A Critique of the Leontief Paradox.

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The exploitation of comparative advantage is one of the central tenets of classical trade theory. When Leontief found evidence of a lack of applicability to the real world, a flurry of research was begun to explain these results. Diarmaid Smyth discusses the apparent paradox and explains how the gap between theory and practice was eventually bridged.

Introduction

The Heckscher-Ohlin (H-O) theorem is one of the most celebrated theorems of International economics. According to the theorem, countries will tend to have a comparative advantage (CA) in the production of those goods that make intensive use of their abundant factor of production. Therefore, a nation will seek to export those goods that use its abundant factor relatively intensively in return for imports of those goods that use its scarce factor relatively intensively. In 1953, Wassily Leontief, using an input-output matrix, sought to test the validity of the theorem with respect to American trade in 1947. At the time, US workers visibly worked with more capital per capita than all other nations, so in accordance with the theorem it was predicted that the US would have a CA in the production of capital intensive goods and should, therefore, export these. However, Leontief's startling results cast huge doubt on the H-O theorem as US imports were found to be more capital intensive than its exports. This famous conclusion was labelled as the Leontief paradox.

The purpose of this paper is to explain why, in fact, the paradox occurred, by primarily focusing on what are known as the natural resource and human capital explanations before going on to discuss the critical importance and modern day relevance of the factor content of trade approach.

The Paradox

As has been mentioned, Leontief's 1953 report on US trade patterns revealed that US exports were less capital intensive than its imports. Table 1 shows Leontief's actual figures, whereby the capital to labour ratio employed in the production of $1m of US imports was 1.3 times as large as the corresponding ratio used in the production of $1m worth of US exports.

Table 1. United States trade - Empirical Investigations.
Capital and labour requirements per million dollars of United States exports and import substitutes:

Leontief:	1947 US Trade	Exports	Imports	Imports/exports
	Capital	$2,550,780	$3,091,339	
	Labour (man-years)	182	170	
	Capital per man	$14,010	$18,180	**1.30**
	1951 US Trade			
	Capital	$2,256,800	$2,363,400	
	Labour (man-years)	174	168	
	Capital per man	$12,977	$13,726	**1.06**
Baldwin:	1962 US Trade			
	Capital	$1,876,000	$2,132,000	
	Labour (man-years)	131	119	
	Capital per man	$14,200	$18,000	**1.27**

Sources: Baldwin (1971) & Leontief (1953).

Leontief's initial result was further reinforced by subsequent studies of US trade in 1951 and 1962. Furthermore, studies examining Canadian, Japanese and Indian trade also revealed the existence of the paradox. For example, Bharadwaj's survey of Indian trade showed how Indian exports to the US were capital intensive despite the overwhelming abundance of labour in India. Even as recently as 1990, the massive gulf between the capital labour ratios in America and India still existed. Thus arguments in defence of the factor proportions theorem on the grounds that Leontief's data was unrepresentative do not hold any weight in light of these subsequent findings. Therefore, how can we account for the existence of the paradox ?

Leontief's results led to a wealth of empirical testing and research, as economists sought some answers to the paradox. A number of theoretical but ultimately fallacious arguments emerged. For example it was argued that demand reversals could have caused the paradox whereby US consumers' tastes might have been overly biased in favour of capital intensive goods, and consequently US imports would have been more capital intensive than US exports. However there is a complete lack of evidence behind such an argument and if anything US consumers had a stronger preference for labour intensive goods. Similarly, the factor intensity reversal explanation of the paradox holds little or no weight, in the sense that although a reversal can exist, it is highly unlikely that factor intensity

reversals could fully account for the paradox. Finally, although Heckscher-Ohlin assumed free trade, it has been argued that because the US economy was so heavily protected in 1947, that this may have caused foreign producers to export capital rather than labour intensive goods to the US. However such an argument has also proved to be wholly inadequate and it in fact defies logic upon closer examination.

Thus, I will seek to explain Leontief's results by referring to what are known as the human capital and natural resource explanations, which are basic extensions to the H-O model. These approaches will show how Leontief's two factor test (homogeneous labour and physical capital) of the theorem was in fact too aggregative and over simplified to such an extent that it obscured many underlying trends.

Natural Resources

A glaring omission from Leontief's two factor test of US trade in 1947 were natural resources (NR)s. Thus, subsequent tests sought to take account of NRs and their importance in determining a country's CA and hence their trade patterns. Jaroslav Vanek (1959), was perhaps the leading pioneer of the NR approach. Vanek sought to investigate the NR content of US trade and discovered that the US had become increasingly reliant upon the imports of NR intensive products from less developed countries and Canada in particular. As recently as 1992, the US imported $12.2 billion worth of fuels from Canada while exporting a modest $1.3 billion in return (Table 3). In addition, Vanek argued that physical capital and natural resources were complementary inputs in production, "we can observe a strong degree of complementarity between capital and natural resource requirements."[1] In other words, the extraction and transportation of NR products, such as coal and petroleum, required a very large capital investment, and the use of highly capital intensive techniques. As a result, America was indirectly importing capital intensive products because of her reliance on NR imports. As Vanek concluded ". . . it may well be that capital is actually a relatively abundant factor in the United States. Yet relatively less of its productive services is exported than would be needed for replacing our imports, because resources, which are our scarce factor, can enter productive processes only in conjunction with large amounts of capital"[2]

The importance of natural resources in US trade was further confirmed by Baldwin (1971), in his examination of the factor requirements of US exports and imports for 1962. Using the simple two factor Leontief test, the paradox still existed, with a higher net capital to labour ratio for imports than exports.

[1] Vanek, J., p152, 1959.
[2] Ibid.

Baldwin, however, taking account of the heavy degree of complementarity between NR products and capital in production, excluded NRs from the data and found that the paradox virtually disappeared, as the import/export ratio fell from 1.27 to a mere 1.04.

Table 2. International trade between the United States and Canada.
Canada's International trade, 1992 (billions of US dollars).

	Exports to the US	Imports from the US
Fuels	12.2	1.3
Other primary goods	4.9	2.3
Agriculture	12.1	6.1

Source: Ethier (1995) Modern International Economics, page 38.

Thus studies such as Vanek's and Baldwin's brought home graphically the significance of NRs in US trade and that it is why it is argued that Leontief's simple test which excluded NRs oversimplified matters to an unacceptable level. Some economists such as Hartigan (1981) have gone so far as to say that when NR intensive industries are excluded from empirical tests, a paradox rarely exists. However Baldwin' s extensive study of US trade showed that although in themselves significant, NRs were insufficient to fully account for the paradox. As a result, further explanations are required.

Human Capital

As all economists will testify, labour is far from a homogenous factor and in reality labour skills, educational standards, training programs etc., differ markedly both across and within nations. Countries and particularly wealthier nations invest vast amounts not only in physical capital but also in human capital. However, Leontief's measure of capital failed to take account of this. Therefore, several economists, such as Kenen (1965), Keesing (1966) and Baldwin (1971) recognised that it was essential that one took into account the differing skill levels of labour, or more generally, human capital. It was hypothesised that because America's labour force was so highly educated that the US should export skilled labour intensive products.

Kenen (1965), remarked on the enormous magnitude of sums spent in the US every year in training and educating the labour force and that such investments had outpaced investment in physical capital.[3] By 1957, measured investment in labour was valued at $880 billion or two-thirds as large as physical capital. Kenen obtained a measure of human capital and found that by adding this to physical capital, that the paradox was reversed. In other words, America was found to be

[3] Kenen, P., p441, 1991

abundant in skilled labour and consequently exported skilled labour intensive products, very much along H-O lines.

Keesing (1966), adopted a similar approach, dividing the labour force into eight distinct categories according to skill levels. The highest skill category was category one which consisted of scientists and engineers, whereas the other end of the scale, category eight, consisted of unskilled and semi-skilled labour. Keesing then examined the composition of these labour skills in export and import competing industries. He discovered that "The United States ... has the most skill-intensive exports and, generally, shows signs of having the greatest abundance of hard-to-acquire skills, notably professionals, and especially scientists and engineers."[4]

Thus, Americans CA arose in those industries that required a high proportion of professional labour and a low proportion of unskilled and semi-skilled labour. As Keesing noted "... in 1962 the United States exported manufactures (in forty-six industries) worth $14, 219 million and imported manufactures worth $8, 067 million. ... 34, 430 scientists and engineers were required to produce the commodities exported compared to 9, 762 who would have been required to replace the imports. This leaves a net balance of 24, 668."[5] Thus, Keesing's work explicitly demonstrated the inappropriateness of Leontief's two factor test.

Baldwin's (1971) exhaustive study of US trade in 1962, confirmed that the paradox still existed using a two factor (capital & labour) test, showing how the net capital to labour ratio was higher for imports than exports. However, when one accounted for natural resources and human capital, the paradox succumbed, as the import - export ratio fell to 0.97. In accordance with Keesing's conclusions, the US was found to be exporting highly skilled intensive produce, and what is more, US exports were also discovered to embody a much higher proportion of labour with nine years or more education, whereas in contrast, import competing industries had a higher proportion of labour with eight years or less of education.

Baldwin noted that "the relatively abundant supply of engineers and scientists is an important source of the United States' comparative advantage position, ... This abundance of highly trained labour gives the United States an export advantage, in products requiring relatively large amounts of such labour."[6]

Even as recently as 1980, evidence showed that the US still maintained quite a significant CA with respect to the export of skilled and technology intensive

[4] Keesing, D., p254, 1966.
[5] Ibid.
[6] Baldwin, R., p142, 1971.

products. In fact Table 3 (a & b), reveals that the US had 50.7% of the world's supply of research & development scientists and 27.7% of skilled labour.

Table 3 Part (a):
Factor Endowments of the leading industrial countries, as a percentage of the world total in 1980.

Country	Physical Capital	R&D Scientists	Skilled Labour	Semi-skilled Labour	Unskilled Labour
US	33.6%	50.7%	27.7%	0.19%	19.1%
Japan	15.5	23.0	8.7	0.25	11.5
W. Germany	7.7	10.0	6.9	0.08	5.5
France	7.5	6.0	6.0	0.06	3.9
UK	4.5	8.5	5.1	0.09	4.9
Canada	3.9	1.8	2.9	0.03	2.1
The rest	27.3	0.0	42.7	99.32	53.0
	100.0	100.0	100.0	100.0	100.0

Part (b):
Export / Import Ratios in the Leading Industrial Countries in 1979.

Product	US	Japan	W. Germany	France	The UK	Canada
Tech. Intensive	1.52	5.67	2.40	1.38	1.39	0.77
Services	1.47	0.73	0.80	1.32	1.19	0.50
Standardised	0.39	1.09	0.84	1.03	0.76	1.38
Labour intensive	0.38	1.04	0.59	0.86	0.71	0.20
Primary products	0.55	0.04	0.29	0.52	0.81	2.21

Source: International trade theory, pages 118 & 124.
Note: An export / import ratio above one, indicates that the country is a net exporter of the product, i.e. the country has a comparative advantage in production.

Baldwin's results reaffirmed a belief in the H-O model as America was shown to "....indirectly export professional and technical labour as well as skilled craftsmen and foremen which were in relatively abundant supply" and to ". . . indirectly import semi-skilled and unskilled (non-farm) labour, both of whom are usually considered to be comparatively scarce in the United States."[7]

[7] Baldwin, R., p143, 1971.

In summary, Keesing, Vanek, and Baldwin's findings were consistent with a multi-factor application of the H-O theorem (as the paradox was reversed). These economists showed that it was vitally important to extend the two factor model as Baldwin concluded " . . the labour force must be divided into various skill groups and the notion of relative differences in human capital taken into account."[8] As a result we tend now to treat different types of labour as distinct factors.

However, the problem with approaches such as that of Keesings, was that as (developed) countries become more and more alike, both in terms of factor endowments, technology and tastes, simply dividing labour into eight distinct categories may well prove insufficient, in terms of identifying where a comparative advantage or disadvantage lies. Webster (1993) noted that such approaches tend to "... ignore the possibility that international differences in endowments of specific types of skill may also be a cause of international specialisation. This is particularly likely where, as in the case of the UK, much trade is conducted with economies with broadly similar endowments of human capital in general."[9] In other words, Webster is stressing the need for a factor content approach to trade.

The Factor Content Approach.

The factor content approach (FCA) to international trade is the most modern and recent application of the factor proportions theory and is referred to as the Heckscher-Ohlin-Vanek theorem. This states that the relative factor abundance of a country is revealed through the factor services embodied in a country's trade flows, i.e. if a particular nation is found to be in relative abundant supply of a factor service, its trade flows will reflect the net export of that particular factor's service. Thus the FCA provides a measure of each nations excess endowment of each factor. As Webster remarks regarding UK trade: "...assessing the extent to which the UK specialises in industries intensive in particular types of skills is a way of revealing where the UK is in relatively scarce or abundant supply of a particular skill."[10] This means that countries will not just simply specialise because of a relative abundance of human capital but that they will tend to specialise according to specific types and forms of human capital. According to Webster, "The primary pattern of specialisation tends to be with respect to broad levels of human capital (for example professional labour) but there is also considerable evidence of specialisation according to certain specific skills."[11].

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[8] Ibid.
[9] Webster, A., p143, 1993.
[10] Ibid.
[11] Webster, A., p156, 1993.

Webster applied the FCA to UK net exports in 1984, emphasising human capital. He compared and contrasted a more traditional approach (such as that of Keesings), using five categories of labour, with an FCA, where he decomposed labour into thirty-five different occupational categories. Using the latter approach, Webster noted that the UK was relatively well endowed with professional, managerial, clerical, sales and service labour, whereas (skilled and unskilled) manual labour was revealed to be relatively scarce. However, the FCA provided a far more specific, detailed, and precise analysis of the UK's comparative advantage.

Webster's FCA decomposed professional labour, for example, into occupations such as lawyers, accountants, engineers, economists etc. It quickly became evident that the UK's relative abundance in professional skills were not nearly as marked, as a more traditional approach would have indicated.

Although the UK still had a CA in the export of the services of non manual and professional labour, the FCA revealed that there was considerable variation and heterogeneity within each occupational group. Thus, by use of a more aggregative approach, one could easily have concluded that the UK was a net exporter of skilled labour, while ignoring the stark reality, as the FCA revealed, that the UK is actually quite a heavy net importer of the services of a number of skilled occupations such as those of economists, statisticians, and both electronic and mechanical engineers (to name but a few). As Webster reports "The dis-aggregated analysis reveals many professional skills that are apparently relatively scarce in the UK compared to almost all other types of labour."[12]

Economists aim to be as scientific as is possible and by use of more dis-aggregated analysis such as the FCA, we can quickly highlight, precisely where a country's comparative advantage or disadvantage lies. Thus the FCA is a major addition to the international economist's armoury.

Conclusion.

The Leontief paradox has been referred to as much-ado-about nothing and undoubtedly a more dis-aggregated or a multi-factor application of the H-O model does eliminate the controversy that surrounded Leontief's celebrated 1953 results. Nevertheless, the paradox was an important milestone in economics, in the sense that it led to a flurry of activity and research among economists into the actual determinants of comparative advantage and trade. Four decades on from Leontief's unorthodox conclusions, we are left with a much better understanding of how trade patterns emerge and evolve.

[12] Ibid.

In addition, the paradox has been very influential in that it inspired and led to the search for newer trade theories. Consequently, one of the major recent developments has been the application of imperfectly competitive models of competition to international trade. As a result, economists have become aware of the modern day significance of intra-industry trade (I-I-T) and economies of scale in determining a nations trading patterns. I-I-T is a particularly significant phenomenon, roughly accounting for one-quarter of world trade, and is also extremely important in a European context (especially trade in manufactures).

Some of the more recent trade theories continue to emphasise the importance of expenditures on research and development, as a source of CA, and therefore, for example, nations such as Japan and America with their abundant supply of scientists and engineers continue to be heavy net exporters of high technology goods and services. Clearly this is consistent with a modern day application of H-O. However, I-I-T does not reflect the simple H-O comparative advantage at all, and what is more, increasing returns and monopolistic competition in particular have a lot of modern day relevance. Consequently the patterns of trade that emerge can be quite unpredictable and often the result of history, accident, and good fortune.

To conclude, although the Leontief paradox is to all intents and purposes a closed book, it has been extremely influential in the sense that it was the catalyst that lay behind the development of newer and revamped theories of international trade.

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