Measures of competitiveness in international trade

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Summary

Competitiveness may be defined as the advantage in price, speed of delivery, design, etc., which enables a company or country to secure sales at the expense of its competitors. This article concentrates on price-competitiveness, in manufactured goods, between countries. In particular, it discusses which measure of trade-competitiveness can best help to explain changes in the volume of UK exports and imports; this is a topic of considerable interest at present because in recent years the various different measures of UK competitiveness have followed very different paths.

Probably the most common way to measure this country's international competitiveness is to compare the prices of UK exports relative to those of other countries. Other measures are: consumer prices in this country relative to those abroad; various measures of relative unit labour costs; and the ratio of import prices to UK wholesale prices. All the measures show an improvement in UK competitiveness in 1976 when sterling depreciated sharply, and nearly all some deterioration in competitiveness in 1977. This article argues that the appropriateness of each of the various measures depends mainly on the type of market which is involved. It also stresses that all the measures are subject to drawbacks or defects of one kind or another — partly because of the statistical difficulties involved in compiling them.

It is not possible, on *a priori* grounds alone, to choose which of the various measures best explains movements in UK trade. The explanatory power of various measures of competitiveness can, however, be tested econometrically, by putting them in equations incorporating the major factors influencing the volume of trade, and seeing how far they improve the explanation of past trends. In the light of such tests, the conclusion of this article is that indices of relative unit labour costs performed best at explaining movements in exports; for imports, there was less difference between the various measures. As in other studies, fairly long lags (up to four years) were found between changes in competitiveness and changes in export volume; for imports, the lags appeared to be much shorter (less than a year).

Introduction

As stated above, this article is concerned with the United Kingdom's international competitiveness in trade in manufactured goods. While elements of non-price-competitiveness, such as salesmanship, promptness and reliability of delivery, and after-sales service, undoubtedly have an important effect on the volume of trade, this article concentrates on price and cost-competitiveness.[1] Such competitiveness is in practice very difficult to measure.

The article starts by setting out the various conceptual and statistical problems associated with various measures of price or cost-competitiveness. It then sets out the main measures of competitiveness in detail and examines the movement of various measures over time. The article then describes the results of testing the measures econometrically and draws some conclusions. A list and definition of all the measures considered is given in Appendix 1. Appendices 2 and 3 set out technical details of the econometric tests.

[1] It has been argued that increased cost-competitiveness, and hence higher profitability, will of itself cause improved non-price-competitiveness through inducing greater sales efforts, prompter delivery, better after-sales service and so on. If so, non-price-competitiveness is implicitly also discussed in this article.

Prices or costs: some conceptual considerations

The appropriate measure of competitiveness depends on the nature of the market, i.e. the type of competition which predominates.[1] In practice, conditions are likely to be mixed, but for clarity it is convenient to set out the theoretical possibilities. For exports, there are several possibilities.

(a) UK exporters may sell goods which are effectively identical to those made in other countries, and supply only a small proportion of the market; since in these markets the United Kingdom supplies only a small proportion of world output, any action by UK producers will have only a negligible impact on the price of goods in these markets; UK producers therefore face a 'world' price for these goods. They cannot price their products much above this world price (since buyers would immediately turn to producers still selling at the world price) and they would not choose to price their products much below the world price (since they can sell any amount that they supply, within their limited capacity, at this world price).

(b) UK exporters may sell in markets dominated by a few large producers, in which there are strong inhibitions about changing prices (whether upwards or downwards). Exporters in such oligopolistic markets will face a 'kinked' demand curve for their products, i.e. price *decreases* will not increase the volume of sales much, since they will be matched by other producers — inelastic demand — whereas price *increases,* which other producers would not be expected to follow, will cause a precipitate decline in sales.

(c) UK exports may be sufficiently different from products of other countries to vary from them in price, but sufficiently similar for the price to affect the volume of sales; i.e. markets in which they are sold are imperfectly competitive, and exporters will face a smoothly downward-sloping demand curve.[2]

(d) UK exporters may be part of an international cartel which shares out market volume, perhaps on the basis of historic market shares or perhaps, in the context of multinational companies, on the basis of relative costs. This is a variant of type (b).

(e) The UK exporter may be a monopoly or near-monopoly supplier. The world demand curve for the product is downward-sloping. This is a variant of type (c). [3]

From this classification some important conclusions follow as to the appropriate way of measuring competitiveness. Most frequently export prices in this country have been compared with those in competitor countries. However, only if international markets are characterised by imperfect competition [as defined in case (c)] can relative export price data be expected to shed light on trade performance.

For other markets, the prices at which UK exporters sell in relation to the prices at which other countries export will give little indication as to how much will be sold, and so will reveal little or nothing about competitiveness. Changes in this price relationship might well occur but have very limited implications for the United Kingdom's performance. For example, the relationship could change temporarily after a change in exchange rates, while contracts invoiced in the depreciating currency are worked off; or the relationship may change because of the effect of changes in the composition of trade which this index also picks up.[4]

[1] This article discusses competitiveness indices in the context of differing market structures. An alternative approach would be to highlight the diferent responses of traders to changes in costs, depending upon whether or not their firms are already operating at full capacity.

[2] In these markets, every time the price is lowered more of the goods will be demanded; if the price is raised, less goods will be demanded. The demand curve shows how much will be demanded at any given price. If a price reduction leads to so great an increase in sales that total revenue is increased, the demand curve is considered elastic; if sales increase only to such an extent that total revenue has fallen, the demand curve is inelastic. In markets described in type (a) above, the demand curve is infinitely elastic.

[3] The above description of market structures is not totally exhaustive. In particular it does not include non-profit-maximising strategies such as cost-plus pricing. Cost-plus pricing could probably best be considered a variant of case (c).

[4] See the next section.

On the import side it is generally agreed that, for most categories of goods, the price of imports into this country is set by world market conditions. It is then necessary to examine the market structure under which domestic firms producing import-substitutes operate. If the producers of import-substitutes are producing goods which are effectively identical to the imports, and therefore adjust their prices fully to the world price of their goods, then relative prices (i.e. the price of imports relative to a price index of domestically-produced goods) can tell us nothing about competitiveness. If import-substitutes are somewhat different from imports [analogous to case (c) on the export side] then such a relative price index will be the appropriate measure of competitiveness. In all other cases this type of relationship will tell us little about competitiveness.

Given the above considerations, an alternative approach needs to be tested, namely that some measure of the *profitability*, or relative *cost*, of exporting or producing import-substitutes should be examined.

Probably some goods are sold in each type of market.[1] Thus there is a reasonable presumption that different measures of price-competitiveness will best explain different categories of exports and imports; or that (since it is difficult to divide exports and imports according to the market structure under which they are sold) a measure should be sought which is appropriate under the different market structures; or that a combination of measures of competitiveness might best explain manufactured exports and imports as a whole.

Measures of competitiveness: relative export prices of manufactured goods

Perhaps the most widely used measure of UK competitiveness is export prices relative to a weighted average of competitors' export prices. Where exporters face a downward-sloping demand curve for their products, the quantity demanded will depend partly on their price in relation to that of substitute products.

There are, however, a number of problems with this measure. For example, 'price' is perhaps a misnomer. The indices available are not compiled from the separate prices of all manufactured goods exported, or of a fixed sample of goods, but from indices of unit value, which involves some averaging within trade categories. [2] Indices of unit value (and so competitiveness on this measure) not only change with changes in prices, they also change with changes in the composition of trade. The degree of distortion which this involves cannot be known. Moreover, the unit value indices cover trade in semi-manufactured, as well as finished, goods. Certain categories of semi-manufactured goods are almost raw commodities, with very little value added in manufacture, though UK exports of goods in this category appear in aggregate to be at a more advanced stage of manufacture than UK imports of them.[3] If competitor countries export semi-manufactured goods with different value added in manufacture per unit from semi-manufactured goods exported by the United Kingdom, this measure of export-competitiveness may reflect some movement in commodity prices, which it would be preferable to exclude.

A further reservation about this index is that unit values are a proxy for the price of export goods as they pass through customs. Such data do not take account of unsuccessful tenders, and thus only reflect trade that actually takes place, rather than the underlying competitive conditions. Moreover, in so far as trade is between different branches or subsidiaries

[1] This was found in the case studies reported in D. C. Hague, E. Oakeshott and A. Strain. *Devaluation and Pricing Decisions* (London: George Allen & Unwin Ltd. 1974).

[2] For this purpose, UK exports of manufactured goods are divided into about 1,000 categories. The 'price' index for each category is calculated by dividing the value of exports in that category by an index of their volume — it is thus a measure of the average value of exports in that category. The unit value of exports of all manufactures is a weighted average of these average values, the weights reflecting shares in manufactured exports in 1970.

[3] See R. N. Brown, 'Export competitiveness and profitability,' 24th February 1977; 'Export competitiveness: further notes,' 17th March 1977. Unpublished Bank of England papers, available on request.

of the same multinational company,[1] price indices will reflect internal transfer prices which can differ from the (shadow) prices which the company uses when determining its resource allocation policies.

So relative export prices have evident drawbacks: they are appropriate only if UK exports are sold in imperfectly competitive markets; they do not comprise true price indices but involve some averaging across categories; and they can take no account of situations where firms have been unsuccessful in their attempts to export.

Various alternative measures of competitiveness

In so far as competition is not solely in terms of relative prices, it is useful to examine profitability. A measure of *relative profitability* indicates the incentive to produce for the export market rather than for the domestic market; a measure of *absolute profitability* indicates the incentive to produce, rather than not to produce at all.

One measure which attempts to capture relative profitability is *the ratio of export prices (unit values) of manufactures to wholesale prices of manufactures*. The assumption behind this measure is that the higher export prices are relative to wholesale prices, the more likely it is that producers will wish to export rather than to sell in the domestic market. The ratio suffers from the drawback that wholesale prices refer to current production while export prices are prices at the customs post and thus refer to production at some time in the past. Secondly, in so far as wholesale prices are prices of traded goods, the prices of which move in line with export prices under all circumstances, variations in the ratio may reflect only the different composition of the component indices, and have no implication for competitiveness. Moreover, the wholesale price index incorporates some indirect taxes, and is generally considered a poor proxy for the incentive to produce for the domestic market. Nevertheless, this index of competitiveness is attractive in that data are rapidly available, and no information on other countries is needed.[2]

An alternative, *the ratio of the price deflator for exports of goods and services to that for GDP*, is less often used, partly because of the long delay before figures become available. As in the previous case, it rests on the assumption that the higher the ratio of export to domestic prices the more likely producers are to sell in the export rather than in the domestic market. The export price deflator is the average value index of exports, and is therefore influenced by changes in the composition of exports. The GDP deflator measures the price of value added in the economy as a whole. However, it includes the 'price' of much output (i.e. public services, defence, administration, and so on) which is not sold at all. The 'price' of such output may be artificial, and have little or no effect on the use of resources. Moreover, productivity in the export (or import-substitute) sector generally grows faster than in the economy as a whole: how much adjustment should be made for differential productivity growth is not entirely clear. Given that most exports come from the manufacturing sector, one measure which is sometimes used in order to capture the effects of differential productivity growth is *the ratio of the deflator for exports of goods and services to the GDP deflator multiplied by the ratio of average labour productivity in the manufacturing sector to average labour productivity in the economy as a whole.*

There are a number of other measures of competitiveness which are not solely applicable in one set of market conditions. They are the ratio of the following prices or costs in the United Kingdom to those in competing countries: consumer prices, wholesale prices of manufactured goods, the price deflator for GDP and unit labour costs. In all cases, the lower the ratio, the more competitive is the United Kingdom. These measures may approximate to the relative prices at which UK exports are sold in relation

[1] The *Business Monitor, M4* (1973) shows that the percentage of total UK exports accounted for by exports to related concerns rose from 26% in 1970 to 29% by 1973 (Table 44).

[2] A refinement of this index involves comparing the ratio of export prices of manufactures to wholesale prices of manufactures in the United Kingdom with the weighted average of this ratio for competitor countries. It thus provides an index of 'relative' relative profitability.

to the prices at which other countries export; or, alternatively, they may provide a proxy for (relative and absolute) profitability where exporters 'take' prices in perfectly competitive, or oligopolistic, markets. Such indicators may at the same time be of use in assessing import-competitiveness — they can be used to approximate to the price of imports in relation to that of competing goods and services produced at home.

However, these measures have a number of defects. Indices of *consumer prices* and — to a lesser extent — of *wholesale prices of manufactured goods* pick up changes in indirect taxes and subsidies which are usually levied on imports and not charged on exports. These indices also reflect the pattern of consumer spending — so they can change by different amounts in each country, even if the price of each item included changes by the same amount everywhere. Moreover, they include the price of imported goods consumed at home, and may include so-called productivity bias.[1]

If export prices — properly measured — represent competitiveness, consumer prices may contain the prices of too many goods and services which do not enter international trade to provide a good proxy for them. If, on the other hand, the prices of internationally traded goods are very similar in different countries it may be that indices of wholesale prices will suffer from the same problems as relative export prices under perfect competition and may therefore not be very useful.

Price deflators for GDP are less often used as measures of competitiveness, partly because of the general problems with price deflators discussed above. A further problem with GDP deflators is that some countries' figures include indistinguishably indirect taxes and subsidies. On the other hand, price deflators provide a more comprehensive measure of domestic costs than unit labour costs and are less (if at all) distorted by the trade cycle. They carry useful information regardless of whether prices of exports and substitutes for imports are determined by domestic costs. If these prices *are* determined by domestic costs, then price deflators represent these prices directly, whereas if these prices are not determined by domestic costs (i.e. exporters and producers of import substitutes have to sell their products at some world price on which UK prices have negligible impact) then the ratio of GDP price deflators in different countries represents the profitability of producing exports or substitutes for imports. However, such deflators are (potentially) most vulnerable to productivity bias and, they are, by definition, average values, not prices, and are therefore affected by changes in composition.

Consumer or wholesale prices may act as a useful proxy for domestic costs; but a direct comparison of *unit costs* may prove a more reliable guide to competitiveness. Whether the prices of things actually exported, or produced in competition with imports, reflect costs depends on the structure of markets — but even if changes in costs are not followed through in prices, they will affect the profitability of exporting or producing in competition with imports, and so influence trade flows. Thus a comparison of unit costs provides a more comprehensive measure of competitiveness.

Unfortunately, costs are difficult to measure. The problem is that there is no way of measuring the unit cost of output across the range of a country's industrial activities; for instance, material costs are usually excluded from any estimated index because of limited internationally comparable data.[2] Generally, only unit labour costs are available (and there are severe problems of comparability even with these partly because

[1] It has been argued that differences among countries in the rate of growth of productivity are greatest in manufacturing and perhaps the traded goods sector generally, where productivity generally grows fastest. If this is so, the difference between the growth of productivity in the traded and non-traded sectors will tend to be greatest in fast-growing countries. Thus an international comparison which included the price of non-tradeable goods may suggestthat fast-growing countries are losing competitiveness. Consumer price indices are particularly vulnerable to this so-called productivity bias since they contain a relatively high proportion of non-tradeables. (See B. Balassa, 'The Purchasing-Power Parity Doctrine: A Reappraisal'. *Journal of Political Economy*, December 1964.) Some argue that productivity bias does not exist (see, for example, L. H. Officer, 'The Purchasing-Power-Parity Theory of Exchange Rates: A Review Article'. *IMF Staff Papers*, March 1976).

[2] A total unit cost index has recently been constructed by the OECD, but their figures for non-labour costs are derived from raw materials price data for only three countries.

when calculating labour costs it is necessary to include non-wage costs, such as social security contributions paid by employers). This introduces an immediate limitation in that the exclusion of other costs means that any differences in the composition of factor inputs and in their relative productivity trends may detract from the value of the index as reflecting overall competitiveness.

Unit labour costs possibly have most advantages where trade is conducted by multinational firms. Technology and capital are likely to be relatively mobile internationally (when a firm is deciding where to locate a plant) and raw materials can be obtained at approximately the same cost in different countries. Thus unit labour costs will be the principal cause of cost variation between countries. Firms will tend to concentrate production in the country with the lowest unit labour costs. In this case, a unit labour cost index is the best measure of competitiveness.

A disadvantage of using unit labour costs is that they show marked cyclical variations, because, for instance, labour hoarding occurs during an economic downturn. If no allowance is made for the trade cycle, unit labour costs could give the wrong signal, showing, for instance, a rise — and a loss of competitiveness — as the economy turns down and export markets become more profitable to supply, rather than the reverse. Correct adjustment for the cycle is generally thought to be very important, and may be reasonably straightforward in periods of relative cyclical stability,[1] but against the background of the last few years, with the prolonged period of weak demand and output, no one can be particularly clear about what is now the full employment level of output (which is the 'benchmark' to determine how the unit labour costs should be adjusted). It follows that historically based trend productivity estimates cannot be used without at least some reservation.[2]

Finally, we consider *the ratio of wholesale prices of manufactures to import unit values of finished manufactures in the United Kingdom,* the most commonly-used index to measure the competitiveness of import-substitutes. The index is in most respects analogous to that for relative export prices, discussed above, and suffers from similar drawbacks. Both components of the ratio can vary with the composition of demand. Moreover, if the price of import-substitutes moves very closely with the 'world' price of the imports in all circumstances, then the ratio will give little information about UK competitiveness. Import unit values are calculated at the customs post, and so cannot reflect unsuccessful attempts by foreigners to export to this country. Moreover, the index may be distorted by the differential effects of tariffs. A further problem is that the wholesale price index is not import-weighted, and so includes the prices of many goods which do not compete with imports. The measure is, however, attractive, in that it is not necessary to obtain data from other countries. It is unlikely to suffer as much as the relative export price index from the problem that UK producers are merely 'price-takers,' since it is more likely that producers are price-takers in their export markets than that they should adjust their prices fully to import prices in the UK domestic market.

Recent movements in the United Kingdom's competitiveness

Table A shows how the United Kingdom's relative competitiveness has changed recently, according to various measures. A rise in the index implies a loss in competitiveness.

Because of the sizable delays before data are available, there is only

[1] Cyclical adjustment can be made by replacing actual output in unit labour cost calculations with either trend output or 'potential' output. The IMF 'normalised' unit labour cost index (see below) involves relating labour costs to potential output. The method of calculating potential output requires a number of restrictive assumptions, for instance, about production functions and the mean age of the capital stock.

[2] An alternative viewpoint is that unit labour costs should not be cyclically adjusted (or 'normalised') Competitiveness so the argument runs, is an index that explains trade volumes after all other factors have been taken into account, and the state of the trade cycle is one of these other factors. In theory, an equation which includes a normalised unit labour cost term and one which includes an unnormalised unit labour cost term plus a relative business cycle term should explain trade equally well. However, the unnormalised unit labourcost index would give the wrong signals for official action. For instance, reduced competitiveness caused by labour hoarding during a cyclical depression should not be a signal for depreciation. Moreover, the exporter, who is assumed to be hoarding labour, faces only a very low marginal cost to expanding output, and this is better represented by a normalised unit labour cost index than by the (less favourable) unnormalised index.

limited information on movements in competitiveness since the second quarter of 1977 (and much of the information for earlier quarters is partly estimated). At that time, every indicator except the relative wholesale price index showed the United Kingdom to be more competitive than in 1970, and every indicator except relative unit values of manufactured exports showed a rise in UK competitiveness since 1975. All indices showed an improvement in competitiveness in 1976 (ranging from 1.6% improvement in the relative export price index to 9.7% in the relative normalised unit labour costs index, comparing the average level for 1976 with the average level for 1975). All indices except that for adjusted relative profitability showed a deterioration in the first half of 1977, (ranging up to 11.5% deterioration in the relative wholesale price index; the IMF normalised unit labour cost index deteriorated by 3.4% and the export unit value index by 7.6%). The export unit value indices appear to be more stable than the others. By the second quarter of 1977, the normalised unit labour cost indices showed a much greater improvement in competitiveness (compared with either 1970 or 1975) than any other index.

Table A
Competitiveness

A fall in the index indicates *increased* competitiveness

	Code [a]	1970	1974	1975	1976	1977[b]	1976	1977			
							4th qtr	1st qtr	2nd qtr	3rd qtr	4th qtr
Indices calculated by the Bank											
Relative unit value of manufactured exports[c]	*REP*	100	93.1	96.5	94.9	99.6	90.6	96.5	97.7	99.9	104.6
Relative profitability (manufactures only)	*SCO*	100	100.5	98.2	93.0	91.4	92.2	92.4	92.2	91.4	90.9
Ratio of import unit values to wholesale prices	*MCO*	100	98.4	99.6	92.5		88.9	94.5	97.0	99.8	
Relative profitability	*APX*	100	93.2	99.5	91.7		89.4	85.1	87.3	91.3	
Indices calculated by the IMF											
Relative unit labour costs in manufacturing	*ULC*	100	93.0	99.3	92.0		83.5	88.5	88.6		
Relative normalised unit labour costs	*NULC*	100	95.2	98.3	88.8		80.1	83.5	82.8	84.3	
Relative wholesale price indices	*WPI*	100	103.8	107.7	99.1		93.6	100.9	103.7		
Indices calculated by the OECD											
Relative unit labour costs in manufacturing	*SULC*	100	93.2	98.2	91.2	88.4	83.0	87.0	87.2	88.4	91.0
Relative consumer price indices	*CPI*	100	91.6	94.1	86.2	87.7	80.5	86.2	86.7	87.8	90.1
Relative total unit costs in manufacturing	*STUC*	100	96.0	97.3	94.1	93.1	88.6	92.5	92.5	92.6	94.7

[a] Indices are defined in Appendix 1.

[b] 1977 figures are provisional in all cases where data from other countries are involved.

[c] As published in *Economic Trends*. Competitors' weights differ from those used in the regressions.

Table B
Recent performance of United Kingdom and competitor countries

	United Kingdom			United States			Western Germany			France		
	SULC	CPI	EUV	SULC	CPI	EUV	SULC	CPI	EUV	SULC	CPI	EUV
1975 1st quarter	95.2	92.8	94.7	70.6	75.9	86.9	109.6	111.1	108.7	98.3	101.1	102.5
2nd quarter	98.5	95.1	96.0	69.4	75.5	89.1	107.5	108.8	107.4	105.1	106.2	108.9
3rd quarter	99.5	94.5	97.1	70.1	78.6	94.1	103.5	105.3	105.5	106.8	106.0	106.6
4th quarter	99.7	93.9	97.1	70.8	79.0	95.9	101.1	104.1	102.8	106.1	106.6	109.6
1976 1st quarter	99.8	93.9	98.3	70.1	78.4	95.7	100.6	105.5	103.7	101.3	106.3	108.0
2nd quarter	91.6	85.5	93.8	71.9	78.7	96.1	104.7	107.8	105.0	102.9	104.3	104.7
3rd quarter	90.4	84.7	94.6	71.9	78.1	95.1	105.6	107.5	105.6	97.2	99.6	101.5
4th quarter	83.0	80.5	90.3	71.4	77.3	96.4	108.8	110.1	107.8	96.0	96.6	99.5
1977 1st quarter	87.0	86.2	96.6	71.6	77.2	92.7	108.0	109.7	106.1	99.5	96.2	100.8
2nd quarter	97.2	86.7	98.4	71.6	77.0	93.1	109.2	109.5	106.3	93.4	96.7	100.9
3rd quarter	88.4	87.8		71.4	76.0		110.3	109.7		92.7	97.4	
4th quarter	91.0	90.1		69.6	74.5		111.0	112.3		93.4	96.6	

Sources: OECD (SULC and CPI) and IMF (EUV). [a]

Key
SULC = Smoothed unit labour costs.
CPI = Consumer price index.
EUV = Export unit values.

Notes:
All indices are based on 1970 = 100 and are in common-currency terms.
A fall in the index indicates increased competitiveness. 1977 figures are provisional.

[a] The IMF index, rather than the Bank index, for relative export prices is used here, to ensure comparability with competitor countries' indices.

Table B on the preceding page shows movements of three of the competitiveness indices for the United Kingdom and three other countries over the last two years. Again, a higher number implies less competitiveness. All indices represent the country's own costs or prices relative to a weighted average[1] of competitor countries' costs or prices.

The United Kingdom was substantially more competitive in the second quarter of 1977 on the unit labour cost index than it was in 1975; it was also more competitive on the consumer price index, but was slightly less competitive on the export unit value index. The United States had lost competitiveness on all three indices from 1975 until the recent depreciation of the dollar. Western Germany had lost slightly on the unit labour cost index, but had gained since the beginning of 1975 on the export unit value index and the consumer price index. France had become more competitive on all three indices.

A striking feature of Table B is the large change since 1970 in the West German and US indices, in opposite directions.[2] Over this period, the depreciation of the dollar and appreciation of the deutschemark have been associated with a large gain in international competitiveness for the United States and a corresponding loss for Western Germany.

Since it is impossible to choose between the various measures of competitiveness on *a priori* grounds or by casual examination of their recent movements, the next section describes econometric tests performed in order to determine which measure best explains UK trade flows.

Explaining trade: competitiveness and other factors

A measure of competitiveness is useful in so far as it helps to explain the level of exports and imports, once other factors have been taken into account. These other factors exert a powerful influence on flows of internationally traded goods and cannot be ignored if competitiveness is to be viewed in its proper perspective. Therefore the choice of a measure of competitiveness will depend largely, but not solely,[3] on how well the measure explains trade, in conjunction with all the other explanatory variables.

The measures of competitiveness, as defined in Appendix 1, were tested by placing them, singly, and in various combinations, in equations designed to explain respectively the volume of manufactured exports and the volume of finished manufactured imports. The equations, the method of estimation and more detailed results are shown in Appendix 2 and in Tables C and D. On all measures of competitiveness except one, an improvement in competitiveness was associated with a significant increase in the volume of exports and a significant fall in the volume of imports. The relative unit labour cost measures were the best at explaining the volume of exports; and the IMF normalised unit labour cost index was the best of these measures. The performance of the index of relative export prices was not as good. On the import side, there was less difference in the predictive power of equations using the alternative measure of competitiveness. The best were the smoothed unit labour cost index, the relative consumer price index, the total unit cost index, and the ratio of import prices to wholesale prices.

All the competitiveness indices on the export side had estimated elasticities which were not significantly different from unity when the equations were run over the entire period for which data were available.[4] The estimated elasticities on the import side, however, are not invariant over the estimation period: for 1977 the elasticities of the various indices were between one and two. The export elasticities are

[1] The construction of the weights is discussed in Appendix 2.

[2] Refuting the crude version of the purchasing power parity theorem.

[3] It is also important that the data that are required to construct the index are available as soon as possible after the period to which they refer.

[4] That means, that a 1% fall in relative prices or costs, or a 1% increase in profitability, will lead to a 1% increase in the volume of exports.

rather lower than those that have generally been found elsewhere, and the import elasticities rather higher.

It was earlier suggested that a combination of competitiveness indices might be able to explain the volume of exports and imports better than any individual index. It was found in these tests that a combination giving equal weights to the smoothed unit labour cost index and the ratio of import prices to wholesale prices, was able to explain the volume of finished manufactured imports better than any single index. However, no combination of indices was better at explaining the level of exports than the normalised unit labour cost index on its own. The superiority of this particular measure was confirmed in an additional test described in Appendix 3. The asymmetry between the export and import sides is curious, and not entirely satisfactory; there is a further asymmetry in the lag structure, with the lags on the competitiveness indices on the export side being spread over four years, whilst on the import side the lags were typically less than a year. [1][2]

So far as other factors are concerned, the tests showed that on the export side, the growth of world trade is highly significant, with the elasticity generally slightly over one half. It is interesting that there was no significant trend in any of the export equations. On the import side, the domestic business cycle was always significant (confirming that the higher the pressure of domestic demand, the higher the proportion of that demand that will be satisfied from imports). All import equations incorporated a strong trend. [3]

To summarise, therefore, the normalised unit labour cost index seemed best able to explain the volume of UK manufactured exports, especially over the period 1975-76. On the import side, a composite index, giving equal weight to the smoothed unit labour cost index and the ratio of import prices to wholesale prices, seemed to give the best results.

Conclusions

On empirical grounds, the unit labour cost indices perform best at explaining the volume of manufactured exports; using the IMF procedure to adjust cyclically (normalise) the unit labour cost index further improves its explanatory power; the major drawback with these indices is the difficulty of constructing them.

The very high significance of the world trade variable in the export equation, and the fact that relative export prices significantly add to the explanatory power of the export equation, provide evidence for the existence of demand constraints on the level of UK exports. The significant effect of the ratio of export prices to the wholesale price index suggests in addition supply constraints in some markets. The success of the unit labour cost indices may be due to the fact that, as explained above, they are applicable to a variety of market conditions.

It is not easy to be confident about the size of the export price-elasticities. Table C suggests an elasticity of unity on the conventional measure. However, as shown in Appendix 2, the elasticity is highly sensitive to the choice of estimation period, and if the period is cut off at end-1975 the elasticity rises to 1.4.

On the import side, the price-elasticities are not invariant within the estimation period of the equation. For 1977, the elasticities for import prices were generally between one and two and were thus higher than those for export prices. On the measure of unit labour costs (but not on most others) the United Kingdom was probably still much more competitive at the end of 1977 than in 1970 and 1975. However, the low coefficient on normalised unit labour costs in the export equation suggests that a large improvement in competitiveness thus defined

[1] Indeed, the shorter lags may have caused the relatively poor performance of the cost indices on the import side. The problems involved in cyclically-adjusting or smoothing these series were discussed earlier. With long lags the adjustment procedure might become relatively less important.

[2] It must be stressed that the 1977 data in the equations are only provisional.

[3] The residuals on all the import equations showed very high first-order autocorrelation.

(whether by depreciation or by incomes policy) would be necessary to achieve any sizable increase in export volumes,[1] and the long lags suggest that there would be considerable delay before the effects of the improvement in competitiveness would be fully realised. The response of the volume of finished manufactured imports to an improvement in competitiveness would be both stronger and more immediate.

[1] Low elasticities have recently been found in other studies, for instance: Mordechai E. Kreinin, 'The Effect of Exchange Rate Changes on the Prices and Volume of Foreign Trade', *IMF Staff Papers*, July 1977, pages 297-329.

Appendix 1

Definition of alternative measures of competitiveness

Indices tested in the empirical work

Indices calculated in the Bank

(a) The unit value index of exports of manufactures divided by the sterling price of competitors' exports of manufactures (REP) (export equation only).

(b) The unit value index of exports of manufactures divided by the wholesale price index of manufactures (SCO) (export equation only).

(c) The index of the unit value of imports of finished manufactures divided by the wholesale price index of manufactures (MCO) (import equation only).

(d) The price deflator for exports of all goods divided by the GDP deflator (RPX); this ratio is adjusted for differential labour productivity growth in the traded and non-traded goods sectors by multiplying the RPX index by relative productivity in the manufacturing sector and in the economy as a whole; the product is called APX. The RPX and APX indices are tested together (export equation only). [1]

Indices calculated by the IMF

(e) The ratio of unit labour costs in the United Kingdom to those in competitor countries (ULC).

(f) The ratio of 'normalised' unit labour costs in the United Kingdom to those in competitor countries (NULC). The normalisation procedure aims to adjust the actual labour cost index for the state of the trade cycle; the procedure was devised by J. R. Artus. [2]

Indices calculated by the OECD

(g) The ratio of the price index for consumers' expenditure in the United Kingdom to that in competitor countries (CPI).

(h) The ratio of smoothed unit labour costs in the United Kingdom to those in competitor countries (SULC). The smoothing involves taking four-quarter moving averages, to eliminate seasonal influences and the effect of irrelevant influences such as strikes.

(i) The ratio of smoothed total unit costs in the United Kingdom to those in competitor countries (STUC). Raw materials costs for each country are proxied by data from three user countries, and are weighted with labour costs, with weights calculated from input-output tables for each country, in order to obtain an index for total unit costs. The smoothing is similar to that for SULC.

Other indices discussed in the text

(j) The ratio of wholesale prices of manufactures in the United Kingdom to those in competitor countries (WPI).

(k) The ratio of the UK GDP deflator to that of competitor countries (PGDP).

For all indices except (b), (c) and (d), a fall in the index represents a gain in competitiveness. [3]

[1] The reason why RPX and APX are tested together is that RPX aims to capture the incentive which domestic consumers have to switch from traded to non-traded goods as export prices increase. The RPX index therefore aims to show the incentive to *consume* tradeables rather than non-tradeables; the APX index attempts to proxy the incentive to *produce* tradeables rather than non-tradeables.

[2] J. R. Artus, 'Measures of Potential Output in Manufacturing for Eight Industrial Countries 1955-78', *IMF Staff Papers*, March 1977. Mr Artus is currently revising his normalisation procedure, but it is understood that the revisions will not lead to drastic changes in the series used here.

[3] The *reciprocals* of indices (b), (c) and (d), as defined here, are included in Table A.

Appendix 2

Empirical test of alternative measures of competitiveness

The various measures of competitiveness were tested by placing them, singly and in various combinations, in the following equations:

Exports—

$$XGMA = \alpha_0 + \alpha_1 WTX + \alpha_2 DWIP + \alpha_3 D674 + \alpha_4 COMP + \alpha_5 trend + \varepsilon_1 \quad (1)$$

Imports—

$$1 - \frac{1.67MPRM - IIFM - 0.58075\,XGMA}{MND^* - 0.58075\,XGMA} = \beta_0 + \beta_1 COMP + \beta_2 CYCLE + \beta_3 trend + \varepsilon_2 \quad (2)$$

where the symbols are defined as follows:

$XGMA$ = Exports of manufactures excluding ships, aircraft, and diamonds (1970 £ millions, seasonally adjusted).

WTX = UK-weighted index of the volume of world trade in manufactures: (1970 = 100).

$DWIP$ = Deviation of OECD industrial production from trend (per cent).

$D674$ = Dummy for 1967 4th quarter (dock strike).[1]

$MPRM$ = Proxy for production of finished manufactured goods (£ millions, seasonally adjusted).

$IIFM$ = Stockbuilding: finished goods held by manufacturers (1970 £ millions, seasonally adjusted).

MND^* = Proxy for the demand for finished manufactured goods (£ millions, seasonally adjusted).

$CYCLE$ = Domestic cyclical variable. Equals

$$\frac{1/8 \sum_{i=0}^{7} (MND^* - 0.58075\,XGMA)_{-i}}{MND^* - 0.58075\,XGMA}$$

$COMP$ = Competitiveness index (1970 = 100), as defined in Appendix 1.

The equations were chosen to be compatible with the equations in the Bank model.[2] The export equation is fairly conventional. It was estimated quarterly, with all variables defined in logarithmic form, for the period 1967 1st quarter to 1977 2nd quarter.[3]

The import equation is more unusual. It is derived from the Bank's equation for manufacturing production. Manufacturing production plus imports, together with the change in the level of stocks, must identically equal the domestic demand for manufactures plus exports. Conventionally, manufacturing production, stockbuilding, imports and exports have been estimated separately, and total manufacturing demand has been derived by residual. In the Bank model, however, domestic manufacturing demand is now estimated separately, and separate equations specify the proportion of manufacturing demand satisfied by domestic production, the demand for manufactured exports, and stockbuilding; imports are treated as the residual. The dependent variable in equation (2) is one minus the dependent variable in the Bank equation for manufacturing production, so that equation (2) attempts to explain the proportion of domestic demand for manufactures that will be satisfied by finished manufactured imports.[4] Exports of finished manufactures are subtracted from total manufacturing demand so as to obtain an estimate for the domestic demand for manufactures.

The equation was estimated quarterly for the period 1965 1st quarter to 1977 2nd quarter, using instrumental variables to obtain an estimated, rather than actual, value for finished manufacturing demand so as to avoid simultaneous equation bias. First-order autocorrelation was found to be present in all runs.[5]

Most of the indices involve weighting the prices or costs of competitor countries. Different countries' indices are geometrically weighted with the weights derived from the IMF Multinational Exchange Rate Model (MERM)[6] used in the effective exchange rate calculation. This model calculates the impact on a country's *trade balance* from a 1% change in prices in any competitor country, taking into account third-country trade effects, and assigns weights to the competitor countries indices accordingly. Ideally, one would like the model to calculate the effects of foreign price changes on a country's exports and imports separately, but such weights are not available. Moreover, one would like to measure the impact of foreign cost changes when calculating the weights for cost-competitiveness indices, but again such weights are not available. The weights used in the IMF indices are slightly different from those in the OECD indices, since a different number of competitor countries are included in the calculations. Competitors' prices in the REP index have here been reweighted using the OECD weights. Recent experience is such that the assessment of changes in the United Kingdom's competitive position depends very heavily upon what weights are attached to foreign countries. The main reason is the improvement in competitiveness of the United States since 1970 and the variation in the weights given to the United States by different calculations. For instance, amongst frequently used methods of weighting, the weight ascribed to the United States in measuring UK competitiveness ranges from 17% to about 35%.

Lagged values of the competitiveness variables were entered into the two equations.[7] In the export equation, sixteen-quarter second-order polynomials with end-point constraints fitted best for all the indices. In the import equation, various alternative polynomials were tested, but it was very difficult to obtain any polynomial lag structures that were sensible and fairly stable. Moving averages were therefore used instead,[8] and it was found that three-quarter moving averages fitted best for virtually all the indices.[9]

[1] A dummy variable was tried for 1968 1st quarter, to see if the effects of the dock strike were reversed, but the coefficient was insignificant.

[2] The non-inclusion of a domestic demand term in the export equation and, to a lesser extent, of a foreign demand term in the import equation is open to question: past attempts to include these variables have not generally proved very successful. However, the fact that this article does take an export equation which was derived from a demand-determined view of exporting, may bias the results in favour of the measure of competitiveness that is based on the demand-determined view, i.e. relative export prices. Furthermore, the tradeables/non-tradeables approach explains net trade as the difference between net production and net consumption, and suggests that explaining the volume of exports and imports separately is of little interest. The approach adopted here may bias the results against the measures that are based on the tradeables/non-tradeables approach (i.e. RPX, APX).

[3] The choice of estimation period was constrained by the availability of data.

[4] Imports of SITC categories 7–9, excluding imports for North Sea oil production.

[5] Higher order autocorrelation was not present.

[6] See J. R. Artus and Rudolf Rhomberg, 'A Multilateral Exchange Rate Model', *IMF Staff Papers*, November 1973.

[7] For various reasons, the influence of changes in competitiveness on trade volumes is believed to be spread over time. As a result lagged values of the competitiveness variables enter the equations. This leads to two estimation problems. First, the degrees of freedom decrease. Second, successive lagged terms are likely to be highly correlated, which can result in imprecise estimates of coefficients. The 'Almon' polynomial lag technique attempts to circumvent both these problems by constraining the coefficients on the lagged terms to follow certain patterns, e.g. a 'hump' shape. A danger arises in that experimenting with alternative Almon lag structures increases the probability of accepting the hypothesis that a variable is significant when it is not.

[8] In fact standard errors on equations using moving averages were consistently lower than those on equations using polynomials.

[9] SULC performed slightly better when using a two-quarter moving average. The lags on SULC are nevertheless longer than for the other indices, since SULC is itself already a four-quarter smoothed series.

The results for the export equation are shown in Table C and for the import equation in Table D. Variables in equations (1) and (2) were omitted in various runs when to do so would reduce the standard error of the equation.[1] The preferred index of competitiveness is the one that produces the smallest standard error in equations (1) and (2).

On the *export* side, the estimated coefficients on each of the indices except the APX index had the expected sign, and all the indices led to a significant increase in the predictive power of equation (1) compared with a run where the competitiveness term was omitted.[2][3] It appears that the IMF normalised unit labour cost index performs best, in that it yields the lowest standard error. The next best index is the IMF (unnormalised) unit labour cost index.[4] The performance of the index of relative export prices, REP, was somewhat inferior to that of unit labour costs. The coefficients on all the single competitiveness variables are not significantly different from unity. Trend variables were tried but excluded from all equations on the grounds that they reduced the standard error of the equation.

It is interesting to investigate the stability of the estimated coefficients with regard to small changes in the estimation period. Table F shows the values of three of the competitiveness variables as successive quarters of 1976 and 1977 are included in the estimation period. It can be seen that the coefficients on the unit labour cost indices are stable; the coefficient on the relative export price index falls drastically as successive quarters until 1977 1st quarter are included.[5]

On the *import* side, there is less difference in the explanatory power of equations using the alternative measures of competitiveness. All the individual competitiveness indices have the expected sign and are significant. The lowest standard error is found in the equation which contains the OECD seasonally-adjusted relative unit labour cost series (as a two-quarter moving average), but the consumer price index, the total unit cost index, and the ratio of import prices to wholesale prices also performed well (all as three-quarter moving averages). Surprisingly, the IMF normalised unit labour cost index, which best explained the volume of manufactured exports, performed less well on the import side.

Attempts were also made to find a composite index of competitiveness by trying various combinations of the competitiveness variables in the export and import equations. When the composites were estimated unconstrained, no composite in the export or import equation added significantly (at 5% level) to the explanatory power of the equation compared with the runs where only the best individual indices were included. This may be largely due to multicollinearity between the indices.

An alternative approach was to create weighted averages of the individual indices so as to obtain a constrained composite index. Different weights were tested for the components of the composite.[6] Thus composite indices were created for both the export and import equations, using a cost index (NULC or SULC in the export equation, SULC in the import equation) and a price index (REP in the export equation, MCO in the import equation). On the export side, as the weighting of REP was increased, there was a monotonic fall in the explanatory power of the equation. On the import side, however, it was found that a composite index giving equal weight to SULC and MCO was able to explain the past better than could any individual index. Therefore, Table D also gives the results using this preferred composite.

Table C
Effect of competitiveness on manufactured exports

1967 1st quarter—1977 2nd quarter

	WTX	D674	DWIP	Constant	Competitiveness[a]	$\bar{R}^2$	SEE	RSS	DW
Relative unit value of manufactured exports (REP)	0·6358 *20.11*	−0.0504 *1.64*	0.0021 *1.53*	5·4569 *9.09*	−0.9964 *2.03*	0.981	0.0286	0.0295	1.72
Relative consumer price index (CPI)	0.5026 *7.70*	−0.0509 *1.76*	0.0023 *2.07*	8.9612 *5.39*	−0.8384 *2.83*	0.978	0.0271	0.0265	1.74
Unit value of manufactured exports divided by the wholesale price index (SCO)	0.5774 *30.85*	−0.0549 *1.91*	—	—	1.0338 *53.29*	0.977	0.0273	0.0283	1.71
Relative unit labour costs (ULC)	0.5302 *11.77*	−0.0451 *1.61*	— —	8.5218 *6.67*	−0.7742 *3.31*	0.979	0.0261	0.0252	1.79
Relative normalised unit labour costs (NULC)	0.5097 *11.47*	−0.0436 *1.62*	— —	8.2990 *7.43*	−0.8381 *3.86*	0.981	0.0252	0.0234	1.88
Relative seasonally-adjusted unit labour costs (SULC)	0.5711 *14.93*	−0.0463 *1.62*	— —	7.7861 *6.30*	−0.6572 *2.82*	0.978	0.0267	0.0263	1.79
Relative seasonally-adjusted total unit costs (STUC)	0.5652 *14.56*	−0.0466 *1.63*	— —	8.5464 *5.93*	−0.8144 *2.95*	0.979	0.0265	0.0259	1.81
Relative profitability[b]	0.8813 *11.79*	— —	−0.0058 *2.01*	19.2496 *3.15*	4.2534(RPX) *3.07* −2.9766(APX) *2.48*	0.978	0.0272	0.0258	2.21

t statistics are given below the coefficient estimates.

[a] Sixteen-quarter lags on second-order Almon with end-point constrained to zero.
[b] Export price deflator relative to GDP deflator (RPX) and RPX multiplied by relative productivity in the manufacturing sector (APX).

[1] The absolute values of the *t* statistics on the variables when included were less than unity.
[2] Results from equations which include no competitiveness variable are shown in Table E.
[3] APX had the wrong sign, perhaps because of its multicollinearity with RPX. In other runs the signs of RPX and APX were reversed.
[4] The fact that the unnormalised unit labour cost index performed so well suggests that the NULC result was not solely dependent on the normalisation procedure adopted.
[5] The NULC index performs extremely accurately in 1975 and 1976 although no better than REP in 1977. Quarterly NULC data were available only from 1970 and annual data from 1961 onwards, so the 1965–69 series were generated by the Bank's Quartann program, which may not be very accurate. This may not matter much on the export side since the lags on the NULC index are very long.
[6] The two component indices were (in successive runs) weighted 90:10, 80:20 ..... 20:80, 10:90.

Table D
Effect of competitiveness on finished manufactured imports

Three-quarter moving averages: 1965 1st quarter — 1977 2nd quarter

	Cycle	Constant	Trend	Competitiveness	α	$\bar{R}^2$	SEE	RSS
Wholesale prices relative to the unit values of imports	−0.3731	−0.2341	0.0051	0.4027	0.5252	0.950	0.0129	0.00375
	4.33	*1.95*	*14.21*	*4.72*	*4.12*			
Relative consumer price indices (CPI)	−0.3845	−0.2787	0.0064	0.3739	0.6800	0.952	0.0126	0.00701
	4.22	*1.91*	*9.77*	*4.28*	*5.80*			
Relative unit labour costs (ULC)	-0.4499	—	0.0058	0.2415	0.6441	0.948	0.0131	0.00769
	6.29		*11.89*	*4.48*	*5.47*			
Relative normalised unit labour costs (NULC)	−0.3949	−0.1492	0.0056	0.3046	0.5423	0.949	0.0130	0.00743
	4.49	*1.34*	*12.57*	*4.52*	*3.85*			
Relative seasonally-adjusted unit labour costs (SULC)[a]	−0.4472	—	0.0052	0.2391	0.7163	0.952	0.0124	0.00697
	6.93		*10.51*	*5.06*	*6.49*			
Relative total unit current costs (STUC)	−0.3745	−0.2496	0.0053	0.4040	0.5848	0.951	0.0127	0.00715
	4.24	*1.97*	*12.84*	*4.63*	*4.56*			
Preferred composite[b]	−0.4315	−0.1345	0.0053	0.3662	0.6541	0.955	0.0122	0.00657
	4.99	*1.41*	*11.89*	*4.87*	*5.45*			

t statistics are given below the coefficient estimates.
α = coefficient of autocorrelation.

[a] Two-quarter moving average results.
[b] This index is constructed from the MCO index and the SULC index, with 50% of the weights being derived from each.

Table E
No competitiveness variables

Exports: 1967 1st quarter — 1977 2nd quarter

	WTX	DWIP	D674	Constant	$\bar{R}^2$	SEE	RSS	DW
Omitted variables (compare Table C)[a]								
REP, CPI	0.6730	0.0000	−0.0588	4.2846	0.973	0.0296	0.0333	1.61
	28.82	*0.03*	*1.87*	*38.59*				
ULC, NULC, SULC, STUC	0.6858	0.0003	—	4.2225	0.971	0.0303	0.0364	1.42
	29.79	*0.26*		*38.63*				
	0.6726	—	−0.0589	4.2868	0.074	0.0292	0.0333	1.61
	37.09		*1.91*	*49.76*				

Imports: 1965 1st quarter — 1977 2nd quarter

	Cycle	Constant	Trend	α	$\bar{R}^2$	SEE	RSS
Omitted variables (compare Table D)							
MCO, CPI, NULC, STUC, Composite	−0.3915	0.2305	0.0044	0.7644	0.935	0.0147	0.00978
	3.95	*2.21*	*6.53*	*7.99*			
ULC, SULC	−0.3836	—	0.0071	0.9278	0.929	0.0151	0.0105
	4.03		*6.20*	*22.19*			

t statistics are given below the coefficient estimates.
α = coefficient of autocorrelation.

[a] Comparison with SCO is not meaningful, since it is not possible to obtain a positive R^2 when the constant is deleted.

Table F
Stability of competitiveness coefficients in export equation

	Relative export prices (REP)		Normalised unit labour costs (NULC)		Smoothed unit labour costs (SULC)	
	Price coefficient	SEE	Cost coefficient	SEE	Cost coefficient	SEE
Estimation period begins 1967 1st quarter						
Estimation period ends						
1975 4th quarter	−1.391	0.0289	−0.780	0.0268	−0.598	0.0278
1976 1st quarter	−1.271	0.0291	−0.795	0.0264	−0.612	0.0277
2nd quarter	−1.148	0.0290	−0.794	0.0260	−0.618	0.0273
3rd quarter	−0.983	0.0295	−0.811	0.0258	−0.635	0.0272
4th quarter	−0.948	0.0291	−0.811	0.0254	−0.636	0.0268
1977 1st quarter	−0.980	0.0287	−0.811	0.0251	−0.636	0.0265
2nd quarter	−0.981	0.0287	−0.843	0.0257	−0.662	0.0267

Appendix 3

Application of the Cox test to the export equation

In Appendix 2 it was found that costs performed better than prices on the export side. However, simple comparison of standard errors can give no indication as to how likely it is that these rankings of the alternative competitiveness indices arise by chance.

This appendix describes a test by which we can estimate how probable it is that one index is truly better than another in explaining the volume of exports.

This test, due originally to Cox[1] and recently applied by Pesaran[2] allows the testing of non-nested[3] regression models. Suppose that there are two competing models:

$$H_0: y = Xb_0 + u_0$$
$$H_1: y = Zb_1 + u_1$$

where X and Z are the observation matrices of the explanatory variables of each model. The Cox test assumes that each hypothesis (H_0 or H_1) in turn is correct. It proceeds as follows:

(a) Assume H_0 is correct, estimate $y = Xb_0 + U_0$ by OLS: the OLS estimates are $\hat{y}_0 = X\hat{b}_0$ and $\hat{\sigma}_0^2 = \dfrac{\hat{u}_0'\hat{u}_0}{n - k_1}$

where k_1 is the number of regressors in X, and n is the number of observations.

(b) Now find the consequences of fitting the second model if the first model is actually correct: regress

$$\hat{y}_0 = Zb_1 + v_1.$$

The estimate of the error variance is

$$\hat{\sigma}_{01}^2 = \frac{\hat{v}_1'\hat{v}_1}{n - k_2}$$

where k_2 is the number of regressors in Z.

(c) Estimate the second model, on its own:

$$y = Zb_1 + u_1$$
$$\hat{\sigma}_1^2 = \frac{\hat{u}_1'\hat{u}_1}{n - k_2}.$$

(d) There are now two estimates of the residual error variance under H_1:

(i) that obtained directly, if H_1 is true: $\hat{\sigma}_1^2$; and

(ii) that obtained if H_1 is tested when H_0 is known to be true: $\hat{\sigma}_0^2 + \hat{\sigma}_{01}^2$.

(e) Now construct the statistic:†

$$T_0 = \frac{n}{2}[1n\hat{\sigma}_1^2 - 1n(\hat{\sigma}_0^2 + \hat{\sigma}_{01}^2)].$$

(f) This is asymptotically normal, has zero mean, and has asymptotic variance†

$$V_0 = \frac{\hat{\sigma}_0^2}{[\hat{\sigma}_0^2 + \hat{\sigma}_{01}^2]^2}[\hat{w}'\hat{w}]$$

where $\hat{w}$ is the OLS estimate of the residual obtained when $\hat{V}_1$ [from step (b)] is regressed on the explanatory variables of model H_0:

$$\hat{V}_1 = X\gamma_0 + w.$$

The procedure set out in steps (a) to (f) is now repeated, assuming the *other* hypothesis, H_1, is true.

Consider the resulting statistic, T_0, calculated under H_0. If T_0 is signficantly negative this means that the residual variance under H_1 is significantly smaller than that expected when the H_1 model is estimated *but* H_0 is true. We therefore accept H_1 and reject H_0. If T_0 is significantly *positive*, on the other hand, we reject both H_1 and H_0. Otherwise we must accept both hypotheses.

Now consider T_1, calculated under H_1. We end up with the same sort of decision process. For the 95% significance level we have the following table:

	Accept both	Reject both	Accept H_0: reject H_1	Accept H_1: reject H_0
T_0	$\left\|\frac{T_0}{\sqrt{V_0}}\right\| < 1.96$	$\left\|\frac{T_0}{\sqrt{V_0}}\right\| > 1.96$	$\left\|\frac{T_0}{\sqrt{V_0}}\right\| < 1.96$	$\left\|\frac{T_0}{\sqrt{V_0}}\right\| > 1.96$
T_1	$\left\|\frac{T_1}{\sqrt{V_1}}\right\| < 1.96$	$\left\|\frac{T_1}{\sqrt{V_1}}\right\| > 1.96$	$\left\|\frac{T_1}{\sqrt{V_1}}\right\| > 1.96$	$\left\|\frac{T_1}{\sqrt{V_1}}\right\| < 1.96$

The results from each sequence may be combined to give the decision table shown.

The NULC, SULC and REP indices were tested to see whether the differences between them, in terms of their explanatory power when put into the export equation, were significant. The results are shown below:

	H_0	H_1	$\frac{T_0}{\sqrt{V_0}}$	$\frac{T_1}{\sqrt{V_1}}$	Conclusion
1	REP	NULC	−6.61	0.78	Accept NULC and reject REP
2	REP	SULC	−4.72	0.68	Accept SULC and reject REP
3	SULC	NULC	−3.15	1.09	Accept NULC and reject SULC

This test demonstrates that both cost indices are significantly superior to the price index in explaining the past, and that the normalised unit labour cost index is significantly superior to the smoothed unit labour cost index.

[1] D. R. Cox, 'Further Results on Tests of Separate Families of Hypotheses', *Journal of the Royal Statistical Society, Series B*, 1962.

[2] M. H. Pesaran, 'On the General Problem of Model Selection', *Review of Economic Studies*, 1974.

[3] By non-nested, it is meant that no one model is a special case of the others. For example, $y = a + bx$ is nested in $y = a + bx + cz$.

† The proof of asymptotic normality was carried out when *population* values of the parameters entering the statistics were used: here the statistics are 'estimated' using consistent OLS estimates.