

# The Heckscher-Ohlin Model

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The Heckscher-Ohlin (HO) model was developed by two Swedish economists - **Eli Heckscher** (in a 1919 article) and his student **Bertil Ohlin** (developed Heckscher's ideas further in his 1924 dissertation). The HO model differs from the Ricardian model along two dimensions. Firstly, it adopts a more realistic framework as compared to Ricardian model by allowing for a second factor of production in the form of capital. Secondly, in the Heckscher-Ohlin model comparative advantage is determined by differences in endowments of factors across countries instead of differences in technology (as in the Ricardian model). In the Heckscher-Ohlin model countries have the same production technologies.

The first innovation implies that the production possibility frontier is going to be concave and hence result in increasing opportunity costs. As a result, complete specialization, as in the Ricardian model, is not very likely. Furthermore, trade will cause redistribution of income between labor and capital. The second innovation of the model implies that a country will export goods that use its abundant factor intensively. For example, Canada is abundant in land and therefore it exports agricultural and forestry products as well as petroleum; the United States, Western Europe and Japan have many high skilled workers as well as capital and therefore export sophisticated manufactured goods and services; China and other Asian countries have large number of unskilled workers and less capital and therefore export less sophisticated manufactured goods.

## 1 The Heckscher-Ohlin (HO) Model

Let us be clear about the key assumptions that we make in the HO model.

1. Production functions for good  $X$  and  $Y$  are CRS.
2. Production functions, which are same in both countries, differ in factor-intensities. We will assume that  $X$  is labor-intensive whereas  $Y$  is capital intensive.
3. There is no factor-intensity reversal within each country.

4. There is a fixed endowment of labor and capital, which are homogeneous and perfectly mobile between industries within each country. However, labor and capital are immobile across countries.
5. There are no market distortions such as imperfect competition, taxes, tariffs, etc.
6. Preferences are identical and homogeneous.
7. Countries differ in their relative factor endowments.

## 1.1 Factor-Endowments

If the capital-labor ratio in the home country,  $H$ , is greater than it is in the foreign country,  $F$ , then country  $H$  is relatively *capital-abundant (and labor-scarce)* whereas country  $F$  is relatively *labor-abundant (capital-scarce)*. Mathematically, it means

$$\left(\frac{K}{L}\right)_h > \left(\frac{K}{L}\right)_f .$$

## 1.2 Factor-Intensities

Good  $Y$  is relatively *capital-intensive* and good  $X$  is relatively *labor-intensive* if the capital-labor ratio used in producing good  $Y$  is higher than in producing good  $X$ , i.e.

$$\left(\frac{K}{L}\right)_y > \left(\frac{K}{L}\right)_x .$$

Note that in equilibrium, the wage rate and the rental rate will be equalized across the two industries because of free mobility of labor and capital within each country. Since firms are going to decide the units of labor and capital they employ in response to the prevailing wage rate and rental rate, it is possible that the factor intensity ranking in the equation above is reversed at a different factor-price ratio ( $w/r$ ). This is termed as *factor-intensity reversal* (FIR).

### 1.3 Effect of Differences in Relative Endowments

Let us analyze the impact of differences in relative factor endowments. In Figure 1, point  $E$  represents identical relative factor endowment for the two countries, i.e. labor endowment is  $\bar{L}$  and capital endowment is  $\bar{K}$  for both countries. The maximum possible outputs of  $X$  and  $Y$  are given by  $\bar{X}$  and  $\bar{Y}$ . Now, suppose the endowment of factors is different for country  $H$ , and is represented by point  $E_h$ . Thus country  $H$  is relatively capital-abundant - it has a greater endowment of capital and a smaller endowment of labor than country  $F$  (which is still at point  $E$ ). As a result the maximum outputs of the two goods that can be produced in country  $H$  are  $\bar{X}_h$  and  $\bar{Y}_h$ . Since country  $H$  is capital-abundant, the output of the capital-intensive good,  $Y$ , increases (isoquant  $\bar{Y}_h$  lies above  $\bar{Y}$ ) while the output of the labor intensive good,  $X$ , decreases (isoquant  $\bar{X}_h$  lies below  $\bar{X}$ ).

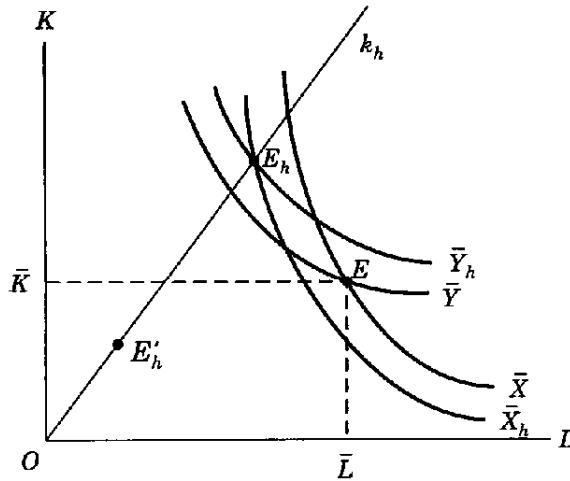


Figure 1: Output and Relative Factor Endowment

The same analysis is also depicted in terms of production possibility frontiers in Figure 2. Since country  $F$  is relatively-labor abundant, its production possibility frontier ( $\bar{X}\bar{Y}$ ) is biased toward the  $X$  axis, and by the same logic the production possibility frontier of country  $H$  ( $\bar{X}_h\bar{Y}_h$ ) is biased toward  $Y$  axis. Furthermore, in Figure 1, the relative endowment remains the same along the ray  $Ok_h$  as the endowment of the two factors shrinks or expands by the same factor. Due to CRS, this implies that output of the two goods expand or shrink by the same factor, which in turn means that the production possibility frontier shifts in or

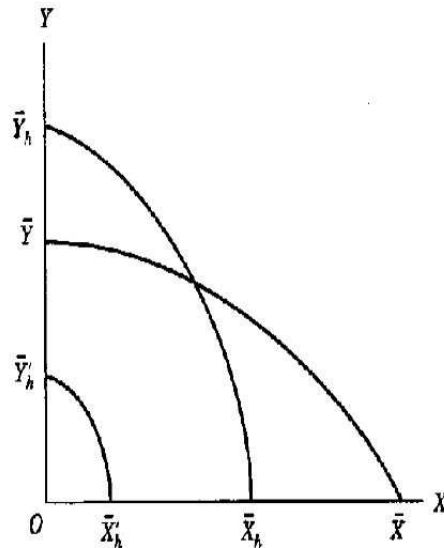


Figure 2: Production Possibilities and Effect of Factor Endowments

shifts out in a parallel fashion. Therefore, changing the endowment point from  $E_h$  to  $E'_h$ , translates into an inward shift of the production possibility frontier from  $\bar{X}_h\bar{Y}_h$  to  $\bar{X}'_h\bar{Y}'_h$ .

## 1.4 Autarky Equilibrium

Given that country  $H$  is relatively capital-abundant and country  $F$  is relatively labor-abundant, let us analyze each countries autarky consumption and production possibilities. Figure 3 shows the production possibility frontiers of the two countries.

Autarky equilibrium for country  $H$  is established at point  $A_h$  and that for country  $F$  is established at point  $A_f$ . Notice both countries have identical and homogeneous preferences, which implies that the slope of the indifference curves are the same along any ray from the origin. The resulting equilibrium price ratios are  $-p_h$  and  $p_f$  for  $H$  and  $F$ , respectively. Thus, in equilibrium  $p_h > p_f$ , implying that the relative price of good  $X$  is higher in  $H$  than in  $F$ .

- **CLASS EXERCISE:** Will there any effect on the equilibrium autarky price ratios if the absolute size of a country were to change, i.e endowment of both labor and capital increase/decrease by the same factor?

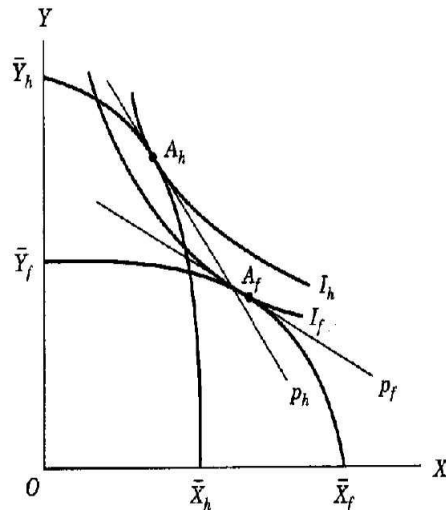


Figure 3: Autarky Equilibrium with Different Factor Endowment

Absolute size does not matter because both the production function and the preferences are homogeneous. Any change in absolute size of a country would just move the equilibrium up or down along the rays  $OA_h$  and  $OA_f$ , which will leave the equilibrium price ratio unaffected. What matters is relative endowment and relative factor intensities, which is why the HO model is often called the *factor-proportions* model.

## 1.5 Trade Equilibrium

So, differences in relative factor endowments and relative factor-intensities determine the pattern of comparative advantage. So, what happens when we allow countries to trade. As we have seen, the relative price of good  $X$  is higher in country  $H$  than in country  $F$ . Therefore, when countries trade, consumers in country  $H$  will shift some of their purchases of good  $X$  to country  $F$ . On the other hand, consumers in  $F$  will shift purchases of  $Y$  to country  $H$ . This shifting of expenditure will continue till prices of the two commodities are equalized. In response to this shift in demand, production will also have to adjust. Country  $F$  will increase the production of good  $X$  and country  $H$  will increase the production of good  $Y$ . Therefore, the production point for  $H$  will move up its production possibility frontier toward the  $Y$  axis, which will imply that the slope of production possibility frontier will flatter. Similarly, production point for country  $F$  will shift toward  $X$  axis, which implies

that slope of its production possibility frontier will become steeper. Therefore, the net effect is that the price ratio will fall (slope of price line will decrease) in country  $H$  and it will rise in country  $F$  (slope of price line will increase). The move from autarky to trade equilibrium is depicted in Figure 4.

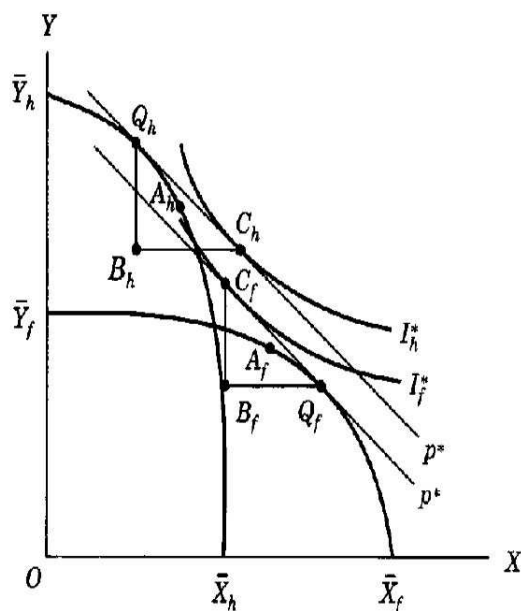


Figure 4: Trade Equilibrium with Different Factor Endowment

Under trade, the production equilibrium is established at point  $Q_h$  for  $H$  and at point  $Q_f$  for  $F$ ; the consumption equilibrium is achieved at point  $C_h$  for  $H$  and at point  $C_f$  for  $F$ .  $H$  attains utility level  $I_h^*$  and  $F$  attains utility  $I_f^*$ . Both countries gain from trade because they consume on indifference curves that lie outside their respective production possibility frontiers. The equilibrium price ratio is  $p^*$ . Remember, equilibrium price ratio ensures that the world excess demand for each good is zero. This is depicted in Figure 5. At  $p^*$ , country  $H$  imports  $OX_h$  amount of good  $X$  (which is equal to  $B_hC_h$  in Figure 4) and country  $F$  exports exactly the same amount of  $X$  ( $OX_f = B_hQ_h$ ).

Notice the link between trading pattern and relative endowments. Country  $H$ , which is relatively capital-abundant, exports good  $Y$ , which is relatively capital-intensive. Country  $F$ , which is relatively labor-abundant, exports good  $X$ , which is relatively labor-intensive.

**The Heckscher-Ohlin Theorem:** *Given the assumptions of the model, a country will export the commodity that intensively uses its relatively abundant factor.*

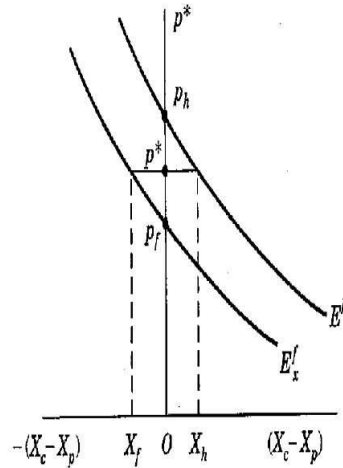


Figure 5: Equilibrium Price Ratio Under Trade

An interesting way to think about this result is the following: through the export of the relatively capital-intensive good  $Y$ , the relatively capital-abundant country  $X$  exports capital services to country  $F$  which faces a shortage of capital. Similarly, country  $F$ , by exporting good  $X$  to  $H$ , exports labor services which are scarce in  $H$ . Thus, through trade countries are able to overcome the scarcity of factors of production.

As compared to the ricardian model, the HO model has contrasting implications.

1. Countries produce both goods. Thus, there is incomplete specialization as compared to complete specialization in the ricardian model.
2. Trade results in equalization of commodity prices in the two countries.

## 2 Factor Price Equalization Theorem

The HO model shows how differences in relative factor endowments lead to comparative advantage, and hence to trade. Trade, we saw, lead to equalization of goods prices across countries. What is the effect of trade on factor prices across countries?

In Figure 6, consider the equilibrium point  $A$ , where the price ratio is  $p_a$  and the outputs of the two goods are  $X_a$  and  $Y_a$ . Point  $A$  is also depicted in the Edgeworth-Bowley



box diagram (combines the output space and input space) of figure 7; it is the point of tangency between the isoquants  $X_a$  and  $Y_a$ . The slope of the line passing through this tangency point gives us the relative factor prices (or the wage-rental ratio) in equilibrium. Let this be given by  $\omega_a$ . Also, note that the slope of the ray  $Ok_{x_a}$  is smaller than the slope of the ray  $Ok_{y_a}$ , which simply tells us that good  $X$  is relatively labor-intensive and good  $Y$  is relatively capital-intensive.

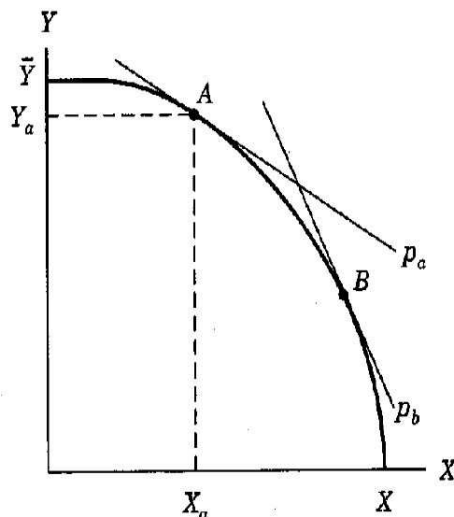


Figure 6: Goods Prices and Output

Now, consider an increase in the relative price of good  $X$ . So, the new equilibrium, in figure 6, is at point  $B$  and the new price ratio is  $p_b$ . As a result the output of  $X$  increases while that of declines  $Y$ . Point  $B$  is also depicted in Figure 7. What is the effect of this change in goods prices on factor prices?

Since the production function is homogeneous, it implies that the slope of the isoquant of good  $X$  will be the same at any point on a ray from the origin. Therefore the slope of the isoquant of good  $X$  at point  $B$  is the same as that at point  $C$ . Since the slope of the isoquant exceeds the slope at  $A$ , it implies that  $\omega_b > \omega_a$ . Therefore, we see that an increase the relative price of a good results in an increase in the relative return to the factor that is used intensively in producing the good. Intuitively, when the price of good  $X$  increases it leads to an increase in the production of good  $X$  and reduction in the production of  $Y$ , which requires a reallocation of resources from  $Y$  to  $X$ . Since  $Y$  is capital-intensive,  $Y$

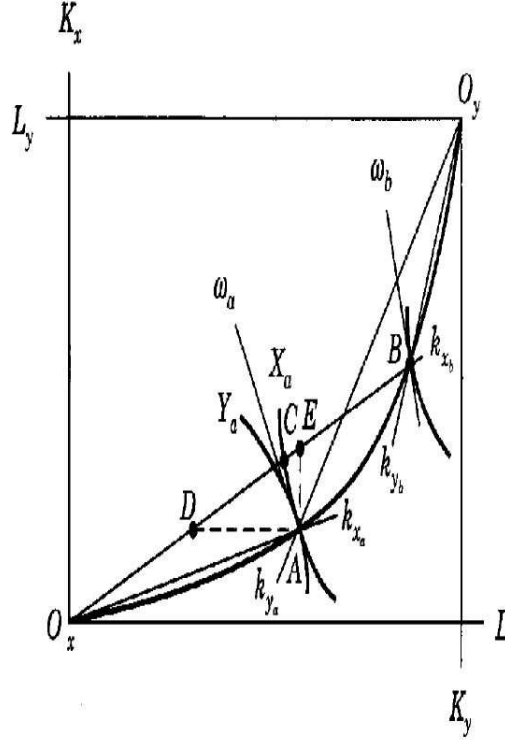


Figure 7: Output and Factor Prices

releases more capital and less labor. On the other hand  $X$  is labor-intensive and it requires more labor than capital. As a result there is shortage of labor and excess supply of capital, which means that the relative return to labor rises. Thus, there exists a unique relationship between relative factor prices and goods' prices, i.e.

$$\frac{w}{r} = G\left(\frac{p_x}{p_y}\right)$$

The function  $G$  depends on the production functions of the two commodities. Now, let us generalize this for our two-country model, where country  $H$  is relatively capital-abundant whereas country  $Y$  is relatively labor-abundant. Since the two countries have identical production functions, the function  $G$  will also be the same for the two countries. Then, given that  $p_h^a > p_f^a$ , it must be the case that  $\omega_h^a > \omega_f^a$ . Since trade results in equalization of relative goods prices, it must also lead to equalization of relative factor prices.

The FPE, as you may have realized, is a very strong result. Clearly, we do not see factor prices being equalized in the real world. So what can explain this disconnect between theory and the data?

1. Trade in the real world is not free. There are costs of trading such as tariffs and import quotas, which prevent commodity prices from being equalized.
2. Furthermore, there are distortions like monopolies, in which case the owners get rents; there are trade unions which sustain wages higher than marginal products. Differences in government policies, in terms of differences in taxes and subsidies across sectors of an economy, can determine comparative advantage.
3. The assumption of CRS production function may not hold. Then, country size may become an important determinant of trade or for that matter product differentiation too.
4. Technologies are assumed to be the same across countries, which obviously does not hold.
5. Labor and capital are assumed to be homogeneous. This is clearly a simplification. Workers differ by their skill levels. Capital may be sector-specific.

### 3 Stolper-Samuelson Theorem

*If there are constant return to scale and both goods continue to be produced, a relative increase in the price of a commodity will increase the real return to the factor used intensively in that industry and reduce the real return to the other factor.*

So, this theorem is essentially saying that movements in commodity prices results in a redistribution of real incomes between labor and capital. This is important in order to understand who will be the gainers and who will be the losers when an economy opens up to trade or when trade policies change.

More specifically, the theorem states that, for the labor-intensive good,  $X$ , when  $p_x/p_y$  increases then  $w/p_x$  and  $w/p_y$  will increase whereas  $r/p_x$  and  $r/p_y$  will decrease.

From the firms' maximization we know that  $w = p_x MP_{LX} = p_y MP_{LY}$  and  $r = p_x MP_{KX} = p_y MP_{KY}$ , which implies that

$$MP_{LX} = \frac{w}{p_x} \quad MP_{LY} = \frac{w}{p_y}$$

$$MP_{KX} = \frac{r}{p_x} \quad MP_{KY} = \frac{r}{p_y}$$

In Figure 7, the movement from point  $A$  to point  $B$ , in response to change in price ratio from  $p_a$  to  $p_b$ , results in an increase in both  $k_x$  and  $k_y$  ( $k_{x_a} > k_{x_b}$  and  $k_{y_a} > k_{y_b}$ ). This is the result of the reallocation of production from  $Y$  to  $X$ , which releases capital in a greater proportion as compared to labor than needed in industry  $X$ , thereby resulting in a higher wage-rental ratio. Given the CRS production function, diminishing returns imply that the higher capital-labor ratio in both industries will cause the marginal product of labor to rise and that of capital to fall. Since the real return to a factor in an industry equals the marginal product of the factor in that industry, the real wage will rise in both sectors and the real return to capital will fall in both sectors.

Let us look at another way to state the Stolper-Samuelson theorem. Since the relative price of  $X$  increases, it must be that the percentage increase in price of  $X$  is larger the percentage increase in the price of  $Y$ . The rise in real wage implies that the percentage increase in wage is greater than the percentage increase in prices of  $X$  and  $Y$ . The fall in real return to capital implies that the percentage increase in rental rate is smaller than the percentage increase in prices of  $X$  and  $Y$ .

$$\% \Delta r < \% \Delta p_y < \% \Delta p_x \% \Delta w$$

The next step is to incorporate this result into this result into our trade model - how does trade change the distribution of factor incomes? We have seen the trade between the capital-abundant country  $H$  and labor-abundant country  $F$  results in the rise of relative price of  $X$  in  $F$  and fall in relative price of  $X$  in  $H$ . As a result the real wage rises and real return to capital falls in country  $F$ . The reverse holds true in country  $H$ . Thus, the abundant factor in each country is made better off by free trade whereas the scarce factor is made worse off. Intuitively, each country through trade exports the services of its abundant factor, resulting in a higher demand for that factor, and it imports the services of its scarce factor, thereby reducing the demand for that factor. Since there are aggregate gains from trade for both countries, it means that the abundant earns more than the total gains from trade making the scarce factor worse off. This result is quite different from what we saw in

the ricardian model. In the ricardian model, all workers are identical and share equally in the gains from trade.

Note that one important precondition for the Stolper-Samuelson Theorem to hold is that both countries produce both goods. If one country specializes in just one good, then since all labor and capital will be allocated to this industry no increase in the good's price will cause the marginal products to change.

An important assumption in the background is that the endowments of factors is fixed.

## 4 Rybczynski Theorem

The Rybczynski theorem establishes a relationship between changes in factor endowments and changes in outputs of commodities, when commodity prices are assumed to be fixed.

*If relative commodity prices are constant and if both commodities continue to be produced, an increase in the supply of a factor will lead to an increase in the output of the commodity using that factor intensively and a decrease in the output of the other commodity.*

The theorem seems a little counter-intuitive because one would think that when endowment of a factor increases, it should shift the PPF outwards and hence increase the output of both commodities.

Figure 8 illustrates this theorem. With the initial endowments of the factors, the Edgeworth-Bowley box has origins  $O_x$  and  $O_y$ . The initial equilibrium is given by point  $A$ , where the capital-labor ratios for the two goods are  $k_x$  and  $k_y$  ( $Y$  is more capital-intensive). Now, consider an increase in the endowment of labor by the amount  $\Delta L$ . This change is represented by a shift of the origin for  $Y$  from  $O_y$  to  $O'_y$ . But, we assume that commodity prices are constant, and therefore, by the Stolper-Samuleson theorem, factor prices are also constant. If factor-prices are unchanged, it would mean that the capital-labor ratios of the two goods (chosen by firms optimally given the factor prices and commodity prices) are unchanged. As a result, with  $O'_y$  as the new origin for  $Y$  and capital-labor ratio unchanged (line  $AO_y$  shifts out in a parallel fashion to  $A'O'_y$ ), the economy reaches the new equilibrium

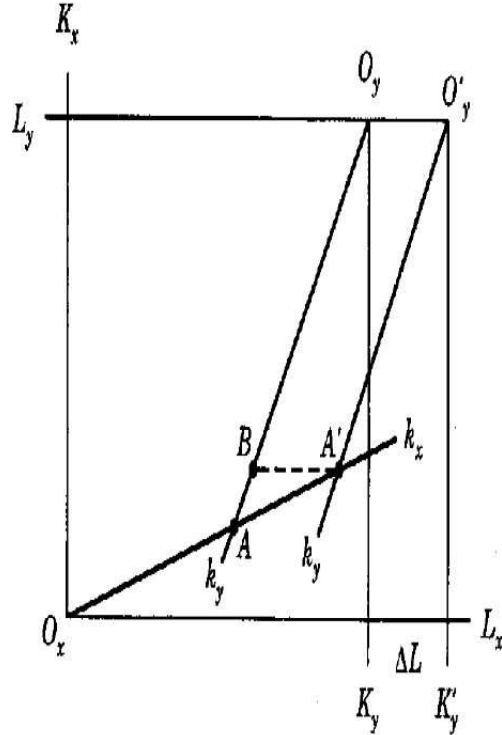


Figure 8: Changes in Endowments and Outputs

at point  $A'$ . Clearly, the output of commodity  $X$  increases (since  $A'$  is farther away from  $O_x$  than  $A$ ). Since  $BO_y$  is equal to  $A'O'_y$ , it must be that  $AO_y$  is longer than  $A'O'_y$ . This means that point  $A'$  is on a lower isoquant than point  $A$ , which implies that the output of  $Y$  decreases. So, the output of labor-intensive good,  $X$ , increases while that of capital-intensive good,  $Y$ , decreases.

Another way to see this through the expansion of production possibility frontier, keeping the commodity price ratio unchanged. In Figure 9 shows the shift of the production possibility frontier from  $\overline{XY}$  to  $\overline{X'Y'}$  in response to an increase in endowment of labor. This shift is biased toward the labor-intensive good,  $X$ . Keeping the price ratio constant, at  $p$ , the equilibrium shifts from point  $A$  to point  $A'$ . Clearly, the output of labor-intensive good,  $X$ , is higher and that of capital-intensive good  $Y$  is lower at  $A'$ . The locus  $R$  through points  $A$  and  $A'$  is called the *Rybczynski Line*. It maps the changes in output in response to changes in the endowment of a factor, keeping the price ratio unchanged. The reason for this line being linear is that the production function is CRS for both goods.

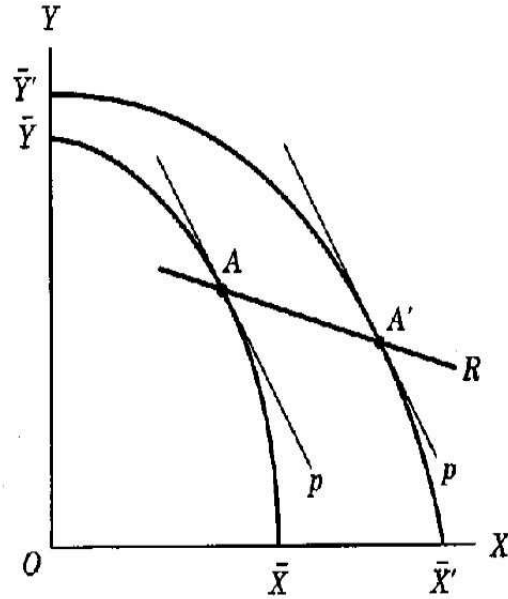


Figure 9: Rybczynski Line

The theorem could be generalized to the case where endowments of both factors change. Suppose the endowment of labor increases by 10 percent while that of capital increases by 15 percent. Then, the shift of the production possibility frontier can be decomposed into two components - a parallel outward shift due to the common 10 percent increase and then shift biased towards the capital-intensive good,  $Y$ , due to an additional 5 percent increase in capital stock.

Holding relative prices constant, the parallel shift of the production possibility frontier results in 10 percent increase in output of both  $X$  and  $Y$ . The additional 5 percent growth in capital stock would increase output of  $Y$  and reduce output of  $X$ . The increase in output of  $Y$  must be greater than 5 percent because industry  $Y$  absorbs the additional labor and capital released from industry  $X$  due to the reduction in output of  $X$ . This also means that the total increase in the output of  $X$  is less than 10 percent.

$$\% \Delta X < \% \Delta \bar{L} < \% \Delta \bar{K} < \% \Delta Y \ .$$

You must realize that these results are crucially dependent on the assumption that the relative prices are constant. In a general-equilibrium analysis, changes in endowments will

result in changes in relative prices of commodities. Thus, this theorem can be realistically applied to study cases of small open economies, where changes in the small economies do not have any effect of world relative prices.

## 5 Empirical Evidence

In assessing the evidence on the predictions of the HO model, we need to focus on the effect of endowment differences on the pattern of trade. Now, we ought to remember that the HO model does not have any prediction for the export of certain types of goods in case of more goods than factors. However, its predictions with respect to trade in factor services still hold, i.e. a capital-abundant country will export a bundle of goods that is more capital-intensive than its bundle of imports.

### 5.1 Leontief Paradox

**Wassily Leontief**, using data on United States from 1947, computed the amount of labor and capital required to produce \$1 million of U.S. exports and \$1 million of U.S. imports. Note that computation of factor content of U.S. imports requires detailed and consistent data on production techniques of all foreign trading partners. Since this was not feasible, Leontief calculated the labor and capital required to produce U.S. goods that are similar to U.S. imports, also referred to as import-competing goods.<sup>1</sup> Since during those times U.S. was the most capital-abundant (or labor scarce) as compared to the rest of the world, the expectation was that exports would be capital-intensive as compared to the imports. Table 1 summarizes the findings. As evident from the table, Leontief found that the capital-labor ratio in the U.S. imports exceeded that in the U.S. exports by about 23 percent. This result is called the **Leontief paradox**.

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<sup>1</sup>This procedure is valid if one of the following conditions holds: (i) if the factor-endowment model holds and international factor prices are equalized and each country uses the same techniques of production; or (ii) production functions exhibit fixed coefficients, i.e. a constant ratio of capital-labor regardless of the factor-price ratio. Leontief chose the second condition.



Table 1: Leontief Paradox

	Exports	Imports
Capital (\$ millions)	2.55	3.1
Labor (persons-years)	182	170
Capital/Labor (\$/person)	14,000	18,200

Other studies for many other countries, also found that the prediction of the HO model did not hold, thereby implying that the Leontief paradox was not a geographically isolated event. However, a compelling objection to Leontief's findings was that 1947 was not an appropriate year for testing the HO model. The model relies on the idea of a long run equilibrium without market distortions, and it could hardly be argued that countries like Europe and Japan (major U.S. trading partners at that time) after World War II were in any kind of long-run equilibrium. **Robert Baldwin** replicated Leontief's work using the 1958 input-output tables and 1962 international trade data and found strong evidence in favor of the paradox.

## 5.2 Explanations for the Leontief Paradox

1. In the HO model we found that free-trade would lower the income of the relatively scarce factor. This provides an incentive for the scarce factor to lobby for import protection. Therefore, the U.S. may have had high trade barriers to labor-intensive imports, and some foreign countries may have had restrictions on capital-intensive imports. These trade barriers could reduce trade below the levels expected from endowment based comparative advantage. However, it has been very hard to test this conclusively because tariffs have complicated effects across sectors in general equilibrium.
2. Another possibility is that preferences could be non-identical and/or non-homogeneous. The pattern of trade could be reversed if a country has strong preference for goods in which it would otherwise have a comparative advantage.
3. Leontief's assumption of just two factors of production is inadequate.

- (a) **Jaroslev Vanek** argued the the paradox is consistent with the possibility that the U.S. was abundant in capital and labor but scarce in natural resources, such as oil, the extraction of which is quite capital-intensive. Thus, by importing services of scarce natural resources the U.S. was also importing services of capital. **Robert Stern** and **Keith Maskus** in their study excluded imports of such commodities. And, they found that the paradox was reversed in 1972.
- (b) **Donald Keesing** disaggregated labor by skill levels and found that U.S. net exports were intensive in highly skilled labor.

4. And then there is the issue that production technologies are not identical across countries. The issue here is that trade data for a particular year may not reflect a long-run, static equilibrium. Instead, it may reflect a short-run transition under varying technologies - product cycles.

### 5.3 Extending the HO Model: Many Goods, Many Factors, Many Countries

The empirical findings discussed above spurred theoretical work in generalizing the results of the two good - two factor - two country HO model to many good - many factor - many country HO model. When there are more than two goods, it is more complicated to evaluate factor intensity and factor abundance. Furthermore, how do we measure the factor intensity of exports and imports when there are thousands of products traded between countries?

#### 5.3.1 Measuring Factor Content of Trade

Using Leontiefs test, we can look at similar data. We can multiply his numbers by the actual value of U.S. exports and U.S. imports. This gives values for “total export” and “total imports.” These values are called the *factor content of exports and factor content of imports*. They measure the amounts of labor and capital used to produce exports and imports. The difference between the factor content of exports and factor content of imports gives factor content of net exports, shown in the Table 2. Since both these factor contents are positive, we see that the U.S. was running a trade surplus in 1947.

Table 2: Factor Content of Trade for United States, 1947

	Exports, X		Imports, M		Net Exports, X – M
	For 1 million Exports	For Total Exports	For 1 million Imports	For Total Imports	
Capital (\$ millions)	2.55	42,600	3.1	19,200	23,400
Labor (person-years)	182	3.04 million	170	1.05 million	2 million
Capital/Labor (\$/person)	14,000	14,000	18,200	18,200	16,700

### 5.3.2 Measuring Factor Abundance

To determine whether a country is abundant in a certain factor, we compare the country’s share in world endowment of that factor with its share of world GDP. If the share of a factor is greater than share of world GDP then the country is abundant in that factor. If, on the other hand, the share of factor is less than share of world GDP then the country is scarce in that factor. Figure 10 shows the country shares for six factors of production and for GDP, for the year 2000, for eight selected countries.

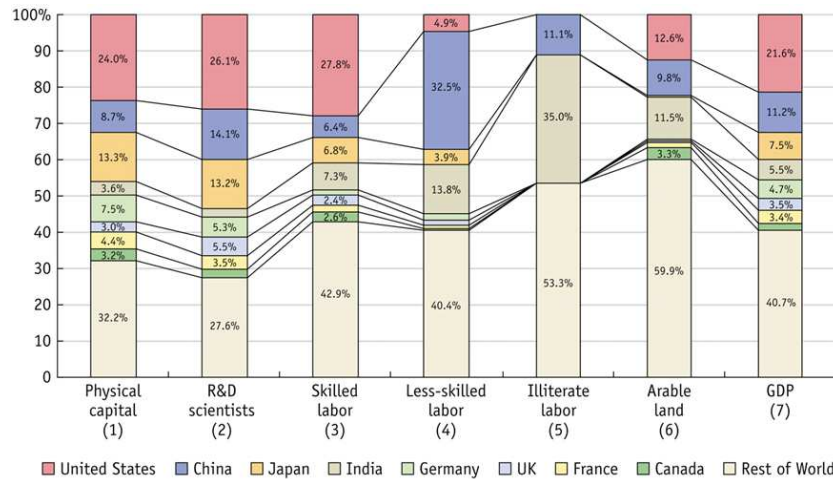


Figure 10: Country Factor Endowments, 2000

For example, 24% of the world’s physical capital is located in the U.S., 8.7% is located in China, 13.3% in Japan, etc. The final bar in the graph shows each country’s share of world GDP. The U.S. had 21.6% of world GDP, China had 11.2%, Japan had 7.5%, etc. We can conclude that the U.S. was abundant in physical capital in 2000. Japan and Germany were also abundant in physical capital. But, China and India are scarce in capital. U.S. is

abundant in *R&D* scientists and skilled labor but is scarce in less-skilled labor and illiterate labor. India is scarce in *R&D* scientists.

The U.S. is scarce in arable land which is surprising since we think of the U.S. as a major exporter of agriculture. Another surprise is that China is abundant in *R&D* scientists. These findings seem to contradict HO model. It is likely that the productivity of *R&D* scientists and arable land are not the same in both countries. In this case, shares of GDP are not the whole story. We need to allow for differences in productivity.

### 5.3.3 Allowing for Differences in Productivities Across Countries

To incorporate difference in productivity across countries we use the concept of *Effective Factor Endowment*, which is nothing but the actual factor endowment times the factor productivity. The amount of effective factor in the world is found by adding up the effective factor endowments across all countries. If share of a country in effective factor is less than its share of world GDP then that country is abundant in that effective factor. If share of a country in effective factor is less than its share of world GDP, then that country is scarce in that effective factor. The effectiveness of an *R&D* Scientist depends on what they have to work with. One way to measure this is through a country's *R&D* spending per scientist. Effective *R&D* scientists is computed as the total number of scientists multiplied by the *R&D* spending per scientist. Figure 11 shows the shares in effective factor endowments.

Now, the U.S. is more abundant in effective *R&D* scientists and China is lower. The U.S. is neither abundant nor scarce in effective arable land.

### 5.3.4 The Sign Test

Now we are in a position to generalize the results of the HO model to many goods - many factors - many countries case. We use something called the *sign test*. The sign test is as follows: Sign of (country's % share of effective factor minus the % share of world GDP) equals Sign of (country's factor content of net exports). The first part of this statement captures factor abundance of a country and the second part of the statement captures the factor content of the country's net exports. If a country is abundant in an effective factor,

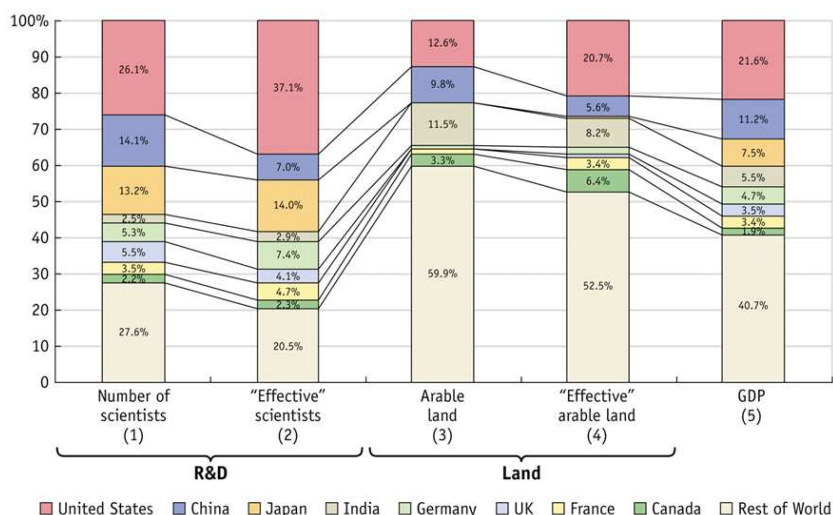


Figure 11: Effective Factor Endowments, 2000

then the factor's content in net exports should be positive. If a country is scarce in an effective factor, then that factor's content in net exports should be negative.

For example, for capital the U.S. had a positive factor content of net exports. Using 35 countries for which GDP data is available in 1947, the U.S. share of GDP of those countries was 33%. Given the timing after WWII, we can assume that the U.S. share of world capital was more than 33%. Therefore, the U.S. was abundant in capital and since that factors content of net exports was positive, it passes the sign test.

The U.S. share of population for the 35 countries was about 8%. This is less than the U.S. share of GDP, 33%. Therefore, the U.S. was scarce in labor. But labor's factor content of net exports was positive. The sign of U.S. factor abundance in labor is thus the opposite of the sign of its factor content of net exports. The sign test seems to fail for the U.S. in 1947 in labor. However, the U.S. share of the population is not the right way to measure the U.S. labor endowment because it does not correct for productivity differences.

One way to measure productivity is to use wages paid to workers. The effective amount of labor found in each country equals the actual amount of labor times the wage. Doing this for 30 countries for which wage data is available for 1947, we find that U.S. accounted for 37% of world GDP and 42% to 44% of effective labor, i.e. U.S. was abundant in effective labor. Given that the U.S. was abundant in effective factor, then labor also passes the sign test, in

addition to capital. There is no “paradox” in the U.S. pattern of trade. This explanation for Leontief’s paradox relies on taking into account the productivity differences in labor across countries.

**As Leontief himself proposed, once we take into account differences in the productivity of factors across countries, there is no “paradox” after all.**