"The relevance of the Stolper-Samuelson theorem to the trade and wages debate"

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The relevance of the Stolper-Samuelson theorem to the trade and wages debate

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Abstract

In this paper we investigate the powerful implications of the Stolper-Samuelson theorem, which uses the Heckscher-Ohlin model to predict strong links between changing trade prices and wage inequalities. We summarise recent work, which shows that these theoretical links are, in fact, far stronger than indicated by empirical evidence or simplified reduced-form regressions. We point out that the literature outlines many reasons to doubt the validity of the Heckscher-Ohlin model, and summarise various general equilibrium studies of advanced countries which indicate that relaxation of the assumptions of the Heckscher-Ohlin model can greatly undermine the Stolper-Samuelson conclusions. We conclude that, while increased trade with developing countries has probably played some part in the widening wage inequalities in the UK and USA, there is considerable doubt over how large this role is. There are good reasons for believing that, contrary to the usual conclusions of the Stolper-Samuelson literature, policies to assist the upskilling of the labour force have considerable potential in offsetting any negative effects of trade on wage inequality.

Keywords: Trade, Income distribution, General Equilibrium

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Non-Technical Summary

This paper surveys some of the recent contributions to the literature on whether increasing openness to trade with developing countries has contributed to the growing wage inequality in some Western countries, notably the United States and UK.

We start by outlining the central economic theorem which links wages to traded prices – propounded by Stolper and Samuelson in a seminal article in 1941. Our paper runs through the theory underlying this relationship, and shows how Stolper and Samuelson's analysis drastically altered economists' perceptions of the determination of wages. If we accept the rather extreme assumptions underlying the Stolper-Samuelson model, under which different countries' products are perfect substitutes for one another, relative wages at home are determined entirely by a combination of world traded prices and the parameters of technology. Within certain bounds, changes in the supply of skilled and unskilled labour or changes in taste of consumers will have no effect on wages.

We outline how this theory has been used by some studies to estimate the determinants of the observed increase in inequality in the USA and UK since the 1970s, using rather simplified models which reduce Stolper and Samuelson's analysis to a single equation, which is then estimated econometrically. This empirical work generally suggests that the main driving force for increasing inequality is not directly falling import prices from the third world, but a related effect where a rapid rise in productivity in the advanced countries in some high-technology sectors compared to the rest of the economy has led to a big change in the structure of production towards exporting high-tech goods and importing unskilled-intensive manufactures. Also that the Stolper-Samuelson analysis leads to the worrying conclusion that there is little practically that Western governments can do to counter this effect.

However, we then outline some more recent work, based on calibrating a full general equilibrium model, with all the equations of the Stolper-Samuelson analysis spelt out fully and fitted to actual data. We show that the Stolper-Samuelson analysis is not consistent with what has actually happened in the UK or USA, since either significant world price shifts or a rapid rise in productivity in high-tech industries would have led in this model to the complete destruction of low-technology manufacturing in the West. This has not happened in practice.

We then point out that Stolper-Samuelson is based upon very restrictive neoclassical assumptions about the workings of the economy: a world of very few produced goods, perfect competition between and within countries, complete factor mobility within countries (but no mobility between countries), no transport costs and full tradability of all goods. We show that relaxing any of these assumptions greatly alters the conclusions of the Stolper-Samuelson theorists, and outline a series of general equilibrium simulations of how some of these assumptions affect results, together with speculation about the effects of other remaining assumptions.

Our conclusions are that there is still considerable uncertainty about what has driven the increase in wage inequality in the Anglo-Saxon world. It seems likely that increasing imports from LDCs have played some part, but that the predominant cause has been direct displacement of jobs within industries by new technology. The evidence that differential technical progress in some industries compared to others is to blame is fairly weak. We also conclude that, contrary to what Stolper-Samuelson might suggest, governments have considerable power to mitigate rising wage differentials by use of education and training policy to increase workforce skills. It is also possible that the specific problems of the UK and the USA may be in part a result of macroeconomic policies over the past two decades: particularly of exchange rate instablility, which has penalised manufacturers.

1. Introduction

In this paper we outline the theoretical implications of the Stolper-Samuelson theorem, and their role in the debate over the effect of increasing imports from developing countries on unskilled wages in the advanced countries. We then examine the evidence from general equilibrium studies, decomposing the observed changes in wage inequality, and compare the implications of models based on the Heckscher-Ohlin (H-O) formulation of trade, upon which the Stolper-Samuelson theorem is based, with alternative formulations which relax some of the H-O assumptions.

2. Background

The Stolper-Samuelson theorem, relating factor price changes to trade liberalisation, has been cited to support the idea that increasing trade with developing countries has been a major cause of the increasing inequality in certain advanced countries (notably the USA and UK) since 1979, as shown in table 1.

Table 1: changes in relative incomes of first, fifth and ninth deciles

1979-1989 various advanced countries (D1 is lowest)

Country	d9/d5	d5/d1	d9/d1
USA	12.0%	11.0%	24.3%
UK	9.0%	5.0%	14.5%
Canada	3.0%	8.0%	11.2%
New Zealand	4.0%	5.0%	9.2%
Japan	5.0%	0.0%	5.0%
Australia	2.0%	2.0%	4.0%
Finland	3.0%	0.0%	3.0%
Austria	2.0%	0.0%	2.0%
Germany	1.0%	-12.0%	-11.1%
Italy	-3.0%	-23.0%	-25.3%

Source: Slaughter 1999.

However, there are counter arguments: (i) technical progress associated with automation, and the 'new economy' could also potentially affect relative wages.

(ii) As the table shows, the increase in inequality is largely an Anglo-Saxon phenomenon. However, Continental Europe has mostly experienced sharp rises in unemployment, leading Davis (1997) and others to argue that they have suffered similar trade and/or technological

shocks, but their inflexible labour markets mean unemployment has risen rather than unskilled wages falling.

(iii) Most studies which have 'decomposed' the observed inequality change in the USA or UK - whether using a price-based method or the alternative factor content analysis - have concluded that technical change has had a larger impact than trade. Nevertheless, there are still considerable methodological problems with this literature.

2a. The Stolper-Samuelson Theorem

The neoclassical H-O trade model used by Stolper and Samuelson (1941) assumes that goods of a particular industry are perfect substitutes, regardless of the country of origin, and that costs of production depend on wages of factors, whose supply in each country is fixed. Transport costs and technology differences are assumed to be negligible.

In a model with two factors, say skilled and unskilled labour, as countries reduce trade barriers, the relative prices of skill-intensive goods will rise in skill-rich countries, and fall in skill-poor countries. As this happens, Stolper and Samuelson predict a rise in skilled wages and a fall (absolute as well as relative) in unskilled wages in the skill-rich countries. Under free trade, according to some versions of the theory, wages of one factor (skilled or unskilled) would be equal across all countries.

The implications of this model are disturbing for advanced countries. The current globalisation tendency can be seen as an opening up to increased trade between the skill-rich advanced countries and developing countries. While the H-O theory predicts this would benefit GNP in both advanced and developing countries, in the former this would be at the expense of falling unskilled wages and increasing inequality. Further, Stolper-Samuelson casts doubt on the popular policy response: to improve education and training. Leamer and Levinsohn (1995) pointed out, if factor wages under free trade are effectively set on World markets, then skilled and unskilled wages in a small, open economy will be insensitive to changes in relative factor endowments (though skill-upgrading policies carried out in concert by all advanced countries could affect wages, by affecting global endowments).

2b. Wages, technology, endowments and trade in a competitive general equilibrium

In order to see how Stolper-Samuelson changes the determination of relative wages, we start by looking briefly at general equilibrium in a closed but competitive economy.

Production in industry i, Y_i is a function of technology, τ, and the employment of skilled and unskilled labour, S_i and U_i:

$$\text{ie } Y_i=Y_i(\tau,S_i,U_i) \qquad (1)$$

Given competition, prices are equal to marginal cost (the zero profit condition), which is a function of technology and factor wages:

$$P = C(\tau,Ws, Wu) \qquad (2)$$

Relative wages are a function of relative employment of the two factors,

$$Ws/Wu = W(\tau,S_i/U_i) \qquad (3)$$

Factor markets are assumed to clear:

$$\Sigma S_i = S;$$
$$\Sigma U_i = U; \qquad (4)$$

In the simplest case, where there is just one industry with a *single representative firm,* a rise in the relative endowment of one factor can only affect wages through technical substitution in production[1] The only factors which affect relative wages are endowments and factor-biased technical progress[2].

Figure 1, below, shows the relationship between endowments and wages in a *two-good, two factor model*, where industry 2 is more intensive in skilled labour S[3]. The curves slope down, reflecting factor substitution within both industries. However, there is now also the possibility of substitution in consumption between the two goods, so endowment changes can be accommodated with less effect on wages. The thick dashed line shows the relationship between endowments and relative wages in this case. With two goods, wages can also be affected by changes in tastes (eg increasing preference for the skill-intensive good) or sector biased technological change, altering the relative production costs of the goods. Whether a rise in relative productivity in industry 2 benefits relative skilled wages depends on whether

[1] The relevant elasticity of substitution is usually assumed to be in the order of -1.
[2] Factor-biased change is where, at a given factor price, the amount of one factor used relative to another changes.

the increased consumer demand for good 2 outweighs the reduction in employment per unit of production - ie if the elasticity of substitution in consumption exceeds unity.

In figure 1, the relationship between endowments and wages in an *open, H-O economy* is shown by the thick solid line. Comparison with dashed line for a closed economy shows that in the H-O case, rather than producing both goods, and gradually shifting towards good 2 as relative skill endowments S/U rise, the economy is now completely specialised in good 1 at skill endowments less than E* and completely specialised in good 2 at skill endowments greater than E**. Between those two levels the country will produce both goods, with both skilled and unskilled wages set on international markets at a wage ratio W*, which is the wage ratio at which the two industries are equally profitable (given world prices and technology).

Points to note are:

1) Substitution in consumption plays no part in determining wages, output or employment in a small, open H-O economy. Prices of the two goods are set on world markets and unaffected by patterns of domestic demand.
2) Over the range E* to E**, changes in endowments do not affect relative wages. Outside that range, the economy behaves like a single representative firm model.
3) If the relative price of good 2 rises, the economy will switch to good 2 at a higher relative skilled wage, say W' on Fig 2.

[3] For simplicity, we assume this is true at all relative factor wages (no factor intensity reversals).

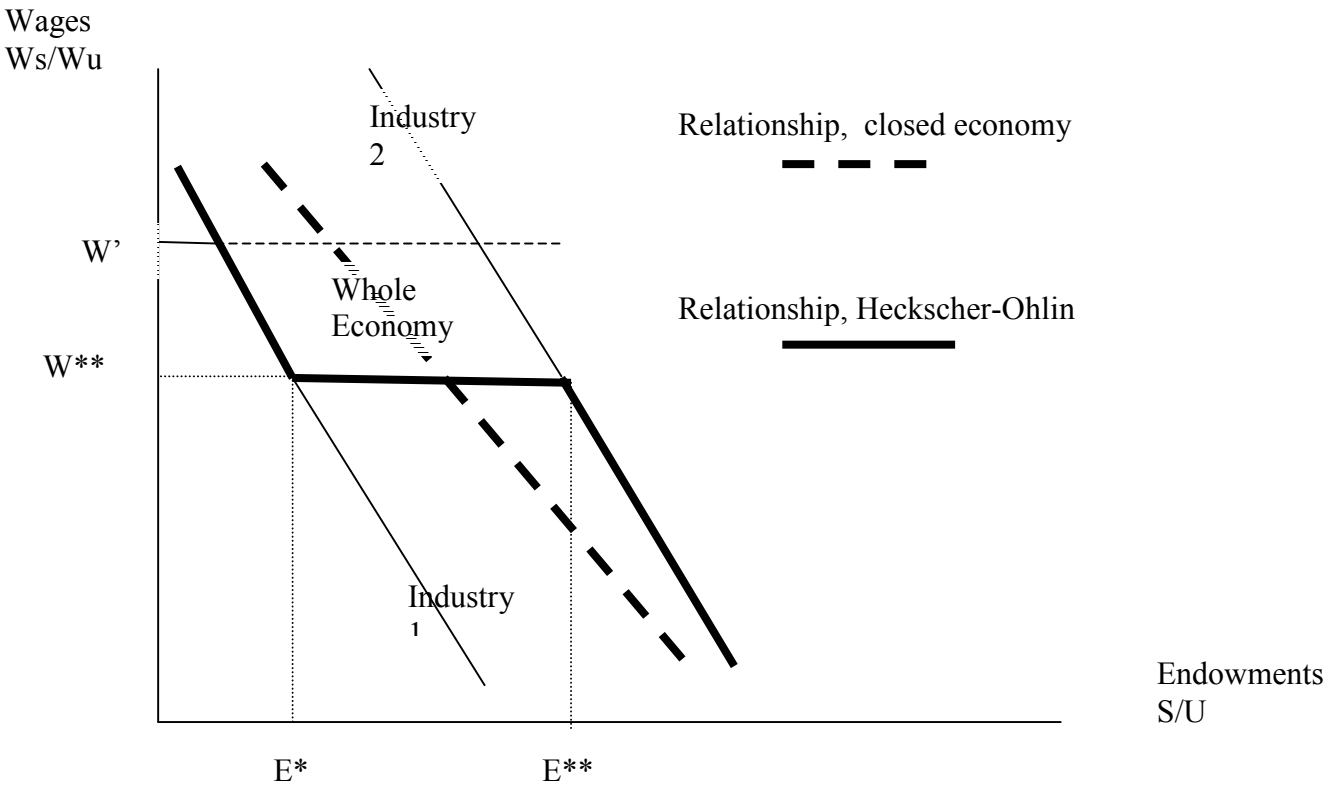

Figure 1: Endowments and wages in a closed economy and a small, open, Heckscher-Ohlin economy.

On Figure 2, the sloping line AB shows the combination of relative wages which satisfies the two zero-profit conditions (equation 2) simultaneously. In a closed

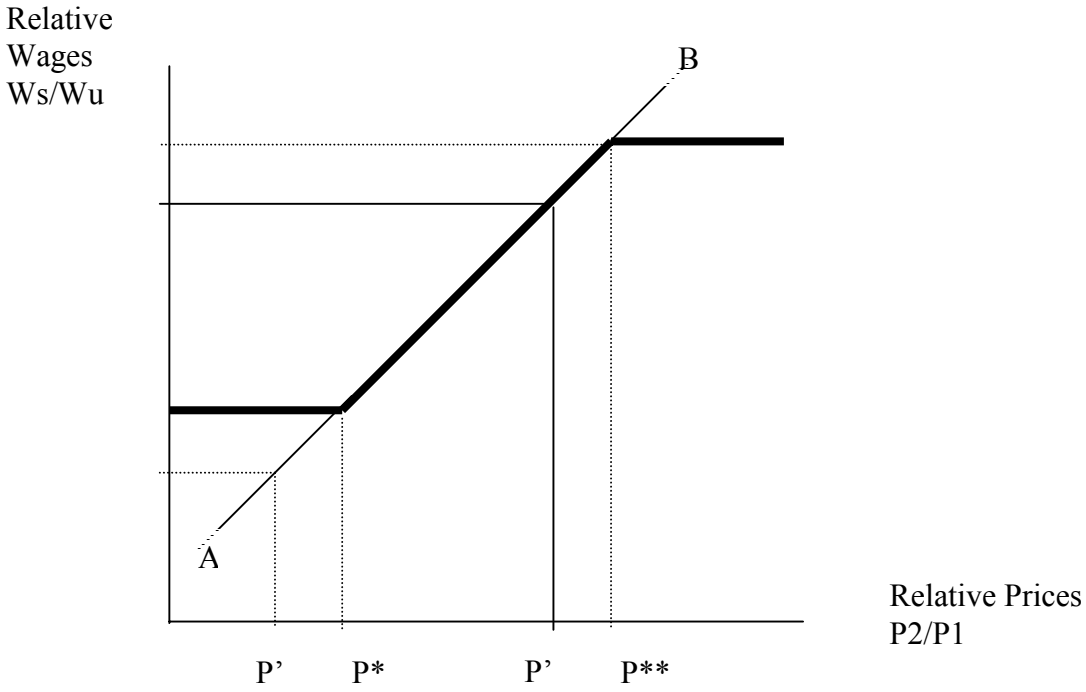

Fig 2: Heckscher-Ohlin model of a small, open economy: relationship of prices to wages.

economy, we can basically interpret prices as being a function of wages (with some feedback via consumer preferences). By contrast, in a small, open H-O economy, the causative direction is solely from (exogenous) world prices to relative wages. Higher relative prices for good 2 mean higher skilled wages. However, this Stolper-Samuelson relationship only holds between P* and P** - outside this range, the economy is completely specialised in one good or another, and relative wages are determined by endowments and technology of a single representative firm within the one industry in which the country is specialised. Far from complete specialisation, say at P, a small change in endowments will not affect relative wages. However, it does shift the range where the economy is not specialised, say to between P' and P''.

Sector-biased technical progress is very important. Assuming the country is not specialised, a 10% reduction in the unit costs (at base wages) of producing good 1 has the same effects on shares of production, employment and relative wages as a 10 % rise in the price of good 1. By contrast, Haskel and Slaughter (1998) point out that factor bias has little effect in this model[4].

3. Empirical application: single equation models

Much of the literature on recent OECD wage inequality change is made up of econometric studies relying on reduced form models. Early literature examined the impact of trade on labour demand via the factor contents of trade (e.g. Borjas et al., 1991; Murphy and Welch, 1991; and Katz and Murphy, 1992). This literature typically used equations linking labour demand and trade flows to estimate the implied changes in labour demand. These estimates were then combined with exogenous estimates of the wage elasticity of labour demand to determine the contribution of trade changes to actual inequality change.

Factor contents based estimates were later criticised on various fronts. First, Wood (1994), using an essentially accounting framework, argued that the contribution of trade is more important than previous factor-content studies had suggested. Among other things, Wood argued that increased trade with low-wage countries gave rise to defensive technical

[4] over the range beween P* and P**. Outside this range, the relative importance of sector and factor bias is reversed.

responses, so that a portion of what traditional factor contents estimations attributed to technology was in fact due to increased trade.

Factor contents studies have also been criticised on conceptual grounds. In particular, the link between labour demand and trade volumes behind their estimates was deemed to be inconsistent with international trade theory[5], which, through the Stolper-Samuelson theorem, relates relative factor prices to relative goods price rather than traded volumes (e.g. Kolster, 1994). A large volume of studies using the more theory-consistent price-based approach equations evolved during the 1990s (e.g. Lawrance and Slaughter, 1993; Baldwin and Cain, 1997; Leamer, 1998; Haskel and Slaughter, 199; Harrigan and Baliban, 1999). This work typically uses reduced-form econometric models derived from general equilibrium structures of a Heckscher-Ohlin type. Most of it concluded that increased OECD wage inequality was mainly the result of skilled-biased technical change, rather than trade.An important question arises, however, about these single equation models: while their authors appeal directly to the Heckscher-Ohlin model as justification for their formulation, a good deal of information is being jettisoned when the model is reduced to a single equation[6]. For example, an equation is estimated relating wage changes to price changes – but no simultaneous equation is estimated relating it to output or employment changes, and the above studies do not check the implications of their estimated equations for output or employment changes against actual observations. Neither is the important issue of complete specialisation being addressed: the models just assume a single smooth relationship between prices and wages, not the inverted-z seen on Fig 2. For this reason, it is instructive to compare these models with full general equilibrium models, calibrated to actual data.

4. Empirical studies of a small, open economy: General Equilibrium models

In this section we summarise the results of studies carried out in recent years covering the decomposition of changes in advanced country (mostly UK) wage inequality into various

[5] However, as long as the economy is not specialised, the change in relative wages in a H-O model can be directly related to changes in output, assuming an elasticity of substitution and assuming that wages clear labour markets. The main drawback is that the observed changes in trade volumes in a H-O model reflect not just changes in prices but sector-biased technical change or changes in consumer taste. Also, the traded volumes would be different had wages not altered.

[6] See Appendix 1 for an illustration of the degree of freedom restrictions implied by adopting a theoretical Cobb-Douglas/Heckscher-Ohlin functional form.

causes, using H-O and a variety of other model formulations which investigate the effects of relaxing various of the neoclassical H-O assumptions. The models consist of a series of simultaneous equations (basically 1-4 above), calibrated to a simplified data set for various countries. Calibration can be to a single year or to two years. This is a double calibration technique explained in Abrego and Whalley. Basically, we need to assume the model structure and elasticity of substitution between factors in production, plus a few other parameters in some of the variant models.

Various studies by Abrego and Whalley and Edwards and Whalley use a UK database for 1979 and 1995 with the following key features:

i) A rise in the average skilled/unskilled earnings ratio from 1.22 to 1.58.

ii) A rise in the skilled share of total employment from 52% to 41 %.

i) A rise in output of skill-intensive goods by 36 % and a rise in output of unskilled-intensive goods of 20 % from 1979-95.

ii) A fall of 7.9% in the relative traded price of unskilled-intensive goods (derived from Neven and Wyplosz).]

Decomposition is carried out either by simulating the effect on the 1979 observations of changing just one of the calibrated price, endowment or technological variables to its 1995 value, or of making the change in a series of small steps (effectively chain-weighting – see Kose and Riezman (2000)).

A summary of the basic results fitted is in table 2

TABLE 2: Decomposition of UK wage differential change 1979-95 by double-calibrated[7]

General equilibrium methods	**Of Which**				
	Trade	*Other Factors*	*Technical Change*	*Endowment Changes*	*Total*
1) Heckscher-Ohlin (Edwards + Whalley)	136.60%	-36.60%	-35.73%	-0.87%	100.00%
2) Differentiated goods (Abrego + Whalley)					
Consumption el subs = 2.5	3.9%	#N/A	96.1%*	#N/A	100.00%
Consumption el subs = 1.5	0.2%	#N/A	99.8%*	#N/A	100.00%
4) Wage bargaining (Abrego)	22.6%	#N/A	77.4%*	#N/A	100.00%
5) Ricardo-Viner (Edwards + Whalley)#	13.37%	86.63%	213.74%	-127.12%	100.00%
6) Ricardo-Viner (Abrego + Whalley)#	17%	-68%	211%	-144%	100.00%
7) Partial mobility (Edwards+ Whalley)	44.54%	55.46%	163.81%	-108.34%	100.00%

* technical change, factor endowments and factor quality changes were not differentiated.
\# while the two studies used similar basic data, they employed different calibration and decomposition methods.

4a. General equilibrium models of a small, open, Heckscher-Ohlin economy.

Probably the first applied general equilibrium study of recent OECD increased inequality was Francois and Nelson (1998), who look at the USA. Their starting point is the traditional two-good (skilled- and unksilled-intensive), two-factor (skilled and unskilled labour) H-O model, which they modified by introducing intersectoral linkages, Armington-type product differentiation, and monopolistic competion (Either/Krugman product differentiation) in the skilled intensive sector. Their analysis focuses on the relative importance of trade effects under different model structures, which they calibrate to 1995 US data. They look at the presence or absence of 'magnification' effects (where factor-price changes are magnified relative to product-price changes, due to shifts in factor demand due to changes in sectoral output[8]) and/or absolute winners or losers under the various models.

[7]

[8] See Neary (1978) or Edwards and Whalley (2001) for more details on the magnification effect.

Francois and Nelson simulate the effect of a hypothetical 1 percent decline in the price of unskilled-intensive good. They find that magnification occurs only when the model assumes goods are homogenous, with this effect being stronger in the model with intermediate goods. With homogeneous goods, there are also absolute winners and losers (skilled and unskilled workers, respectively). When goods are differentiated, magnification breaks down and both factors can win absolutely from improved terms of trade.

Abrego and Whalley (2000) use the traditional H-O model with two production factors (skilled and unskilled labour) and two goods (an exportable, skilled-labour intensive, and an importable, unskilled labour intensive good) to decompose UK wage inequality change into trade and technology components. They model the UK economy as a goods price taker in world markets, and assume production factors to be fully mobile across sectors, but internationally immobile.

The model is calibrated to UK 1990 data on production, trade and factor use, as well as to the relative factor price changes observed in this economy during the period 1976-90. Trade shocks are modelled as changes in world relative prices, and technology shocks as sector specific, Hicks-neutral technical change[9].

Decomposition is carried out by first separately solving the model for the trade and technology shocks and then for the two shocks combined, which allows separation of the contribution of each factor to increased wage inequality. They highlight two main results. First, there are in fact multiple structural-form specifications[10] consistent with the observed change in UK inequality, but each provides different decomposition results. Furthermore, for some specifications, trade is the main source of inequality change, while for others them principal source is technology. They argue that, unless the equilibrium structure is explicitly specified, no meaningful conclusions can be drawn from reduced-form estimates[11].

Abrego and Whalley also identify another difficulty with using the H-O structure in applied general equilibrium setting. With convenient production-function functional forms (e.g.

[9] ie sector-biased but not factor-biased.
[10] For example corresponding to different assumed elasticities of substitution in production. Two models can be calibrated on the same changes in output, employment and wages, but assuming different elasticities of substitution, and can give quite different estimates of the relative importance of trade and technology.
[11] This is consistent with the discussion in Section 4 above.

CES), a H-O structure cannot accommodate the product-price changes observed in countries that have experienced significant wage inequality changes recently (such as the UK). This is because, as Johnson (1966) had shown, unless extreme factor share parameters (inconsistent with observed parameters) are used, small changes to relative goods prices lead to full specialisation. This, in turn, is the result of the near linearity of the transformation frontier associated with the H-O structure with CES production functions.

Edwards and Whalley (2001) modified the Abrego and Whalley model, using a two-pass solution method, so that if complete specialisation was reached equilibrium the model was solved again, this time treating the economy as being of the single representative firm variety (see section 2b. above). The study confirms the extreme sensitivity to price changes shown in Abrego and Whalley's work. Assuming an elasticity of substitution in production of 1.25 between skilled and unskilled labour, trade prices account for more than the total observed change in relative wages. The only way the model can be reconciled with the UK not reaching complete specialisation in the skill-intensive sector in practice is by assuming there must have been substantial factor-biased technical change in the opposite direction (ie in favour of the unskilled-intensive sector). Edwards and Whalley note that this is not consistent with other observations (eg Haskel and Slaughter's study on computerisation rates in different sectors).

Implications of Heckscher-Ohlin General Equilibrium studies

It is very difficult to reconcile observed changes in wages, prices and outputs with what is implied by a simple H-O model. On most plausible elasticity assumptions, a H-O model is far too sensitive, due to the near-linearity of the production function (see Johnson(1966)), and even small changes in world prices tend to produce complete specialisation[12] [13]. This is not what has been observed in practice in terms of output: for example, in the UK, while output of skill-intensive industries did grow by more than the unskilled-intensive industries (36%

[12] Though whether this complete specialisation is accompanied by a large or small change in relative wages depends on the elasticity of substitution assumed in production.

[13] The one exception to this complete specialisation being when the price change is combined, by chance, by an almost exactly offsetting sector-biased technical progress. For example, if the world price of good 1 falls by 5% but at the same time industry A also sees a productivity increase relative to industry 2 of 5%. In this case, there would be no output changes implied by the H-O model.

against 20 % between 1979 and 1995), this is far less of a change in industrial structure than mandated by the observed traded price change if a H-O model is assumed.

As a consequence of this, the single-equation reduced form in Section 3 above should probably be regarded as ad hoc empirical regressions, rather than as applications of a basic H-O model. This is important because in most models other than the strict H-O formulation, relative factor endowments play an important part, yet these have been almost totally ignored by the trade-based literature.

Given the problems in practice with the simple H-O model, it is worth considering what effect other model structures would have on the relationships between trade, technology, endowments and wages.

4b. Diversified goods

One way of getting around the difficulties associated with the traditional H-O model is to use an Armington-type differentiated goods model instead. Abrego and Whalley (2000) employ a simplified form of such a model, for which the traditional H-O, homogeneous goods structure can be thought of as a special case. The model is a variant of the structure set out in de Melo and Robinson (1989), with an import and an exports good, plus a domestically produced good that is not traded, but which is an imperfect substitute for import goods in consumption.

Product differentiation is, however, present on the consumption side only, i.e. for the exportable good, there is no differentiation between the variety consumed domestically and that exported. Production uses both skilled and unskilled labour, both of which are fully mobile across sectors but internationally. The model thus remains effectively a two-good, two-factor model. It converges to its classical H-O counterpart as the elasticity of substitution between domestic goods and imports approaches infinity.

One way of understanding this change is to consider that, in a H-O model, the export good can effectively be exchanged for the importable good at a constant, fixed price, leading to sudden substitution of one good for another (see Fig 1 above). With differentiated goods, however, the exportable and importable goods can still be exchanged at fixed prices, but the

price at which the importable good (and hence indirectly the exportable good) is exchanged for the nontraded good depends on the elasticity of substitution in final consumption. This makes the endowments-wages relationship much more similar to the closed economy model with the dashed line in Fig 1, rather than the solid line of the H-O relationship.

Abrego and Whalley again calibrate this model to 1990 UK data production, trade and factor use data, and 1976-90 relative wage data. They show that this model is able to accommodate price changes of the magnitude observed over 1976-90 in the UK and considerably reduces the range for the decomposition results. For all plausible parameterisations, the change in UK wage inequality is found to come mostly from technological change, with trade playing only a minor role.

Abrego (2000) uses the same heterogeneous goods structure but introduces labour market imperfections. He examines how the presence of trade unions affects the decomposition of wage inequality outcomes into trade and technology components. The model is again calibrated to 1990 data for the UK economy. His principal finding is that the presence of trade union rigidities in the unskilled labour market significantly changes the decomposition of inequality, rising the relative contribution of trade (over 22 percent from 0.5% under fully flexible wages).

The intuition behind Abrego's results has to do with how trade and technology shocks spread throughout the economy. The trade shock is basically driven by a change in the scale of output: the decline in the relative price of the unskilled-intensive product makes this sector contract, which reduce demand for unskilled labour and thereby its relative price. The technology shock is, in turn, fundamentally derived from a substitution effect: technical change biased against unskilled labour makes this factor less productive, leading to substitution away from it and to a decline of its price. Unlike under fully flexible wages, where only output in the unskilled-intensive sector contracts following technical change, wage inflexibility here causes output to fall in both sectors. Thus, with less flexible wages, the technology shock leads to a smaller decline in the relative wage of unskilled workers, i.e. to a diminished role for technical change in increased inequality.

One French study deserves mention: Jean and Bontout (2000) looked at changes between 1979 and 1992, using a nine-sector model with some fixed factors and an Armington trade structure. Technical parameters were calibrated on both years, and once the model was adjusted to remove the effects of involuntary unemployment underlying relative skilled wages were estimated to be virtually constant. Decomposition indicated that traded prices (effect +1%) had virtually no effect on relative wages, while technical change (+39.5%) and a shift in consumer taste towards skill-intensive goods (+11.8%) were offset by an upskilling of the workforce (-34.8%). A sensitivity assuming some of the productivity changes are trade-driven made only small differences. Jean and Bontout's results suggest very little Stolper-Samuelson effects in France. As our own work suggests, this is very much what would be expected in a fixed factor/Armington model framework.

4c. Fixed factors – Ricardo-Viner and partial factor mobility models

The general equilibrium studies above all follow Heckscher-Ohlin in assuming full sectoral mobility of factors (though not international mobility). This assumption is probably unrealistic, at least in the short run (see Mayer, Mussa (both 1974) or Neary (1978)).

As a first test of the robustness of these assumptions, Edwards and Whalley (2001) and Abrego and Whalley (2001) took a modified form of the Abrego and Whalley UK database for 1979 and 1995, but with a third factor, capital, which accounted for somewhat over 30 % of total value added in both sectors in both years. The effects of assuming this capital is immobile, are to slow considerably the movement of output or of the mobile factors in response to price changes. Instead of the very sharp movement towards specialisation in the factors-mobile model, there is only a very small movement as prices alter in this case, and the 'magnification' effect on wages (see Neary) associated with output changes and factor movements is greatly reduced.

The result is that the contribution of prices to relative wages is reduced to about 1/10 of what it was in the H-O factors mobile model, now accounting for 13-17 % of observed relative wage changes. In addition, endowments begin to play a substantial effect. In this case, both studies indicate that, taken on its own, the rise in the skilled share of the total workforce would have reduced greatly relative skilled wages.

Given the small increase in differentials from world prices and large fall from the workforce shifting towards higher skills, it follows by elimination that the overwhelming contribution to increased inequality, in this model, must have come from factor-biased technical change[14].

While it may be unrealistic to assume all the capital stock is immobile over a 16 year period, Edwards and Whalley also investigated sensitivities where an immobile capital stock accounted for a much smaller proportion of GDP. Even with a fixed factor share of just 2 % of value added, the effects of price changes on relative wages are halved compared to the Heckscher-Ohlin model.

Edwards and Whalley also investigate the effect in just a two-factor model of introducing 'iceberg' mobility costs on one of the factors. Effectively, unskilled labour is assumed to move from a declining to an expanding sector only if the wage differential it receives in the expanding sector exceeds λ per cent, where λ represents the costs of moving. For high values of λ this model approaches a two-factor Ricardo-Viner model (as examined in Mayer's, Mussa's and Neary's papers).

A key result is that reducing the mobility of *any* factor dampens the changes in sectoral output and the 'magnification' effect on relative wages associated with this output shift. Somewhat counter-intuitively, the incomes of the factor affected adversely by goods-price changes (in this case unskilled labour) will actually fall less, even in the declining sector, if that factor is immobile than if it is fully mobile.

As with the Ricardo-Viner model, the output and employment effects of relative price changes are much smaller and more plausible than in the H-O model, while the observed rise in the skilled workforce has a significant effect in reducing inequality. Price rises account for about 45 % of the observed rise in wage differentials, with technology accounting for over 100 % of the rise, but offset by endowment effects. Also in common with the Ricardo-Viner model, sensitivity analysis shows that relatively small mobility costs can greatly affect the scale of Stolper-Samuelson effects. While neither the Ricardo-Viner nor the partial mobility model actually challenges the direction of the implied wage effects of world prices under

[14] The role of sector-biased technical change is greatly reduced in a Ricardo-Viner model, since this acts analogously to world price changes on incomes.

Stolper-Samuelson, the simulations show that the scale of these effects is not robust when there are even small barriers to factor mobility.

5. Alternative formulations not yet investigated by general equilibrium study:

It is worth speculating on the possible implications of a couple of other model structures mentioned in the literature, but not yet, to our knowledge, used for explicit general equilibrium decomposition exercises of wage inequality.

5a. The Multi-Good Heckscher-Ohlin model

In this model, countries across the World produce a large number of different goods, varying in factor intensity[15]. However, as a country is assumed to employ just two factors of production, it will produce at most two goods, adjacent in the ranking, the rest being imported.

As endowments change, the country's specialisation will change. Figure 1, relating endowments to prices, becomes a series of steps: sloping downward sections, where the economy produces just one good and behaves like a single representative firm model, and flat sections where the economy produces two goods and prices are locally affected by traded prices, but not by endowments. This raises the first obvious conclusion: the Leamer-Levinsohn factor price insensitivity result no longer holds (except extremely locally on the flat segments) in this model. A second conclusion is there are a whole range of different wage rates associated with the same set of goods prices, if endowments change. However, world prices do have some 'Stolper-Samuelson effect' on relative wages.

The precise relationship between a fall in the price of unskilled-intensive goods and relative wages in advanced countries is not easy to determine in this model. For one thing, in model advanced countries are already specialised towards the skill-intensive end of the spectrum. It may be that a fall in goods at the low-skill end of the spectrum may cause changes in the relative prices of goods right across the spectrum, but this would require a multi-country

[15] Again, factor intensity reversals are ruled out to avoid complication.

general equilibrium model to examine in practice. Such a model would be complicated (given all the specialisation options) and has never, to our knowledge, been calibrated in practice.

5b. New trade theory

The New Trade Theory (NTT - see Krugman and Helpman) incorporates increasing returns to scale, imperfect competition and transport costs, and is seen as more emipirically satisfying than the H-O model, being more consistent with observed two-way trade observed within an industry between countries with similar endowments.

The most popular formulation is the Dixit-Stiglitz model, in which, within an industry, each country produces a range of goods, all of which are imperfect substitutes for one another. In the short run, if the number of varieties produced per country is fixed, this model should behave rather similarly to the Armington differentiated goods model above. In the longer term, NTT models raise the possibility of path dependency. If for some reason local capacity in a supplying industry is greatly reduced, this can adversely affect the competitiveness of industries dependent on their output. For example, extreme macroeconomic fluctuations in the UK and USA in the Thatcher and Reagan years may conceivably have led to a permanent loss of manufacturing capacity, adversely affecting demand for unskilled workers in those economies relative to Continental Europe.

Contrary to the model formulations above, it is conceivable under NTT that policies to retrain unskilled workers as skilled may simply accelerate the decline of unskilled-intensive industries. For this reason, the implications of NTT deserve more careful empirical investigation. We are not aware of any general equilibrium trade-wage decompositions using NTT model formulations.

6. Summary and Conclusions

The labour economics literature emphasises factor-biased technological change, changes in skill endowments, labour laws and bargaining as the main determinants of inequality. By contrast, in the Heckscher-Ohlin-Samuelson literature, trade factors – in the form of changes in world prices, changes in openness of trade policies and sector-biased technological change – are all-important. This suggests that the explanation of increases in inequality in the UK and USA is driven either by increased access to imports from developing countries or by

technological improvements favouring increased trade specialisation in skill-intensive products.The policy implications of Stolper-Samuelson are also potentially important, suggesting labour market policies should be based on redistribution rather than upskilling, since upskilling by a single country is unlikely to affect factor wages significantly.

Our survey suggests these conclusions should be treated with some scepticism. While empirical research based on single-equation models has found evidence of 'Stolper-Samuelson effects' from globalisation, general equilibrium work makes it clear these observed results are not, in fact, consistent with the H-O model. This model in fact implies very rapid changes in specialisation in response to either price or technological shocks, such that the economy would rapidly reach complete specialisation: such changes have not remotely been observed in practice.

We therefore suggest that the changes which have been observed in practice are far more consistent with modified models. We examine general equilibrium studies by Abrego and Whalley and Edwards and Whalley based on relaxing various H-O assumptions (allowing differentiated goods, wage bargaining and fixed factors and/or labour mobility). These suggest that the results of the H-O literature need to be taken with a degree of caution. Most of the variants examine uphold the direction of trade effects on wages implied by Stolper-Samuelson - that unskilled wages in advanced countries will decline in the face of trade liberalisation - but greatly reduce the scale of this effect. However:

i) the differentiated goods model casts doubt even on the direction of these changes, if imports and domestic unskilled-intensive goods are complements (elasticity of substitution less than 1).

ii) Once we assume the presence of even small amounts of fixed factors, the effects of either sector-biased technological change or trade price changes on wages are greatly reduced in scale, while factor bias and endowments play an important role.

iii) The multi-good version of the Heckscher-Ohlin model makes the linkage between trade with developing countries and wages in the advanced countries much more indirect and tenuous.

In the light of this, we suggest that single-equation regression studies should be seen essentially as ad hoc empirical studies, rather than as direct attempts to estimate a H-O

economy. While their implied conclusions about the 'Stolper-Samuelson' effects of trade prices on wages - that they have been a contributing factor, but probably not the major factor - are broadly consistent with some of the general equilibrium model structures we have examined, there are important caveats: in particular, studies of this sort should not rule out that factor endowment changes may have had an important effect on relative wages (despite what some of the simpler H-O models suggest).

We also believe there is a strong case for further investigation of general equilibrium decompositions, expanding the analysis to incorporate multi-good, multi-country models and the effects of different labour market structures. The New Trade Theory may have important long-term implications both for decomposition and for policy, and should be investigated further.

Bibliography

Abrego, L. (2000), "Labour market institutions and decomposition of wage inequality outcomes", *mimeo*, CSGR Warwick.

Abrego, L. and J. Whalley (2001), "Decomposing wage inequality using general equilibrium models". *mimeo*, CSGR Warwick.

Abrego, L. and J. Whalley (2000), "The Choice of Structural Model in Trade-Wages Decompositions." *Review of International Economics*, Vol. 9, No. 3 (August).

Baldwin, R.E. and G.G. Cain (1997), "Shifts in US Relative Wages: The Role of Trade, Technology and Factor Endowments," *NBER Working Paper* No. 5934.

Borjas, G.J., Freeman, R.B., and L.F. Katz (1992): "On the Labour Market Implications of Immigration and Trade", in G.Borjas and R.Freeman,(eds) *Immigration and the Work Force*. Chicago, University of Chicago Press, pp 213-44.

Davis, D.R. (1997), 'Technology, Unemployment and Wages in a Global Economy', *European Economic Review*, 1997.

De Melo, J. and S. Robinson (1989), "Product Differentiation and the Treatment of Foreign Trade in Computable General Equilibrium Models of Small Economies." *Journal of International Economics* 27: 47-67.

Edwards, T.Huw and J.Whalley (2001), "Short and Long Run Decompositions of OECD Wage Inequality Changes", *Mimeo*, CSGR Warwick.

Francois, F. and D. Nelson (1998), "Trade, Technology and Wages: General Equilibrium Mechanics," *Economic Journal* 108: 1483-1499.

Harrigan, J. and R. Balaban (1999), "US Wages in General Equilibrium: The Effects of Prices, Technology, and Factor Supplies, 1963-1991," *NBER Working Paper* No. 6981.

Haskel, J. and M. Slaughter (1998), "Does the Sector Bias of Skilled-Biased Technical Change Explains Changing Wage Inequality?" *NBER Working Paper* No. 6565.

Haskel, J. and M. Slaughter (1999), "Trade Technology and UK Wage Inequality." *NBER Working Paper* No. 6978.

Jean, S. and O. Bontout: "What Drove Relative Wages in France? Structural Decomposition Analysis in a General Equilibrium Framework, 1970-1992". *Working paper* 2000-03, CEPII, Paris.

Johnson, H.G. (1966), "Factor Market Distortions and the Shape of the Transformation Frontier." *Econometrica* 34: 686-98.

Katz, L.F. and K.M. Murphy (1992): "Changes in Relative Wages, 1963-1987: Supply and Demand Factors", *Quarterly Journal of Economics* pp 35.78.

Kose, A and R.Riezman (2000): "Understanding the Welfare Implications of Preferential Trade Agreements", *Working Paper* 45/99, CSGR, Warwick.

Kosters, M. (1994), "An Overview of Changing Wage Patterns in the Labour Market," in Bhagwati, J. and M. Kosters (eds.), *Trade and Wages: Levelling Wages Down?*. Washington: AEI Press.

Krugman, P. (2000), "Technology, Trade and Factor Prices" *Journal of International Economics* 50: 51-71.

Krugman, P. and E. Helpman (1985): *"Market Structure and International Trade: increasing returns, foreign competition".* Wheatsheaf, Brighton.

Lawrence, R.Z. and M.J. Slaughter (1993): "International Trade and American Wages in the 1980s: Giant Sucking Sound or Small Hiccup?" in M.N.Baily and C.Winston (eds) *Exports, Imports and the American Worker*, Washington D.C.: The Brookings Institution.

Leamer, E. (1998), "In Search of Stolper-Samuelson Linkages between International Trade and Lower Wages." In S. M. Collins (ed.) *Imports, Exports, and the American Worker*. Washington, D.C.: Brookings Institution.

Leamer, E.E., and Levinsohn, J. (1995): "International Trade Theory: The Evidence", in Gene M. Grossman and Kenneth Rogoff(eds) *Handbook of International Economics Volume 3*, Amsterdam, North Holland Press, pp 1338-1394.

Machin, S. and J. van Reenen (1998), "Technology and Changes in Skill Structure: Evidence from Seven OECD Countries." *Quarterly Journal of Economics* 113: 1215-44.

Mayer, W. (1974): 'Short-Run and Long-Run Equilibrium for a Small Open Economy'. *Journal of Political Economy*, vol 82 no 5 pp955-967.

Murphy, K. and F. Welch (1989), "Wage Premiums for College Graduates: Recent Growth and Possible Explanations." *Educational Researcher* 18: 17-26.

Mussa, M. (1974), "Tariffs and the Distribution of Income: The Importance of Factor Specificity, Substitutability, and Intensity in the Short and Long Run." *Journal of Political Economy* 82: 1191-1204.

Neary, J.P. (1978): 'Short-Run Capital Specificity and the Pure Theory of International Trade'. *Economic Journal* Vol 88, Issue 351 pp488-510.

OECD (1995), *The OECD Input-Output Database*. OECD: Paris.

Office for National Statistics: (1981-82), *Employment Gazette* (various issues).

(1996), *Labour Market Trends* (May issue).
(1997a), *United Kingdom National Accounts*.
(1997b), *Input-Output Balances for the UK*. ONS London UK.

Slaughter, M. (1999), "Globalization and Wages: A Tale of Two Perspectives *World Economy* 22: 609-29.

Stolper, W. and P. Samuelson (1941), "Protection and real wages", Review of Economic Studies 9: 58-73.

Wood, A. (1994), *North-South Trade, Employment and Inequality*, Oxford: Clarendon Press.

Appendix 1: Estimation of theoretical trade models and degrees of freedom.

A common strand in the Heckscher-Ohlin epirical literature is to derive from a Heckscher-Ohlin model a theoretical reduced form equation linking relative wages in one country to traded prices, given technical parameters. A residual term is then added, and the equation is then estimated econometrically.

There is however a potential danger in carrying out this kind of exercise: reduced form equations of this kind usually involve a large number of parameter restrictions, which are not always observed in the econometric literature. In fact, there may be little or nothing left to estimate, once the proper Heckscher-Ohlin restrictions are assumed to apply.

To illustrate this, consider a two-good two-factor Cobb Douglas model of a small open economy. The two industries produce with the zero profit conditions:

$$P_i = (1/A_i).(Wu/\beta_i)^{\beta_i}.(Ws/1-\beta_i)^{1-\beta_i}\ i = 1,2 \text{ -(F1)}$$

Assuming the economy is not completely specialised, (f1) can be rearranged to relate wages to prices:

$$(Wu/Ws)^{\beta_1-\beta_2} = (A_1/A_2).(P_1/P_2).((1-\beta_1)/(1-\beta_2)).[(1-\beta_1)/\beta_1]^{\beta_1}/[(1-\beta_2)/\beta_2]^{\beta_2} \text{ -(f2)}$$

This can easily be written as: $\theta.\ln W = \phi + \ln A + \ln P$ -(f3)

where W is Ws=Wu, A is A_1/A_2 and P is P_1/P_2, and estimated by OLS. However, such an estimation is neither necessary nor theoretically consistent: it ignores the fact that the theory dictates that θ is actually β_1-β_2, the difference in factor shares, and that φ is also a direct function of the factor shares - ie there are actually nothing left to be estimated, as the model can simply be calibrated once a Cobb-Douglas form is assumed. The CES version allows only a little more scope for estimation, since the elasticity of substitution can be allowed to vary.