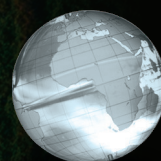


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Theory and Policy

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Paul R. Krugman • Maurice Obstfeld • Marc J. Melitz



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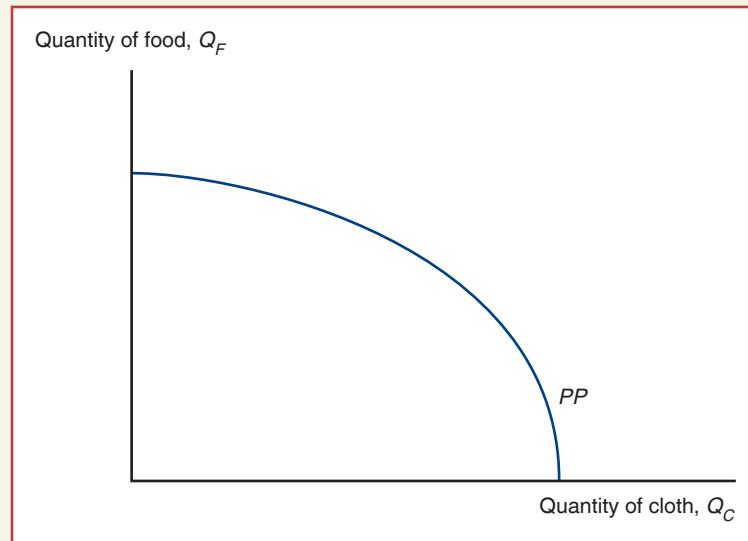
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**FIGURE 5-2****The Production Possibility Frontier with Factor Substitution**

If capital can be substituted for labor and vice versa, the production possibility frontier no longer has a kink. But it remains true that the opportunity cost of cloth in terms of food rises as the economy's production mix shifts toward cloth and away from food.

of production. Figure 5-3 shows what this implies. The value of the economy's production is

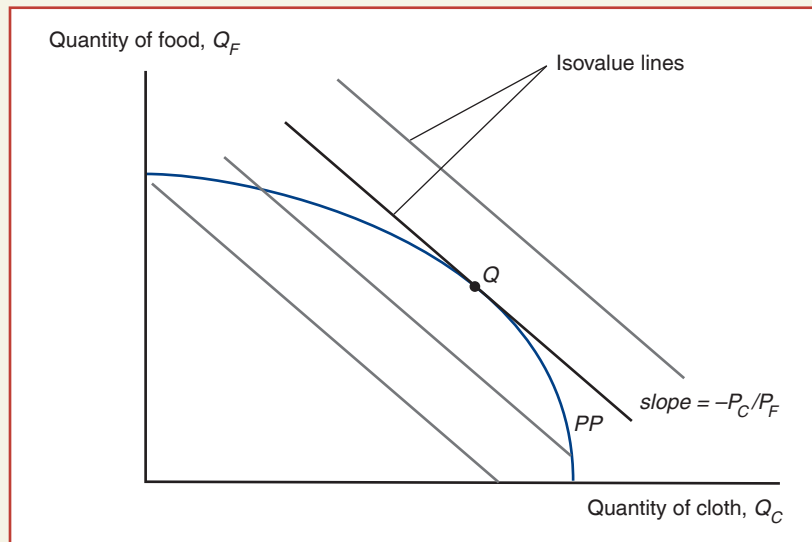
$$V = P_C \times Q_C + P_F \times Q_F,$$

where P_C and P_F are the prices of cloth and food, respectively. An isovalue line—a line along which the value of output is constant—has a slope of $-P_C/P_F$. The economy produces at the point Q , the point on the production possibility frontier that touches the highest possible isovalue line. At that point, the slope of the production possibility frontier is equal to $-P_C/P_F$. So the opportunity cost in terms of food of producing another unit of cloth is equal to the relative price of cloth.

Choosing the Mix of Inputs

As we have noted, in a two-factor model producers may have room for choice in the use of inputs. A farmer, for example, can choose between using relatively more mechanized equipment (capital) and fewer workers, or vice versa. Thus, the farmer can choose how much labor and capital to use per unit of output produced. In each sector, then, producers will face not fixed input requirements (as in the Ricardian model) but trade-offs like the one illustrated by curve II in Figure 5-4, which shows alternative input combinations that can be used to produce one calorie of food.

What input choice will producers actually make? It depends on the relative costs of capital and labor. If capital rental rates are high and wages low, farmers will choose to produce using relatively little capital and a lot of labor; on the other hand, if the

**FIGURE 5-3****Prices and Production**

The economy produces at the point that maximizes the value of production given the prices it faces; this is the point on the highest possible isovalue line. At that point, the opportunity cost of cloth in terms of food is equal to the relative price of cloth, P_C/P_F .

FIGURE 5-4**Input Possibilities in Food Production**

A farmer can produce a calorie of food with less capital if he or she uses more labor, and vice versa.

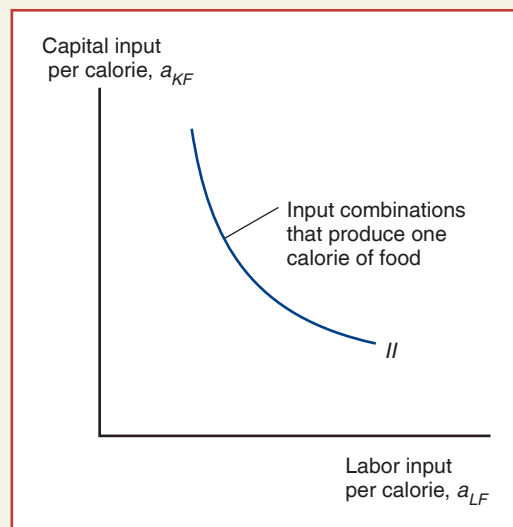
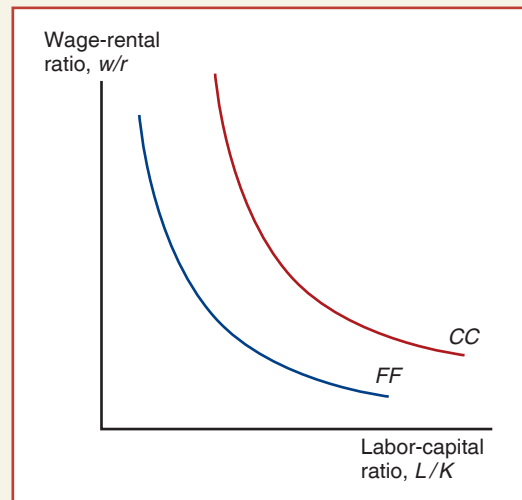


FIGURE 5-5

Factor Prices and Input Choices

In each sector, the ratio of labor to capital used in production depends on the cost of labor relative to the cost of capital, w/r . The curve FF shows the labor-capital ratio choices in food production, while the curve CC shows the corresponding choices in cloth production. At any given wage-rental ratio, cloth production uses a higher labor-capital ratio; when this is the case, we say that cloth production is *labor-intensive* and that food production is *capital-intensive*.



rental rates are low and wages high, they will save on labor and use a lot more capital. If w is the wage rate and r the rental cost of capital, then the input choice will depend on the ratio of these two **factor prices**, w/r .² The relationship between factor prices and the ratio of labor to capital use in production of food is shown in Figure 5-5 as the curve FF .

There is a corresponding relationship between w/r and the labor-capital ratio in cloth production. This relationship is shown in Figure 5-5 as the curve CC . As drawn, CC is shifted out relative to FF , indicating that at any given factor prices, production of cloth will always use more labor relative to capital than will production of food. When this is true, we say that production of cloth is *labor-intensive*, while production of food is *capital-intensive*. Notice that the definition of intensity depends on the ratio of labor to capital used in production, not the ratio of labor or capital to output. Thus a good cannot be both capital- and labor-intensive.

The CC and FF curves in Figure 5-5 are called relative factor demand curves; they are very similar to the relative demand curve for goods. Their downward slope characterizes the substitution effect in the producers' factor demand. As the wage w rises relative to the rental rate r , producers substitute capital for labor in their production decisions. The previous case we considered with no factor substitution is a limiting case, where the relative demand curve is a vertical line: The ratio of labor to capital demanded is fixed and does not vary with changes in the wage-rental ratio w/r . In the remainder of this chapter, we consider the more general case with factor substitution, where the relative factor demand curves are downward sloping.

Factor Prices and Goods Prices

Suppose for a moment the economy produces both cloth and food. (This need not be the case if the economy engages in international trade because it might specialize completely in producing one good or the other, but let us temporarily ignore this

²The optimal choice of the labor-capital ratio is explored at greater length in the appendix to this chapter.

possibility.) Then competition among producers in each sector will ensure that the price of each good equals its cost of production. The cost of producing a good depends on factor prices: If wages rise—other things equal—the price of any good whose production uses labor will also rise.

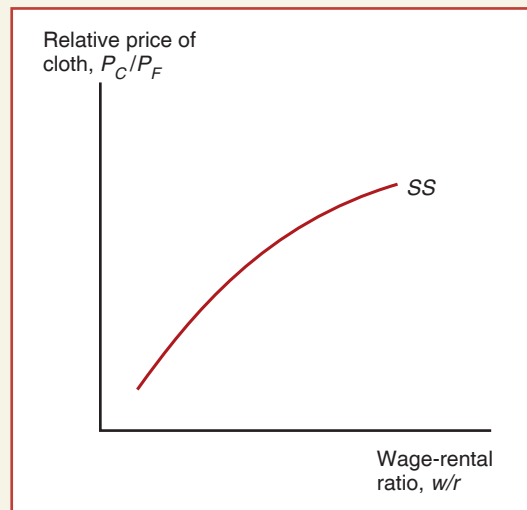
The importance of a particular factor's price to the cost of producing a good depends, however, on how much of that factor the good's production involves. If food production makes use of very little labor, for example, then a rise in the wage will not have much effect on the price of food, whereas if cloth production uses a great deal of labor, a rise in the wage *will* have a large effect on the price. We can therefore conclude that there is a one-to-one relationship between the ratio of the wage rate to the rental rate, (w/r) , and the ratio of the price of cloth to that of food, P_C/P_F . This relationship is illustrated by the upward-sloping curve SS in Figure 5-6.³

Let's look at Figures 5-5 and 5-6 together. In Figure 5-7, the left panel is Figure 5-6 (of the SS curve) turned counterclockwise 90 degrees, while the right panel reproduces Figure 5-5. By putting these two diagrams together, we see what may seem at first to be a surprising linkage of the prices of goods to the ratio of labor to capital used in the production of each good. Suppose the relative price of cloth is $(P_C/P_F)^1$ (left panel of Figure 5-7); if the economy produces both goods, the ratio of the wage rate to the capital rental rate must equal $(w/r)^1$. This ratio then implies that the ratios of labor to capital employed in the production of cloth and food must be $(L_C/K_C)^1$ and $(L_F/K_F)^1$, respectively (right panel of Figure 5-7). If the relative price of cloth were to rise to the level indicated by $(P_C/P_F)^2$, the ratio of the wage rate to the capital rental rate would rise to $(w/r)^2$. Because labor is now relatively more expensive, the ratios of labor to

FIGURE 5-6

Factor Prices and Goods Prices

Because cloth production is labor-intensive while food production is capital-intensive, there is a one-to-one relationship between the factor price ratio w/r and the relative price of cloth P_C/P_F ; the higher the relative cost of labor, the higher must be the relative price of the labor-intensive good. The relationship is illustrated by the curve SS .



³This relationship holds only when the economy produces both cloth and food, which is associated with a given range for the relative price of cloth. If the relative price rises beyond a given upper-bound level, then the economy specializes in cloth production; conversely, if the relative price drops below a lower-bound level, then the economy specializes in food production.

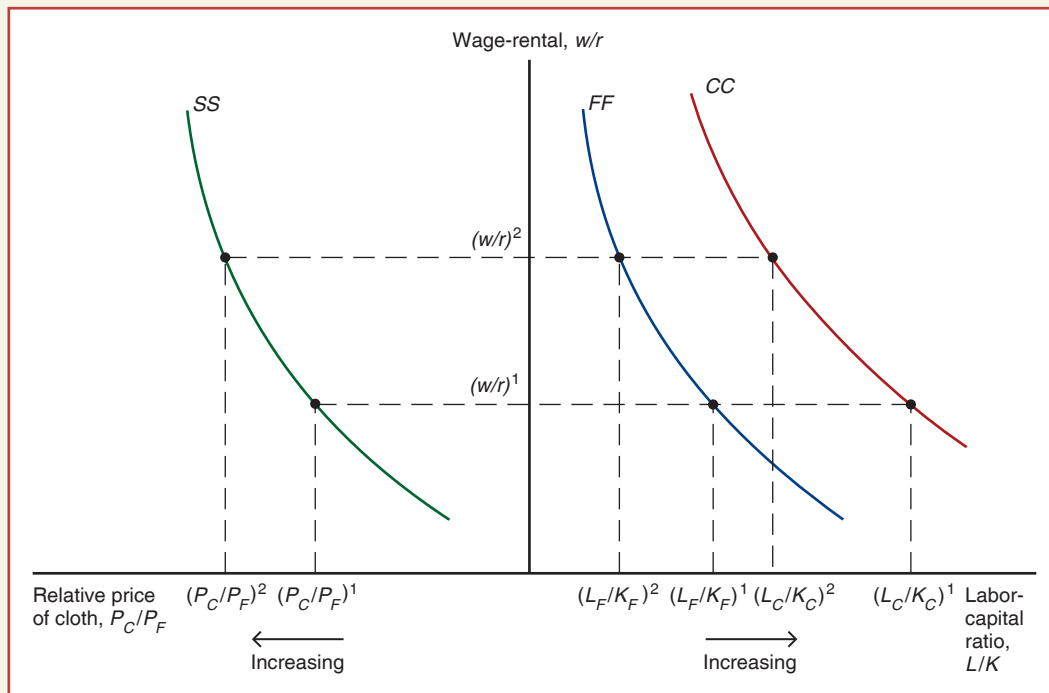


FIGURE 5-7

From Goods Prices to Input Choices

Given the relative price of cloth $(P_C/P_F)^1$, the ratio of the wage rate to the capital rental rate must equal $(w/r)^1$. This wage-rental ratio then implies that the ratios of labor to capital employed in the production of cloth and food must be $(L_C/K_C)^1$ and $(L_F/K_F)^1$. If the relative price of cloth rises to $(P_C/P_F)^2$, the wage-rental ratio must rise to $(w/r)^2$. This will cause the labor-capital ratio used in the production of both goods to drop.

capital employed in the production of cloth and food would therefore drop to $(L_C/K_C)^2$ and $(L_F/K_F)^2$.

We can learn one more important lesson from this diagram. The left panel already tells us that an increase in the price of cloth relative to that of food will raise the income of workers relative to that of capital owners. But it is possible to make a stronger statement: Such a change in relative prices will unambiguously raise the purchasing power of workers and lower the purchasing power of capital owners by raising real wages and lowering real rents in terms of *both* goods.

How do we know this? When P_C/P_F increases, the ratio of labor to capital falls in both cloth and food production. But in a competitive economy, factors of production are paid their marginal product—the real wage of workers in terms of cloth is equal to the marginal productivity of labor in cloth production, and so on. When the ratio of labor to capital falls in producing either good, the marginal product of labor in terms of that good increases—so workers find their real wage higher in terms of both goods. On the other hand, the marginal product of capital falls in both industries, so capital owners find their real incomes lower in terms of both goods.

In this model, then, as in the specific factors model, changes in relative prices have strong effects on income distribution. Not only does a change in the prices of goods change the distribution of income; it always changes it so much that owners of one factor of production gain while owners of the other are made worse off.⁴

Resources and Output

We can now complete the description of a two-factor economy by describing the relationship between goods prices, factor supplies, and output. In particular, we investigate how changes in resources (the total supply of a factor) affect the allocation of factors across sectors and the associated changes in output produced.

Suppose we take the relative price of cloth as given. We know from Figure 5-7 that a given relative price of cloth, say $(P_C/P_F)^1$, is associated with a fixed wage-rental ratio $(w/r)^1$ (so long as both cloth and food are produced). That ratio, in turn, determines the ratios of labor to capital employed in both the cloth and the food sectors: $(L_C/K_C)^1$ and $(L_F/K_F)^1$, respectively. Now we assume that the economy's labor force grows, which implies that the economy's aggregate labor to capital ratio, L/K , increases. At the given relative price of cloth $(P_C/P_F)^1$, we just saw that the ratios of labor to capital employed in both sectors remain constant. How can the economy accommodate the increase in the aggregate relative supply of labor L/K if the relative labor demanded in each sector remains constant at $(L_C/K_C)^1$ and $(L_F/K_F)^1$? In other words, how does the economy employ the additional labor hours? The answer lies in the allocation of labor and capital across sectors: The labor-capital ratio in the cloth sector is higher than that in the food sector, so the economy can increase the employment of labor to capital (holding the labor-capital ratio fixed in each sector) by allocating more labor and capital to the production of cloth (which is labor-intensive).⁵ As labor and capital move from the food sector to the cloth sector, the economy produces more cloth and less food.

The best way to think about this result is in terms of how resources affect the economy's production possibilities. In Figure 5-8, the curve TT^1 represents the economy's production possibilities before the increase in labor supply. Output is at point 1, where the slope of the production possibility frontier equals minus the relative price of cloth, $-P_C/P_F$, and the economy produces Q_C^1 and Q_F^1 of cloth and food. The curve TT^2 shows the production possibility frontier after an increase in the labor supply. The production possibility frontier shifts out to TT^2 . After this increase, the economy can produce more of both cloth and food than before. The outward shift of the frontier is, however, much larger in the direction of cloth than of food—that is, there is a **biased expansion of production possibilities**, which occurs when the production possibility frontier shifts out much more in one direction than in the other. In this case, the expansion is so strongly biased toward cloth production that at unchanged relative prices, production moves from point 1 to point 2, which involves an actual fall in food output from Q_F^1 to Q_F^2 and a large increase in cloth output from Q_C^1 to Q_C^2 .

The biased effect of increases in resources on production possibilities is the key to understanding how differences in resources give rise to international trade.⁶ An increase

⁴This relationship between goods prices and factor prices (and the associated welfare effects) was clarified in a classic paper by Wolfgang Stolper and Paul Samuelson, "Protection and Real Wages," *Review of Economic Studies* 9 (November 1941), pp. 58–73, and is therefore known as the *Stolper-Samuelson effect*.

⁵See the appendix for a more formal derivation of this result and additional details.

⁶The 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 (November 1955), pp. 336–341. It is therefore known as the *Rybczynski effect*.