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In general, those choices will depend on the factor prices for labor and capital. However, let's first look at a special case in which there is only one way to produce each good. Consider the following numerical example: Production of one yard of cloth requires a combination of two work-hours and two machine-hours. The production of food is more automated; as a result, production of one calorie of food requires only one work-hour along with three machine-hours. Thus, all the unit input requirements are fixed at $a_{KC} = 2$; $a_{LC} = 2$; $a_{KF} = 3$; $a_{LF} = 1$; and there is no possibility of substituting labor for capital or vice versa. Assume that an economy is endowed with 3,000 units of machine-hours along with 2,000 units of work-hours. In this special case of no factor substitution in production, the economy's production possibility frontier can be derived using those two resource constraints for capital and labor. Production of Q_C yards of cloth requires $2Q_C = a_{KC} \times Q_C$ machine-hours and $2Q_C = a_{LC} \times Q_C$ work-hours. Similarly, production of Q_F calories of food requires $3Q_F = a_{KF} \times Q_F$ machine-hours and $1Q_F = a_{LF} \times Q_F$ work-hours. The total machine-hours used for both cloth and food production cannot exceed the total supply of capital:

$$a_{KC} \times Q_C + a_{KF} \times Q_F \leq K, \text{ or } 2Q_C + 3Q_F \leq 3{,}000 \quad \textbf{(5-1)}$$

This is the resource constraint for capital. Similarly, the resource constraint for labor states that the total work-hours used in production cannot exceed the total supply of labor:

$$a_{LC} \times Q_C + a_{LF} \times Q_F \leq L, \text{ or } 2Q_C + Q_F \leq 2{,}000 \quad \textbf{(5-2)}$$

Figure 5-1 shows the implications of (5-1) and (5-2) for the production possibilities in our numerical example. Each resource constraint is drawn in the same way that we drew the production possibility line for the Ricardian case in Figure 3-1. In this case, however, the economy must produce subject to *both* constraints. So the production possibility frontier is the kinked line shown in red. If the economy specializes in food production (point 1), then it can produce 1,000 calories of food. At that production point, there is spare labor capacity: Only 1,000 work-hours out of 2,000 are employed. Conversely, if the economy specializes in cloth production (point 2), then it can produce 1,000 yards of cloth. At that production point, there is spare capital capacity: Only 2,000 machine-hours out of 3,000 are employed. At production point 3, the economy is employing all of its labor and capital resources (1,500 machine-hours and 1,500 work-hours in cloth production, and 1,500 machine-hours along with 500 work-hours in food production).[1]

The important feature of this production possibility frontier is that the opportunity cost of producing an extra yard of cloth in terms of food is not constant. When the economy is producing mostly food (to the left of point 3), then there is spare labor capacity. Producing two fewer units of food releases six machine-hours that can be used to produce three yards of cloth: The opportunity cost of cloth is $^2/_3$. When the economy is producing mostly cloth (to the right of point 3), then there is spare capital capacity. Producing two fewer units of food releases two work-hours that can be used to produce one yard of cloth: The opportunity cost of cloth is 2. Thus, the opportunity cost of cloth is higher when more units of cloth are being produced.

[1]The case of no factor substitution is a special one in which there is only a single production point that fully employs both factors; some factors are left unemployed at all the other production points on the production possibilities frontier. In the more general case below with factor substitution, this peculiarity disappears, and both factors are fully employed along the entire production possibility frontier.

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How do we know this? When P_C/P_F increases, the ratio of labor to capital rises 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 rises 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 that 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

[4] This 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.*

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

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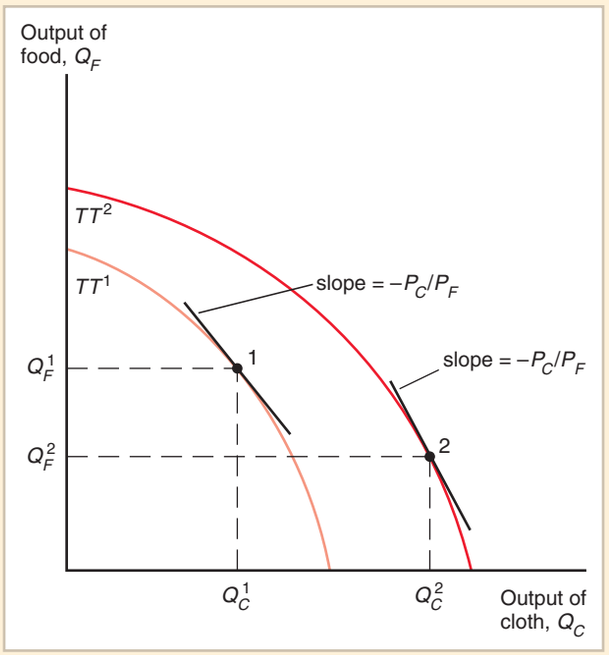
Figure 5-8

Resources and Production Possibilities

An increase in the supply of labor shifts the economy's production possibility frontier outward from TT^1 to TT^2, but does so disproportionately in the direction of cloth production. The result is that at an unchanged relative price of cloth (indicated by the slope $-P_C/P_F$), food production actually declines from Q_F^1 to Q_F^2.



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 in the supply of labor expands production possibilities disproportionately in the direction of cloth production, while an increase in the supply of capital expands them disproportionately in the direction of food production. Thus an economy with a high relative supply of labor to capital will be relatively better at producing cloth than an economy with a low relative supply of labor to capital. *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.*

We will further see below that there is some strong empirical evidence confirming that changes in a country's resources lead to growth that is strongly biased toward the sectors that intensively use the factor whose supply has increased. We document this for the economies of Japan, South Korea, Taiwan, Hong Kong, and Singapore, which all experienced very rapid growth in their supply of skilled labor over the last half-century.

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

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

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relative demands for food and cloth when faced with the same relative prices of the two goods. They also have the same technology: A given amount of land and capital yields the same output of either cloth or food in the two countries. The only difference between the countries is in their resources: Home has a higher ratio of labor to capital than Foreign does.

Relative Prices and the Pattern of Trade

Since Home has a higher ratio of labor to capital than Foreign, Home is *labor-abundant* and Foreign is *capital-abundant.* Note that abundance is defined in terms of a ratio and not in absolute quantities. For example, the total number of workers in the United States is roughly three times higher than that in Mexico, but Mexico would still be considered labor-abundant relative to the United States since the U.S. capital stock is more than three times higher than the capital stock in Mexico. "Abundance" is always defined in relative terms, by comparing the ratio of labor to capital in the two countries; thus no country is abundant in everything.

Since cloth is the labor-intensive good, Home's production possibility frontier relative to Foreign's is shifted out more in the direction of cloth than in the direction of food. Thus, other things equal, Home tends to produce a higher ratio of cloth to food.

Because trade leads to a convergence of relative prices, one of the other things that will be equal is the price of cloth relative to that of food. Because the countries differ in their factor abundances, however, for any given ratio of the price of cloth to that of food, Home will produce a higher ratio of cloth to food than Foreign will: Home will have a larger *relative supply* of cloth. Home's relative supply curve, then, lies to the right of Foreign's.

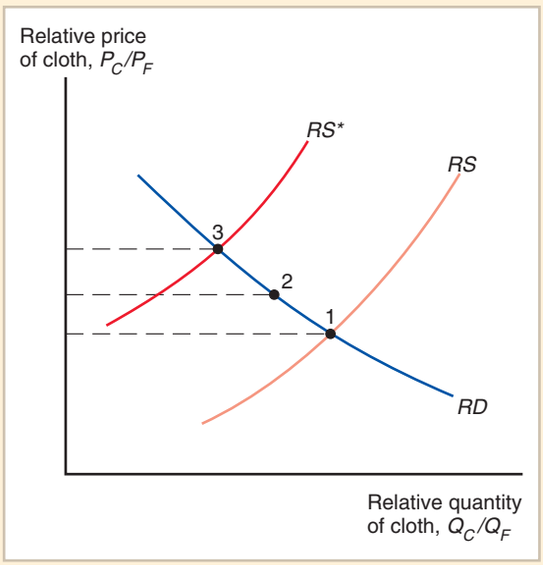
The relative supply schedules of Home (*RS*) and Foreign (RS^*) are illustrated in Figure 5-9. The relative demand curve, which we have assumed to be the same for both countries, is shown as *RD.* If there were no international trade, the equilibrium for Home would be at point 1, while the equilibrium for Foreign would be at point 3. That is, in the absence of trade the relative price of cloth would be lower in Home than in Foreign.

When Home and Foreign trade with each other, their relative prices converge. The relative price of cloth rises in Home and declines in Foreign, and a new world relative price of

Figure 5-9

Trade Leads to a Convergence of Relative Prices

In the absence of trade, Home's equilibrium would be at point 1, where domestic relative supply *RS* intersects the relative demand curve *RD.* Similarly, Foreign's equilibrium would be at point 3. Trade leads to a world relative price that lies between the pre-trade prices, that is, at point 2.



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cloth is established at a point somewhere between the pretrade relative prices, say at point 2. In Chapter 4, we discussed how an economy responds to this trade opening based on the direction of the change in the relative price of the goods: The economy exports the good whose relative price increases. Thus, Home will export cloth (the relative price of cloth rises in Home), while Foreign will export food. (The relative price of cloth declines in Foreign, which means that the relative price of food rises there).

Home becomes an exporter of cloth because it is labor-abundant (relative to Foreign) and because the production of cloth is skill-intensive (relative to food production). Similarly, Foreign becomes an exporter of food because it is capital-abundant and because the production of food is capital-intensive. These predictions for the pattern of trade (in the two-good, two-factor, two-countries version that we have studied) can be generalized as the following theorem, named after the original developers of this model of trade:

Hecksher-Ohlin Theorem: *The country that is abundant in a factor exports the good whose production is intensive in that factor.*

In the more realistic case with multiple countries, factors of production, and numbers of goods, we can generalize this result as a correlation between a country's abundance in a factor and its exports of goods that use that factor intensively: *Countries tend to export goods whose production is intensive in factors with which the countries are abundantly endowed.*[7]

Trade and the Distribution of Income

We have just discussed how trade induces a convergence of relative prices. Previously we saw that changes in relative prices, in turn, have strong effects on the relative earnings of labor and capital. A rise in the price of cloth raises the purchasing power of labor in terms of both goods while lowering the purchasing power of capital in terms of both goods. A rise in the price of food has the reverse effect. Thus international trade can have a powerful effect on the distribution of income, even in the long run. In Home, where the relative price of cloth rises, people who get their incomes from labor gain from trade, but those who derive their incomes from capital are made worse off. In Foreign, where the relative price of cloth falls, the opposite happens: Laborers are made worse off and capital owners are made better off.

The resource of which a country has a relatively large supply (labor in Home, capital in Foreign) is the **abundant factor** in that country, and the resource of which it has a relatively small supply (capital in Home, labor in Foreign) is the **scarce factor**. The general conclusion about the income distribution effects of international trade in the long run is: *Owners of a country's abundant factors gain from trade, but owners of a country's scarce factors lose.*

This conclusion is similar to the one reached in our analysis of the case of specific factors. There we found that factors of production that are "stuck" in an import-competing industry lose from the opening of trade. Here we find that factors of production that are used intensively by the import-competing industry are hurt by the opening of trade. The theoretical argument regarding the aggregate gains from trade is identical to the specific factors case: Opening to trade expands an economy's consumption possibilities (see Figure 4-11), so there is a way to make everybody better off. However, there is one crucial difference regarding the income distribution effects in these two models. The specificity of factors to particular industries is often only a temporary problem: Garment makers cannot become computer manufacturers

[7]See Alan Deardorff, "The General Validity of the Heckscher-Ohlin Theorem," *American Economic Review* 72 (September 1982), pp. 683–694, for a formal derivation of this extension to multiple goods, factors, and countries.

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labor, while advanced-country exports to the NIEs consisted of capital- or skill-intensive goods such as chemicals and aircraft ("high-tech goods").

To many observers the conclusion seemed straightforward: What was happening was a move toward factor-price equalization. Trade between advanced countries that are abundant in capital and skill and NIEs with their abundant supply of unskilled labor was raising the wages of highly skilled workers and lowering the wages of less-skilled workers in the skill- and capital-abundant countries, just as the factor-proportions model predicts.

This is an argument with much more than purely academic significance. If one regards the growing inequality of income in advanced nations as a serious problem, as many people do, and if one also believes that growing world trade is the main cause of that problem, it becomes difficult to maintain economists' traditional support for free trade. (As we have previously argued, in principle taxes and government payments can offset the effect of trade on income distribution, but one may argue that this is unlikely to happen in practice.) Some influential commentators have argued that advanced nations will have to restrict their trade with low-wage countries if they want to remain basically middle-class societies.

While some economists believe that growing trade with low-wage countries has been the main cause of rising income inequality in the United States, however, most empirical researchers believed at the time of this writing that international trade has been at most a contributing factor to that growth, and that the main causes lie elsewhere.[8] This skepticism rests on three main observations.

First, the factor-proportions model says that international trade affects income distribution via a change in relative prices of goods. So if international trade was the main driving force behind growing income inequality, there ought to be clear evidence of a rise in the prices of skill-intensive products compared with those of unskilled-labor-intensive goods. Studies of international price data, however, have failed to find clear evidence of such a change in relative prices.

Second, the model predicts that relative factor prices should converge: If wages of skilled workers are rising and those of unskilled workers are falling in the skill-abundant country, the reverse should be happening in the labor-abundant country. Studies of income distribution in developing countries that have opened themselves to trade have shown that at least in some cases, the reverse is true. In Mexico, in particular, careful studies have shown that the transformation of the country's trade in the late 1980s—when Mexico opened itself to imports and became a major exporter of manufactured goods—was accompanied by rising wages for skilled workers and growing overall wage inequality, closely paralleling developments in the United States.

Third, although trade between advanced countries and NIEs has grown rapidly, it still constitutes only a small percentage of total spending in the advanced nations. As a result, estimates of the "factor content" of this trade—the skilled labor exported, in effect, by advanced countries embodied in skill-intensive exports, and the unskilled labor, in effect, imported in labor-intensive imports—are still only a small fraction of the total supplies of skilled and unskilled labor. This suggests that these trade flows cannot have had a very large impact on income distribution.

[8] Among the important entries in the discussion of the impact of trade on income distribution have been Robert Lawrence and Matthew Slaughter, "Trade and U.S. Wages: Giant Sucking Sound or Small Hiccup?" *Brookings Papers on Economic Activity: Microeconomic* 2 (1993), pp. 161–226; Jeffrey D. Sachs and Howard Shatz, "Trade and Jobs in U.S. Manufacturing," *Brookings Papers on Economic Activity* 1 (1994), pp. 1–84; and Adrian Wood, *North-South Trade, Employment, and Income Inequality* (Oxford: Oxford University Press, 1994). For a survey of this debate and related issues, see Robert Lawrence, *Single World, Divided Nations?:* International Trade and OECD Labor Markets (Paris: OECD Development Centre, 1996).

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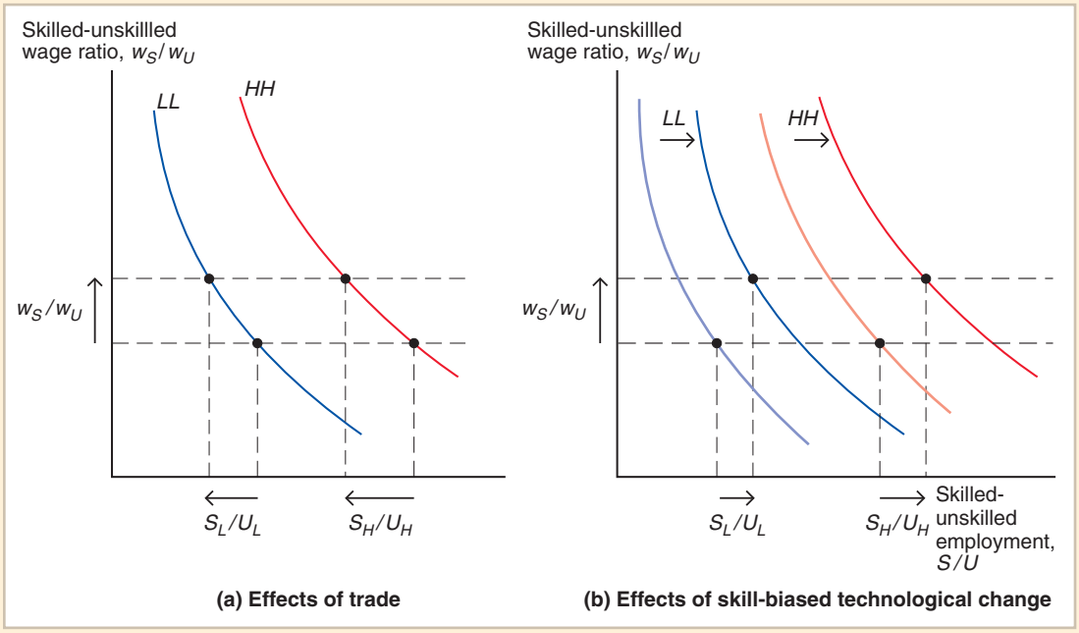
What, then, *is* responsible for the growing gap between skilled and unskilled workers in the United States? The view of the majority is that the villain is not trade but rather new production technologies that put a greater emphasis on worker skills (such as the widespread introduction of computers and other advanced technologies in the workplace).

How can one distinguish between the effects of trade and those of technological change on the wage gap between skilled and unskilled workers? Consider the variant of the model we have described where skilled and unskilled labor are used to produce "high-tech" and "low-tech" goods. Figure 5-10 shows the relative factor demands for producers in both sectors: the ratio of skilled-unskilled workers employed as a function of the skilled-unskilled wage ratio (*LL* curve for low-tech and *HH* for high-tech).

We have assumed that production of high-tech goods is skilled-labor intensive so the HH curve is shifted out relative to the LL curve. In the background, there is an SS curve (see Figure 5-7) that determines the skilled-unskilled wage ratio as an increasing function of the relative price of high-tech goods (with respect to low-tech goods).

In panel (a), we show the case where increased trade with developing countries generates an increase in wage inequality (the skilled-unskilled wage ratio) in those countries (via an



(a) Effects of trade **(b) Effects of skill-biased technological change**

Figure 5-10

Increased Wage Inequality: Trade or Skill-Biased Technological Change?

The *LL* and *HH* curves show the skilled-unskilled employment ratio, S/U, as a function of the skilled-unskilled wage ratio, w_S/w_U, in the low-tech and high-tech sectors. The high-tech sector is more skill-intensive than the low-tech sector, so the *HH* curve is shifted out relative to the *LL* curve. Panel (a) shows the case where increased trade with developing countries leads to a higher skilled-unskilled wage ratio. Producers in both sectors respond by *decreasing* their relative employment of skilled workers: S_L/U_L and S_H/U_H both decrease. Panel (b) shows the case where skill-biased technological change leads to a higher skilled-unskilled wage ratio. The *LL* and *HH* curves shift out (increased relative demand for skilled workers in both sectors). However, in this case producers in both sectors respond by *increasing* their relative employment of skilled workers: S_L/U_L and S_H/U_H both increase.

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increase in the relative price of high-tech goods). The increase in the relative cost of skilled workers induces producers in both sectors to *reduce* their employment of skilled workers relative to unskilled workers.

In panel (b), we show the case where technological change in both sectors generates an increase in wage inequality. Such technological change is classified as "skill-biased," as it shifts out the relative demand for skilled workers in both sectors (both the *LL* and the *HH* curves shift out). Then, a given relative price of high-tech goods is associated with a higher skilled-unskilled wage ratio (the SS curve shifts). In this case, the technological change induces producers in both sectors to *increase* their employment of skilled workers relative to unskilled workers.

We can therefore examine the relative merits of the trade versus **skill-biased technological change** explanations for the increase in wage inequality by looking at the changes in the skilled-unskilled employment ratio within sectors in the United States. A widespread increase in these employment ratios for all different kinds of sectors (both skilled-labor-intensive and unskilled-labor-intensive sectors) in the U.S. economy points to the skill-biased technological explanation. This is exactly what has been observed in the U.S. over the last half-century.

In Figure 5-11, sectors are separated into four groups based on their skill intensity. U.S. firms do not report their employment in terms of skill but use a related categorization of

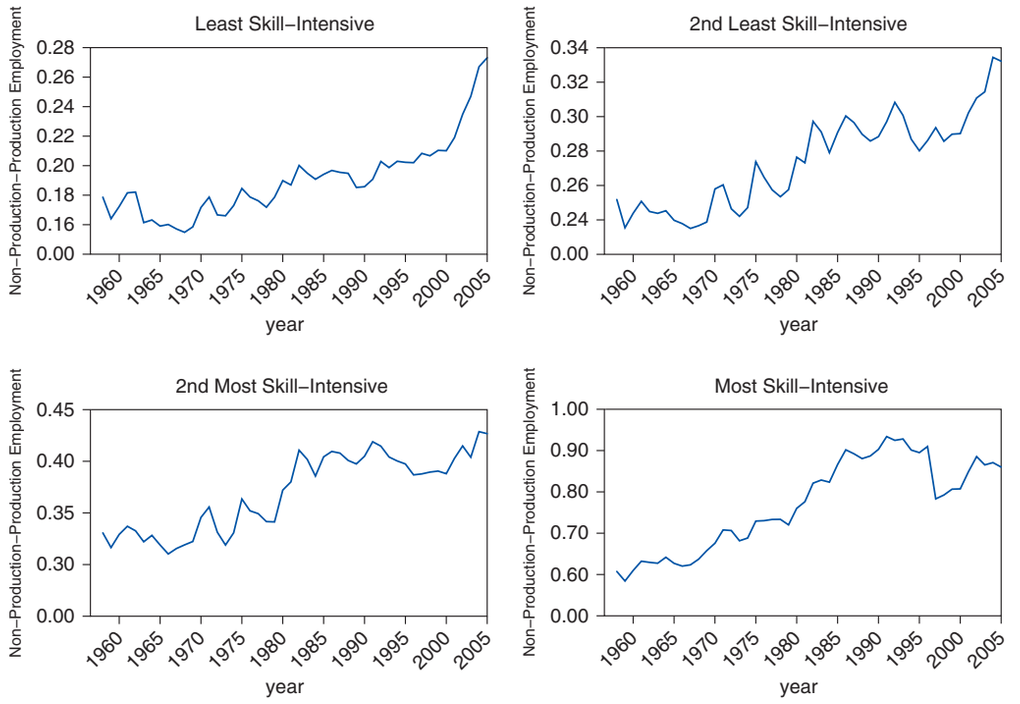

Figure 5-11

Evolution of U.S. Non-Production–Production Employment Ratios in Four Groups of Sectors

Sectors are grouped based on their skill intensity. The non-production–production employment ratio has increased over time in all four sector groups.

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production and non-production workers. With a few exceptions, non-production positions require higher levels of education—and so we measure the skilled-unskilled employment ratio in a sector as the ratio of non-production employment to production employment.[9] Sectors with the highest non-production to production employment ratios are classified as most skill-intensive. Each quadrant of Figure 5-11 shows the evolution of this employment ratio over time for each group of sectors (the average employment ratio across all sectors in the group). Although there are big differences in average skill intensity across the groups, we clearly see that the employment ratios are increasing over time for all four groups. This widespread increase across most sectors of the U.S. economy is one of the main pieces of evidence pointing to the technology explanation for the increases in U.S. wage inequality.

Yet, even though most economists agree that skill-biased technological change has occurred, recent research has uncovered some new ways in which trade has been an indirect contributor to the associated increases in wage inequality, by accelerating this process of technological change. These explanations are based on the principle that firms have a choice of production methods that is influenced by openness to trade and foreign investment. For example, some studies show that firms that begin to export also upgrade to more skill-intensive production technologies. Trade liberalization can then generate widespread technological change by inducing a large proportion of firms to make such technology-upgrade choices.

Another example is related to foreign outsourcing and the liberalization of trade and foreign investment. In particular, the NAFTA treaty (see Chapter 2) between the United States, Canada, and Mexico has made it substantially easier for firms to move different parts of their production processes (research and development, component production, assembly, marketing) across different locations in North America. Because production worker wages are substantially lower in Mexico, U.S. firms have an incentive to move to Mexico the processes that use production workers more intensively (such as component production and assembly). The processes that rely more intensively on higher-skilled, non-production workers (such as research and development and marketing) tend to stay in the United States (or Canada). From the U.S. perspective, this break-up of the production process increases the relative demand for skilled workers and is very similar to skill-biased technological change. One study finds that this outsourcing process from the United States to Mexico can explain 21 to 27 percent of the increase in the wage premium between non-production and production workers.[10]

Thus, some of the observed skill-biased technological change, and its effect on increased wage inequality, can be traced back to increased openness to trade and foreign investment. And, as we have mentioned, increases in wage inequality in advanced economies are a genuine concern. However, the use of trade restrictions targeted at limiting technological innovations—because those innovations favor relatively higher-skilled workers—is particularly problematic: Those innovations also bring substantial aggregate gains (along with the standard gains from trade) that would then be foregone. Consequently, economists favor longer-term policies that ease the skill-acquisition process for all workers so that the gains from the technological innovations can be spread as widely as possible.

[9] On average, the wage of a non-production worker is 60% higher than that of a production worker.

[10] See Robert Feenstra and Gordon Hanson, "The Impact of Outsourcing and High-Technology Capital on Wages: Estimates for the United States, 1979–1990," *Quarterly Journal of Economics* 144 (August 1999), pp. 907–940.

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both goods; (2) technologies are the same; and (3) trade actually equalizes the prices of goods in the two countries.

1. To derive the wage and rental rates from the prices of cloth and food in Figure 5-6, we assumed that the country produced both goods. This need not, however, be the case. A country with a very high ratio of labor to capital might produce only cloth, while a country with a very high ratio of capital to labor might produce only food. This implies that factor-price equalization occurs only if the countries involved are sufficiently similar in their relative factor endowments. (A more thorough discussion of this point is given in the appendix to this chapter.) Thus, factor prices need not be equalized between countries with radically different ratios of capital to labor or of skilled to unskilled labor.

2. The proposition that trade equalizes factor prices will not hold if countries have different technologies of production. For example, a country with superior technology might have both a higher wage rate and a higher rental rate than a country with an inferior technology. As described later in this chapter, recent work suggests that it is essential to allow for such differences in technology to reconcile the factor-proportions model with actual data on world trade.

3. Finally, the proposition of complete factor-price equalization depends on complete convergence of the prices of goods. In the real world, prices of goods are not fully equalized by international trade. This lack of convergence is due to both natural barriers (such as transportation costs) and barriers to trade such as tariffs, import quotas, and other restrictions.

Empirical Evidence on the Heckscher-Ohlin Model

The essence of the Heckscher-Ohlin model is that trade is driven by differences in factor abundance across countries. We just saw how this leads to the natural prediction that goods trade is substituting for factor trade, and hence that goods trade across countries should *embody* those factor differences. This is a very powerful prediction that can be tested empirically. However, we will see that the empirical successes of such tests are very limited—mainly due to the same reasons that undermine the prediction for factor-price equalization (especially the assumption of common technologies across countries). Does this mean that differences in factor abundance do *not* help explain the observed patterns of trade across countries? Not at all. We will see how the pattern of trade between developed and developing countries does fit quite well with the predictions of the Heckscher-Ohlin model.

Trade in Goods as a Substitute for Trade in Factors

Tests on U.S. Data Until recently, and to some extent even now, the United States has been a special case among countries. Until a few years ago, the United States was much wealthier than other countries, and U.S. workers visibly worked with more capital per person than their counterparts in other countries. Even now, although some Western European countries and Japan have caught up, the United States continues to be high on the scale of countries as ranked by capital-labor ratios.

One would then expect the United States to be an exporter of capital-intensive goods and an importer of labor-intensive goods. Surprisingly, however, this was not the case in the 25 years after World War II. In a famous study published in 1953, economist Wassily Leontief (winner of the Nobel Prize in 1973) found that U.S. exports were less capital-intensive than U.S. imports.[11] This result is known as the **Leontief paradox**.

[11] See Wassily Leontief, "Domestic Production and Foreign Trade: The American Capital Position Re-Examined," *Proceedings of the American Philosophical Society* 97 (September 1953), pp. 331–349.

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TABLE 5-3 Testing the Heckscher-Ohlin Model

Factor of Production	Predictive Success*
Capital	0.52
Labor	0.67
Professional workers	0.78
Managerial workers	0.22
Clerical workers	0.59
Sales workers	0.67
Service workers	0.67
Agricultural workers	0.63
Production workers	0.70
Arable land	0.70
Pasture land	0.52
Forest	0.70

*Fraction of countries for which net exports of factor runs in predicted direction.

Source: Harry P. Bowen, Edward E. Leamer, and Leo Sveikauskas, "Multicountry, Multifactor Tests of the Factor Abundance Theory," *American Economic Review* 77 (December 1987), pp. 791–809.

Table 5-3 shows one of the key tests of Bowen et al. The authors calculated the ratio of each country's endowment of each factor to the world supply of that factor. They then compared these ratios with each country's share of world income. If the factor-proportions theory was right, a country would always export factors for which the factor share exceeded the income share, and import factors for which it was less. In fact, for two-thirds of the factors of production, trade ran in the predicted direction less than 70 percent of the time. This result confirms the Leontief paradox on a broader level: Trade often does not run in the direction that the Heckscher-Ohlin theory predicts. As with the Leontief paradox for the United States, explanations for this result have centered on the failure of the common technology assumption.

The Case of the Missing Trade Another indication of large technology differences across countries comes from discrepancies between the observed volumes of trade and those predicted by the Heckscher-Ohlin model. In an influential paper, Daniel Trefler[14] at the University of Toronto pointed out that the Heckscher-Ohlin model can also be used to derive predictions for a country's volume of trade based on differences in that country's factor abundance with that of the rest of the world (since, in this model, trade in goods is substituting for trade in factors). In fact, factor trade turns out to be substantially smaller than the Heckscher-Ohlin model predicts.

A large part of the reason for this disparity comes from a false prediction of large-scale trade in labor between rich and poor nations. Consider the United States, on one side, and China on the other. In 2008, the United States had about 23 percent of world income but only about 5 percent of the world's workers; so a simple factor-proportions theory would suggest that U.S. imports of labor embodied in trade should have been huge, something like four times as large as the nation's own labor force. In fact, calculations of the factor content of U.S. trade showed only small net imports of labor. Conversely, China had 7 percent of world income but approximately 20 percent of

[14] Daniel Trefler, "The Case of the Missing Trade and Other Mysteries," *American Economic Review* 85 (December 1995), pp. 1029–1046.

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TABLE 5-4 Estimated Technological Efficiency, 1983 (United States = 1)

Country	
Bangladesh	0.03
Thailand	0.17
Hong Kong	0.40
Japan	0.70
West Germany	0.78

Source: Daniel Trefler, "The Care of the Missing Trade and Other Mysteries," *American Economic Review* 85 (December 1995), pp. 1029–1046.

the world's workers in 2008; it therefore "should" have exported most of its labor via trade—but it did not.

Allowing for technology differences also helps to resolve this puzzle of "missing trade." The way this resolution works is roughly as follows: If workers in the United States are much more efficient than those in China, then the "effective" labor supply in the United States is much larger compared with that of China than the raw data suggest—and hence the expected volume of trade between labor-abundant China and labor-scarce America is correspondingly less.

If one makes the working assumption that technological differences between countries take a simple multiplicative form—that is, that a given set of inputs produces only δ times as much in China as it does in the United States, where δ is some number less than 1—it is possible to use data on factor trade to estimate the relative efficiency of production in different countries. Table 5-4 shows Trefler's estimates for a sample of countries; they suggest that technological differences are in fact very large. However, this exercise does not prove that technology differences do have this simple multiplicative form. If they don't, then some country could have bigger technological advantages in particular sectors, and the predictions for the pattern of trade would be a mix between those of the Ricardian and Hecksher-Ohlin models.

Patterns of Exports Between Developed and Developing Countries

Although the overall pattern of international trade does not seem to be very well accounted for by a pure Heckscher-Ohlin model, comparisons of the exports of labor-abundant, skill-scarce nations in the third world with the exports of skill-abundant, labor-scarce nations do fit the theory quite well. Consider, for example, Figure 5-12, which compares the pattern of U.S. imports from Bangladesh, whose work force has low levels of education, with the pattern of U.S. imports from Germany, which has a highly educated labor force.

In Figure 5-12, which comes from the work of John Romalis of the University of Chicago,[15] goods are ranked by skill intensity: the ratio of skilled to unskilled labor used in their production. The vertical axes of the figure show U.S. imports of each good from Germany and Bangladesh, respectively, as a share of total U.S. imports of that good. As you can see, Bangladesh tends to account for a relatively large share of U.S. imports of low-skill-intensity goods such as clothing, but a low share of highly skill-intensive goods. Germany is in the reverse position.

[15] John Romalis, "Factor Proportions and the Structure of Commodity Trade," *American Economic Review* 94 (March 2004), pp. 67–97.

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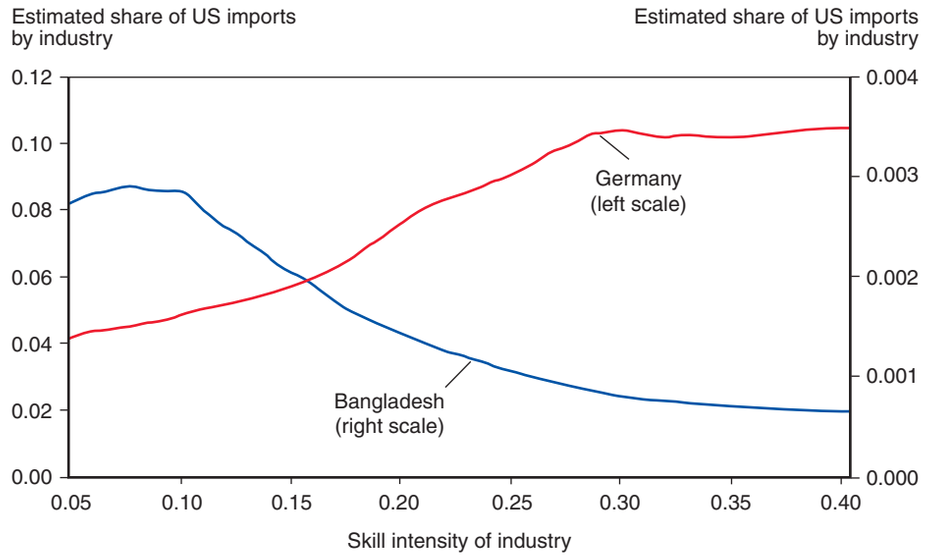

Figure 5-12

Skill Intensity and the Pattern of U.S. Imports from Two Countries

Source: John Romalis, "Factor Proportions and the Structure of Commodity Trade," *American Economic Review* 94 (March 2004), pp. 67–97.

Changes over time also follow the predictions of the Heckscher-Ohlin model. Figure 5-13 shows the changing pattern of exports to the United States from Western Europe, Japan, and the four Asian "miracle" economies—South Korea, Taiwan, Hong Kong, and Singapore—which moved rapidly from being quite poor economies in 1960 to relatively rich economies with highly skilled work forces today.

Panel (a) of Figure 5-13 shows the pattern of exports from the three groups in 1960; the miracle economies were clearly specialized in exports of low-skill-intensity goods, and even Japan's exports were somewhat tilted toward the low-skill end. As shown in panel (b), by 1998, however, the level of education of Japan's work force was comparable to that of Western Europe, and Japan's exports reflected that change, becoming as skill-intensive as those of European economies. Meanwhile, the four miracle economies, which had rapidly increased the skill levels of their own work forces, had moved to a trade pattern comparable to that of Japan a few decades earlier.

A key prediction of the Heckscher-Ohlin model is that changes in factor abundance lead to biased growth toward sectors that use that factor intensively in production. We can see that the experience of those Asian economies fit very well with these predictions: As the supply of skilled labor increased, they increasingly specialized in the production of skill-intensive goods.

Implications of the Tests

We have just seen that the empirical testing of the Heckscher-Ohlin model has produced mixed results. In particular, the evidence is weak concerning the prediction of the model that, absent technology differences between countries, trade in goods is a substitute for trade in factors: The factor content of a country's exports does not always reflect that

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FURTHER READINGS

Donald R. Davis and David E. Weinstein. "An Account of Global Factor Trade." *American Economic Review* 91 (December 2001), pp. 1423–1453. The authors review the history of tests of the Heckscher-Ohlin model and propose a modified version—backed by extensive statistical analysis—that allows for technology differences, specialization, and transportation costs.

Alan Deardorff. "Testing Trade Theories and Predicting Trade Flows," in Ronald W. Jones and Peter B. Kenen, eds. *Handbook of International Economics.* Vol. 1. Amsterdam: North-Holland, 1984. A survey of empirical evidence on trade theories, especially the factor-proportions theory.

Gordon Hanson and Ann Harrison. "Trade and Wage Inequality in Mexico." *Industrial and Labor Relations Review* 52 (1999), pp. 271–288. A careful study of the effects of trade on income inequality in our nearest neighbor, showing that factor prices have moved in the opposite direction from what one might have expected from a simple factor-proportions model. The authors also put forward hypotheses about why this may have happened.

Ronald W. Jones. "Factor Proportions and the Heckscher-Ohlin Theorem." *Review of Economic Studies* 24 (1956), pp. 1–10. Extends Samuelson's 1948–1949 analysis (cited below), which focuses primarily on the relationship between trade and income distribution, into an overall model of international trade.

Ronald W. Jones. "The Structure of Simple General Equilibrium Models." *Journal of Political Economy* 73 (December 1965), pp. 557–572. A restatement of the Heckscher-Ohlin-Samuelson model in terms of elegant algebra.

Ronald W. Jones and J. Peter Neary. "The Positive Theory of International Trade," in Ronald W. Jones and Peter B. Kenen, eds. *Handbook of International Economics.* Vol. 1. Amsterdam: North-Holland, 1984. An up-to-date survey of many trade theories, including the factor-proportions theory.

Bertil Ohlin. *Interregional and International Trade.* Cambridge: Harvard University Press, 1933. The original Ohlin book presenting the factor-proportions view of trade remains interesting—its complex and rich view of trade contrasts with the more rigorous and simplified mathematical models that followed.

Robert Reich. *The Work of Nations.* New York: Basic Books, 1991. An influential tract that argues that the increasing integration of the United States in the world economy is widening the gap between skilled and unskilled workers.

John Romalis. "Factor Proportions and the Structure of Commodity Trade." *The American Economic Review* 94 (March 2004), pp. 67–97. A recent, state-of-the-art demonstration that a modified version of the Heckscher-Ohlin model has a lot of explanatory power.

Paul Samuelson. "International Trade and the Equalisation of Factor Prices." *Economic Journal* 58 (1948), pp. 163–184; and "International Factor Price Equalisation Once Again." *Economic Journal* 59 (1949), pp. 181–196. The most influential formalizer of Ohlin's ideas is Paul Samuelson (again!), whose two *Economic Journal* papers on the subject are classics.

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produce a unit of food using a_{LF} units of labor and a_{KF} units of capital, the total cost of producing that unit, c, is

$$c = wa_{LF} + ra_{KF}.$$

A line showing all combinations of a_{LF} and a_{KF} with the same cost has the equation

$$a_{KF} = (c/r) - (w/r)\, a_{LF}.$$

That is, it is a straight line with a slope of $-w/r$.

The figure shows a family of such lines, each corresponding to a different level of costs; lines farther from the origin indicate higher total costs. A producer will choose the lowest possible cost given the technological trade-off outlined by curve *II*. Here, this occurs at point 1, where *II* is *tangent* to the isocost line and the slope of *II* equals $-w/r$. (If these results seem reminiscent of the proposition in Figure 4-5 that the economy produces at a point on the production possibility frontier whose slope equals minus P_C/P_F, you are right: The same principle is involved.)

Now compare the choice of labor-capital ratio for two different factor-price ratios. In Figure 5A-2 we show input choices given a low relative price of labor, $(w/r)^1$, and a high relative price of labor, $(w/r)^2$. In the former case, the input choice is at 1, in the latter case at 2. That is, the higher relative price of labor leads to the choice of a lower labor-capital ratio, as assumed in Figure 5-5.

Goods Prices and Factor Prices

We now turn to the relationship between goods prices and factor prices. There are several equivalent ways of approaching this problem; here we follow the analysis introduced by Abba Lerner in the 1930s.

Figure 5A-2

Changing the Wage-Rental Ratio

A rise in w/r shifts the lowest-cost input choice from point 1 to point 2; that is, it leads to the choice of a lower labor-capital ratio.