chapter

5

Factor Endowments and the Heckscher–Ohlin Theory

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, $\frac{2}{2}$ in the production of Y. If at the same time $1K$ and $4L$ are required to produce one unit of X, $K/L = \frac{1}{4}$ for commodity X. Since $K/L = 1$ for Y and $K/L = \frac{1}{4}$ 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, $K/L = \frac{2}{2}$ for Y, but $K/L = \frac{3}{12} = \frac{1}{4}$ 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, $K/L = \frac{2}{2} = \frac{4}{4} = 1$ 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, $K/L = \frac{1}{4}$ for X in Nation 1. This is given by the slope of $\frac{1}{4}$ 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.

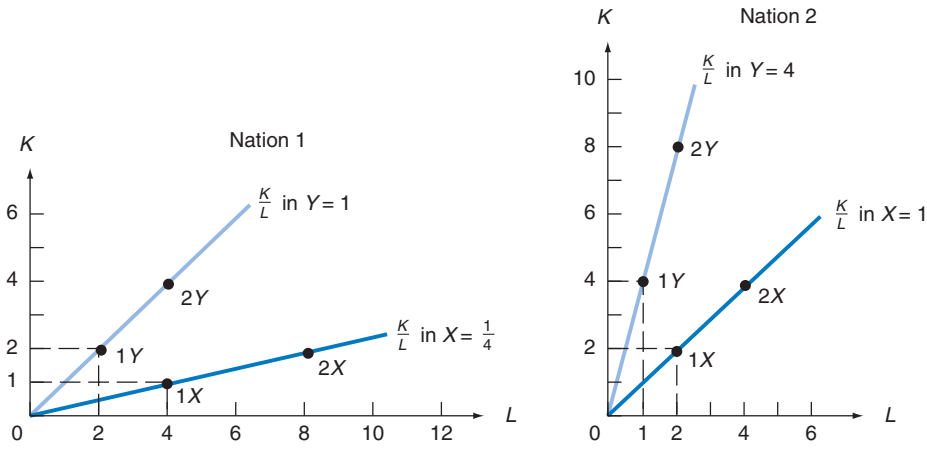

FIGURE 5.1. Factor Intensities for Commodities X and Y in Nations 1 and 2.
In Nation 1, the capital–labor ratio (K/L) equals 1 for commodity Y and $K/L = \frac{1}{4}$ for commodity X. These are given by the slope of the ray from the origin for each commodity in Nation 1. Thus, commodity Y is the K-intensive 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

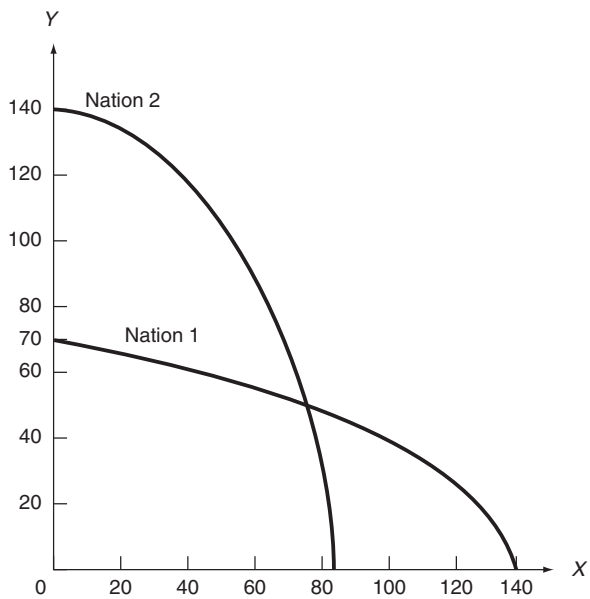

FIGURE 5.2. The Shape of the Production Frontiers of Nation 1 and Nation 2.
The production frontier of Nation 1 is flatter and wider than the production frontier of Nation 2, indicating that Nation 1 can produce relatively more of commodity X than Nation 2. The reason for this is that Nation 1 is the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