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# Heckscher-Ohlin in theory and reality

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*Most economists think that H-O works well in theory, but badly in reality, whereas the opposite is closer to the truth. After a long decline, H-O has recently experienced an empirical revival, but the standard Samuelsonian formalisation of the theory is still unsatisfactory. A modified formalisation of the theory, which gives trade costs more of a role, fits the evidence better. Appropriately interpreted, H-O is a useful part of the theory of economic development, as well as of international trade.*

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## 1. Introduction

At the start of 1965, in my first year as an undergraduate at Cambridge, Robin Marris took leave to join the new Labour government's Overseas Development Ministry, and Ajit Singh replaced him as my supervisor. Some time in the spring or summer, he set me to work on international trade. My essay, now alas lost, was a scathing critique of Heckscher-Ohlin theory, based mainly on reading about Samuelson's formalisation of Ohlin. The long list of assumptions required to make the theory work struck me as absurd, as I stated with all the arrogance of youth. Ajit's comment on its cover page was 'too polemical'.

Two decades later, I came back to Heckscher-Ohlin (H-O) theory, in search of a way of analysing the effects of rapidly growing imports of manufactures from developing countries on the labour markets of developed countries. This line of research yielded a book (Wood, 1994a) and led me on to other related research into the determinants of manufactured exports from developing countries. Indeed, H-O has been at the core of almost all my academic work for over twenty years.

How can this be explained? Was what I wrote for Ajit completely wrong, or is there some way of reconciling it with my subsequent H-O enthusiasm? The answer seems to me to be that the essay was misdirected: my criticisms were actually of the formal theorising of Samuelson, but I aimed them at H-O in general, failing to appreciate the empirical power of the less formal theorising of Heckscher and Ohlin (which I can see from a re-reading of Samuelson's articles that he himself did appreciate).

Happily, I now have the chance to resubmit my essay to Ajit – to write what, with the benefit of forty years of hindsight, I should have written back in 1965. I shall argue that most trade economists have got H-O wrong: they believe that it works well in theory, but badly in reality, whereas the opposite is closer to the truth – H-O works well in reality, but badly in theory. (The title of my paper, incidentally, is similar to that of Leamer, 1995, acknowledging another important intellectual debt.)

Section 2 discusses the empirical decline of nearly four decades into which Leontief sent H-O in 1953, and section 3 discusses its recent empirical revival. Section 4 reviews the problems of the standard Samuelsonian formalisation of H-O theory, and section 5 outlines a modified formalisation that fits the evidence better. Section 6 considers the relevance of H-O theory to economic development.

## 2. Empirical decline

The origins of H-O theory were empirical. Heckscher was an economic historian, and his seminal 1919 formulation of the theory was stimulated by a dispute with Wicksell about the policy implications for Sweden of trans-Atlantic trade. Ohlin's 1933 book was likewise firmly and frequently based on observation of actual patterns of trade.

From the 1950s to the 1980s, however, H-O had a hard time empirically. Although Leontief's (1953) disproof of the theory was effectively challenged by Leamer (1980), further econometric work yielded little support for H-O theory and many inconsistent findings (for surveys, see Wood, 1994a, section 3.5.2; and Leamer and Levinsohn, 1995). Vanek's (1968) articulation of the theory in terms of factor content provided a

new way of testing it, but the results of the fullest such test of H-O's empirical accuracy, by Bowen, Leamer and Sveikauskas (1987), were discouraging.

In retrospect, these unfavourable empirical results seem to me to have arisen from three misunderstandings of the theory.

*2.1 Confusing relative with absolute magnitudes.*

Like all theories of comparative advantage, H-O is about relativities (indeed, double relativities): a country 1 that has more of factor A, relative to factor B and relative to country 2, will produce and export more of factor-A intensive good X, relative to factor-B intensive good Y and relative to country 2. This says nothing about absolute magnitudes: country 1 might have more of factor A than country 2, and yet export less of good X, because its technology was uniformly inferior to that of country 2.

A problem with many of the tests, and in particular with those based on the Vanek reformulation, was that they examined relationships between absolute magnitudes which depended on the implicit assumption that all countries had the same levels of technology (or total factor productivity).[2] That this assumption is wildly misleading had long been recognised by development economists, but it became increasingly better documented by statistical analysis of the causes of cross-country differences in per capita income (from Krueger, 1968, to Hall and Jones, 1999).

The significance of this assumption for tests of H-O theory was emphasised by Trefler (1995). He showed that, if allowance is made for uniform cross-country differences in technology, H-O theory provides a better explanation of the facts. The assumption of uniformity matters: if cross-country differences in technology vary among sectors, comparative advantage is affected also by Ricardian considerations (Harrigan, 1997). Even uniform differences, moreover, make H-O a more modest theory than some earlier tests supposed: it cannot explain the absolute amounts of goods that countries export or import, but only the amounts of some goods relative to other goods.[3]

*2.2 Working at the wrong level of aggregation*

H-O theory cannot provide a complete explanation of trade, even in relative terms and even abstracting from government policies. For Ricardian reasons, as mentioned, a country that is particularly efficient at producing some good will export that good, even though its mixture of factor endowments gives it no special cost advantage. Economies of scale are also important, especially in explaining the large volume of trade that occurs among countries with similar factor endowments, and in explaining the fine details of the composition of trade.

H-O works best at a high level of aggregation, with a few broadly defined goods (primary products and labour-intensive manufactures, for example) and a few broadly defined factors that are used in all sectors (labour, land and skill, for example). To try to use a H-O model with a few factors to explain more detailed patterns of trade, as many tests have done, is to ignore the standard theory (in which models with more

[2] The tests also assumed, unrealistically, that all countries were equally open to trade.
[3] As is clear in Jones' classic (1965) reworking of the Samuelsonian formalisation of H-O.

goods than factors are indeterminate) and to invite empirical disappointment, since the effect on comparative costs of differences in factor endowments tends to be swamped by other influences. But to extend a H-O model to include many more, sector-specific factors is to risk trivialising H-O into saying, as Samuelson (quoted by Robinson, 1964) joked, 'that the export of tropical fruit from the tropics is due to the prevalence of tropical conditions there'.

The contribution of H-O theory is thus to provide a broad-brush explanation of major features of the pattern of world trade, especially among countries with widely varying endowments, and of their consequences for domestic factor markets. Even at this level, H-O is necessarily an incomplete explanation – other forces are also at work – but it is at this level that it is most useful. An important implication, however, is that aggregation problems are inevitable in applying H-O theory: both goods and factors are far from homogeneous, which, as noted by Davis and Weinstein (2001) as well as by Schott (2003), requires unusual care in the design of empirical work and in the interpretation of its results.

### *2.3 Treating capital as a factor of production*

Samuelson, who understood capital theory, was careful to make the two factors in his H-O models labour and land. Most textbook presentations, however, make capital the second factor, and most empirical tests of H-O theory have likewise treated capital as a factor of production, measuring its stock in each country as the cumulation of past investment. This approach is questionable, both theoretically and empirically, as was emphasised by Joan Robinson (1964) at about the time I was being taught by Ajit and is explained more fully in Wood (1994a, section 2.2; 1994b). The main empirical difficulty is that capital is internationally mobile: machines are traded, buildings can be put up anywhere in a year or two, and finance flows around the world on a massive scale. This mobility matters because – as is clear intuitively and is shown formally by Ethier and Svensson (1986) – the factors relevant to the H-O explanation of trade in goods are only those that are internationally immobile.

Capital is not, of course, perfectly mobile. The prices even of traded capital goods differ somewhat from country to country (a fact with which recent empirical work has grappled: Eaton and Kortum, 2001; Debaere and Demiroglu, 2003). Obstacles to capital flows also cause interest rates in some countries, particularly developing ones, to diverge persistently from world levels. But as a first empirical approximation it is reasonable to suppose that, as a result of mobility of both capital goods and finance, there is little variation among countries in the 'rental' rate of capital (the real interest rate times the price of capital goods). And in capital theory it is a country's rental rate that determines how cheaply it can produce capital-intensive goods, defined as those with high capital-output ratios.[4] So if rental rates are similar in most countries, there should be little variation among countries in comparative advantage as between more and less capital-intensive goods. Most tests of H-O theory, however, have measured this aspect of comparative advantage by the size of a country's stock of capital goods, relative to its other factor endowments – a ratio that varies widely among countries – which helps to explain why they have often yielded peculiar results.

[4] By contrast, most tests of H-O theory focus on the ratio of the rental rate to the wage rate, and assume the appropriate measure of capital intensity to be the capital-labour ratio. This approach is misleading, as explained in Wood (1994a: 38-40, 75-8).

A simple solution is to drop capital from the list of H-O factors, as I have done in my own research. But this raises two questions, of which the first is 'if capital is left out, what do we put in its place?' Part of the answer is 'land' (or natural resources), but an even bigger part is 'skill' (or human capital). Education, training and knowledge are a vital factor of production, there is wide variation among goods in skill intensity, and skill endowments vary widely among countries because of barriers to international mobility (though barriers are lower for some countries and for some types of skilled workers, of which more later). The second question is 'if we leave non-human capital out of the explanation of trade, where do we put it in our model, since it is clearly of vital importance for production?' The answer is to make it one of the determinants, along with technology, of the productivity of the immobile factors.

## 3. Empirical revival

Since about 1990, partly because of recognition of the misunderstandings outlined above, the reputation of H-O theory as an explanation of how the world works has improved substantially. It still has detractors, and even among its supporters debate continues about the areas and respects in which it is helpful. But H-O has played a major role in two areas of recent empirical work: the effects of trade on wages; and variation in the structure of exports and output.

### *3.1 Effects of globalisation on wage inequalities*

In Wood (1994a), which got a nice review from Ajit (Singh, 1995), I suggested a H-O connection between several facts: rapid growth of manufactured exports from the East Asian tigers to developed countries; reduced wage inequalities in the tigers; and increased wage inequalities and unemployment of unskilled workers in developed countries. My model had two countries (North and South), two factors (skilled and unskilled labour) and two goods (skill-intensive and labour-intensive manufactures). Reduction of barriers to trade had caused the North to specialise in the skill-intensive good, reducing the demand for unskilled workers, and vice versa in the South.

This suggestion, on a sensitive subject, precipitated an avalanche of other work, some supportive, some highly critical. Most of the contributions were about the developed-country story (I surveyed the first wave of these in Wood, 1998). Some critics argued that I had misinterpreted the theory (more on this in section 4). Others argued that, although rising wage inequality was consistent with a H-O explanation, the relative demand for unskilled workers had declined mainly because of changes in technology unrelated to trade. The 'trade versus technology' debate was lively, but eventually ran out of steam, partly for lack of conclusive evidence and partly because the answer did not affect the policy implications.

Some subsequent critics, including Ajit (Singh, 2003), argued that after the 1980s the behaviour of wage inequalities in developed countries ceased to be consistent with either the trade or the technology explanations, since the relative wages of unskilled workers ceased to fall (Anderson, 2001). This could be rationalised in H-O terms: the North had become fully specialised in skill-intensive manufactures and its labour-intensive manufacturing sector had been extinguished, so that no further harm could be inflicted on its unskilled workers. But this rationalisation was not satisfactory, as

Ajit noted, because imports from developing countries continued to grow. Moreover, the biggest change in wage inequality in developed countries since the early 1990s has been among skilled workers: a small group at the top has pulled rapidly away from the rest, for which there does not seem to be a H-O explanation.

My simple H-O story about trade narrowing wage inequalities in the South, too, has come under fire. Although it fitted the facts of East Asia in the 1960s and 1970s, it seemed to be contradicted by the experience of Latin America in the 1980s and 1990s (Robbins, 1996; Wood, 1997). Evidence for other developing regions and countries was sparse, but it, too, suggested a mixed picture (Anderson, 2005). Part of the variation can be explained in H-O terms: only in some developing countries is unskilled labour the abundant factor and hence predicted to gain from openness to trade; in other developing countries the abundant factor is land or (in upper-middle-income ones) skilled labour. But even in some countries where unskilled labour is the abundant factor – Vietnam, for example – wage inequalities have risen.

Ajit's (Singh, 2003) explanation of changes in unskilled relative wages in the North is changes in labour market institutions, macro-economic conditions and social norms, all of which surely contributed. Changing institutions are a plausible explanation also for rising inequality in Southern countries such as Vietnam. But my own explanation for most of the anomalies – wage changes which cannot be explained in H-O terms – in both North and South is falling travel and communications costs, which enable highly-skilled Northern workers to operate globally, raising their wages and those of many Southern workers, but depressing the wages of most other Northern and some Southern workers (Wood, 2002; Anderson, Tang and Wood, 2006).

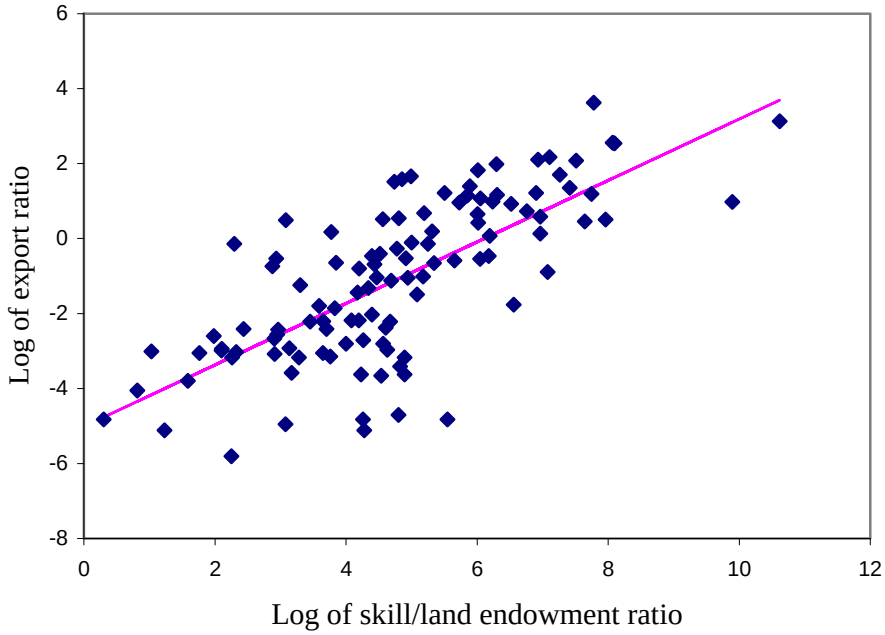
The debate about globalisation and wage inequality, both recently and historically (Williamson, 1997), has attracted a lot of attention to H-O theory, which remains the only analytical framework that links trade and labour markets, but what has been the effect on its empirical credibility? Opinions differ, but my impression is that most people now see H-O as part of a complete explanation and as the main explanation of parts of the outcome. In any event, that is my view, but I also recognise that, as with trade more generally, H-O is not the whole story, for which it is essential to combine it with other sorts of explanation (as in Wood, 2002).

### *3.2 Effects of endowments on sectoral structure*

A fundamental aim of H-O theory is to explain the pattern of trade, and in this regard its empirical reputation has been revived recently by the work particularly of Trefler (1995), Harrigan (1997), Davis and Weinstein (2001) and Schott (2003). In my own work, with various co-authors, I have tried to respond to all three of what I described in section 2 as the earlier misunderstandings of H-O theory: by assuming sectorally uniform differences in technology among countries; by working at a high level of aggregation; and by omitting capital as a H-O factor of production.

Figure 1, an earlier version of which was in Wood and Berge (1997), is the simplest possible illustration of a strong H-O relationship. For all countries with populations of more than one million for which the necessary data are available in 1990, it plots the ratio of their manufactured exports to their primary exports against the ratio of their skill (or human capital) endowment to their land endowment, both ratios being

*Figure 1* Cross-country variation in manufactured/primary export ratio, 1990




Source: calculated from data in Wood and Mayer (2001); for more details of the variables, see the notes to table 1 (in this figure, manufactures are NM and primary products are BP). The line is that of the first regression in table 1.

logged. Skill is measured by the total number of years of schooling in the adult population and land by the area of the country: these measures are far from perfect, not least in their lack of control for variation in land quality (Wood and Mayer, 2001, section 1.3), but their imperfections make the strength of the relationship in the figure even more remarkable.

The H-O interpretation of the positive slope of the line in this figure is that there is a difference in the relative factor intensities of manufacturing and primary production. Manufacturing is more compact than agriculture, and needs a more educated labour force: its production technology involves a higher ratio of skill to land.[5] Because of their different factor intensities, a country's comparative advantage as between these two sorts of goods depends on its relative endowments of skill and land. The exports of countries with high ratios of skill to land are concentrated on manufactures, while countries with low ratios of skill to land export mainly primary products.

Table 1 contains more H-O regressions, drawn from Wood (2003, table 3), which contains a fuller explanation and references to related articles. The first regression is the one shown in the figure. The second improves on it by separating the skill/land ratio into two separate ratios, skill/labour ($h$) and land/labour ($n$), which allows for differing labour intensity as well as skill/land intensity, and by including a country size variable (population, $p$), which allows for economies of scale in manufacturing. The ratio of manufactured to primary exports tends to be higher in countries which have more skill per worker and less land per worker, and which are bigger.

[5] Mining, which is also part of primary exports, is different in its factor intensities from agriculture, but also has a lower skill/land ratio than manufacturing.

*Table 1* Cross-country regressions explaining export and output structures, 1990

| *Dependent variable* | *Intercept* | *Coefficients on independent variables* | | | | *R-squared* | *Number of countries* |
|---|---|---|---|---|---|---|---|
| | | *h/n* | *h* | *n* | *p* | | |
| Export ratios | | | | | | | |
| NM / BP | -5.01 | 0.82 | | | | 0.53 | 111 |
| | (-13.3) | (11.2) | | | | | |
| NM / BP | -7.43 | | 1.44 | -0.57 | 0.27 | 0.62 | 111 |
| | (-9.0) | | (7.1) | (-6.3) | (2.9) | | |
| PP / NP | -4.78 | | 1.49 | -0.13 | 0.10 | 0.40 | 111 |
| | (-5.5) | | (6.9) | (-1.4) | (1.0) | | |
| NMH / NML | -3.70 | | 1.59 | -0.07 | 0.01 | 0.38 | 69 |
| | (-4.1) | | (6.2) | (-0.8) | (0.1) | | |
| Output ratio | | | | | | | |
| BM/NP | -2.64 | 0.50 | | | | 0.46 | 96 |
| | (-9.2) | (8.9) | | | | | |
| BM/NP | -3.27 | | 1.30 | -0.28 | 0.03 | 0.60 | 96 |
| | (-5.6) | | (8.6) | (-4.4) | (0.4) | | |

Notes: NM = narrow manufactures (SITC 5-8 less 68); BM = broad manufactures (ISIC manufacturing); BP = broad primary products (SITC 0-4 plus 68); NP = narrow (unprocessed) primary products (ISIC agriculture and mining); PP = processed primary products (BM less NM); NMH = skill-intensive manufactures; NML = labour-intensive manufactures; $h$ = skill per worker (average adult years of schooling); $n$ = land per worker (square kilometres per adult); $p$ = total adult population (thousands). All variables in natural logarithms. All regressions estimated by OLS. t-statistics in brackets.

Source: Wood (2003, table 3); for information on the coverage of NMH and NML, see Mayer and Wood (2001, table 1)

The next two regressions in the table explain cross-country variation in the ratio of processed to unprocessed primary exports and in the ratio of skill-intensive to labour-intensive manufactured exports. In both of them, the coefficients on skill per worker are positive and significant: processing requires more skill than unprocessed primary production, as does more skill-intensive manufacturing, so that countries with more skilled workforces export relatively more of these sorts of items. But the coefficients on land per worker are insignificant, because there is little difference in land-intensity between processed and unprocessed primary production, and between skill-intensive and labour-intensive manufacturing, so that these dimensions of export structure are largely unaffected by variation across countries in land/labour endowment ratios.

The final two regressions in the table refer to output structure, rather than to export structure: their dependent variable is the ratio of manufacturing to primary net output (value added). The dividing line between manufacturing and primary is not the same as in the export regressions (in the output data, processed primary products are part of manufacturing, and in the export data are part of primary), but the results are similar. The manufacturing to primary output ratio tends to be higher in countries with higher endowments of skill per worker and with lower endowments of land per worker.

All these regressions leave unexplained around half of the cross-country variation in the sectoral structures of exports and output, and there is room for debate about the choice of variables and method of estimation. But the relationships are qualitatively robust to variation in country coverage and choice of year (for example, essentially similar in 1960: Wood and Berge, 1997, table 1B), and variations in coefficient size by region and year are economically illuminating (Wood and Mayer, 2001, p. 379). Thus H-O theory, appropriately applied, provides a powerful empirical explanation of important aspects of the pattern of world trade.

## 4. Theoretical problems

Samuelson's formalisation of H-O theory, refined later by other economists, is of compelling elegance and usefulness as a tool for analysis and teaching. H-O-S, to use a briefer label, is in the words of Bliss (2007) 'to an international economist what a sharp knife is to a chef'. Its 2x2x2 version is in every textbook, and its five theorems (Heckscher-Ohlin, factor price equalisation, Stolper-Samuelson, Rybsczynski and reciprocity) are taught to every graduate student – rightly so. But it also has problems (illuminatingly reviewed, in more technical detail than could be accommodated in the present paper, by Deardorff, 2006).

The commonest objection to H-O-S – as in my original essay for Ajit – is its long list of unrealistic assumptions (Ajit, too, criticises them in Singh, 2003; and Leamer, 1984, p. 45, describes them as 'incredible'). But I now think that they are not the main problem. Only one really matters, which is non-reversal of factor intensities: the simple H-O principle of factor-A abundant countries exporting factor-A intensive goods would be unhelpful if the relative A-intensities of goods often varied with the level of relative factor prices (and with endowments). But factor intensity reversal is rare, at least when the theory is applied at a high level of aggregation.[6]

The other assumptions matter less. Deviations from them just make the relationships imprecise – reducing the $R^2$ of regressions – and some of them can be allowed for in estimation (as, for example, with non-constant returns to scale in table 1). If H-O theory is about relativities, as argued in section 2.1, technology does not need to be identical in every country – only to vary among countries in a roughly neutral way. Consumer preferences do not need to be strictly homothetic or to be identical in every country. Competition in product markets does not need to be perfect – prices must just be linked in some way to costs of production – and institutional imperfections in factor markets can be incorporated into the theory.

[6] A notable exception is electronics, of which exports are of high skill intensity in developed countries and low skill intensity in developing countries, as a result of the aggregation of different sorts of items into a single statistical category.

The basic problem with H-O-S is therefore not that its assumptions are unlikely to be exactly satisfied: it is the way in which the model behaves even when its assumptions *are* exactly satisfied. In several respects, its predictions diverge widely from readily observable features of the real world.

A glaring example is that factor prices are not equalised, as Robinson (1964) stated in the title of her article, Leamer (1984, pp. 11-12) noted two decades later, and Bliss (2007) another two decades later describes as 'always a cause of embarrassment'. This is not quite so serious as it seems: if the quality of technology varies among countries, then absolute factor prices must also vary – which accounts for most of the variation in wage rates which Robinson and Leamer noted. What is a problem, though, is that *relative* factor prices are not equalised, and that their variation across countries is correlated with endowments – factors are relatively cheaper where they are relatively more abundant, despite countries being open to trade. For example, the relative wage of skilled workers is lower in developed than in developing countries, and land rents are lower, relative to wages, in the US than in Japan.

There are two ways, in H-O-S, to explain why relative factor prices vary with relative factor endowments, but both these cures seem as unattractive as the disease. One is to assume that there are fewer goods than factors, but that too seems unrealistic: if the definition of factors is limited to inputs that are used in most sectors (as distinct from sector-specific factors), there are thousands more goods than factors. The other cure is specialisation – trade causing countries to produce only one good (in the two-good version of the theory) or no more goods than there are factors (in higher-dimensional versions). But as Deardorff (2006) emphasises, which particular subset of goods is produced is in theory hypersensitive to small changes in prices. In reality, moreover, countries are manifestly not highly specialised: most countries produce most goods, albeit in widely varying quantities.

Another glaring (and related) problem is that the H-O-S description of how the world works is highly sensitive to its choice of dimensions – meaning the numbers of goods and factors in the model. The 2x2x2 model paints one picture of reality, in which (within limits) factor prices are equalised and both countries produce both goods in quantities that depend on their endowments. If the numbers of goods and factors are increased in parallel (higher-dimensional 'even' models), things unsurprisingly get much more complicated. More worrisome are the effects of uneven numbers of goods and factors. If the number of factors exceeds the number of goods, factor prices cannot be equalised. If the number of goods exceeds the number of factors, the structure of output becomes either indeterminate or unrealistically specialised.[7]

This asymmetry seems fatal for using H-O-S to explain reality. As Samuelson was well aware (1953, para. 14), aggregation of goods and factors is both unavoidable and arbitrary. I argued in section 2.2, moreover, that H-O is most useful at high levels of aggregation. A model whose predictions vary dramatically with small changes in how the data are aggregated is thus unhelpful. It is also actively misleading, since the behaviour of the world from which the data are drawn obviously does not vary with how the data happen to be aggregated.

[7] Samuelson (1953) argued that the apparently indeterminate outcome might be determinate if countries had similar factor endowments or there were small transport costs (see also Leamer, 1984, pp. 17-18).

Some of the problems of using H-O-S to interpret reality surfaced in the debate about trade and wages in developed countries. Using the 2x2 version of the model, trade economists argued that all that mattered were prices: trade could reduce the relative wages of unskilled workers only by reducing the prices of labour-intensive goods relative to skill-intensive goods; changes in imports, exports and sectoral output were irrelevant (Lawrence, 1996; Leamer, 2000). In defence of my use of trade flows in factor content calculations and of my idea of defensive innovation, I appealed to another version of the model, arguing that the North had moved from 'manufacturing autarky' to complete specialisation in skill-intensive goods (Wood, 1998). Regardless of who was right, this choose-the-version-that-suits-your-case approach to the theory was intellectually unsatisfactory.

It is also hard to make sense, in the H-O-S framework, of the regression results in figure 1 and table 1. At first sight, the upward slope of the regression line in figure 1 is a Rybczynski relationship between the relative outputs of two goods and the relative endowments of two factors. On closer inspection, though, this interpretation is not sustainable. The slope (an elasticity) is less than unity, and is only about one-half for the output ratio, while Rybczynski predicts magnification – an elasticity greater than unity. In H-O-S theory, moreover, the line should slope upwards only over the range in which country endowment ratios lie between the factor intensity ratios of the two goods: on either side of this range, countries should produce only one of the goods, a pattern of which there is no trace in the figure.

The puzzle deepens with examination of the NMH/NML (or the PP/NP) regression in table 1. The insignificant coefficient on the land per worker variable in each of these regressions was attributed above to the small difference in land intensity between the two goods. But if this were genuinely a Rybczynski relationship, a small difference in land intensity would have the opposite effect: it would make the elasticity (absolutely) larger, because adjusting the demand for land to match changes in its supply would require more of a shift in the relative outputs of the two goods than if the difference in land intensity between the goods were large.

## 5. Theoretical revival

These odd properties of H-O-S – its sensitivity, both to changes in dimensionality, as emphasised above, and to small changes in prices, as emphasised by Deardorff (2006) – stem largely from an assumption that does not even appear in the usual 'incredible' list, because it is common to most trade theories and not special to H-O-S. It is that goods prices in an open economy are determined by world market prices (sometimes referred to as 'the law of one price').

The internal prices of an open economy may be affected also by tariffs, as famously analysed by Stolper and Samuelson, but unless tariffs change, internal prices move in lock-step with world prices. Internal prices depend, too, on transport and other trade costs, but these are almost always modelled as proportional wedges, like *ad valorem* tariffs.[8] Demand is thus infinitely elastic: depending on whether its production cost

[8] The literature on trade costs is surveyed by Anderson and van Wincoop (2004). A more recent H-O-S model of a single open economy with proportional trade costs is Markusen and Venables (2007).

for a tradable good is above or below the world price adjusted for trade costs, a country either sells nothing or it sells as much as it can produce. In this sense, at the individual country level, H-O-S is a model without a demand side.

*5.1 Trade costs reduce demand elasticities*

Introducing demand inelasticity – inverse relationships between relative goods prices and relative outputs – yields more robust and realistic H-O models. The question is how to explain the demand inelasticity in an economically plausible way. The usual approach, used by Trefler (1995) as well as by computable general equilibrium (CGE) modellers, is to follow Armington (1969) in recognising that foreign and local varieties of goods are imperfect substitutes. But to get demand elasticities down to realistically low levels, CGE modellers need to assume that national varieties are worse substitutes for one another than is suggested by the casual observation of trade theorists (who remain unconvinced). To achieve realistically low elasticities, CGE models also assume, without clear theoretical foundations, imperfect substitutability for firms between home market sales and export sales, and sometimes also world prices that decline with quantities exported, which in reality is rare.

A better explanation for low demand elasticities is provided by trade costs, viewed in a way that differs from the standard proportional wedges and is more realistic (Wood, 2008a).[9] The essential point is that the relative costs of trading any pair of goods do not, in practice, vary among countries in proportion to the relative costs of producing them. Physical features of goods tend to make the costs of trading them similar for all countries: a good that is heavier than another good has this property in every country. Trade costs vary among countries with, for example, their locations, the efficiency of their ports and their trade policies. But relative trade costs are largely independent of relative production costs – there is no general reason why a country that can produce one good more cheaply than some other good should also be able to trade it more cheaply than the other good.

Because relative trade costs are largely independent of relative production costs, relative purchaser prices (the sum of production costs and trade costs) vary less across countries than do relative production costs – a lot less, because trade costs are large (170 per cent of production costs is the developed-country average in the survey by Anderson and van Wincoop, 2004). The relative demand for goods is to some degree inelastic with respect to relative purchaser prices, since (as already mentioned) buyers view goods from different countries as imperfect substitutes. The effect of trade costs is to lower further the demand elasticity that matters for H-O theory – how much the relative quantities of goods sold vary with the relative prices that producers receive.

To put the point algebraically, define the purchaser price, $p$, as the sum of the producer price, $c$ (which in equilibrium equals production cost), and the per-unit trade cost, $t$. The elasticity of relative demand with respect to relative producer prices for a pair of goods, $j$ and 1, can then be written as

[9] That non-proportional trade costs reduce demand elasticities is shown in a narrower context by Hummels and Skiba (2004). Aldaz-Carroll (2003) suggests that elasticities are reduced by unit costs of trade that rise with the quantity sold (at the margin, sales must be made in ever more distant and difficult markets). Rising trade costs are suggested as a possible way of improving the realism of Heckscher-Ohlin models also by Deardorff (2006).

$$\varepsilon_{j1} = \frac{\tilde{\varepsilon}_{j1}}{1+\tau_{j1}}, \tag{1}$$

where $\tilde{\varepsilon}_{j1}$ is the elasticity of substitution in demand with respect to relative purchaser prices and $\tau_{j1}$ is the average ratio of trade costs to producer prices ($t/c$) for goods $j$ and 1. The producer price elasticity, $\varepsilon_{j1}$, is lower than the purchaser price elasticity, $\tilde{\varepsilon}_{j1}$, to a degree which depends on the size of $\tau_{j1}$.[10] For equation (1) to make sense, the purchaser price elasticity, $\tilde{\varepsilon}_{j1}$, must be less than infinite. The equation also holds only approximately when the trade cost ratios ($\tau_j$ and $\tau_1$) differ between the goods. But it conveys simply a proposition of general relevance (discussed at length in Wood, 2008a), which is that trade costs damp producer price elasticities of demand. It also allows openness to be a matter of degree, as in reality, rather than qualitatively different from 'closedness'.

*5.2 A modified H-O-S model*

The H-O-S model can be modified to allow for demand inelasticity. Wood (2008b) follows Jones (1965) in expressing all variables as proportional changes in relative amounts (ratios of outputs of different goods and of endowments of different factors). The effect of proportional changes (denoted by hats) in the relative endowments of a pair of factors, $v_i$ and $v_1$, on the relative outputs of a pair of goods, $q_j$ and $q_1$, is described by the following equation:

$$\hat{q}_j - \hat{q}_1 = \varepsilon_{j1}\left(\theta_{ij} - \theta_{i1}\right)\varphi_{i1}\left(\hat{v}_i - \hat{v}_1\right). \tag{2}$$

There can be any number, $m$, of factors and hence ($m$ – 1) additive terms on the right-hand side, each with factor 1 as numeraire and referring to one of the other factors ($v_2$ and $v_1$, $v_3$ and $v_1$, and so on). There can also be any number, $n$, of goods and hence ($n$ – 1) of these equations, each with good 1 as numeraire and referring to one of the other goods ($q_2$ and $q_1$, $q_3$ and $q_1$, and so on).

The composite elasticity $\varepsilon_{j1}\left(\theta_{ij} - \theta_{i1}\right)\varphi_{i1}$, which is a slope coefficient in the sorts of regressions shown in Table 9.1, is the product of three elasticities. The first, $\varepsilon_{j1}$, is the effect of changes in relative producer prices on relative sales of the two goods in world markets, derived from equation (1) above. The middle term is the effect on relative production costs (and hence on relative producer prices) of changes in relative factor prices, which depends on the shares of the non-numeraire factor $i$ in the costs of producing the two goods ($\theta_{ij} - \theta_{i1}$): its sign depends on the direction of the difference in factor intensity between the goods (which determines the sign of the composite

[10] A higher value of $\tau_{j1}$ lowers $1/(1 + \tau_{j1})$, which is the average share of the producer price in the purchaser price and so is also the weight of producer price changes in purchaser price changes: for example, if trade costs were equal to producer prices ($\tau_{j1} = 1$) and hence producer prices accounted for half the purchaser price of a good, a 20 per cent rise in the producer price would cause a 10 per cent rise in the purchaser price; but if trade costs were double the producer price ($\tau_{j1} = 2$), the share of the producer price in the purchaser price would be only one-third, so that a 20 per cent producer price rise would cause only a 6.7 per cent purchaser price rise.

elasticity – both $\varepsilon_{j1}$ and $\varphi_{i1}$ have negative signs, which cancel). The third elasticity, $\varphi_{i1}$, is the effect on relative factor prices of changes in relative endowments. It summarizes a more complicated relationship

$$\varphi_{i1} = \left[ \sum_{j=1}^{n} (\lambda_{ij}\sigma_{iji} - \lambda_{1j}\sigma_{1ji}) + \sum_{j=2}^{n} (\lambda_{ij} - \lambda_{1j})\varepsilon_{j1}(\theta_{ij} - \theta_{i1}) \right]^{-1}, \quad (3)$$

where, as in Jones, $\lambda_{ij}$ is the share of the economy-wide supply of factor $i$ that is used by sector $j$, and $\sigma_{ijk}$ (following the notation of Smith and Wood, 2005) is the elasticity of the input of factor $i$ into good $j$ with respect to the price of factor $k$. The two terms reflect the two mechanisms by which changes in relative factor prices can bring relative factor demands into line with relative factor supplies: the first is through changes in technique (or detailed product mix) in each sector; the second is through changes in the sectoral mix of outputs of different factor intensities.[11] Equation (3) is inverted because the stronger are these two mechanisms (and hence the larger are the two corresponding terms), the smaller is the change in relative factor prices required by a change in relative endowments. The equation is defined so as to have a positive sign, like an ordinary elasticity of substitution.

This model has the basic H-O property that the relative outputs of goods of different factor intensities vary among countries with their relative factor endowments, but it is more realistic and more robust than the standard form of H-O-S. It allows relative factor prices to vary among countries with their relative factor endowments, it behaves in the same way with any numbers of goods and factors, and it does not predict extreme specialization in production. It is also consistent with the regressions in Table 9.1, both in its form (constant-elasticity relationships between goods ratios and factor ratios) and in its substance (elasticities can be less than unity, and their absolute sizes vary directly with the differences between the factor intensities of goods – measured by $\theta_{ij} - \theta_{i1}$).

This gain in realism comes at a price: trade costs have been added, so there are more variables (but this can be seen as a benefit, since trade costs should be an integral part of any theory of trade); and the algebra is somewhat more complicated than in the standard H-O-S model. Nor can this or any other formalization escape from the fact that higher-dimensional H-O models are inherently complicated and can potentially generate a wide variety of outcomes: to get clear analytical results, simplifying assumptions are needed (Bliss, 2007, ch. 6). For example, in equation (3) changes in the relative endowments of each pair of factors are assumed to have negligibly small effects on the relative prices of all other pairs of factors. This greatly simplifies the model, but one needs to watch out for cases in which this assumption would be seriously misleading.

The modified H-O-S model presented here is also simplified in other ways. Equation (1) is elaborated in Wood (2008a) to distinguish between home sales and exports. The effects of changes in world prices, and in tariffs and trade costs, also need to be spelled out, and the properties of the model explored in more detail. Some of this is

[11] In a standard H-O-S model, $\varphi_{i1}$ would be zero and $\varepsilon_{j1}$ would be infinite. Factor prices would not vary with endowments, and (within a cone of diversification) changes in output mix would fully absorb variation in endowments, without changes in technique.

done in Wood (2008b), but the model as outlined above is sufficient to illustrate that allowing for the effects of trade costs on demand elasticities permits H-O theory to be formalized in ways that avoid the most unrealistic properties of the standard H-O-S model.

## 6. Relevance to development

Development economists have never much liked H-O. The assumptions that it is said to require – above all, identical technology, but also constant returns to scale and perfectly competitive product and factor markets – seem particularly unrealistic for developing countries. Its policy implications seem even more unattractive: if your factor endowments give you a comparative advantage in hewing wood and drawing water, that is what you should do and is what you will do even more of if you open your economy to trade. Forget industrialisation, whose importance for development has been emphasised by, among others, Ajit (Dasgupta and Singh, 2007).

This view of H-O is understandable, given the way in which the theory is usually presented by trade economists, but inaccurate. In earlier sections of this paper I have explained that the assumptions on which the theory depends are not all that strong. I have shown that H-O fits well to cross-country data – in which most of the countries are developing. I have argued that H-O purports to explain only certain facets of the pattern of trade. All this waters down the 'unrealistic' component of the development economists' critique. But what about its 'anti-developmental policy' component?

H-O is a positive theory, and could be argued to be policy-neutral – descriptive rather than prescriptive. But I do not want to put on that fig leaf. H-O theory was born out of a policy debate, and has often been used in later policy debates, including that on trade and wages. I believe, moreover, that economic theory is of value ultimately as a tool for policy design. So what does H-O theory really have to say about the design of development policies?

Like any other theory of comparative advantage, it says that the incomes of countries (though not of all those within them) will be higher if they specialise in goods which they can produce relatively cheaply, and that increased openness to trade will lead to greater specialisation and hence to income gains. The policy message is that barriers to trade and other government actions that discourage specialisation have costs, which should be taken into account in making decisions. These costs need not be large, but they may be large, and it is unwise to ignore them.

The more distinctive development policy message of H-O theory is that the sectoral structure of production should evolve differently in different countries, depending on their initial land/labour ratios (as was initially argued by Krueger, 1977, extended by Leamer, 1987, and applied to Africa in Wood, 2003). In all countries, in H-O theory, accumulation of human capital both raises per capita income and shifts the structure of production towards more skill-intensive goods. But at any given level of income, a country with more land per worker will have a larger primary sector and a smaller manufacturing sector – and more so, the more open is its economy to trade.

In the early stages of development, the structure of production in all countries moves away from unprocessed primary goods, but in land-scarce countries it moves mainly

towards labour-intensive manufacturing, whereas in land-abundant countries it moves mainly towards primary processing.[12] As development proceeds further, both sorts of countries begin to produce skill-intensive manufactures. But land-abundant countries remain net exporters of primary products for longer than land-scarce countries, and do not at any stage export labour-intensive manufactures. These sectoral differences in trajectories matter for policy, because they should influence the detailed design of government actions on infrastructure, education and R&D.

Ajit (Singh, 1993, 1999; Dasgupta and Singh, 2007) has rightly drawn attention to the differing development experiences of East Asian countries, on the one hand, and African and Latin American countries, on the other hand, emphasising the differences in the trajectories of their industrial sectors. Liberalisation of trade policies caused manufacturing to shrink in Africa and Latin America, while East Asian manufacturing went from strength to strength. Ajit attributes this difference to the absence of East Asian industrial policies in Africa and Latin America, but the difference is also what H-O theory would predict as a result of increased openness to trade in land-scarce East Asia compared to land-abundant Africa and Latin America.

Even if this H-O explanation of these regional differences in experience is correct, however, it does not necessarily follow that development in Africa and Latin America benefited from the liberalisation of trade policies. Ajit's view is clearly that they did not – that the resulting deindustrialisation has harmed their long-term development prospects. My view is less clear-cut, but does not depend just on what liberalisation did to sectoral structures of production. It depends on whether liberalisation was good or bad, over the longer term, for economy-wide investment (in physical and human capital) and for technical progress, relative to the initial negative investment caused by the scrapping of sector-specific import-substituting skills and equipment.

This is a question to which the answer appears to have varied widely among countries (good in Chile, for example, but bad in Zambia), depending on other policies and on other aspects of their economic, institutional and political circumstances. It is also a question that H-O theory is not of much help in answering, because it is a theory of how endowments shape outcomes, given technology, and not, with one partial exception, a theory of what determines endowments or technology.

The partial exception, explored in Wood and Ridao-Cano (1999), is that trade-induced changes in factor prices can affect accumulation. In particular, in countries with initially low levels of education, increased openness to trade, by lowering returns to education, may tend to discourage enrolment in schools and colleges and hence further to reduce levels of education. This concern, that openness may reduce skill accumulation, is not one on which Ajit himself has focused, but it resonates with the research of Ajit's late brother-in-law, Sanjaya Lall (for example, 1992), who argued that the accumulation of technological capability is vital to development, that it can be slowed by trade causing specialisation according to comparative advantage, and that it can be stimulated by protection or promotion of selected industries.

[12] Whether and how soon a land-abundant country moves into primary processing, however, depends on the exact nature of its primary products: some products do not need processing, and the processing of some is far more skill-intensive than of others.

The Lall model fits neatly into a H-O framework: accumulating a greater endowment of technological capability shifts a country's comparative advantage into higher-tech products. Lall himself, however, would not have liked this association. He believed that the most important channel of causation, in the context of policy design, goes in exactly the opposite direction: a country can accumulate technological capability only through the experience of producing higher-tech goods, and that governments should therefore encourage and support new and more advanced sorts of production.

To me, both channels seem relevant. Supply-side policies to increase the economy-wide stock of skills through education and training are crucial. Governments can also usefully promote new lines of economic activity, and not only in manufacturing (Ajit argues for the importance of services in India: Dasgupta and Singh, 2007). But this needs to be done cautiously, not usually just by protection against imports, and paying attention to the limits that endowments of skill and knowledge put on what is feasible in particular countries at particular times. For instance, in the 1980s Korea moved successfully into semi-conductors, but Uganda could not have done so. H-O, then, is only one element of a complete theory of development, just as it is only one element of a complete theory of trade, but in both fields it is a useful element.

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