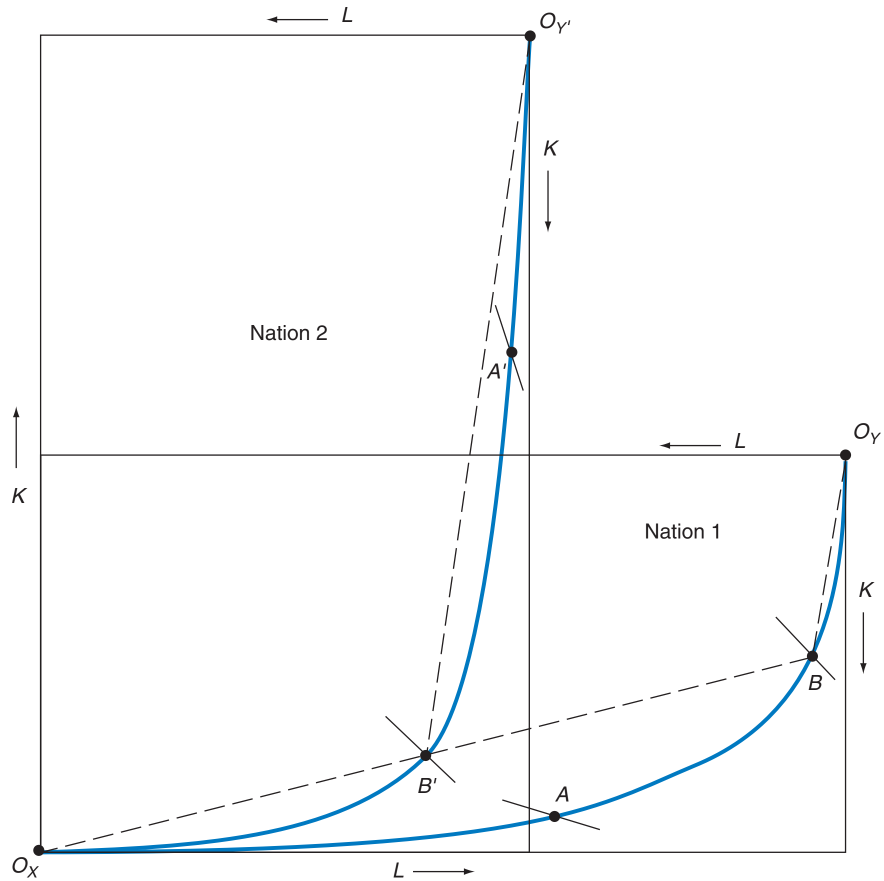


FIGURE 5.8. Formal Proof of the Factor–Price Equalization Theorem.
At the no-trade equilibrium point A in Nation 1 and A' in Nation 2, K/L is lower in the production of both commodities in Nation 1 than in Nation 2. These are given by the lower slopes of straight lines (not shown) from O_X and O_Y or $O_{Y'}$ to points A and A'. Since w/r (the absolute slope of the solid line through point A) is lower in Nation 1 and commodity X is L intensive, Nation 1 specializes in the production of commodity X until it reaches point B. Nation 2 specializes in Y until it reaches point B'. At B and B', K/L and therefore w/r are the same in both nations.

of the (short and solid) straight line through point A as opposed to the corresponding line at point A'. (The straight lines are the common tangents to the X- and Y-isoquants—not shown in Figure 5.8—at point A and point A'.)

To summarize, we can say that at the no-trade equilibrium point A, Nation 1 uses a smaller K/L ratio in the production of both commodities with respect to Nation 2. This results in lower productivity of labor and higher productivity of capital in Nation 1 than in Nation 2. As a result, w/r is lower in Nation 1 (the L-abundant nation) than in Nation 2.

Since Nation 1 is the L-abundant nation and commodity X is the L-intensive commodity, with the opening of trade Nation 1 will specialize in the production of commodity X (i.e., will move from point A toward O_Y along its production contract curve). Similarly, Nation 2 will specialize in the production of commodity Y and move from point A' toward O_X.

Specialization in production continues until Nation 1 reaches point B and Nation 2 reaches point B', where K/L is the same in each commodity in both nations. This is given by the slope of the dashed line from O_X through points B' and B for commodity X, and by the parallel dashed lines from O_Y and $O_{Y'}$ to points B and B' for commodity Y, for Nation 1 and Nation 2, respectively.

Note that as Nation 1 moves from point A to point B, K/L rises in the production of both commodities. This is reflected by the steeper slope of the dashed lines from O_X and O_Y to point B as opposed to point A. As a result of this increase in K/L, the productivity and therefore the wage of labor rise in Nation 1 (the low-wage nation). On the other hand, as Nation 2 moves from point A' to B', K/L falls in the production of both commodities. This is reflected by the smaller slope of the dashed lines from $O_{Y'}$ and O_X to point B' as opposed to point A'. As a result of this decline in K/L, the productivity and therefore the wage of labor falls in Nation 2 (the high-wage nation). The exact opposite is true for capital.

In the absence of trade, w/r was lower in Nation 1 than in Nation 2 (see the absolute slopes of the solid straight lines through points A and A'). As Nation 1 (the low-wage nation) specializes in the production of commodity X, K/L and w/r rise in the production of both commodities in Nation 1. As Nation 2 (the high-wage nation) specializes in the production of commodity Y, K/L and w/r fall in the production of both commodities. Specialization in production continues until K/L and w/r have become equal in the two nations. This occurs when Nation 1 produces at point B and Nation 2 produces at point B' with trade. This concludes our formal proof that international trade equalizes relative factor prices in the two nations when all the assumptions listed in Section 5.2A hold.

Problem Show graphically that with sufficiently less capital available, Nation 1 would have become completely specialized in the production of commodity X before relative factor prices became equal in the two nations.

A5.3 Absolute Factor–Price Equalization

This proof of absolute factor-price equalization is more difficult than the proof of relative factor-price equalization and is seldom if ever covered in undergraduate courses, even when all students in the course have had intermediate microeconomics and macroeconomics. The proof is included here only for the sake of completeness and for more advanced undergraduate students and first-year graduate students.

The proof makes use of Euler's theorem. According to Euler's theorem, if constant returns to scale prevail in production and if each factor is rewarded (paid) according to its productivity, the output produced is exhausted and just exhausted. Specifically, the marginal physical product of labor *(MPL)* times the amount of labor used in production *(L)* plus the marginal physical product of capital *(MPK)* times the amount of capital used in production *(K)* exactly equals the output produced. The same is true for commodity Y. In equation form, Euler's theorem in the production of commodity X can be expressed as

$$(MPL)(L) + (MPK)(K) = X \tag{5A-1}$$

Dividing both sides by L and rearranging:

$$X/L = MPL + (MPK)(K)/L \tag{5A-2}$$

Factoring out *MPL*:

$$X/L = MPL[(1 + K/L)(MPK/MPL)] \tag{5A-3}$$

With trade, Nation 1 produces at point B and Nation 2 produces at point B' in Figure 5.8. Since at points B and B', w/r is the same in both nations, *MPK/MPL* is also the same in both nations. We also know that at points B and B', K/L in the production of commodity X is the same in both nations. Finally, X/L is the average product of labor in the production of commodity X—and this is also the same in the two nations because of the assumptions of constant returns to scale and the same technology. As a result, the last remaining component (*MPL*) in Equation (5A-3) must also be the same in the production of commodity X *in both nations* if Equation (5A-3) is to hold.

Since the real wage is equal to *MPL*, the equality of *MPL* in the two nations means that real wages are the same in the two nations in the production of commodity X. With perfect competition and perfect internal factor mobility, real wages in the production of commodity Y are equal to real wages in the production of commodity X in each nation as well. In a completely analogous way, we can prove that the rate of interest is the same in the two nations in the production of both commodities. This concludes our proof that international trade equalizes absolute factor prices in the production of both commodities in both nations (under highly restrictive assumptions). That is, we have proved that real wages (w) are the same in both nations in the production of both commodities. Similarly, the real rate of interest (r) is also the same in both nations in the production of both commodities.

A5.4 Effect of Trade on the Short-Run Distribution of Income: The Specific-Factors Model

Suppose that in Nation 1 (the *L*-abundant nation) labor is mobile between industries but capital is not. Since labor is mobile, the wage of labor will be the same in the production of commodities X and Y in Nation 1. The equilibrium wage and the amount of labor employed in the production of X and Y in Nation 1 are given by the intersection of the value of the marginal product of labor curve in the production of X and Y. From micro economic theory, we know that the value of the marginal product of labor in the production of X is equal to the price of commodity X times the marginal physical product of labor in the production of X. That is, $VMPL_X = (P_X)(MPL_X)$. Similarly, $VMPL_Y = (P_Y)(MPL_Y)$. We also know that if a firm employs more labor with a given amount of capital, *VMPL* declines because of the law of diminishing returns. Finally, to maximize profits, firms will employ labor until the wage they must pay equals the value of the marginal product of labor (i.e., until $w = VMPL$).

We can show the no-trade equilibrium wage and employment of labor in the production of commodities X and Y in Nation 1 with the aid of Figure 5.9. In the figure, the horizontal axis measures the total supply of labor available to Nation 1, and the vertical axis measures the wage rate. To begin with, concentrate on the $VMPL_X$ curve (which is read from left to right, as usual) and on the $VMPL_Y$ curve (which is read from right to left). The equilibrium wage rate is *ED* and is determined at the intersection of the $VMPL_X$ and $VMPL_Y$ curves. The wage rate is identical in the production of X and Y because of perfect labor mobility in the nation between the two industries. The amount *OD* of labor is used in the production of X, and the remainder, or DO', is used in the production of Y.

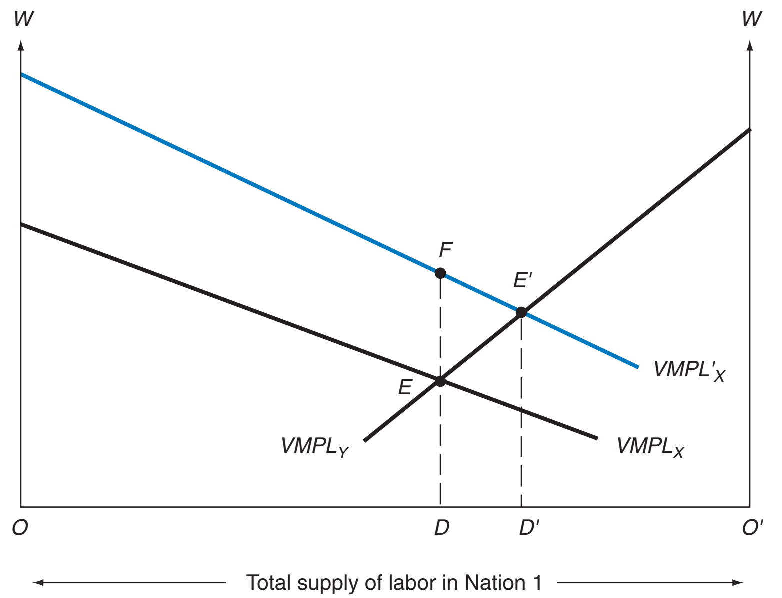


FIGURE 5.9. Specific-Factors Model.
Labor is mobile between industries, but capital is not. The horizontal axis measures the total supply of L available to Nation 1, and the vertical axis the wage rate (w). Before trade, the intersection of the $VMPL_X$ and $VMPL_Y$ curves determines $w = ED$ in the two industries. OD of L is used in the production of X and DO' in Y. With trade, P_X/P_Y increases and shifts $VMPL_X$ up to $VMPL_X{}'$, w rises from ED to $E'D'$, and DD' of L shifts from Y to X. Since w rises less than P_X, w falls in terms of X but rises in terms of Y (since P_Y is unchanged). With more L used with fixed K in the production of X, $VMPK_X$ and r increase in terms of both X and Y. With less L used with fixed K in Y, $VMPK_Y$ and r fall in terms of both commodities.

Since Nation 1 (the L-abundant nation) has a comparative advantage in commodity X (the L-intensive commodity), the opening of trade increases P_X/P_Y. Since $VMPL_X = (P_X)(MPL_X)$, the increase in P_X shifts the $VMPL_X$ curve upward proportionately, by EF, to $VMPL_X{}'$. The wage rate increases less than proportionately, from ED to $E'D'$, and DD' units of labor shift from the production of Y to the production of X. Since w increases by less than the increase in P_X, w falls in terms of X but rises in terms of Y (since P_Y is unchanged). Thus, the effect of the increase in P_X on the real income of labor is ambiguous and depends on spending patterns. Workers who consume mainly commodity X will be worse off, while those who consume mainly commodity Y will be better off.

The rewards (r) to the specific factor (capital) change unambiguously, however. Since the specific capital in the production of commodity X has more labor to work with, $VMPK_X$ and r increase in terms of both commodities X and Y. On the other hand, since less labor is used with the fixed capital in the production of commodity Y, $VMPK_Y$ and r fall in terms of commodity X, and therefore in terms of commodity Y as well.

Thus, with the opening of trade, the real income of the immobile capital (the nation's scare factor) rises in the production of X and falls in the production of Y, whereas real wages (which are equal in the production of both commodities) fall in terms of commodity X and rise in terms of commodity Y. This is the result we obtain in the short run with the specific-factors model when capital is specific to or immobile between the two industries of the nation.

Generalizing the specific-factors model, we can say that *trade will have an ambiguous effect on each nation's mobile factors, benefit the immobile factors specific to the nation's export sectors, and harm the immobile factors specific to the nation's import-competing sectors*. This is what we can expect in the short run when some factors are specific or immobile (i.e., can only be used in some industries). In the long run, of course, when all inputs are mobile among all industries of a nation, the Heckscher–Ohlin model postulates that the opening of trade will lead to an increase in the real income or return of the inputs used intensively in the nation's export sectors and to a reduction in the real income or return of the inputs used intensively in the production of the nation's import-competing sectors.

Problem What effect will the opening of trade have on the real income of labor and capital in Nation 2 (the K-abundant nation) if L is mobile between the two industries in Nation 2 but K is not?

A5.5 Illustration of Factor-Intensity Reversal

Figure 5.10 shows a single isoquant for commodity X and a single isoquant for commodity Y. From Section A3.1, we know that with a homogeneous production function of degree one, a single isoquant completely describes the entire production function of each

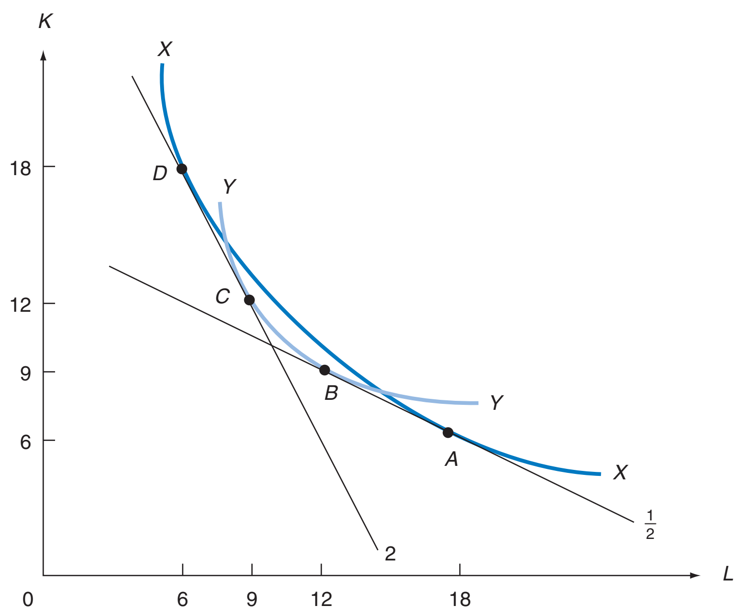


FIGURE 5.10. Factor-Intensity Reversal.
At $w/r = 1/2$, commodity X is produced at point A with $K/L = 6/18 = 1/3$, while commodity Y is produced at point B with $K/L = 9/12 = 3/4$. Thus, commodity X is the L-intensive commodity. On the other hand, at $w/r = 2$, commodity Y is produced at point C with $K/L = 12/9 = 4/3$, while commodity X is produced at point D with $K/L = 18/6 = 1/3 = 3$. Thus, commodity X is L intensive at $w/r = 1/2$ and K intensive at $w/r = 2$ in relation to commodity Y, and factor-intensity reversal is present.

commodity. Furthermore, since both nations are assumed to use the same technology, we can use the single X- and Y-isoquants to refer to both nations.

Figure 5.10 shows that at $w/r = 1/2$, commodity X is produced at point A, where the X-isoquant is tangent to the isocost line with slope (w/r) equal to $1/2$ and $K/L = 6/18 = 1/3$. Commodity Y is produced at point B, where the Y-isoquant is tangent to the same isocost line with slope (w/r) equal to $1/2$ and $K/L = 9/12 = 3/4$. Thus, at $w/r = 1/2$, K/L is higher for commodity Y, so that commodity X is the relatively L-intensive commodity.

On the other hand, at $w/r = 2$, commodity Y is produced at point C, where the Y-isoquant is tangent to the isocost line with slope (w/r) equal to 2 and $K/L = 12/9 = 4/3$. Commodity X is produced at point D, where the X-isoquant is tangent to the same isocost line with slope (w/r) equal to 2 and $K/L = 18/6 = 3$. Thus, at $w/r = 2$, commodity X is the relatively K-intensive commodity.

As a result, commodity X is L intensive at $w/r = 1/2$ and K intensive at $w/r = 2$ with respect to commodity Y, and we say that factor-intensity reversal is present.

With factor-intensity reversal, both the H–O theorem and the factor-price equalization theorem must be rejected. To see this, suppose that Nation 1 is the relatively L-abundant nation with $w/r = 1/2$, while Nation 2 is the relatively K-abundant nation with $w/r = 2$. With $w/r = 1/2$, Nation 1 should specialize in the production of and export commodity X because Nation 1 is the L-abundant nation and commodity X is the L-intensive commodity there. With $w/r = 2$, Nation 2 should specialize in the production of and export commodity X because Nation 2 is the K-abundant nation and commodity X is the K-intensive commodity there. Since both nations cannot export to each other the same *homogeneous* commodity (i.e., commodity X), the H–O theorem no longer predicts the pattern of trade.

When the H–O model does not hold, the factor–price equalization theorem also fails. To see this, note that as Nation 1 (the low-wage nation) specializes in the production of commodity X (the L-intensive commodity), the demand for labor rises, and w/r and w rise in Nation 1. With Nation 1 specializing in and exporting commodity X to Nation 2, Nation 2 must specialize in and export commodity Y to Nation 1 (since the two nations could not possibly export the same homogeneous commodity to each other). However, since commodity Y is the L-intensive commodity in Nation 2, the demand for labor rises, and w/r and w rise in Nation 2 (the high-wage nation) also. Thus, wages rise both in Nation 1 (the low-wage nation) and in Nation 2 (the high-wage nation).

If wages rise faster in Nation 1 than in Nation 2, the difference in wages between the two nations declines, as predicted by the factor–price equalization theorem. If wages rise more slowly in Nation 1 than in Nation 2, the wage difference increases. If wages rise by the same amount in both nations, the wage difference remains unchanged. Since there is no a priori way to determine the effect of international trade on the difference in factor prices in each case, we must reject the factor–price equalization theorem.

From Figure 5.10, we can see that factor-intensity reversal arises because the X-isoquant has a much smaller curvature than the Y-isoquant and the X- and Y-isoquants *cross twice within the two relative factor price lines*. When the two isoquants have similar curvature, they will only cross once and there is no factor-intensity reversal.

Problem Draw a figure similar to Figure 5.10 with the X-isoquant and the Y-isoquant crossing only once within the relative factor price lines of the two nations and show that in that case there is no factor-intensity reversal.

A5.6 The Elasticity of Substitution and Factor-Intensity Reversal

We have said that for factor-intensity reversal to occur, the X-isoquant and the Y-isoquant must have sufficiently *different* curvatures to cross twice within the relative factor price lines prevailing in the two nations. The curvature of an isoquant measures the ease with which L can be substituted for K in production as the relative price of labor (i.e., w/r) declines. When w/r falls, producers will want to substitute L for K in the production of both commodities to minimize their costs of production.

The flatter (i.e., the smaller the curvature of) an isoquant, the easier it is to substitute L for K (and vice versa) in production. A measure of the curvature of an isoquant and the ease with which one factor can be substituted for another in production is given by the elasticity of substitution. The elasticity of substitution of L for K in production (e) is measured by the following formula:

$$e = \frac{\Delta(K/L)/(K/L)}{\Delta(\text{slope})/(\text{slope})}$$

For example, the elasticity of substitution of L for K for commodity X between point D and point A is calculated as follows. $K/L = 3$ at point D and $K/L = \frac{1}{3}$ at point A in Figure 5.10. Therefore, the change in K/L for a movement from point D to point A along the X-isoquant is $3 - \frac{1}{3} = 2\frac{2}{3} = \frac{8}{3}$. Thus, $\Delta(K/L)/(K/L) = (\frac{8}{3})/3 = \frac{8}{9}$. The absolute slope of the X-isoquant is 2 at point D and $\frac{1}{2}$ at point A. Therefore, $\Delta(\text{slope}) = 2 - \frac{1}{2} = 1\frac{1}{2} = \frac{3}{2}$. Thus, $\Delta(\text{slope})/(\text{slope}) = (\frac{3}{2})/2 = \frac{3}{4}$. Substituting these values into the formula, we get

$$e = \frac{\Delta(K/L)/(K/L)}{\Delta(\text{slope})/(\text{slope})} = \frac{8/9}{3/4} = 32/27 = 1.19$$

Similarly, the elasticity of substitution of L and K between point C and point B along the Y-isoquant is

$$e = \frac{\Delta(K/L)/(K/L)}{\Delta(\text{slope})/(\text{slope})} = \frac{[(4/3) - 3/4)]/(4/3)}{(2 - \frac{1}{2})/(2)}$$

$$= \frac{(7/12)/(4/3)}{(1\frac{1}{2})/2} = \frac{21/48}{3/4} = 84/144 = 0.58$$

Thus, the X-isoquant has a much smaller curvature and a much greater elasticity of substitution than the Y-isoquant. It is this difference in curvature and elasticity of substitution between the X-isoquant and the Y-isoquant that results in their crossing twice within the relative factor price lines, giving factor-intensity reversal. Note that a difference in the curvature of the isoquants and in the elasticity of substitution is a necessary but not sufficient condition for factor-intensity reversal. For factor-intensity reversal to occur, the elasticity of substitution must be sufficiently different so that the isoquants of the two commodities cross *within* the relative factor price lines of the two nations.

Problem Calculate the elasticity of substitution of L and K for the X-isoquant and Y-isoquant of the previous problem (where there is no factor-intensity reversal), and verify that the elasticity of substitution for the two isoquants does not differ much because of their similar curvature. Assume that the coordinates are A (4,2), B (3,3), C (3,2.5), D (2,4), and that the absolute slope of the isoquants is 1 at points A and C and 2 at B and D.

A5.7 Empirical Tests of Factor-Intensity Reversal

Until 1961, economists used almost exclusively the Cobb–Douglas production function in their work. This implied that the elasticity of substitution of L for K was equal to 1 in the production of all commodities. As a result, this production function was not at all useful to measure the prevalence of factor-intensity reversal in the real world.

Partially in response to the need to measure factor-intensity reversal in international trade, a new production function was developed in 1961 by *Arrow, Chenery, Minhas, and Solow*, called the constant elasticity of substitution (CES) production function. As its name implies, the CES production function kept the elasticity of substitution of L for K constant for each industry but allowed the elasticity of substitution to vary from industry to industry.

It was this CES production function that Minhas used to measure factor-intensity reversal. That is, Minhas found that the elasticity of substitution of L and K differed widely in the six industries that he studied and that factor-intensity reversal occurred in one-third of the cases. This rate of occurrence is too frequent for factor reversal to be treated as an exception; if true, it would have seriously damaged the H–O model.

However, *Leontief* calculated the elasticity of substitution of all 21 industries used to derive the CES production function (rather than just the six selected by Minhas) and found that factor reversal occurred in only 8 percent of the cases. Furthermore, when he removed two industries intensive in natural resources, factor reversal fell to about 1 percent of the cases. Thus, Leontief concluded that factor-intensity reversal is a rather rare occurrence and that the H–O model should not be rejected on account of these exceptions.

Minhas also conducted another test in his study. He calculated K/L for the same 20 industries in the United States and Japan, ranked these industries according to the K/L in each nation, and then found the coefficient of rank correlation between the industry rankings in the two nations. Since the United States was the relatively K-abundant nation, all industries could be expected to be more K intensive in the United States than in Japan. However, the K-intensity *ranking* of the industries would have to be very similar in the United States and Japan in order for factor-intensity reversal to be rare. That is, the most K-intensive industries in the United States should also be the most K-intensive industries in Japan. Minhas found that the rank correlation was only 0.34 and concluded that factor reversal was fairly common.

However, *Ball* found that when agriculture and two industries intensive in natural resources were removed from the list, the rank correlation rose to 0.77, so that, once again, the conclusion could be reached that factor-intensity reversal is not a common occurrence.

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A great deal of trade statistics for the United States by country and region can be found through the home page of the U.S. Department of Commerce, International Trade Administration, at:

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Trade statistics for European countries are provided by EuroStat (the Statistical Office of the European Communities) at:

http://ec.europa.eu/trade/statistics

A wealth of detailed international trade statistics by country, industry, and year for 175 countries and areas is also provided in *International Trade Statistics Yearbook*, Vol. 1, published by the United Nations at:

http://comtrade.un.org/pb/

The IMF publishes the Direction of Trade Statistics (yearly and quarterly) on the volume of trade to and from each of the 187 member countries of the IMF, Click "Direction of Trade Statistics (DOTS)" at:

http://www.imf.org/external/data.htm

The hourly compensation of U.S. workers in manufacturing and how it compares with that of foreign workers is found at:

http://www.bls.gov/data/home.htm#international

The capital stock per worker of many countries is found on the University of Pennsylvania website at:

http://pwt.econ.upenn.edu