On measuring comparative advantages of foreign trade

By
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David Ricardo's most famous principle concerns the comparative advantages of foreign trade, although Ricardo uses the words "comparative advantage" only once in passing in his *Principles*[1]. It is therefore well to begin by quoting the words in which Ricardo himself describes this principle in Chapter VII On Foreign Trade:

> *Under a system of perfectly free commerce, each country naturally devotes its capital and labour to such employments as are most beneficial to each. This pursuit of individual advantage is admirably connected with the universal good of the whole. By stimulating industry, by rewarding ingenuity, and by using most efficaciously the peculiar powers bestowed by nature, it distributes labour most effectively and most economically: while, by increasing the general mass of production, it diffuses general benefit, and binds together by one common tie of interest and intercourse, the universal society of nations throughout the civilized world. It is this principle which determines that wine shall be made in France and Portugal, that corn shall be grown in America and Poland, and that hardware and other goods shall be manufactured in England*.[2]

The quote first emphasizes that labour is not the only factor of production, but that comparative advantages are often also determined by the peculiar powers bestowed by nature, i.e. by all kinds of natural resources such as fertile soil, valuable raw materials, sun, wind, water and hydropower, and so on. Furthermore, it stresses the importance of deploying labour as efficiently and economically as possible, so that net production reaches an optimal level throughout the countries.

The principle bears a strong resemblance to the principle with which Ricardo begins his *Principles*, and which I would like to repeat here.

> *The value of a commodity, or the quantity of any other commodity for which it will exchange, depends on the relative quantity of labour which is necessary for its production, and not on the greater or less compensation which is paid for that labour.*[3]

The comparative advantages of foreign trade are, as we shall see, equally independent of wages and prices and determined solely by technical production circumstances, which are, of course, also

[1] D. Ricardo, *On the Principles of Political Economy and Taxation*, Volume I of 'The Works and Correspondence of David Ricardo', ed. by P. Sraffa, Cambridge, 1951 (to be referred to as *Principles*). You can find the words at the beginning of Chapter XIX On Sudden Changes in the Channels of Trade, p. 263.
[2] *Principles*, p. 133-4.
[3] *ib*., p. 11.

determined by the natural environment, which varies from country to country. However, Ricardo's principle of comparative advantages explicitly emphasizes the importance of an efficient and economical use of labour. It explicates the pursuit of efficient production, which is implicitly the driving force in Ricardo's first principle.

Ricardo begins his chapter On Foreign Trade as follows:

> No extension of foreign trade will immediately increase the amount of value in a country, although it will very powerfully contribute to increase the mass of commodities, and therefore the sum of enjoyments. As the value of all foreign goods is measured by the quantity of the produce of our land and labour, which is given in exchange for them, we should have no greater value.[4]

If I had to start this chapter I would perhaps prefer an alternative formulation: countries that produce the same commodities, but differ in their ability to produce these commodities efficiently, can powerfully increase the mass of commodities through mutual trade. Each country can benefit from this trade by increasing the production of commodities it can produce relatively efficiently, by shifting the labour needed for this increased production away from the production of commodities it can only produce relatively less efficiently. If labour remains the same in all countries, the value of the commodities produced in each country will also remain the same.

That the production of the countries remains unchanged in value is consistent with the fundamental principle or axiom that in *Reappraisal*[5] is used to demonstrate the correctness of Ricardo's first principle, cited above, namely, that the varying product of a quantity of labour which remains constant in time, remains always invariable in value. Only on the basis of this axiom we are able to use the exchange values of commodities as they arise on the market to determine precisely where and when the production circumstances of a commodity change, and this independently of wages, i.e. independently of the way the net production is divided between wages for the work done and the profits received by the capital providers. The same method that allows for the measurement of actual technical change in a single country also allows for the measurement of the actual comparative advantages of mutual trade. And here too, it turns out that this determination is independent of the actual exchange conditions that arise in mutual trade of commodities, and also independently of the distribution of comparative advantages between the countries involved.

Measuring actual changes in comparative advantage is simple: simply add up the input-output tables needed to measure technical change for the countries involved in mutual trade, so that, for the countries together, it can be determined where and when additional production occurs as a result of specialization between countries. If the production techniques used in each individual country were to remain unchanged, so that the measured technical change in the countries remained zero, the mutual specialization and the resulting increase in production would be reflected in the combined measurement of changes in production techniques, making the comparative advantages visible.

In the above quotation, Ricardo examines the increase in the quantity of commodities in a country resulting from foreign trade and assumes that the value of all foreign goods can be measured by the total of goods "given in exchange for them". However, the alternative formulation I prefer does not include any valuation of the goods involved in mutual trade. It only considers how specialization is

[4] *ib*., p. 128.
[5] A. Moons, *A Reappraisal of Ricardo's Principles - On measuring technical change*, published on www.davidricardo-firstprinciple.com (to be referred to as *Reappraisal*).

reflected in increased production in the individual countries. For determining comparative advantages, the exchange ratios between the commodities involved in the mutual trade appear to be irrelevant. This is explained below using examples.

But first of all, it must be emphasized that the actual measurement of both technical change and comparative advantages, does not mean that wage and price formation is less important for an accurate picture of economic development. On the contrary, as Ricardo himself shows, this is primarily determined by the least favourable production circumstances, which can also be characterized by firms that keep machines in use as long as they are still profitable[6]. With regard to price formation in the mutual trade between England and Portugal, Ricardo points out the following rule:

> Thus, cloth cannot be imported into Portugal, unless it sell there for more gold than it cost in the country from which it was imported; and wine cannot be imported into England, unless it will sell for more there than it cost in Portugal.[7]

Ricardo places his analysis in the time in which he lives and starts with a merchant: by the purchase of English goods he can obtain a quantity of foreign goods, which he can sell in the English market with the general rate of profit. If his profit would exceed this rate, then, Ricardo states[8], capital would naturally flow into this advantageous trade, till the fall of the price of the imported goods had brought the profit to the former general level.

Ricardo points out that this general rate of profit is characteristic of an area with free movement of labour and capital, such as England, in his time. If, at any point, innovations lead to higher profits in one part of England, this will attract capital and labour, so that over time, the same rate of profit is achieved everywhere. In other areas without free movement of capital with England, such as Portugal, a different rate of profit may exist, while trade between these countries can develop to exploit comparative advantages. But before he elaborates on this, Ricardo reiterates his time-bound position.:

> It has been my endeavour to shew throughout this work, that the rate of profits can never be increased but by a fall in wages, and that there can be no permanent fall of wages but in consequence of a fall of the necessaries on which wages are expended. If, therefore, by the extension of foreign trade, or by improvements in machinery, the food and necessaries of the labourer can be brought to market at a reduced price, profits will rise. If, instead of growing our own corn, or manufacturing the clothing and other necessaries of the labourer, we discover a new market from which we can supply ourselves with these commodities at a cheaper price, wages will fall and profits rise; but if the commodities obtained at a cheaper rate, by the extension of foreign commerce, or by the improvement of machinery, be exclusively the commodities consumed by the rich, no alteration will take place in the rate of profits. The rate of wages would not be affected, although wine, velvets, silks, and other expensive commodities should fall 50 per cent., and consequently profits would continue unaltered.
> Foreign trade, then, though highly beneficial to a country, as it increases the amount and variety of the objects on which revenue may be expended, and affords, by the abundance and cheapness of commodities, incentives to saving, and to the accumulation of capital, has no tendency to raise the profits of stock, unless the commodities imported be of that description on which the wages of labour are expended.[9]

[6] A. Moons, *History of my economic thinking in dialogue with Schumpeter*, published on www.davidricardo-firstprinciple.com (to be referred to as *My History*), p. 9-13. See also *Reappraisal*, p. 21-3.
[7] *Principles*, p. 137.
[8] *ib*., p. 128.
[9] *ib*., p. 132-3.

As for the time-bound nature of trade that Ricardo analyses, it should first be noted that trade has always existed. Throughout the centuries, traders have observed where products can be produced more easily than elsewhere and where the exchange of goods brings prosperity. For example, it was precisely thanks to enterprising traders that the Hanseatic League, or The Hansa, emerged in the Middle Ages: an alliance of merchants and city-states in Northern Europe that managed to utilize and regulate comparative advantages so that the benefits of trade could be widely shared.

The relationship between wages and the rate of profit assumed by Ricardo typifies only one phase of economic development. This phase must be carefully distinguished from later phases, such as those of oligopolistic competition, in which there is no longer an general rate of profit**.** Furthermore, the supposed absence of free movement of capital is also a time-bound assumption and therefore not necessary.

Regardless of whether free movement of capital and labour exists, comparative advantages between countries arise when one country produces a certain type of commodity more efficiently than another. This can occur, for example, in the car industry. The export of efficiently produced cars can put pressure on the less efficient car industry in another country, resulting in unemployment among the affected car workers. Measuring the comparative advantages of both countries will then show that the production of the entire car industry becomes more efficient. It is important to note that this explicitly takes into account the reduced employment in the outcompeted, less efficient car industry, without considering whether the redundant car workers have found work elsewhere. When measuring changes in production circumstances, only the total amount of actual labour performed is considered, even if the total amount of labour decreases over time. The twofold valuation of both technical change and comparative advantages automatically corrects for changes in the total amount of actual labour performed.

Measuring actual changes in applied production techniques must therefore always be placed in the context of broader economic development. However, it is precisely this measurement that reveals the essential forces that determine and explain this broader economic development. Below, we will address the question of what the causes are if, at any given time, comparative advantages between countries emerge in a particular industry. Which country produces most efficiently? Is this efficiency the result of innovation in production techniques used? And how do other countries respond to this? Do they focus more on other, more efficiently operating industries, so that comparative advantages also arise for those other industries? Or are there adaptation problems? How does this emerge from the available data? Using examples, we will further examine the significance of measuring comparative advantages.

Measuring comparative advantages: the case of direct labour only

Shortly after formulating the principle of the comparative advantages of foreign trade, Ricardo reiterates that “if in consequence of the diminished rate of production in the lands of England, from the increase of capital and population, wages should rise, and profits fall, it would not follow that

capital and population would necessarily move from England to Holland, or Spain, or Russia, where profits might be higher"[10] to then illustrate his theory of comparative advantage with a simple example.

> England may be so circumstanced, that to produce the cloth may require the labour of 100 men for one year; and if she attempted to make the wine, it might require the labour of 120 men for the same time. England would therefore find it her interest to import wine, and to purchase it by the exportation of cloth.
> To produce the wine in Portugal, might require only the labour of 80 men for one year, and to produce the cloth in the same country, might require the labour of 90 men for the same time. It would therefore be advantageous for her to export wine in exchange for cloth. This exchange might even take place, notwithstanding that the commodity imported by Portugal could be produced there with less labour than in England. Though she could make the cloth with the labour of 90 men, she would import it from a country where it required the labour of 100 men to produce it, because it would be advantageous to her rather to employ her capital in the production of wine, for which she would obtain more cloth from England, than she could produce by diverting a portion of her capital from the cultivation of vines to the manufacture of cloth.[11]

This same example is further elaborated in the accompanying Excel file, where we assume for convenience that the production of both cloth and wine is equal in physical units in both countries at the initial stage. Additionally, a profit rate of 20 percent in England is assumed, and 30 percent in Portugal. The wage per worker is assumed to be equal to 1 unit of gold in both countries.

Table 1 shows the results from the first worksheet of the Excel file *direct labour only (first).* The sheet shows a merchant recognizing the comparative advantages of England and Portugal in period 1, who in period 2 manages to increase English cloth production by 10 percent by withdrawing labour from wine production, while simultaneously reducing Portuguese textile production by 10 percent, allowing the labour no longer needed to be redeployed to additional wine production. This results in more wine becoming available than England and Portugal could have produced without mutual trade. However, the merchant will have to sell the quantity of cloth purchased in England in Portugal at a loss.[12], but this loss will be more than compensated by the profit he will make on the increased wine production.

Table 1 Merchant/trader exploits comparative advantages

	England				**Portugal**				**Both countries**			
	labour	production	price	export import	labour	production	price	export import	labour	production	price	comp adv
Period 1												
cloth	100	50	2.4	0	90	50	2.34	0	190	100	2.37	0
wine	120	50	2.88	0	80	50	2.08	0	200	100	2.48	0
Period 2												
cloth	110	55	2.4	5	81	45	2.34	-5	191	100	2.37	-0.526
wine	110	45.83	2.88	-4.17	89	55.62	2.085	5.625	199	101.46	2.44	1.9302
Period 3												
cloth	120	60	2.4	10	72	40	2.34	-10	192	100	2.38	-0.524
wine	100	41.67	2.88	-8.33	98	61.25	2.08	11.25	198	102.92	2.4	1.9124

The price per unit of cloth in England, after all, amounts to 2.4 (=(100*1.2)/50) units of gold, compared to 2.34 (=(90*1.3)/50)) in Portugal. Due to the more efficient production of cloth in Portugal, the price of production there is still lower than in England, despite the higher profit rate.

[10] *ib*., p. 134.
[11] *ib*., p. 135.
[12] According to the above-quoted price rule the merchant has to buy the less efficiently produced and therefore more costly English cloth.

So, when exporting 5 units of clothing from England to Portugal, the merchant's loss is -0.3 (=5*(2.4-2.34)) units of gold.

The production cost of a unit of wine in England is 2.88 (=(120*1.2/50)) units of gold, and in Portugal 2.08 (=(80*1.3)/50)) units. The profit on the wine to replace the 4.17 units lost in England is then 3.34 (=4.17*(2.88-2.08)) units of gold. In addition, there is a profit on the extra wine production of 1.455 (=5.625-4.17) units, with a sales value of 4.19 units of gold in England, or 3.03 units in Portugal.

In period 3, 10 workers are again withdrawn from wine production in England, allowing cloth production to expand by another 5 units. With the additional labour saved on cloth production in Portugal, wine production in Portugal increases further, and with it the merchant's profit.

The last column of Table 1 shows the comparative advantages. It is clear, however, that the export of less efficiently produced English cloth leads to an increase in the labour intensity of the total cloth produced by England and Portugal by approximately 0.5 percent per period. This negative effect, however, is more than offset by the decrease in the labour intensity of wine production. The resulting labour savings here amount to almost 2 percent per period.

Before I discuss how Ricardo draws conclusions from this example, I want to use the Excel file again to show exactly what the measurement of the comparative advantage of assumed mutual trade entails. This trade is assumed because trade itself plays no role in the measurement of comparative advantages. In a situation where there are no technical changes in production circumstances in any country, only the actual expansion of the production of a commodity in one country and the reduction of that commodity in another are considered. By examining the production of both countries together, it is determined whether the labour intensity of the total production of the commodity in question increases or decreases, or more precisely: the comparative advantage (disadvantage) indicates the extent to which the labour savings on total production increase (decrease). Nothing more, nothing less.

If technical changes do occur in one or both countries, these changes will also be reflected in the total production of the countries involved. To gain a clear understanding of pure comparative advantages, the overall picture must be corrected for technical changes in the individual countries. This correction mechanism is examined in the second worksheet of the Excel file *basic correction* and will be discussed in more detail in the next section. First, we return to Ricardo's example.

In addition to the comparative advantage of the wine industry in Portugal, Ricardo's example actually also shows a comparative advantage of the cloth industry there. Ricardo demonstrates that it is precisely the differences in potential comparative advantages that can lead to mutual trade. Although comparative advantages can only arise through mutual trade, it is important to point out that the proposed measurement can hardly reveal potential advantages, but only advantages that actually materialize through mutual trade. Only on the basis of actual production developments in individual countries it can become clear, by looking at the whole of countries, whether and to what extent comparative advantages are being utilised.

Ricardo sees international trade primarily as barter:

> If the trade were purely a trade of barter, it could only continue whilst England could make cloth so cheap as to obtain a greater quantity of wine with a given quantity of labour, by manufacturing cloth than by growing vines; and also whilst the industry of Portugal were attended by the reverse effects.[13]

He perhaps describes the effects of profitable trading even more clearly as follows:

> It is thus that the money of each country is apportioned to it in such quantities only as necessary to regulate a profitable trade of barter. England exported cloth in exchange for wine, because, by so doing, her industry was rendered more productive to her; she had more cloth and wine than if she had manufactured both for herself; and Portugal imported cloth and exported wine, because the industry of Portugal could be more beneficially employed for both countries in producing wine.[14]

This is precisely what the measurement of the comparative advantages of international trade reveals. Ricardo, however, does not address the question of where the additional wine production shown in Table 1 is consumed. This could be the country where the initiator of the trade, the merchant/trader, resides. In any case, this will be clear from the development of wine consumption recorded in the National Accounts of both countries linked to the input-output tables used.

In the last worksheet *direct labour only (second)*, the initiative for trade lies with the efficient wine producer in Portugal. He proposes to his English colleague: if you will send ten of your workers to make cloth, I will give you in exchange for those clothes (at least) the wine which you yourself were unable to produce. In this way he also tries to make his proposal attractive to the English wine producer. With the prospect of obtaining the clothes, he can divert labour from the cloth sector in Portugal to increase his wine production. The question now is how much the Portuguese wine producer will let the English share in the profits.

Table 2 The efficient wine producer takes the initiative

	England				**Portugal**				**Both countries**			
	labour	production	price	export import	labour	production	price	export import	labour	production	price	comp adv
Period 1												
cloth	100	50	2.4	0	90	50	2.34	0	190	100	2.37	0
wine	120	50	2.88	0	80	50	2.08	0	200	100	2.48	0
Period 2												
cloth	110	55	2.4	5	81	45	2.34	-5	191	100	2.37	-0.526
wine	110	45.83	2.88	-4.17	86.67	54.17	2.085	4.17	196.67	100	2.45	1.6667
research					2.33	2.33	1.3	0	2.33	2.33	1.3	
Period 3												
cloth	120	60	2.4	10	72	40	2.34	-10	192	100	2.38	-0.524
wine	100	41.67	2.88	-8.33	93.33	61.25	2.08	8.33	193.33	100	2.41	1.6949
research					4.678	4.678	1.3	0	4.67	4.67	1.3	

For England, the picture in Table 2 is no different from Table 1. The changes occur in Portugal. On the sale of wine to England, which is just enough to offset the reduced production in England, the Portuguese wine producer gains 3.34 units of gold. After deducting the loss on the clothing transaction, a profit of 3.04 units of gold remains. Of the 9 workers no longer needed in the Portuguese textile industry, he needs 6.67 to produce the minimum amount of wine he must supply to England. This makes it possible to use the profit of 3.04 units of gold to employ the freed-up 2.33 workers for his own account, or partly to further increase wine production so that the English wine producer could also share in the profits.

[13] *ib*., p. 137.
[14] *ib*., p. 140.

Table 2 clearly shows that, while the comparative advantages in table 2 are smaller than in table 1, the efficient wine producer in Portugal can free up labour through his trade agreement, which he can then use, if he do not allow the English wine producer to share in his profits, for example, to further improve his production techniques. An alternative, of course, is to use the freed-up labour to produce other goods that consumers actually want.

The hypothesis that presents itself here is that the comparative advantages of mutual trade might primarily benefit firms that produce more efficiently than their competitors abroad. This hypothesis will be further examined below once indirect labour is taken into account in addition to direct labour.

Here we refer again to the Excel file to show how innovation in period 3 leads to additional wine production in Portugal, which is entirely exported to England, where production falls and unemployment rises: for every one percent of additional production, this leads to a reduction in the number of workers at the English wine producer of 1.4.

How to separate comparative advantages from technical change?

When measuring comparative advantages resulting from mutual trade between two counties, it is evident that if production processes change in one or both countries, this technical change will also be reflected in the measurement of changes in production processes of both countries together. Therefore, it is important to have a mechanism that corrects for technical changes in the individual countries in order to obtain a true picture of only comparative advantages.

To find such a mechanism, the second set of worksheets of the accompanying Excel file *basic correction* compares England and Portugal without any form of mutual trade. First, sheet *basic correction (1)* examines the situation in which the figures for period 1 as shown in the first worksheet remain the same in subsequent periods, with this difference that England shows an increase in the labour productivity of the cloth industry in periods 2 and 3, while at the same time there is also a relative labour saving in the wine production of Portugal. The correction mechanism is then quite simple: the unadjusted technical change in the cloth industry of both countries in periods 2 and 3 is then reduced by the technical change observed in England after multiplying it by the production of the English cloth industry divided by the total production of the cloth industry. Similarly, the development of comparative advantages in the wine industry can be corrected for the technical change in Portuguese wine production. Because there is no mutual trade, the change in comparative advantages in both the cloth and wine industries is then equal to zero.

The situation becomes more complicated in case of a shift in labour in England from wine production to cloth production, as shown by the worksheet *basic correction (2)*. Although mutual trade is also assumed to be absent here, the shift in employment in England is nevertheless reflected in changes in the total production of England and Portugal: due to the increase in relatively inefficient cloth production, labour productivity falls by 0.25 percent in both countries, despite the absence of technical change, while the decrease in inefficient wine production in England leads to an increase in

labour productivity of almost 1 percent in both countries. In fact, these figures demonstrate potential comparative advantages that can be realized through mutual trade. Furthermore, this sheet primarily aims to demonstrate how the measurement of comparative advantages should be corrected if the expansion of employment in the English cloth industry is accompanied by a 5 percent increase in production in both periods 2 and 3. Without correction, labour productivity in the total cloth industry increases by approximately 2.5 percent, while after the slightly adjusted correction, it falls back to almost the original level. This is particularly true for period 3. In period 2, the adjusted correction of -0.35 percent causes a sharper decline in labour productivity than the original -0.25 percent decline measured before the assumed technical change. This suggests that the adjustment of the correction still needs some improvement. The adjustment is currently limited to the change in employment in the English clothing industry as a percentage of total employment in the clothing industry. In the next section, which also takes indirect labour into account, we will further investigate whether this adjustment can be improved.

The reader can optionally calculate any technical change in both the cloth and wine industries by filling in the appropriate green boxes in the worksheets *direct labour only*. For the total production of England and Portugal, the uncorrected calculation of technical change and comparative advantage combined will then appear. The automatic correction will then provide a good picture of the comparative advantage alone.

The worksheets also show that an assumed increase in labour productivity of two times 5 percent leads to English labour productivity in the cloth industry becoming virtually equal to Portuguese labour productivity (see the calculation in red in the worksheet). If the increase in England were limited to 1 percent per year, the difference with Portugal would still be large, as you can see by replacing the 5 percent in green with 1 percent. The next section will further discuss the relationship between comparative advantage and the ever-present technical change. Differences in technical change naturally influence the development of the comparative advantage of mutual trade over time.

Measuring comparative advantages: the case of direct and indirect labour

To illustrate the importance of mutual deliveries between firms at home and abroad, I would like to return to Ricardo and emphasize that mutual trade "will very powerfully contribute to increase the mass of commodities, and therefore the sum of enjoyments"[15]. The analysis of direct and indirect labour in the attached Excel file begins with an example in which the English machine industry supplies agricultural machinery to Poland, leading to higher agricultural production that facilitates higher population growth in both Poland and England. Table 3 shows the results, with labour productivity in the English machine industry clearly higher than in the Polish one, while the reverse is true for agriculture in both countries. With labour productivity remaining the same in both countries, the table demonstrates how the English specialization in machine construction and the Polish

[15] *ib*., p. 128.

specialization in agriculture leads to increased labour productivity when both countries are considered as a whole. This utilization of comparative advantages then results in labour savings in the machine industry of 7.3 percent in period 2 and 5.9 percent in period 3. Depending on the extent to which agriculture makes use of machinery, labour productivity there increases by 4,4 or 7,9 percent in period 2 and by 3,6 or 6,4 percent in period 3.

Table 3 Labour productivity of England and Poland together by shifting employment shares

period	England and Poland together		England				Poland			England and Poland together
	labour productivity		employment share		labour productivity		employment share		labour productivity	labour saving in % compared to previous period
	Average of sector A and B (machine industry)									
1	0.1417	=	60/120	*	0.2	+	60/120	*	0.0833	
2	0.1551	=	80/130	*	0.2	+	50/130	*	0.0833	7.3015
3	0.1667	=	100/140	*	0.2	+	40/140	*	0.0833	5.9080
	Average of sector D and E (agriculture)									
1	0.9083	=	60/120	*	0.7167	+	60/120	*	1.1	
2	0.9526	=	50/130	*	0.7167	+	80/130	*	1.1	4.4118 - 7.9265
3	0.9905	=	40/140	*	0.7167	+	100/140	*	1.1	3.6437 - 6.4061

The reader can see in the Excel file how comparative advantages are affected if he or she assumes a technical progress of, say, 1 percent for the English machinery industry and 3 percent for Polish agriculture. Especially in Ricardo's time, comparative advantages were largely determined by "the peculiar powers bestowed by nature"[16].

With the example in table 3, I hope to evoke memories of the time in which Ricardo lived. In this regard, I would like to refer to Toynbee, who so vividly described the industrial revolution in England[17], a development that is also so clearly reflected in Ricardo's *Principles*[18].

While the measurement of comparative advantage, whether combined with the measurement of technological change or not, could so clearly demonstrate the influence of natural forces at the time, this method of measurement is still able to show where and between which countries mutual trade enables more efficient production of commodities. The method can also help to examine other developments more closely, such as the practice whereby firms, often to achieve cost advantages, outsource parts of their production to countries with a lower average wage level. Does this outsourcing then lead to less efficient production? This question is central to the following Excel sheet, which shows that Germany initially produces more efficiently than Hungary on all fronts. In addition, it has been assumed that available labour is limited in both Germany and Hungary.

Excel sheet *Germany and Hungary*

Period 1 of this sheet represents the initial situation which is purely hypothetical and shows that the total demand in German industry for commodities produced by sector A exceeds the supply. To meet this demand, Germany have to import commodities produced by sector A from Hungary. Moreover, in period 1, Hungary produces more engines than it needs for its own car production. In this

[16] *ib*., p. 134.
[17] A. Toynbee, *Lectures on the Industrial Revolution in England*, Beacon Press, 1884.
[18] See *My History*, p. 3-9. These pages show the development described by Toynbee in parallel with the way Ricardo expresses the development in the successive editions of his *Principles*.

situation, a German car manufacturer, represented by sector C, decides in period 2 to relocate half of its engine production, represented by sector B, to Hungary by acquiring the engine factory there, partly for cost reasons, but also to be able to use the freed-up workforce in Germany for expanding his car production to 60.

The sheet shows that the German car manufacturer would then have to import 35 engines from his factory in Hungary. Maintaining production for the domestic market would require an increase there from 40 to 55 engines. To facilitate this production increase, the workforce in sector A is assumed to be reduced from 25 to 20, while the remaining required additional workers are drawn from sector C. Due to all these changes in production circumstances, Germany no longer needs to import commodities from sector A but can instead fill the shortage arising in Hungary.

When measuring comparative advantage and technological change, we see that in both countries there is no technological change in the production processes used between periods 1 and 2. However, a comparative advantage does emerge in sector A: as a result of the expansion of production in the efficient German sector and the contraction in the Hungarian sector, the labour required for the production of one commodity A in Germany and Hungary together decreases by 2.2 percent. Because the commodities of sector A are also used in sectors D and E, a comparative advantage also exists there.

The comparative advantage associated with the use of product A in sectors B and C is offset by the comparative disadvantage created by the expansion of less efficient engine production in Hungary, which in sector B for both countries leads to a net increase in labour required for the production of one engine by 6.6 percent. Because engines also constitute input for car production, the total direct and indirect labour required for the production of one car in sector C also increases by a net 0.8 percent.

In period 3, the German car manufacturer achieved its initial objective of raising the quality of engine production in Hungary to German levels as quickly as possible. At the same time, the company limited its own engine production to five engines, freeing up a workforce to further increase car production. Ultimately, this outsourcing, which reduced its own engine production by 90 percent, allowed the German car manufacturer to increase car production from 50 to 70 vehicles, a 44 percent increase, without the need for any additional technical change. In period 3, sector A's production remains just sufficient to meet the increasing demand from sectors B and C.

The technical improvement in engine production in Hungary leads to labour savings per engine of no less than 24.4 percent. This labour savings also indirectly results in labour savings of 10.5 percent in car production in Hungary. In Germany, there are no labour savings at all in the production techniques used. However, the outsourcing initiated by Germany is reflected in significant comparative advantages for Germany and Hungary together: 18.8 percent in the engine industry and 9.8 percent in the car industry. Although the advantage in the engine industry remains small after adjusting for the technical change in Hungary, this does not apply to the car industry: here, the comparative advantage remains at 7.8 percent after adjusting for the technical change in Hungary. These differences are related to the concentration of engine production in Hungary, while the reverse holds, however less pronounced, for the car production of both countries.

The extent to which this example reflects actual developments in Germany and Hungary over a longer period of time will only become clear when the input-output tables needed to measure comparative advantage and technological change are available for both countries. Then we can see precisely what actually happened from year to year.

Excel sheet *Oligopolistic competition*

In this worksheet, we first examine the overview of the comparative advantages and technical change of two countries together, country 1 and country 2, without even looking at the required input-output tables of the individual countries. From period 1 to period 2, the overview shows a comparative advantage of 2.5 percent for sector B: this means that the total production of both countries in sector B has become more efficient, meaning that on average, 2.5 percent less direct and/or indirect labour is required per unit of output in sector B. In period 3, sector B has an additional comparative advantage of 1.5 percent.

Because the overview also shows that there have been no technical changes in sector B in either country, we must examine the individual country's input-output tables to determine which country host the efficient sector. There are three possibilities:

- The efficient sector B has increased in one of the countries.
- The less efficient sector has decreased in one of the countries.
- The efficient sector has increased in one country while the less efficient sector in the other country has decreased.

The last case appears to be a case of oligopolistic competition, with the more efficient sector expanding output to increase its market share at the expense of less efficient competitors abroad.

It is important to note that if there were no change in production, so that the efficient and less efficient parts of sector B produced the same amount from period to period, the measurement of comparative advantages would not detect any exploitation of those advantages. In the measurement proposed here, comparative advantages can only become visible if they are actually being utilized.

It is also important to note that if you want to determine whether there are comparative advantages between two countries, you need more information. The proposed measurement method in no way reflects the actual trade relations between the two countries. In principle, it is possible to compare countries that have no connection whatsoever. Indeed, you need information demonstrating that both countries are closely linked. To determine whether there is actually oligopolistic competition, the import and export tables of the countries involved can provide clarity. But price developments also provide clarity if they are causing the profits of less efficient sectors to be eroded. As soon as the input-output tables necessary for measuring comparative advantage and technical change become available, we will also gain insight into actual price developments. The prices shown in the Excel sheet *Oligopolistic competition* are meaningless. A characteristic of the “twofold valuation method” is that, while prices are needed to determine the underlying changes in labour requirements, these underlying changes would remain unchanged if the price structure were completely different. The twofold valuation essentially filters prices out of the measurement[19].

[19]You can see this for yourself by randomly changing the prices in the Excel file. However, the prices must be chosen ‘realistically’ so that the valuation method avoids division by zero. This can happen if the sales revenue of a sector becomes equal to the purchased supplies. For more information about the twofold valuation method see also *Reappraisa*l, p.11.

So, looking at the input-output tables for the individual countries in the Excel file, we see that sector B in country 1 produces more efficiently than in country 2, and that the efficient sector B expands its output in period 2 at the expense of the less efficient sector in country 2. In that country, employment in sector B falls from 50 to 37.5 in period 2, while in country 1 it rises from 50 to 60. To curb rising unemployment, country 2 invests in sector D in period 2 to make sectors D and E more productive in period 3. But costs precede earnings: on balance, the labour required per unit of output in sector D increases by 12 percent in period 2, followed by a decrease of 16.7 percent in period 3. The labour required per unit of output in sector E also decreases in country 2, from 1.25 (=50/40) in period 2 to 1.09 (=60/55) in period 3. Since the labour required per unit of output in sector E in country 1 remains unchanged at 1.25, sector E in country 2 can expand its production and force its competitor in country 1 to reduce its production from 40 to 35.5 through oligopolistic competition. However, employment in country 1 remains unchanged because sector B continues to force sector B in country 2 to reduce production, so that employment in this sector falls from 37.5 in period 2 to 30 in period 3. On balance, unemployment in country 2 falls from 4.75 percent in period 2 to 3.5 percent in period 3.

Excel sheet *EU and China*

The car industry remains a valuable subject of study. In the final two worksheets, we assume that the German traditional car industry, as representative of the European Union, initially produces more efficiently than China, but that China subsequently catches up in electric car production and, thanks to efficient battery production, start to produce more cars than the EU.

The first three sectors are suppliers to the car industry, with sector A supplying steel, sector B engines, and sector C electronics, including batteries. The supplying sectors also supply each other. The remaining two sectors produce cars: sector D, traditional gasoline-powered cars, and sector E electric cars.

The initial situation for period 1 in the Excel sheet *EU and China* shows that the traditional car industry in the EU is more efficient than in China. This also applies to the required engines. In contrast, battery production in China is significantly more efficient than in the EU, thanks to the availability of necessary raw materials there. The production process for electric cars in China is comparable to that in the EU, although the volume of batteries in China is larger. Steel production is initially equally efficient in both countries.

In period 2, German industry produces more traditional cars at the expense of production in China. China uses the freed-up labour to significantly expand electric car production, but also at the expense of production in the EU.

The first column of Table 4 shows that the traditional car industry, and in particular battery production, has a comparative advantage in period 2 due to the increasing production of traditional cars in the EU and electric cars in China. However, the engine industry faces a comparative disadvantage because inefficient engine production is increasing in China, while it is declining in the EU. The production of electric cars also appears to have a comparative disadvantage: this is related to the increasing supply of the inefficient engine industry which is insufficiently compensated by the comparative advantage of the battery industry which provides only little more than 20 percent of employment in sectors B, C and E combined. The expansion and contraction in both sectors of the car

industry continues in period 3, with similar comparative advantages, which are slightly lower across the board due to shifting employment, although this is not visible everywhere due to the rounding applied.

Table 4 Comparative (dis)advantages of the car industry in EU and China together in successive scenarios

Sector	Initial situation	Chinese sector A requires 50 percent more labour	China begins purchasing all additional engines from the EU in period 2	EU buys batteries from China for 5 cars in period 3
Period 2				
A	**0**	**-0.33**	**-0.05**	**-0.05**
B	**-0.71**	**-0.77**	**0.06**	**0.06**
C	**2.65**	**2.65**	**2.79**	**2.79**
D	**0.44**	**0.39**	**0.65**	**0.65**
E	**-0.14**	**-0.19**	**0.01**	**0.01**
Period 3				
A	**0**	**-0.33**	**-0.05**	**0.35**
B	**-0.69**	**-0.76**	**0.06**	**0.42**
C	**2.58**	**2.58**	**2.71**	**3.05**
D	**0.44**	**0.39**	**0.65**	**0.83**
E	**-0.14**	**-0.19**	**0.01**	**0.38**

Column 2 shows the same development as column 1, with the difference that steel production in China requires 50 percent more labour. The net increase in demand for steel in China creates a comparative disadvantage for the EU and China together, which is also reflected in a growing disadvantage for engine and electric car production.

The perceived comparative disadvantages largely disappear if the growing demand for engines in China were entirely met by the engine industry in Europe, as shown in the third column. And Europe and China would benefit even more from their comparative advantages if electric car production in Europe were to source batteries from China: column 4 shows the effect of a 16.6 percent production increase in period 3.

The last worksheet *EU and China (trial)* shows the initial situation. You can customize this sheet to your liking.

Some concluding remarks

To determine whether a sector produces efficiently, we need two countries. The input-output tables required to determine technical changes within a country cannot be used to draw conclusions about the efficiency of the sectors distinguished in the tables. Only changes in the extent to which the sectors use direct and indirect labour become visible. Therefore, we cannot determine, for example, whether the traditional production of cars using fossil fuels in the EU is more efficient than the production of electric vehicles. This will only be possible if we distinguish between two countries within the EU, each with the required input-output tables, such as France and Germany. A production change in the traditional car industry in Germany can then be used to determine whether or not this industry produces more efficiently than its competitor in France. This is expressed in a comparative advantage by adding both countries together. Of course, we can also look at the efficiency of the entire car industry in both countries. If the necessary input-output tables are available per substate or province, those areas can also be assessed for the presence of efficient industries.

As previously indicated, the twofold valuation method allows us to determine precisely, based on actual market prices — the rates at which produced commodities are exchanged — whether more or less direct and indirect labour was required for the production of these commodities. Although observed prices are used, these prices are, as it were, averaged out in the final determination of technical changes in production processes. Similarly, any government subsidies to encourage consumers to purchase electric cars are also irrelevant to the question of whether these cars are produced efficiently. However, these subsidies can ensure that increased demand pushes production to a level where it can compete effectively.

I also would like to refer to my closing remarks in *My History*. At the end of that article, I reflect on the need to build a bridge "to a truly sustainable economy that should ideally encompass the entire world"[20]. Although individual countries each have considerable freedom on the path to sustainable consumption, for example, by determining that at some point in the future only new cars that do not use fossil fuels may be sold, it remains important that the steel required for new electric vehicles that are permitted is also produced in a sustainable manner. When determining how the global steel market can evolve towards sustainable steel production in the most orderly and efficient way possible, the methodology described here can be useful in examining the effectiveness of different options once they are implemented as pilot projects. In that case, provisional input-output tables that do not extend beyond the steel pilots involved can be compared with each other in terms of efficiency.

When it comes to the efficiency of electric car production in the EU and China, taking into account all actual inputs, only the input-output tables required for measuring comparative advantages and technical changes can determine where production is most efficient. And, again, the most efficient production is determined solely by the technical production conditions under which the required direct and indirect labour is performed. The measurement of comparative advantages lets the facts speak for themselves.

[20] *My History*, p. 38.