

Ricardo

Ricardo as you will have read was a very smart man. He developed the first model of trade that affected the discussion of international trade from 1820 to the present day. Crucial predictions of his model are about the circumstances that give rise to the pattern of trade - who imports one good and exports another; the pattern of specialization in production; and the sources of wealth or income. Two ideas that have become commonplaces in both professional and popular literature first arise in Ricardo: comparative advantage and absolute advantage. While frequently abused in popular discussion you will learn about them more systematically.

The Model

Ricardo starts with a theory of production in which there is only a single factor: labour. It is sometimes described, therefore, as a labour theory of value. More careful understanding suggests that Ricardo was well aware of other factors of production but chose to suppress the complication.¹

Ricardo's model has several assumptions:

1. Two countries each of which has two perfectly competitive industries. In each country one industry produces 'Cloth' while the other produces 'Wine'. (I will stick with goods "1" and "2", but you are free to think about cloth and wine.)
2. Each industry has a fixed technology so that the marginal product of labour is equal to the average product of labour: Ricardo talked about the labour input per unit of output. Notation is always difficult to absorb, but we could represent Ricardo's characterization of production as: $a_{Lj} = \left(\frac{L_j}{x_j}\right)$. This describes the labour input per unit of output. This characterization of technology is assumed to be exogenous. Further, each a_{ij} is fixed. In perhaps more familiar notation we could also write: $\left(\frac{1}{a_{Lj}}\right) = \left(\frac{x_j}{L_j}\right) = APL_j = MPL_j$ for each industry j . The two industries, j , have different marginal physical products of labour, MPL, (which are also average products of labour [APL] in Ricardo.) Sometime one form of the notation is more convenient than the other and we shall use both. Ricardo's explanations of trade hinge on differences in technology between industries.
3. Labour is paid competitive wages and within a country is perfectly mobile between industries.
4. Labour is internationally immobile.
5. Countries differ in their technologies. This means that the a_{Lj} 's differ among countries even if they are producing the same goods.

These assumptions are starkly simple and lead to powerful results. The role of theory is to provide a set of predictions based on a set of assumptions. Ricardo's model fills the bill.

¹ George J. Stigler, "Ricardo and the 93% Labor Theory of Value" American Economic Review 48(3) (June 1958): 357-367.

Ricardo's Model of the Economy

The easiest way to see what the Ricardian assumptions suggest for the domestic economy is to look at the production possibilities frontier – the production possibilities curve. To develop the frontier, begin with the (exogenous) stock of labour, L , and assume that it is fully allocated between the two industries:

$$1. L = L_1 + L_2$$

Since the amount of labour used in each industry to produce output is a function of the technology, from our definition of the input-output coefficient, $L_1 = a_{L1}x_1$ and $L_2 = a_{L2}x_2$. Thus we can rewrite equation 1 as a function of the technology and output:

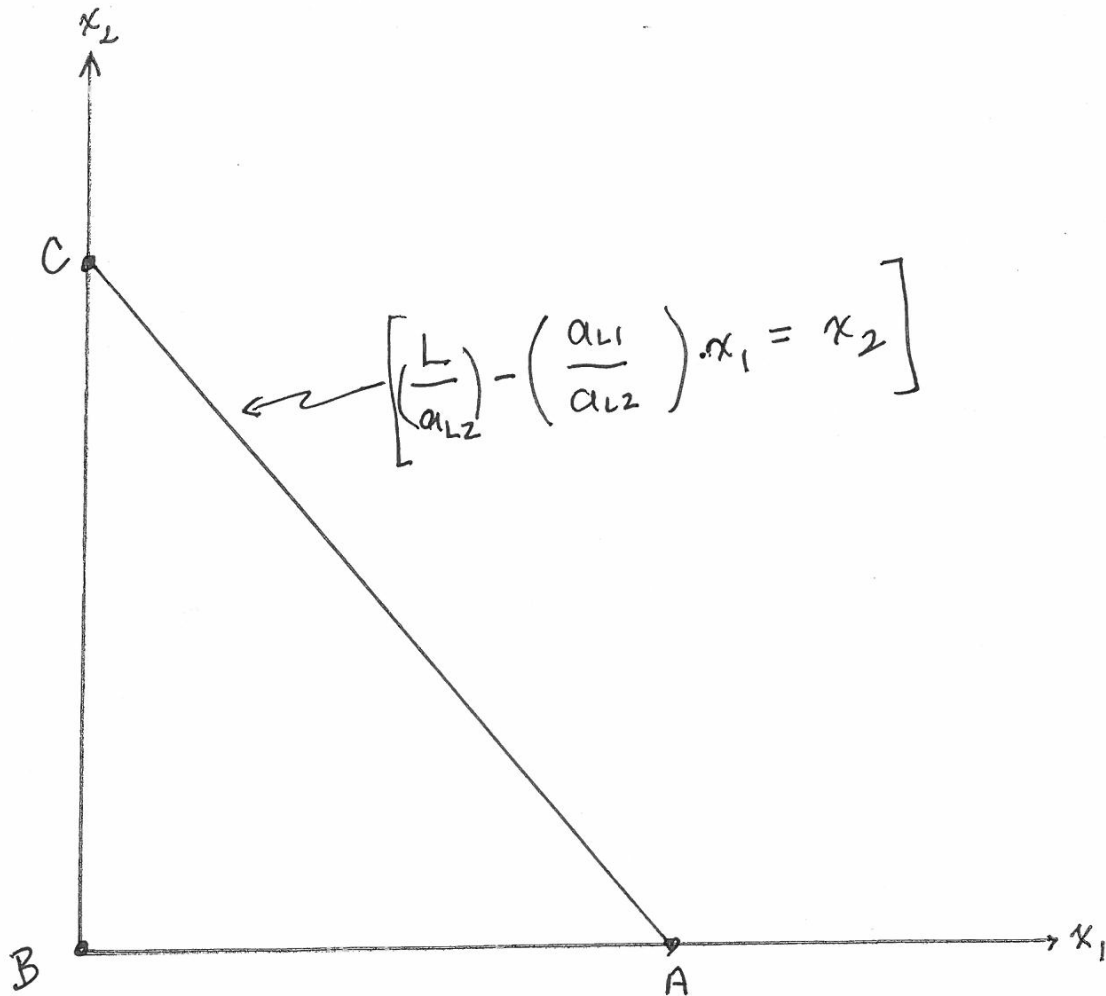
$$2. L = a_{L1}x_1 + a_{L2}x_2.$$

This allows us to characterize the production possibilities frontier as we can plot this labour constraint in output space. Since the a_{Lj} 's (the technology of production) are fixed, by writing 2 as

$$2' x_2 = \left(\frac{L}{a_{L2}}\right) - \left(\frac{a_{L1}}{a_{L2}}\right)x_1$$

lets us describe the slope and location of the production possibilities curve. Figure 1 describes the production possibilities frontier as it demarcates the points of maximum output of each good with the technology and labour resources available in a competitive environment. (The triangle ABC is sometimes referred to as a

Figure 1



production block as it describes all feasible levels of output although those in the interior are dominated by the full employment points along AC.)

Notice that at the endpoints of the production possibilities frontier, the maximum amount of output is L/a_{Lj} or, $L \cdot APL_j$.

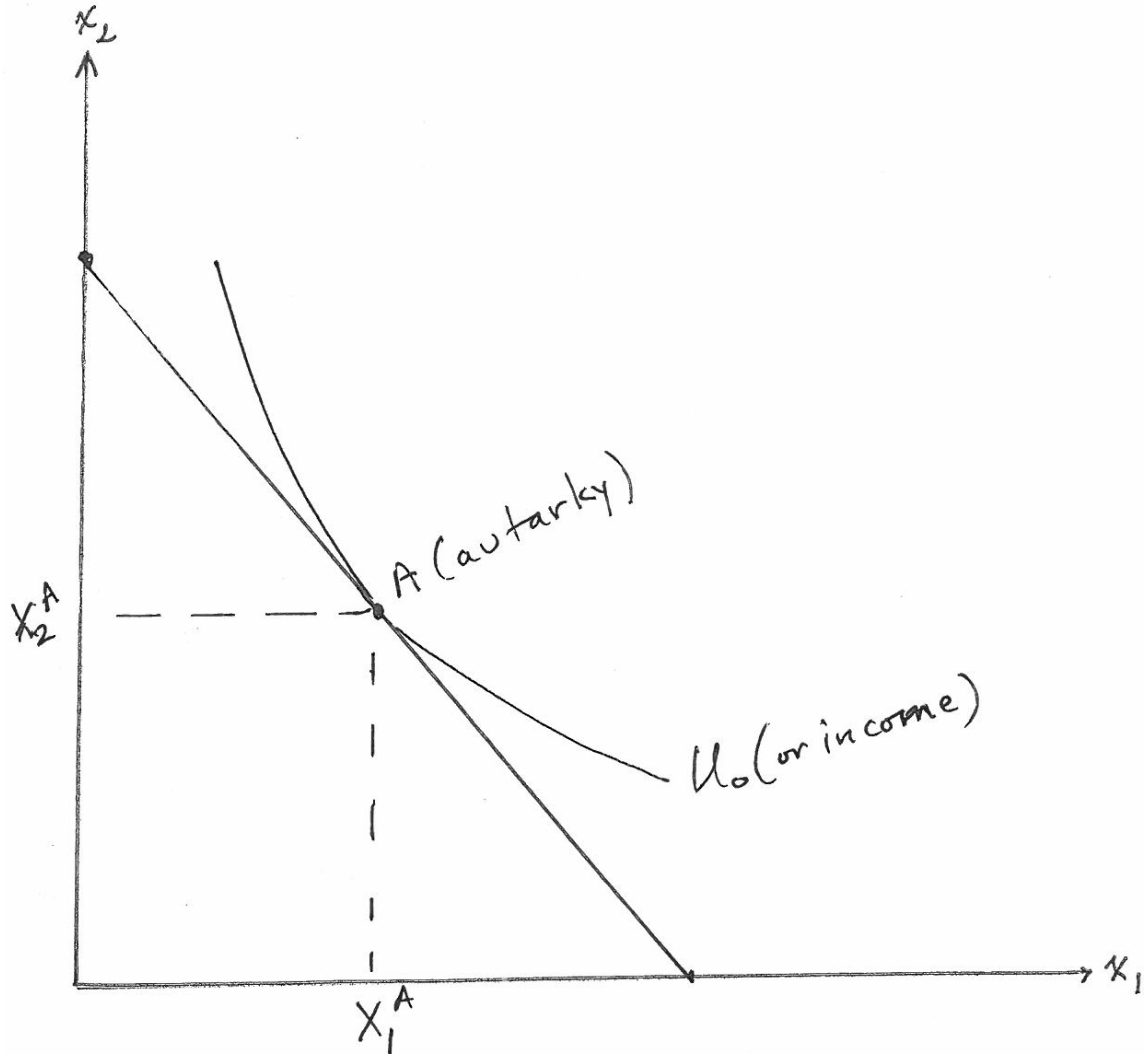
How much of good 2 is sacrificed to produce an additional unit of good 1 is determined entirely by the technologies. Thus the slope of the production possibilities frontier is simply the ratio of the input-output coefficients $\left(\frac{a_{L1}}{a_{L2}}\right)$. Notice, too, that the slope of the production possibilities frontier is simply the ratio of the marginal (and average) products of labour: $\left(\frac{MPL_2}{MPL_1}\right)$. [You might want to explain to yourself why this makes good economic sense and keep it in mind when you look at more complicated models.]

It is also important to recognize that when both goods are produced (and consumed) in autarky, the (absolute value of the) slope of the production possibilities frontier is the relative price ratio in the home economy: $\frac{p_1}{p_2}$ (although of course one of them arbitrarily will be a numeraire since there is only one relative price ratio in our two-good economy.) In the Ricardian model, the domestic pre-trade price ratio is determined entirely by the technology.

The Domestic Pre-Trade *Equilibrium*

To complete our characterization of the initial equilibrium in the Ricardian pre-trade economy, imagine that the indifference map of the society puts us at a point like A.

Figure 2



At point A both goods are produced and consumed. We think of income as the utility level U_0 . Since we have assumed competition in both goods and factor markets, there are zero profits and we know that the value of output will equal the wages paid to the single factor of production, labour, in each industry. For example in industry 1:

$$3. \quad p_1 x_1 = w L_1.$$

Or, rewriting 3 to be consistent with our notation that characterizes the amount of labour input per unit of output $a_{Lj} = \left(\frac{L_j}{x_j}\right)$, we divide both sides of 3 by x_1 :

$$3'. \quad p_1 = w a_{L1},$$

And, of course,

$$4. \quad p_2 = w a_{L2}$$

At this point it pays to emphasize that the actual production conditions written more generally look like:

$$5. \quad p_1 \leq w a_{L1}$$

$$6. \quad p_2 \leq w a_{L2}$$

The reason for the distinction is that while we had positive output represented in the conditions of 3' and 4, in 5 and 6 we leave room for the case in which production costs – wage costs – are greater than the price, and consequently output is *zero*.

$$\text{That is if } p_j < w a_{Lj} \Rightarrow x_j = 0$$

In both 3' and 4, and 5 and 6, the conditions characterize an equilibrium. That is, writing the zero profit conditions as an inequality ensures that the equilibrium is consistent with either positive output or zero output.

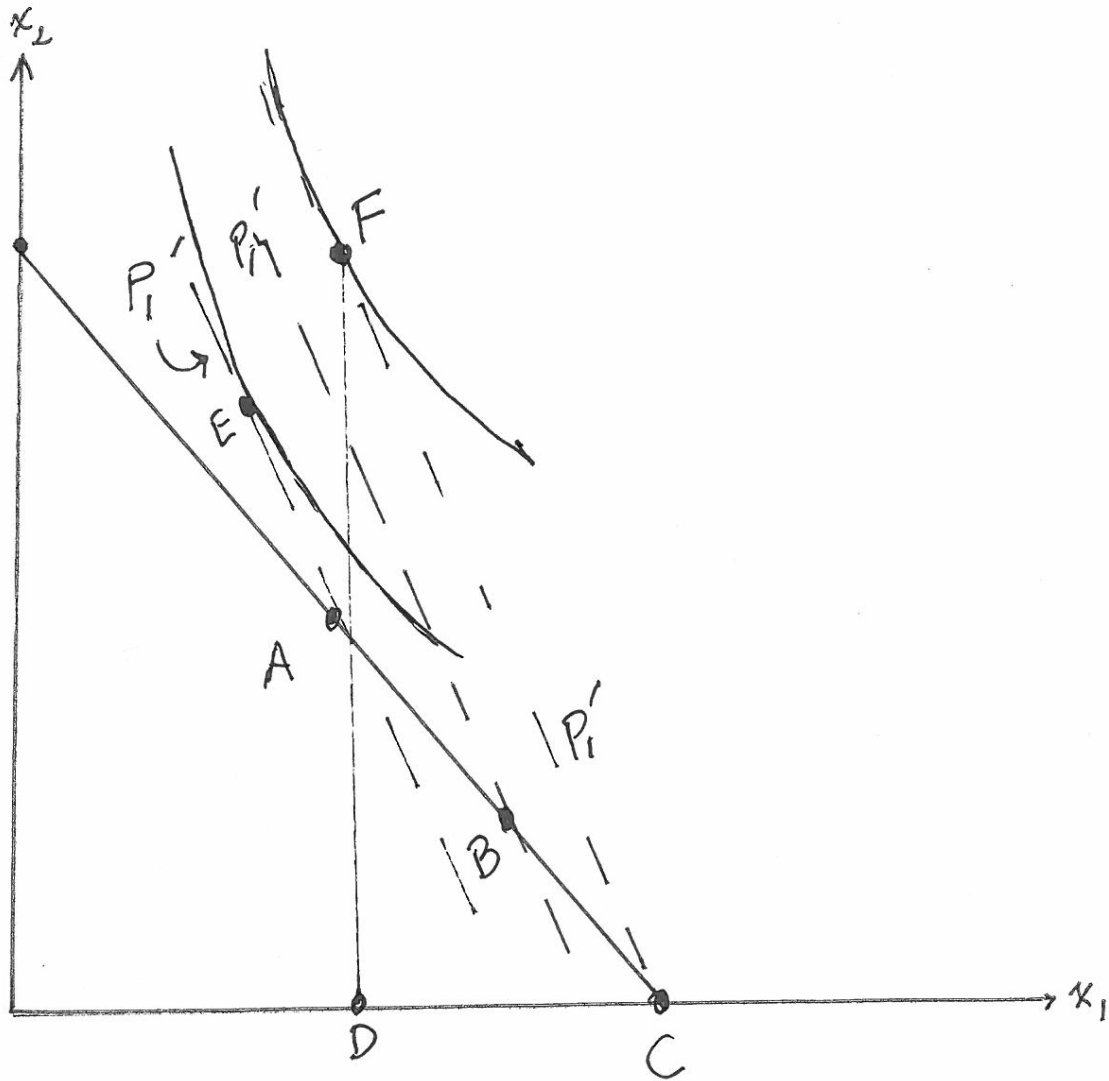
However, what does it mean if $p_1 > w a_{L1}$? This characterization of events suggests that the industry is making positive profit. Something has to give because in a competitive equilibrium, profits are zero. In this case the obvious thing is that output has to expand in industry 1. Positive profits act as a signal to expand production.

Facing World Prices

We will carry this thought further as we look to Figure 3 in which at point A, our home country that was previously in autarky, is now confronted with world prices that reflect a higher relative price of good 1. (For simplicity of exposition let good 2 be the

numeraire: $p_2 = 1$.) Thus the world price is now p'_1 . What are the consequences? We imagine a sequence of events starting at point A the initial site of both production and consumption.

Figure 3



With the higher price of good 1, at point A we have $p'_1 > wa_{L1}$. This is clearly not an equilibrium as positive profits in industry 1 are a signal for output to expand. Suppose output expands to B? Will anything change? By now the discerning reader will probably be asking, "Why doesn't the wage go up and reduce profits and reestablish the equality between price and factor payments?" Think about conditions in the "other" industry, industry 2. In industry 2 the factor payments to labour are $p_2 = 1 = wa_{L2}$. Thus the wage is frozen in industry 1 by conditions in industry 2. Why? In industry 2 the value of the marginal product of labour, $w = (1 / a_{L2})$ is fixed by the technology embodied in a_{L2} . Since labour moves freely from one industry to the other, the expanding industry 1

can draw labour from industry 2 *at the wage that is fixed in industry 2* and pays that same wage.²

Thus at point **B**, labour is still being drawn from industry 2 into industry 1 at economy-wide fixed wages. This continues on “down” the production possibilities frontier until we end up at a point like **C**. The price line p'_1 in the figure shifts to point B and then to point C. Why?

At point C things change. There is now no labour to be drawn from industry 2. Consequently the wage rises and we have a new equilibrium wage:

$$w' = (p'_1 / a_{L1})$$

And at this higher wage rate the cost of producing good 2 is greater than the price so that:

$$p_2 = 1 < a_{L2}w', \text{ and, consequently, } x_2 = 0.$$

As at point A before the price change, point C is an equilibrium although all points like B are not.

Free Trade at World Prices

In the Figure 3, point **F** is our new consumption point corresponding to production at point **C**. Notice that consumption at point **E** would also improve our income but production is constrained at point **A**. It would answer the question: can we gain from trade even if we were locked-in to production at point **A**. This is just the endowment model of course.

At point F we have consumption of both goods and because the world price line acts like an improved opportunity set. Income is clearly higher at F than anywhere along the original production possibilities schedule.

Thus the home country will be a producer only of good 1 and perforce will be an exporter of good 1 and an importer of good 2. Since both goods are consumed, the home country will trade its exports of good 1 for imports of good 2. These “trade triangle” in the figure has a (horizontal) base of exports **CD** and a vertical side of imports **DF** with an hypotenuse of world relative prices, p'_1 .

Foreign Production

Suppose now that the **foreign** country, too, has a Ricardian production structure

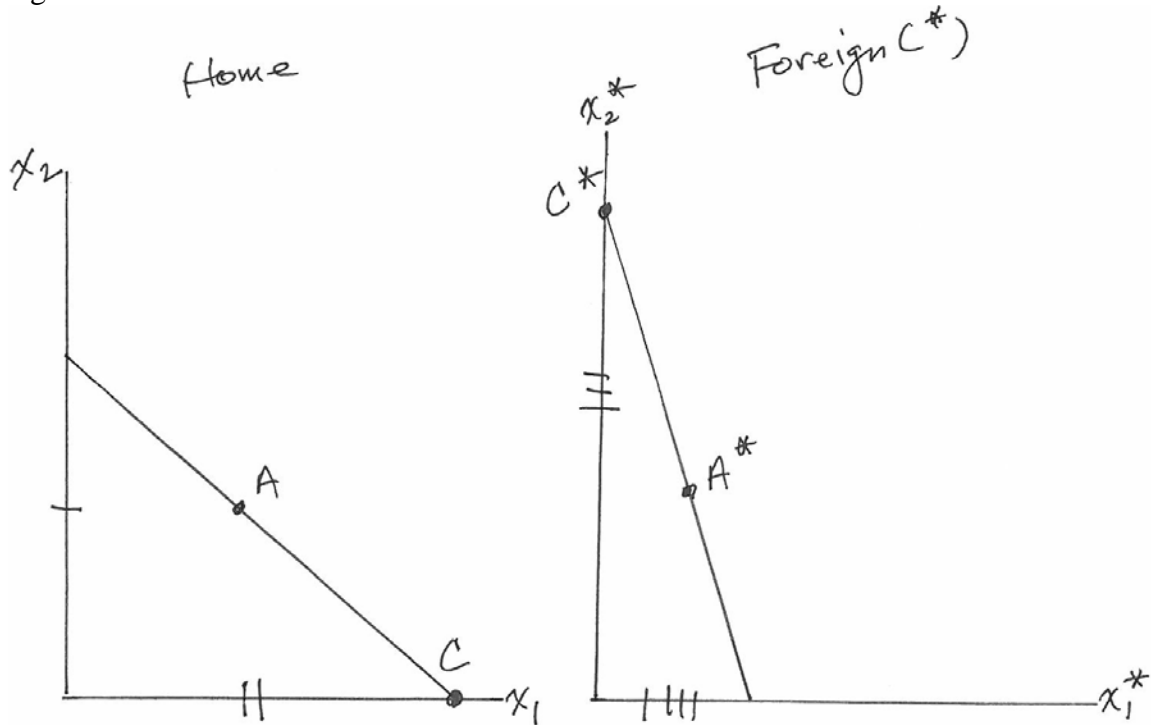
² We can imagine that industry 1 pays an infinitesimally greater wage than industry 2 to move labour from one to the other. Since we do not worry about the dynamics except to show why we move to the new equilibrium, the exact story of how workers move does not have to be fleshed out here.

$$7. L^* = a_{L1}^* x_1^* + a_{L2}^* x_2^*$$

so that their production possibilities frontier has a slope of (a_{L1}^*/a_{L2}^*) in absolute value.

Figure 4 draws the two production possibility frontiers where it is clear that the slope of the home production possibility frontier is less steep than that of the foreign country. Be sure you understand why and what this means. Autarky consumption is at A and A*.

Figure 4

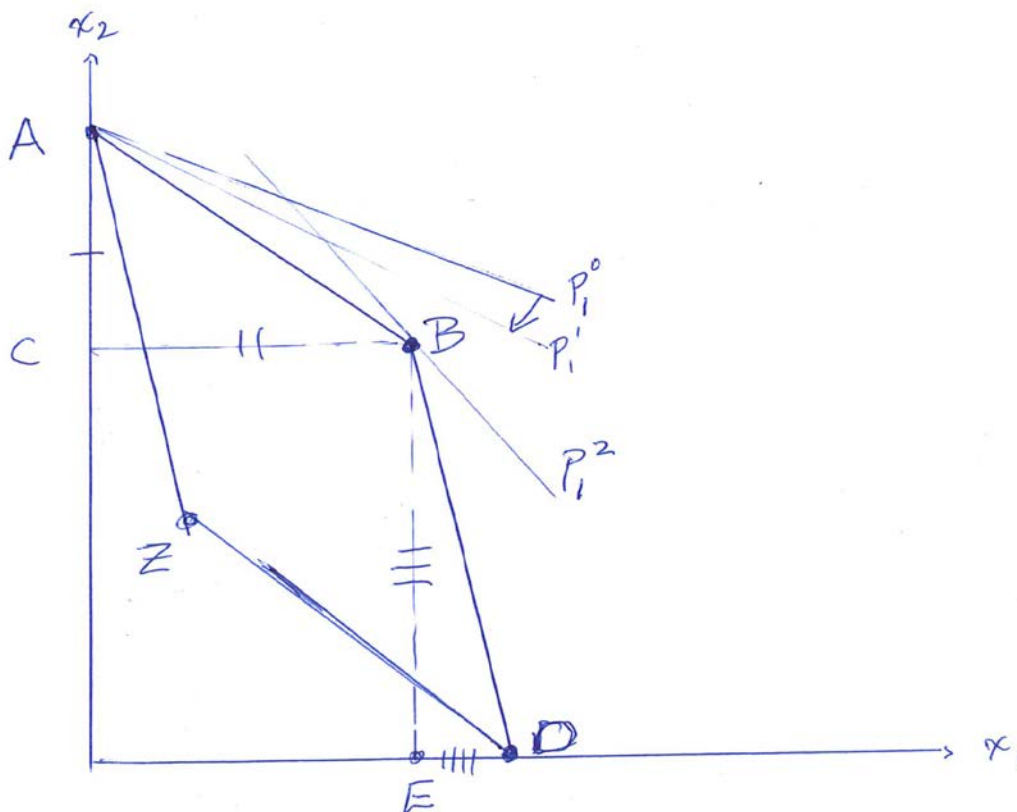


Now if world prices are such that they lie between the slopes of the two production possibility frontiers, then it should be clear from the argument developed above that the home country will specialize in good 1 (point C) and the foreign country in good 2 (point C*). Can you show why? Start at the initial autarky point A or A* in which there is no trade in each country and set a world price ratio that is the same for both countries the slope of which lies between the slopes of the two production possibility frontiers. Then describe the gains from trade in each country and explain which country imports (and exports) which goods. How does technology influence the pattern of trade?

The World Production Possibilities Frontier

Another useful way of seeing the trading environment is to look at the *world production possibility frontier*. To construct it, assume initially that both countries are specialized in the production of good 2. This means that point A in Figure 5 is the sum of the maximum amount each country can produce of good 2. To support such a production pattern, the world relative price of good 2 would have to be very high (the price of good 1 may be thought of as very low: p_1^0 .) That means that the slope of the world price line would be very flat going through point A.

Figure 5



Now let the world price good 1 start to rise. From point A (where both countries are specialized in the production of good 2) the slope of the world price line increases – becomes steeper. But if it is still not too steep, the dotted line, p_1^1 , world production remains at point A. Only when world prices (of good 1) rise sufficiently so that the slope of the line becomes one with the slope of the world production possibilities frontier (AB) is good 1 being produced in addition to good 2. Since the technology of the home country, $\left(\frac{a_{L1}}{a_{L2}}\right)$, means that it produces good 1 relatively cheaply - compared to the foreign

country, $\left(\frac{a_{L1}^*}{a_{L2}^*}\right)$, as the price of good 1 rises, it moves first to produce good 1 while the foreign country remains specialized in the production of good 2. Notice that along AB, the slope of the world production possibilities frontier is the same as the slope of the home production possibilities frontier. The triangle ABC is exactly the production block of the home country. For easy reference, the "slash" marks in figure 5 correspond to the production blocs in figure 4.

If the relative price of good 1 increases still further to p_1^2 , then production is located at point B. At point B, which country is producing which goods? ³At point B both countries are completely specialized: the home country in good 1 and the foreign country in good 2. At point B notice that there is a wide range of prices for which both countries remain specialized. How do we see this?⁴ If the price of good 1 becomes sufficiently high then we move to complete specialization of both countries in the production of good 1 at point C. Notice that the production block BDE is simply the production block of the foreign country.

The world production possibilities frontier is consequently ABD and it describes the maximum output possible in the world economy with given technologies and supplies of labour.

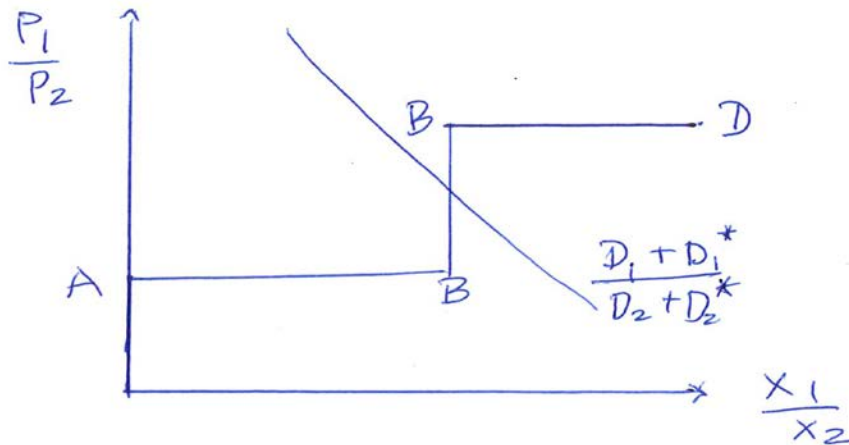
The Relative Supply Curve

Suppose we plot the relative price of good 1 on the vertical axis and the relative output of good 1 on the horizontal axis. From figure 5 we can see that at point **A** there is a range of prices at which the world is specialized in the production of good 2. Since this means that in Figure 6, there is a vertical segment along the vertical axis reflecting zero output of industry 1. However, as the price of good 1 increases (in figure 5 this means that the relative price line falls anchored at point **A**), eventually the lower price of good 1 takes us to the flat segment **AB** (the production possibilities schedule of the home country). Along this segment, the relative output of good 1 increases. In figure 6, this is indicated by the segment, **AB**. At point **B** in figure 5, however, there is now a range of prices consistent with production being specialized in each country in different commodities—good 1 in the home country and good 2 in the foreign country. As we continue to raise the price of good 1, eventually the price ratio is the same as the relative cost of production in the foreign country along the segment **BD**. In figure 6 this is the segment **BD** along the relative supply curve.

³ At point B, the home country is completely specialized in the production of good 1 and the foreign country in good 2. Along the segment AB (not including the end points), the home country is incompletely specialized. That is it is producing both goods and the foreign country remains specialized in the production of good 2.

⁴ There are many relative price lines that keep the two countries anchored at B,

Figure 6



Although relative demand (D_1/D_2) can cross the relative supply schedule anywhere, we usually assume that in a two-good world, both goods are produced and that the wide range of prices in the segment **BB** is the likely outcome. DD_1 illustrates this case. (If one of the countries is incompletely specialized, draw the relative demand in figure 6. Where are we in figure 5 in that case?)

World Trade and Comparative Advantage

If trade takes place at point B in figure 5, we can see that the pattern of trade is determined entirely by the relative costs of production. That is, who exports and imports which goods depends exclusively on technology.⁵ That pattern arises from which country has the comparative advantage in producing each good. The rule for comparative advantage can be described by the slopes of the production possibility frontiers which display the relative costs of production: how much it costs the society to produce a unit of good 1 in terms of the sacrifice of good 2 (and of course *vice versa*.)

This leads to the characterization of comparative advantage as the ratio of the two countries' relative cost ratios as seen in the slopes of their production possibilities frontiers:

⁵ If we produce along the "flats" of the production possibilities frontier like at point C, then the home country still exports good 1 in exchange for good 2. The only exception would be at the end points like A, but these are not important since we generally assume that both goods are being consumed in both countries.

$$8. \left(\frac{a_{L1}^*}{a_{L2}^*} \right) > \left(\frac{a_{L1}}{a_{L2}} \right)$$

As is immediately apparent, absolute advantage is not relevant to the pattern of trade since an improvement in technology (say divide both the home labour cost coefficients by 2, will have no effect on the ratio and hence the pattern of trade generated by comparative advantage.

Suppose the Alternative to Comparative Advantage

Imagine that the configuration of prices in the domestic economy that forces production to be such that output is at point **Z** in the Figure 5. That is, the home country produces good 2 and the foreign country good 1. Visually it is clear that point **Z** lies below point **B**. This also emphasizes the efficiency of point **B** compared to point **Z**. If you know the technology and the labour force in each economy you can easily calculate the cost in forgone output resulting from the misallocation of production. Keep this in mind when you are thinking about the costs of tariffs and other impediments to trade!

The Distribution of Income

Since each country has but a single factor of production, the only interesting distribution question has to do with the relative wage rates (income) between countries. In Figure 5, imagine that both countries are specialized in good 2 at point **A**. In this case, the wage relationships are straightforward:

$$\begin{aligned} p_2 &= a_{L2}w \\ p_2 &= a_{L2}^*w^* \end{aligned}$$

This tells us that the relative wage rates are determined strictly by technology:

$$\frac{w}{w^*} = \frac{a_{L2}^*}{a_{L2}}$$

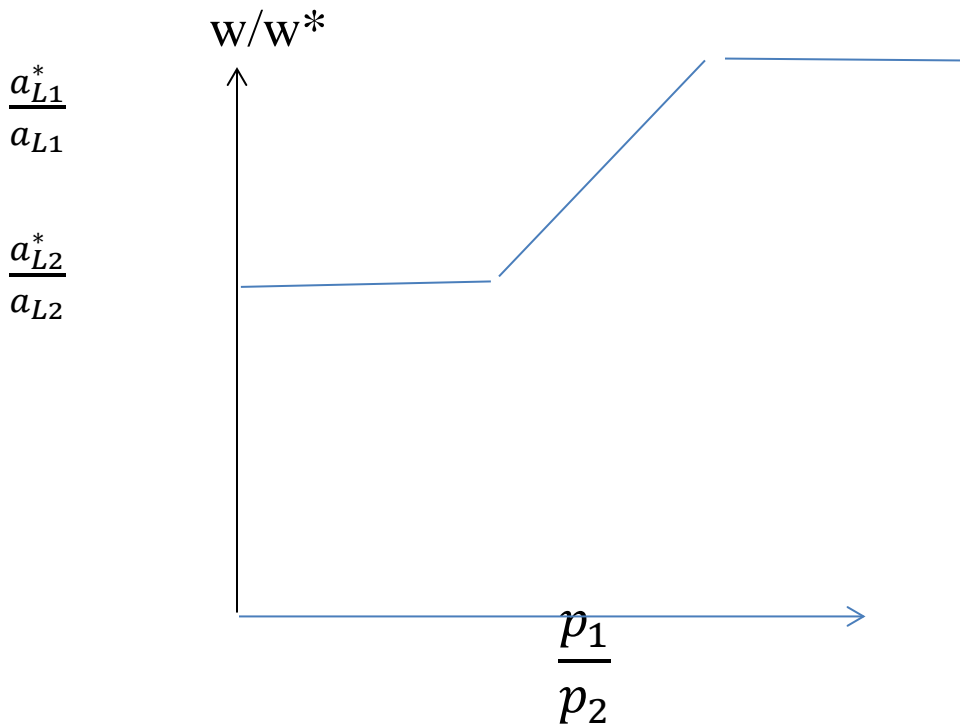
Notice, too, that relative wealth is determined by absolute rather than comparative advantage. That is, the better the technology in the home country, a lower a_{L2} , the higher the domestic wage relative to the foreign wage.

However, if both goods are produced and each country is specialized according to comparative advantage at point **B**, then the determination of relative wages depends on prices as well as the technology of production:

$$\frac{w}{w^*} = \left(\frac{p_1}{p_2} \right) \left(\frac{a_{L2}^*}{a_{L1}} \right)$$

In the figure below we have mapped the relationship between relative wages and prices. At the lowest price of good 1 (relative to good 2) both countries are producing good 2. This is reflected in the relative “absolute” technical labour utilization in production.⁶ Figure 7 below plots the relationship and emphasizes the technical as well as financial dependence of the real wage ratio.

Figure 7

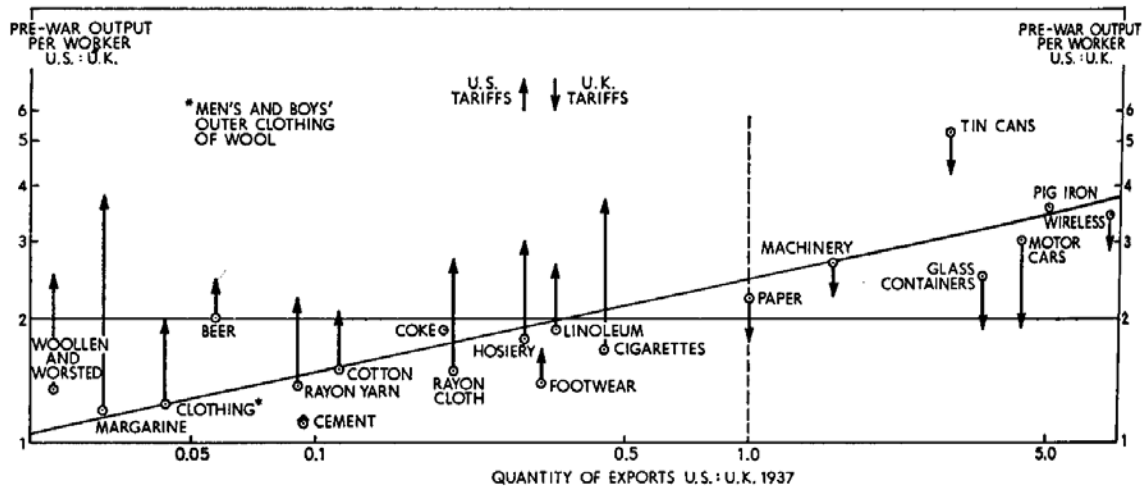


How do we go about testing the Ricardian Model?

One of the implications of Ricardo is that comparative advantage tells us who is going to export what. Robinson argued that the way to see a prediction of the model in the world of tariffs and other impediments to trade was to look at different industries and calculate their output/labour ratios. Then plot their exports. To do this he decided to look at US and UK exports to third country markets so that both exporters would face the same tariffs or other trade taxes. Figure 8 plots the points. Ignoring the arrows in the figure, the points seem to be consistent with the model. Higher ratios of output to labour in the US relative to output to labour ratios in the UK– relative technical efficiency – lead to relatively more exports.

⁶ As elsewhere this section is drawn from Caves and Jones, various editions.

FIGURE 1
Productivity, Exports, and Tariffs



G.D.A. MacDougall, *British and American Exports: A Study Suggested by the Theory of Comparative Costs*. Part I *The Economic Journal* Vol. 61, No. 244 (Dec., 1951), pp. 697-724 reprinted in Caves, Richard E. and Harry G. Johnson, eds. *AEA Readings in International Economics*, (Richard D. Irwin, Inc: 1969): 553-578.

There are a number of other issues in the diagram having to do with tariffs and wages, but they need not concern us at the moment.

Some questions to ponder.

1. In figure 2, show that the price ratio is equal to slope of the production possibilities frontier when both goods are produced. [Hint: look at the competitive profit conditions.]
 2. At point C in Figure 3, why is output of good 2 is zero?
 3. Explain why comparative advantage rather than absolute advantage determines the pattern of trade.
 4. Why is a higher or lower a_{Lj} a measure of better technology?
- Harder questions:*
5. As we move from A to B to C in Figure 5, draw a diagram that plots relative wages between countries on the vertical axis and relative prices on the horizontal axis. Identify relative wages at point A as purely a function of technology.

- Identify relative wages at point C. If the relative price of good 1 rises by 10%, what is the effect on relative wages? [Hint: There are two cases.]*
6. *Draw the relative supply curves for the endowment and Ricardian models.*
 7. *What would the world production possibilities schedule look like if there were a third country producing goods 1 and 2? [As in the two country case, start by assuming that all countries are producing good 2, etc.]*
 8. *What would the Ricardian production block look for a country that produced three goods?*
 9. *Can you imagine what the world production possibilities frontier would look like if three countries each could produce three goods.*

Appendix

Deriving the production possibilities frontier in the Ricardian model.

Deriving the Ricardian production possibilities frontier may be too easy, but it illustrates a method that is useful for highlighting the underlying structure of the model. For example in Ricardo we have a production function for good 1:

$$x_1 = L_1/a_{L1}$$

that tells us that increasing the amount of labour used to produce good 1 increases output. We can draw the picture of output and labour input as Figure 7. Notice that the slope of each production function is just the marginal product of labour: $1/a_{Lj}$.

The same can be done for the second industry although the slope of the line will be different because good 2 uses a different technology.

Of course we also know from equation 1 that the total supply of employed labour is equal to the amount of labour employed in each industry. In Figure 6 we derive the production possibilities frontier as a relationship among the two production functions and the labour constraint [Notice that in quadrant III we have a line with a slope of -1 that is the labor constraint of equation 1.]

To generate a point on the production possibilities frontier in Figure 8, start by employing all the labour in industry 1: $L_1=L$. Plot the output of industry 1 and 2 on each axis. Notice that there is no output on industry 2 axis since all the labour and consequent output is in industry 1. Plot that point on the x_1 axis: point **A**. Now, plot the point on the x_2 axis when all labour is employed in industry 2 ($L_2=L$): point **B**. Now find a point, **H**, for which about half the labour is employed in each industry. Notice that this means that each production function produces output. Plot the pair of outputs in quadrant I. Do this for several points along the labour constraint line in quadrant III and you will generate the Ricardian production possibilities frontier in quadrant I.

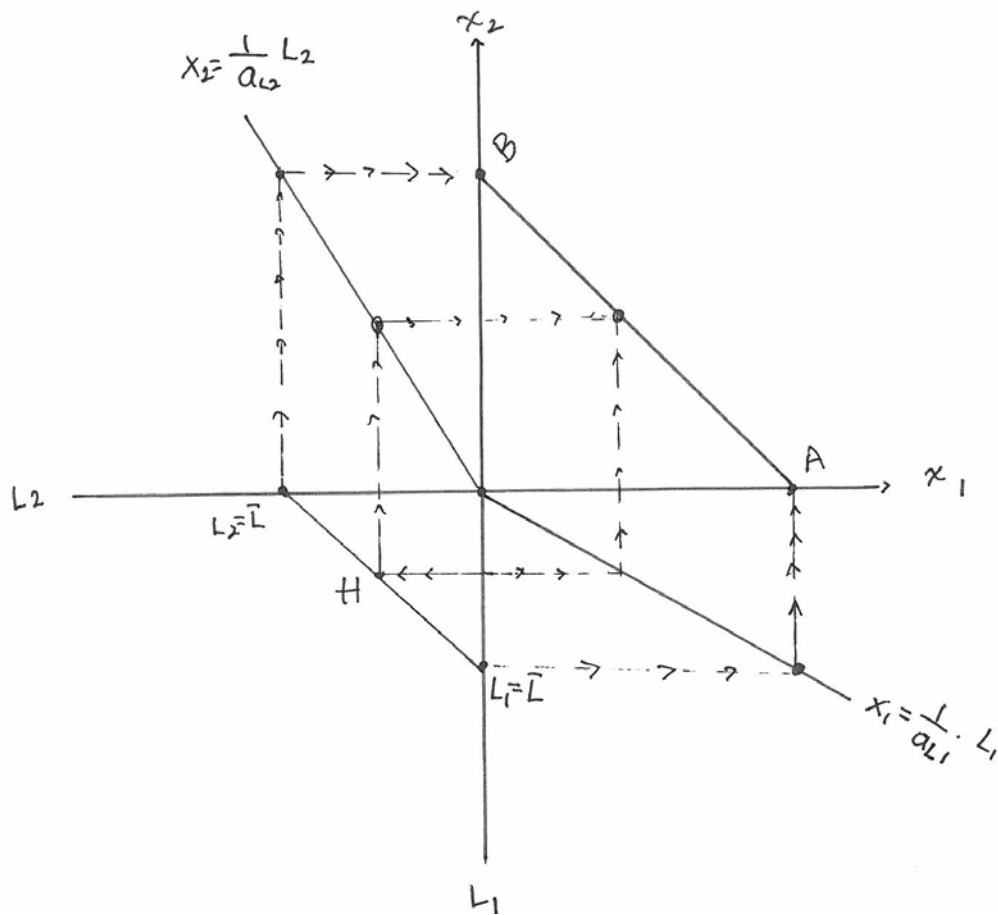


Figure 8

Some questions to assure your understanding.

- 1 What happens to the production possibilities frontier when the labour force is increased?
2. What happens to the production possibilities frontier when one industry becomes more productive?