Chapter 4

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

To explain the role of resource differences in trade, this chapter examines a model in which resource differences are the *only* source of trade. This model shows that comparative advantage is influenced by the interaction between nations' resources (the relative **abundance** of factors of production) and the technology of production (which influences the relative **intensity** with which different factors of production are used in the production of different goods). The same idea was present in the specific factors model of Chapter 3, but the model we study in this chapter puts the interaction between abundance and intensity in sharper relief.

That international trade is largely driven by differences in countries' resources is one of the most influential theories in international economics. Developed by two Swedish economists, Eli Heckscher and Bertil Ohlin (Ohlin received the Nobel Prize

in economics in 1977), the theory is often referred to as the **Heckscher-Ohlin theory.** Because the theory emphasizes the interplay between the proportions in which different factors of production are available in different countries and the proportions in which they are used in producing different goods, it is also referred to as the **factor-proportions theory.**

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

A Model of a Two-Factor Economy

The simplest factor-proportions model is in many ways very similar to the specific factors model developed in Chapter 3. As in that model, it is assumed that each economy is able to produce two goods and that production of each good requires the use of two factors of production. In this case, however, we no longer assume that one of the factors used in each industry is specific to that industry. Instead, the *same* two factors are used in both sectors. This leads to a somewhat more difficult model, but also to some important new insights.

ASSUMPTIONS OF THE MODEL

The economy we are analyzing can produce two goods: cloth (measured in yards) and food (measured in calories). Production of these goods requires two inputs that are in limited supply: labor, which we measure in hours, and land, which we measure in acres. Initially we assume that the technology of production is one of **fixed coefficients;** that is, there is only one way to produce each good. A yard of cloth can be produced only using a certain fixed number of hours of labor and acres of land; we cannot use less land and more labor, or vice versa. The same is true for producing a calorie of food.

In general we would not expect the production of food and of cloth to require land and labor in the same proportions. Let's assume that cloth production is *labor-intensive,* that is, it requires a higher ratio of labor to land than food production. Food production is correspondingly more *land-intensive* than cloth production. Notice that the definition of labor or land intensity depends on the ratio of land to labor used in production, not the ratio of land or labor to output. Thus a good cannot be both land- and labor-intensive.

Let's define the following expressions:

a_{TC} = acres of land required per yard of cloth,
a_{LC} = hours of labor required per yard of cloth,
a_{TF} = acres of land required per calorie of food,
a_{LF} = hours of labor required per calorie of food,
L = economy's supply of labor,
T = economy's supply of land.

The assumption that cloth production is labor-intensive and food production land-intensive can be stated in two equivalent ways:

$$a_{LC}/a_{TC} > a_{LF}/a_{TF}$$

or

$$a_{LC}/a_{LF} > a_{TC}/a_{TF}.$$

PRODUCTION POSSIBILITIES

The principle that underlies the derivation of a production possibility frontier in this model is the same as in earlier ones: the economy cannot use more of either input than it has available. If the country produces Q_C yards of cloth and Q_F calories of food, it must use $a_{LC}Q_C + a_{LF}Q_F$ hours of labor to produce these goods, and this amount must not exceed the total labor force L. The economy will also use $a_{TC}Q_C + a_{TF}Q_F$ acres of land, and this must not exceed the total supply of land T. Together, these two constraints define the economy's production possibilities. First, total use of labor cannot exceed the available supply:

$$a_{LC}Q_C + a_{LF}Q_F \leq L. \tag{4-1}$$

Second, total use of land must not exceed the available supply:

$$a_{TC}Q_C + a_{TF}Q_F \leq T. \tag{4-2}$$

The limited supplies of labor and land limit what the economy can produce.

By rearranging the labor constraint, we can write the expression

$$Q_F \leq L/a_{LF} - (a_{LC}/a_{LF})Q_C. \tag{4-3}$$

The logic behind this expression should be clear. If all labor (L) were used to produce food, there would be enough to produce at most L/a_{LF} calories, that is, the total labor force divided by the number of hours it takes to produce each calorie. If some cloth is also produced, each unit of cloth requires that a_{LC} units of labor be diverted from food production and thus reduces the maximum food output by a_{LC}/a_{LF} calories.

Similarly, by rearranging the land constraint we get

$$Q_F \leq T/a_{TF} - (a_{TC}/a_{TF})Q_C. \tag{4-4}$$

The labor and land constraints are illustrated in Figure 4-1. Because cloth is more labor-intensive than food— $a_{LC}/a_{LF} > a_{TC}/a_{TF}$ —the labor constraint is a steeper line than the land constraint.

The two-tone lines in Figure 4-1 show how the two constraints together determine the economy's production possibilities. If the economy is producing a high ratio of food to cloth, as at point 1, the binding constraint, that is, the constraint that actually limits production, is the land constraint. If, on the other hand, the economy is producing a low ratio of food to cloth, as at point 2, the labor constraint is the one that binds. The fact that which constraint is binding depends on the mix of goods the economy produces suggests that changes in the economy's resources will have uneven effects on its ability to produce different goods. Specifically, an increase in the economy's supply of land will expand production possibilities more in the direction of food than in that of cloth, while an increase in the supply of labor will expand production possibilities more in the direction of cloth than in that of food.

FIGURE 4-1
The production possibility frontier in the factor proportions model.
The limited supplies of labor and land constrain the economy's production. Because cloth is more labor-intensive than food, the labor constraint is steeper than the land constraint.

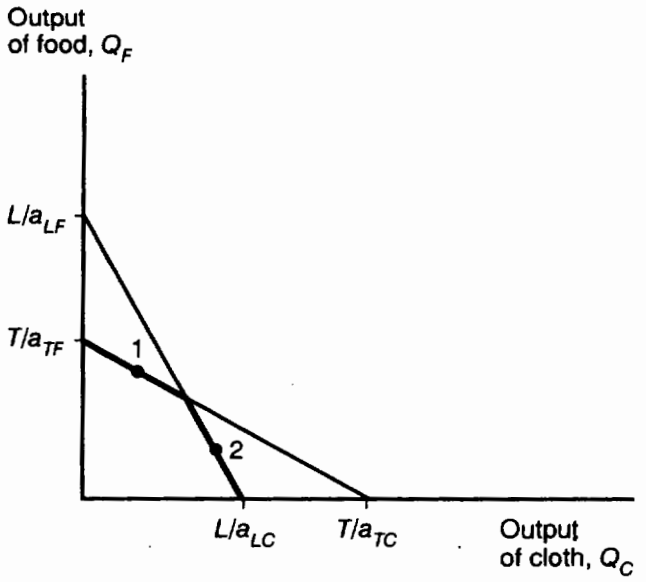


Figure 4-2 shows explicitly how an increase in the supply of land changes production possibilities. When the supply of land is increased from T^1 to T^2, the land constraint on the economy's production possibilities is relaxed, so that the production possibility frontier is shifted outward. What is immediately clear from the diagram, however, is that this is a **biased expansion of production possibilities**—that is, the expansion is greater, the higher the ratio of food to cloth in production. In fact, if the economy tries to produce a high ratio of cloth to food, the expansion of land supply does not permit any increase in production at all.

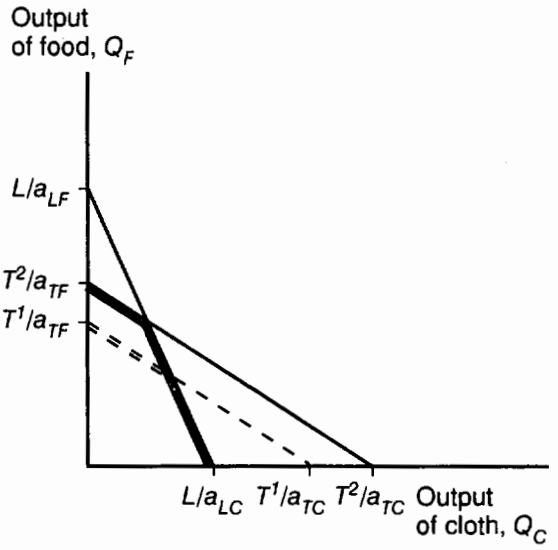
The biased effect of increases in resources on production possibilities is the key to understanding how differences in resources give rise to international trade.[1] An increase in the supply of land expands production possibilities disproportionately in the direction of food production, while an increase in the supply of labor expands them disproportionately in the direction of cloth production. Thus an economy with a high ratio of land to labor will be relatively better at producing food than an economy with a low ratio of land to labor. *More generally, an economy will tend to be relatively effective at producing goods that are intensive in the factors with which the country is relatively well endowed.*

GOODS PRICES AND FACTOR PRICES

In Chapter 3 the assumption that some factors of production were specific to particular sectors was shown to imply that changes in relative prices produce strong effects on income distribution. Since international trade leads to a convergence of relative prices, these effects on income distribution will sharply qualify the conclusion that trade produces gains for everyone. In the Heckscher-Ohlin model each factor of production

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

FIGURE 4-2
Increasing the supply of land.
When land supply is increased from T^1 to T^2, the land constaint is relaxed. This expands production possibilities in a direction biased toward food production.



can be used in both sectors, but because there are two factors income distribution may still be an issue. An analysis of the effects of changes in the prices of cloth and food on the earnings of land and labor involves the following:

P_C = price of 1 yard of cloth,
P_F = price of 1 calorie of food,
w = wage rate for 1 hour of labor,
r = rent that must be paid for the use of 1 acre of land.

To analyze the relationship between prices and earnings, we assume there is perfect competition in the production of cloth and food. This means that any monopoly profits are competed away, so that the price of each good is exactly equal to the cost of producing it. This cost, in turn, is the sum of the cost of land and labor used in production:

$$P_C = a_{LC}w + a_{TC}r, \tag{4-5}$$

$$P_F = a_{LF}w + a_{TF}r. \tag{4-6}$$

Equations (4-5) and (4-6) define combinations of w and r for which the cost of production equals the price for cloth and food, respectively. These two relationships are shown in Figure 4-3. Remember that we have assumed that cloth production is more labor-intensive than food production—that is,

$$a_{LC}/a_{TC} > a_{LF}/a_{TF}.$$

This implies that the cloth line must be steeper than the food line, as drawn.

The economy will produce both goods only if price equals cost in both sectors. This equality holds for both goods at the point in the diagram where the two lines cross, point 1, where $w = w^1$ and $r = r^1$. The diagram thus shows that we can determine factor prices given goods prices. Notice that we did *not* need to ask about the relative supplies of land and labor to do this: as long as both goods are produced, there is a one-to-one relationship between goods prices and factor prices.

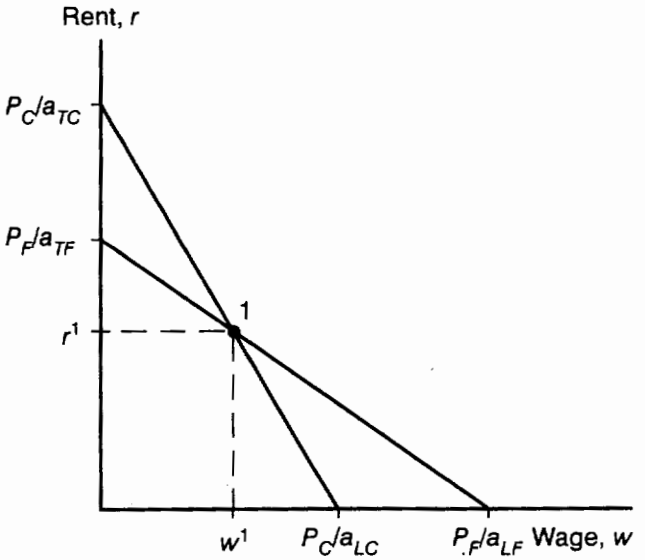


FIGURE 4-3
Determination of factor prices.
The wage rate and the rental rate on land are determined by the requirement that price equal cost of production in both cloth and food.

When goods prices change, factor prices will also change. You might not be surprised to find that when the price of cloth is increased, the price of labor rises more than that of land. In fact, however, the effect on the relative price of land and labor is so strong that the price of land actually *falls.*

In Figure 4-4, we show what happens when the price of cloth is increased from P_C^1 to P_C^2. The increase in the price of cloth shifts the cloth line out. The equilibrium factor price point therefore shifts from point 1 to point 2. This movement involves a rise in the wage rate, from w^1 to w^2, and a fall in the rental rate on land, from r^1 to r^2. Similarly, a rise in the price of food would raise the rental rate on land and lower the wage rate.

When the price of cloth increases, the wage rate rises more than proportionately—that is, if the price of cloth increases by 10 percent, the wage rate will rise by more than 10 percent. This must be so because the rental on land actually falls. Consider the following numerical example. A yard of cloth takes 1 hour of labor and 1 acre of land to produce. Initially the labor and the land each cost \$5, and the price of cloth is \$10. Now suppose that the price of cloth rises by 10 percent, to \$11. When the price of cloth rises, we know that the rental on land actually falls, say to \$4.50. Correspondingly, the wage rate must therefore have risen to \$6.50—a 30 percent rise, three times as large as the increase in the price of cloth.

In a two-factor economy, then, changes in relative goods prices have very strong effects on income distribution. There is a **magnified effect of goods prices on factor prices.**[2] Because an increase in the price of cloth leads to a fall in the rent on land, someone who derives all her income from land rent will find her purchasing power reduced in terms of *both* goods. At the same time, the wage rate rises more than proportionately to the increase in the price of cloth; so someone who derives his income

[2] The effect of changes in relative goods prices on factor prices was first analyzed by Wolfgang Stolper and Paul Samuelson, "Protection and Real Wages," *Review of Economic Studies* 9 (1941), pp. 58–73, and is thus known as the **Stolper-Samuelson effect.**

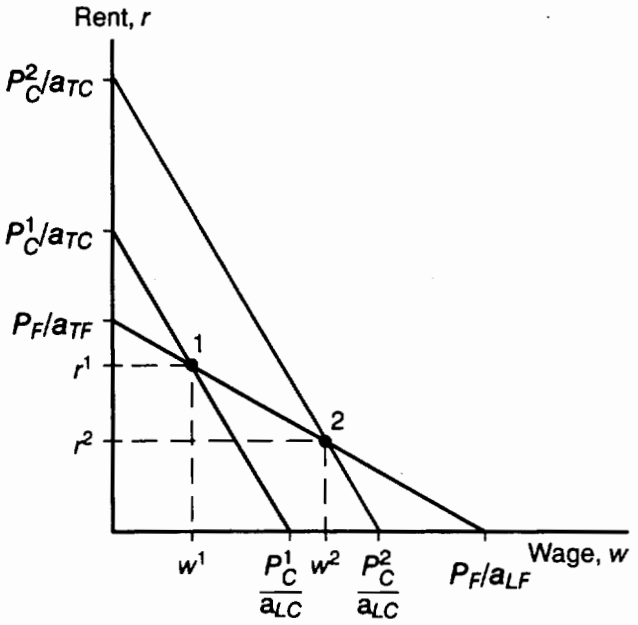


FIGURE 4-4
An increase in the price of cloth.
When the price of cloth rises from P_C^1 to P_C^2, the wage rate rises from w^1 to w^2, while the rental rate on land actually declines from r^1 to r^2.

entirely from wages will find that his purchasing power has *increased* in terms of both goods.

ALLOWING SUBSTITUTION BETWEEN INPUTS

Up to now, we have examined an economy with fixed coefficients, where it takes a certain number of hours of labor and acres of land to make a yard of cloth and there is no way to trade off more land for less labor. The results must be modified slightly for an economy in which the ratio of land to labor in production can vary. (The two-factor model with **variable coefficients** is discussed in more detail in the appendix to this chapter.)

One difference is that there is no longer a simple, physical definition of which goods are land-intensive and which are labor-intensive: the ratio of land to labor used in production depends on the relative price of land and labor. In the United States, where land is abundant, cattle raising is land-intensive compared with wheat growing. Yet in Japan, where land is very scarce, cows may be raised with a lower land-labor ratio than the United States uses in growing wheat. When comparing factor intensities, we must therefore be careful always to compare the land-labor ratio that would have been used given the same incentives. Specifically, we describe cloth production as more labor-intensive than food production as long as the cloth sector will use a higher labor-land ratio than the food sector *when the two sectors face the same factor prices.*

Another difference that arises when factor substitution is allowed is that we can no longer say that only one resource constrains production at each point in time. In the fixed-coefficients model, production possibilities are defined by two constraints. If the economy tries to produce a high ratio of food to cloth, only the land constraint matters; if it tries to produce a high ratio of cloth to food, only the labor constraint matters. Once we allow trade-offs between use of the two factors, however, this sharp-edged result gets a little fuzzy. Even if the economy is producing mostly food and very little

cloth, an increase in the labor supply will allow it to produce more of *either* good by substituting labor for land.

Because of the additional flexibility allowed by land-labor substitution, the production possibility frontier loses the "kinked" shape that it has in the case of fixed coefficients. Instead, it becomes more of a smooth curve, as illustrated by *TT* in Figure 4-5.

Although the shape of the production possibility frontier is softened by allowing land-labor substitution, the basic result of our fixed-coefficient analysis remains valid: increases in factor supplies shift production possibilities in a biased way (Figure 4-6). An increase in the labor supply shifts the production possibility curve outward from T^1T^1 to T^2T^2, but it shifts production possibilities out more in the direction of the labor-intensive product (cloth) than in the direction of the land-intensive product (food). Similarly, an increase in the supply of land would shift production possibilities out more in the direction of food than in the direction of cloth.

One conclusion that is *not* softened by allowing factor substitution is the relationship between goods prices and factor prices: a rise in the price of cloth leads to a more than proportional increase in the wage rate and to an actual fall in the price of land.

● Effects of International Trade between Two-Factor Economies

Having outlined the production structure of a two-factor economy, we can now look at what happens when two such economies, Home and Foreign, trade. As always, Home and Foreign are similar along many dimensions. They have the same tastes and therefore have identical relative demands for food and cloth when faced with the same relative price of the two goods. They also have the same technology: a given amount of land and labor yields the same output of either cloth or food in the two countries. The only

FIGURE 4-5
Production possibilities with land-labor substitution.
The possibility of substitution removes the "kink" in the production possibility frontier, causing it instead to be a smooth curve.