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Inequality Changes”**

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# SHORT AND LONG RUN DECOMPOSITIONS OF OECD WAGE INEQUALITY CHANGES\*

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## Abstract

This paper focuses on the causes of increased wage inequality in OECD countries in recent years and its decomposition into the component factors of trade surges in low wage products and technological change that has preoccupied the trade and wages literature. It argues that the length of production run and degree of fixity of factors is crucial in such analyses. In particular, if the observed wage inequality response to price and technology shocks reflects a short-run response in which factors and output have not adjusted fully across industries, then decomposition analysis of the causes of the observed increases in inequality is substantially altered relative to a long-run factors mobile world. This conclusion applies both when one type of labour has mobility costs and in the Ricardo-Viner case where there is an additional, sectorally immobile factor. Furthermore, only small departures from the fully mobile model can greatly change decompositions. This finding is important because most data used in earlier work are interpreted as reflective of a long-run full mobility response, when this may not be the case. Incorrect conclusions as to how trade surges and technology contribute to wage inequality can be easily drawn, if the data are in fact generated by a short-run adjustment process.

## 1. INTRODUCTION

This paper focuses on the causes of increased wage inequality in OECD countries in recent years, more specifically its decomposition into the component factors of trade surges in low wage products and technological change that has preoccupied the trade and wages literature<sup>1</sup>. We argue that if we assume that if the observed wage inequality response to price and technology shocks reflects a short-run response in which factor allocations and output have not fully adjusted across industries, then decomposition analysis of the causes of the observed increases in inequality is substantially altered relative to a long-run world in which all factors are mobile. This finding is important because most data used in the debate are interpreted as reflective of a long-run full mobility response, when this may not be the case. Incorrect conclusions as to how trade surges and technology contribute to wage inequality can be easily drawn if the data are generated by a short-run adjustment process.

We examine two cases of factor immobility: a two-factor model where one factor is subject to mobility costs, and a Ricardo-Viner model with a third factor, immobile in the model run. In both cases, relatively small departures from the fully mobile Heckscher-Ohlin model greatly change the decomposition results.

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<sup>1</sup>See Wood (1994), Haskel and Slaughter (1998), Slaughter (1999) and Leamer (1998).

## 2. LONG AND SHORT RUN MODELS FOR TRADE AND WAGES ANALYSIS

We use trade-based models to decompose the observed change in skilled-unskilled wage inequality in the UK between 1979 and 1995 to evaluate the relative importance of world prices (trade changes) and technological progress (whether sector- or factor-biased) in generating wage change. We compare results from short-run models in which some factors are either immobile or face adjustment costs moving between sectors, to those from a longer-run Heckscher-Ohlin type model where all factors are fully mobile between industries.

Models where not all factors can move easily between sectors (Mayer, Mussa, 1974, and Neary, 1978) have investigated the implications of this feature for relative incomes in a two-factor model (such as whether the Stolper-Samuelson theorem still holds) and are the starting point for this paper. In these papers, the factor inputs are labour and capital, with capital immobile between sectors.

We discuss the case where the factor inputs are unskilled ( $U$ ) and skilled ( $S$ ) labour, with  $U$  being the factor subject to adjustment costs. In this case, if there is a fall in the world price of the  $U$ -intensive good, with  $S$  freely mobile between sectors, then since  $U$  cannot easily move towards the  $S$ -intensive sector in the short run, its wage will rise in the expanding sector

and fall more steeply than the goods price in the declining sector. The wage of  $S$  will fall in the short run, though by less than that of the  $U$ -intensive good. In the longer run, as factor  $U$  becomes free to move towards the  $S$ -intensive sector where its wage is higher, the output of this sector will expand. Given the shift towards the  $S$ -intensive sector,  $S$ 's wages will rise, while  $U$ 's wage will fall further in both sectors<sup>2</sup>. This relative wage effect reflecting the shift over time in factors can be more marked than the initial impact effect of the price shock, and is the main factor behind the long-run Stolper-Samuelson influences on relative wages (a fall in the  $U$ -intensive good price will reduce  $U$ 's wage and raise  $S$ 's wage).

Although  $U$ 's income will fall sharply in the  $U$ -intensive sector when the goods price falls, it will actually fall further, rather than be mitigated, once  $U$  becomes free to move to the other sector, as  $S$ 's share of income gets bid up by the shift of output to the  $S$ -intensive sector. This suggests that some

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<sup>2</sup>The mechanism behind this seemingly counter-intuitive result can be seen as follows. Looking at a 2-good, 2-factor Heckscher-Ohlin model, compare a base case and two cases,  $V$ , where both factors are variable, and  $F$ , where factor  $U$  is fixed in particular sectors. Both  $V$  and  $F$  see an identical fall in the world price of the  $U$ -intensive good. In case  $V$ , both factors move out of  $M$  to sector  $E$ , and there is a change in output composition. As the export good is much more intensive in  $S$ , the relative wage of  $S$  is driven up and that of  $U$  falls.

In case  $F$ ,  $U$  is immobile. As sector  $M$  contracts,  $S$  is still free to move to sector  $E$ , but the expansion of that sector is greatly dampened because of a shortage (in that sector) of unskilled factor  $U$  (which drives up  $U$ 's wage in the expanding sector  $E$ ). Consequently, there is much less demand for  $S$ , and its wage does not rise as in case  $V$ . Since  $S$  is cheaper, and the price of output of good  $E$  is the same in case  $V$  as case  $F$  in a Heckscher-Ohlin model, it follows that the wage of  $U$  is higher in case  $V$  than case  $F$ , even in the declining sector.

For more formal proof please contact the authors.

of the conclusions of the short-run model may differ from the longer-run H-O model, in that much of the impact of trade on relative factor rewards takes place only as trade and output here are able to change (the 'magnification' effect). Also factor price insensitivity to endowments does not apply when not all factors are able to move, so any 'short-run' study of the causes of changing wage inequality needs to take account of changing endowments, not simply world prices and technology.

This conclusion is supported by our alternative, Ricardo-Viner case, where both types of labour are mobile, but capital is immobile. Again, the capital immobility greatly reduces the shift in output between sectors in response to a price change, and this has a very large damping effect on changes in labour demand and wages. Sector output movement and changes in factor demand are greatly reduced even when only 2% of value added comprises a fixed factor.

We consider the possibility that the changes in relative wages observed in a small open economy reflect the short-run response of the economy to a combination of world price, technological and demographic shocks. The procedures we employ are to calibrate a numerical general equilibrium model to the UK economy using data for 1979 and 1995, and then to make computations to decompose the observed change into component parts by considering the effects of changes separately. We use a Heckscher-Ohlin model, which

assumes that factors can freely move between sectors, a short-term model which incorporates adjustment costs for unskilled labour and a Ricardo-Viner model.

## 2.1 A Long-run Trade and Wages Model

For our long-run model, we use a 2-factor, 2-sector Heckscher-Ohlin type formulation of a small, open economy<sup>3</sup>. Of the two sectors, sector  $E$  (exportables) is assumed to be intensive in the use of skilled factor  $S$  compared to unskilled factor  $U$  relative to sector  $M$  (importables): ie  $U_E/S_E < U_M/S_M$ . This holds for any pair of wage rates  $W_u$  and  $W_s$  (ie there are no factor intensity reversals). The factor input-output ratios for  $E$  and  $M$ ,  $au_E$ ,  $as_E$ ,  $au_M$  and  $as_M$  are all functions of  $W_u$  and  $W_s$ .

We assume both labour markets are perfectly competitive. In equilibrium, these markets will clear, and factor prices and the associated input-output ratios and goods outputs will all adjust to clear the two factor markets. These equilibrium conditions imply that

$$\begin{aligned} au_E(W_U, W_S) \cdot Y_E + au_M(W_U, W_S) \cdot Y_M &= \bar{U} \\ as_E(W_U, W_S) \cdot Y_E + as_M(W_U, W_S) \cdot Y_M &= \bar{S} \end{aligned} \tag{1}$$

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<sup>3</sup>Strictly speaking, Heckscher-Ohlin trade models provide an explanation of trade patterns between countries in terms of relative factor abundance. We use the term here to refer to a mobile factors formulation of a single country.



where  $Y_E$  and  $Y_M$  are outputs of the two goods and  $\bar{U}$  and  $\bar{S}$  are the economy wide endowments of unskilled and skilled labour.

Competition ensures prices equal unit costs in both sectors, ie

$$au_E(W_u, W_S) \cdot W_U + as_E(W_u, W_S) \cdot W_S = \bar{P}_E \quad (2)$$

$$au_M(W_u, W_S) \cdot W_U + as_M(W_u, W_S) \cdot W_S = \bar{P}_M$$

where  $\bar{P}_E$  and  $\bar{P}_M$  are the two goods prices set on the world market.

In order to capture the separate effects of factor- and sector-biased technical progress, we use a CES production function for each sector of the form

$$Y_i = A_i \left[ \beta_i (\alpha^u U_i)^{((1+\sigma_i)/\sigma_i)} + (1 - \beta_i) (\alpha^s S_i)^{((1+\sigma_i)/\sigma_i)} \right]^{\sigma_i/(1+\sigma_i)} \quad (3)$$

where  $A_i$  is a scale parameter,  $\sigma_i$  is the elasticity of substitution between skilled and unskilled labour in production,  $\beta_i$  is a share parameter and  $\alpha^u$  and  $\alpha^s$  are factor-augmenting technical change parameters. We can interpret an increase in  $A_i$  as representing a general increase in total factor productivity in sector  $i$ , which is purely sector-biased in its effects. Changes in  $\alpha^u$  and  $\alpha^s$  represent technical progress which increases the productivity of one factor across both sectors (factor biased technological change).

Differentiation of these production functions yields the following first-

order conditions:

$$\begin{aligned}
 W_u &= P_i \cdot A_i \cdot (Y_i/A_i \cdot U_i)^{-1/\sigma_i} \beta_i (\alpha^u)^{\sigma_i/(1+\sigma_i)} \\
 W_s &= P_i \cdot A_i \cdot (Y_i/A_i \cdot S_i)^{1/\sigma_i} \cdot (1 - \beta_i) (\alpha^s)^{\sigma_i/(1+\sigma_i)}
 \end{aligned} \tag{4}$$

If we make the simplifying assumption that the elasticity of substitution between factors is the same in both sectors ( $\sigma_i = \sigma$  for all  $i$ ) the effects of various influences on the ratio of skilled to unskilled wage rates can be summarized in this model by equation (5) (derived by rearranging the indirect cost functions for the two industries). This links relative wage rates to relative goods prices over the price range for which there is no specialisation:

$$W_s/W_u = \langle [\theta_{um} \cdot (P_E \cdot A_E / P_M \cdot A_M)^{1+\sigma} - \theta_{uE}] / [\theta_{SE} - \theta_{SM} \cdot (P_E \cdot A_E / P_M \cdot A_M)^{1+\sigma}] \rangle. \tag{5}$$

Where the  $\theta$  parameters represent the composite effect of share and factor-augmenting change for each sector and each factor, ie

$$\begin{aligned}
\theta_{si} &= (1 - \beta_i)^{-\sigma} / \alpha^{s1+\sigma} \\
&= \theta_{ui} \beta_i^{-\sigma} / \alpha^{u1+\sigma} \\
i &= \{E, M\}
\end{aligned} \tag{6}$$

In this formulation,  $W_s/W_u$  is higher the larger is  $P_E$  or  $A_E$ , and the smaller is  $P_M$  or  $A_M$ . An increase in  $\alpha_u/\alpha_s$  will reduce  $W_s/W_u$  (this is the same result as in Davis (1997) and Haskel and Slaughter (2002)). Changes in the CES share parameters,  $\beta$ , however, have ambiguous effects on relative wages.

As Abrego and Whalley (2000) note, following Harry Johnson (1966), in the CES case specialization can occur for surprisingly small changes in goods prices. If specialization does occur, beyond this point traded goods prices do not affect relative wages, though changes in factor supplies will have an influence.

It is perhaps worth noting that the model equations outlined above do not contain any statement of consumer demand or utility. In this framework, prices of all goods are set on the world markets, and consumer demand at home does not affect prices or output if we assume the economy is small and open. This means that the production and consumption sides of the

economy are separable; and given our focus on the determination of relative wage change we can concentrate on modelling the production side alone. The same argument applies for the short run model to which we turn next.

## 2.2 A Short-run Adjustment Model of Trade and Wages

We formulate a short-run trade and wages model similar to the long-run model above, but in which labour cannot move costlessly between sectors due to adjustment costs. These may be search costs, transportation or removal costs, transactions costs in housing markets, or even psychological costs and preference for location.

In the model, we assume these transactions costs create a wedge between the wage offered in the sector where labour is currently employed and the wage needed to be offered in another sector in order for a worker to move. Wage rates in sectors which are expanding following an international price shock to the economy are thus higher than those in contracting sectors where labour shedding occurs.

In this model, factor  $U$  will only move from a declining sector  $M$  to an expanding sector  $E$  if wages in  $E$  exceed those in  $M$  by some proportionate amount  $\lambda_{ui}$ : ie if  $W_{uE} - W_{uM} \geq \lambda_u \cdot W_{uM}$ , and likewise for factor  $S$  if it also faces adjustment costs. This means there are 3 kinds of sectors; expanding sectors, where employers pay a high wage (gross of adjustment cost); declining sectors where the wage is lower, but adjustment costs are lower; and

sectors where employment is not changing. These sectors are paying wages high enough that their labour force does not find it attractive to move to the expanding sector once adjustment costs are taken into account.

In expanding sectors, we define the wage gross of adjustment costs as  $W_{Ui}^g$  where  $i \subset e$ , the set of expanding sectors. The wage net of adjustment costs  $W_{Ui}^n = W_{Ui}^g / (1 + \lambda_U)$ . In declining sectors ( $i \subset d$ , the set of declining sectors) the wage rate will be the same as the wage in expanding sectors net of adjustment costs is  $W_{Uj} = W_{Uj}^n = W_{Uj}^g / (1 + \lambda_U)$  (where  $j \subset e$  is the set of expanding sectors). A sector  $i$  will have unchanged employment if its wage lies between  $W_{Uj}^g$  and  $W_{Uj}^g / (1 + \lambda_U)$  (where, once again  $j$  is an expanding sector  $j \subset e$ ).

To capture these features we modify equation (4) to apply different wages to different sectors, expressing wages in all sectors in relation to the gross wage in the expanding sectors:  $W_{Uj}^g$  where  $j \subset e$ . We will call this our reference wage, and label it as  $W_U^R$ . As we consider a two sector model, we can limit ourselves to only expanding and contracting sectors.

For each sector, we express the proportional difference between the wage received by labour in the unskilled intensive sector  $W_U^R$ , and the (gross of adjustment cost) wage paid by employers,  $W_U^g$  as  $lU_i$ . This allows us to characterize the difference in sectoral wage rates as follows:

In expanding sectors ( $i \in e$ ) :  $lU_i = 0$

In declining sectors ( $i \in d$ ) :  $lU_i = \lambda_u$  (7)

We define the benchmark (pre-shock) levels of employment of  $U$  and  $S$  in each sector as  $U_i^*$  and  $S_i^*$ ; the levels of employment if nobody leaves the sector. In a declining sector  $i$  ( $i \in d$ ,) adjustment costs mean that the wage discount factor  $lU_i$  equals the maximum permitted,  $\lambda_u$ , and labour can move (ie the sector is ‘declining’).

The adjustment costs borne by those factors which move (which may be in the form of either temporary unemployment or a loss of productive efficiency) are given by:

$$\begin{aligned}\mu_u &= W_u^R \cdot \sum_i l u_i \cdot (U_i^* - U_i) \\ \mu_s &= W_s^R \cdot \sum_i l s_i \cdot (S_i^* - S_i)\end{aligned}\tag{8}$$

If adjustment costs are denominated in labour, this reduces effective econ-

omywide endowments

$$\begin{aligned}\sum_i U_i &= \bar{U} - M_{ui}/W_u^R \\ \sum_i S_i &= \bar{S} - M_{si}/W_s^R\end{aligned}\tag{9}$$

The effects of introducing adjustment costs into the model are thus: i) the wage of each factor will now differ between sectors by a proportion  $\lambda_U$  for  $U$  and  $\lambda_S$  for  $S$ . (ii) factors are now less mobile in response to a price or other shock. In particular, there is a range of traded goods prices over which factors will not move, and this is wider the larger are  $\lambda_u$  and  $\lambda_s$ . (iii) following Neary (1998) reduced mobility reduces the effects of price changes on relative wage changes in both sectors. (iv) because of the effects of the adjustment costs on factor movements and relative wages, the specialisation effects in a classical Heckscher-Ohlin model less likely to occur. The model is easier to reconcile with observed data, where extreme changes in specialisation are not observed. (v) if we assume that in the long run  $\lambda_u$  and  $\lambda_s$  are zero, a price change will have larger effects on output, employment and wages in the long run than over the short-run. (vi) the long-run model is simply the short-run model with the parameters  $\lambda_u$  and  $\lambda_s$  set to zero.

### 2.3 A Ricardo-Viner Fixed Factor Model of Trade and Wages

Our Ricardo-Viner model utilizes a nested CES function to combine three

factors: unskilled labour,  $U$ , skilled labour,  $S$ , and capital. Skilled and unskilled labour are mobile across sectors with a common wage,  $W_S, W_U$ , while capital is sector specific, set at a level  $K_i$ . A CES nesting structure is used in which the two types of labour are used in each sector  $i$  are combined to form aggregate labour  $L_i$  using a CES aggregate. This is then combined with capital in a Cobb-Douglas function to yield total sectoral output,  $Y_i$ .

The CES aggregation function for the sectoral labour aggregate,  $L_i$ , is of the same form as equation (3)

$$L_i = A_i \left[ \beta_i \cdot (\alpha^u \cdot U_i)^{(1+\sigma_i)/\sigma_i} + (1 + \beta_i) (\alpha^s \cdot S_i)^{(1+\sigma_i)/\sigma_i} \right]^{\sigma_i/(1+\sigma_i)} \quad (i = u, s) \quad (10)$$

We can differentiate this to obtain first order conditions for the two wages  $W_U$  and  $W_S$  in terms of a sectoral aggregate wage  $W_i$  and  $L_i$ :

$$W_U = W_i \cdot A_i \cdot (L_i/A_i U_i)^{-1/\sigma_i} \cdot \beta_i \cdot \alpha^{u\sigma_i/(1+\sigma_i)} \quad (i = u, s) \quad (11)$$

$$W_S = W_i \cdot A_i \cdot (L_i/A_i S_i)^{-1/\sigma_i} \cdot (1 - \beta_i) \cdot \alpha^{s\sigma_i/(1+\sigma_i)} \quad (i = u, s)$$

The aggregate labour wage,  $W_i$  is given by :

$$W_i = (W_u \cdot U_i + W_s \cdot S_i) / L_i \quad (12)$$



The Cobb-Douglas aggregation of  $L_i$  and  $K_i$  to form  $Y_i$  is given by:  $Y_i = \Upsilon_i K_i^{\gamma_i} \cdot L_i^{1-\gamma_i}$

where  $\gamma_i$  is the capital share coefficient for industry  $I$ ,  $\Upsilon_i$  is a scale coefficient and from the first order conditions

$$W_i \cdot L_i = (1 - \gamma_i) \cdot P_i Y_i \quad (14)$$

$$R_i = \gamma_i \cdot P_i Y_i$$

where  $R_i$  is the rental return to capital.

### 3. CALIBRATION AND DATA

To use these models in decomposition experiments to assess the relative importance of trade surges and technological change for changes in wage inequality, we can calibrate each to observed data for 1979 and 1995 for the UK. Since we compare the effects of alternatively assuming changes between those dates represent either short- or the long-run responses, we use three calibrations. In the Ricardo-Viner model we have three factors: capital, skilled and unskilled labour. In the other two versions (Heckscher-Ohlin or H-O, and partial mobility) we reallocate capital income from our database proportionately by sector, so the simplified model just has two factors. The H-O model differs from the partial mobility one in that  $\lambda_u$  and  $\lambda_s$  are set to zero: calibration based on this assumption means assuming a long-run equilibrium in the economy (ie the standard H-O model), whereas with  $\lambda_u$  set at a non-zero level we are assuming the economy is at a short-run equilibrium only. This latter treatment means that the adjustment process for the unskilled factor reflects an outcome influenced by short-run adjustment costs.

To calibrate either the H-O or partial mobility models to the start- and end-years, we solve the model for parameter values given data for the two years, 1979 and 1995 with prices, wages, output and employment set at their observed values. We assume a value for the elasticity of substitution between

factors in production  $\sigma$  (we assume the same elasticity for both sectors, to rule out the possibility of factor intensity reversals), and we assume values for the differential between skilled and unskilled wages in the expanding and declining sectors  $E$  and  $M$ . The unknowns at this stage are the model parameters for each sector and each time period ( $\alpha_{it}^u, \alpha_{it}^s, \beta^{it}$  and  $A_{it}$ ).

We use the eight first-order conditions for cost-minimising behaviour (equations for 2 factors for 2 sectors for 2 years, (1979 and 1995)).

$$\begin{aligned} W_{uit} &= P_{ti} \cdot A_{it} \cdot (Y_{it}/A_{it} \cdot U_{it})^{1/\sigma_i} \cdot \beta_{it} \cdot \alpha_{it}^{s\sigma_i/(1-\sigma_i)} \\ W_{st} &= P_{ti} \cdot A_{it} \cdot (Y_{it}/A_{it} \cdot S_{it})^{1/\sigma_i} \cdot (1 - \beta_{it}) \cdot \alpha_{it}^{s\sigma_i/(1+\sigma_i)} \end{aligned} \quad (15)$$

We assume a value for the elasticity of substitution between factors in production, which we also assume to be constant across sectors (we carry out the calibration and simulations for a central case  $\sigma = 1.25$  with sensitivity values of  $\sigma = 0.5$  and  $\sigma = 2.0$ ). Using this, it is possible to calibrate the model so as to generate values of the technical coefficients ( $\alpha^u, \alpha^s, \beta$ , and  $A$ ) for each sector. The other constraint we assume is that there is no decline in industry-specific technology in either sector (ie  $A_i$  cannot decline from period 0 to period 1), based on the assumptions that technological innovations will not be unlearned once developed.

For the Ricardo-Viner model, we calibrate capital share coefficients  $\gamma_i$

from income shares. The unskilled share parameters,  $\beta_i$ , and the labour quality coefficients,  $\alpha_i^u$  and  $\alpha_u^s$  are the same as in the H-O model, while the  $A_i$  scale parameters for labour income are smaller.

Having determined parameter values in each of the models using the calibration procedures described above (which we use for the long-run model where  $\lambda_u, \lambda_s = 0$  and the short-run model where  $\lambda_u > 0$ ), we then compute counterfactual equilibria with each model. Using the 1979 UK price, technology and endowment data as inputs, we compute equilibria for the UK economy if endowments, prices and/or technological parameters are separately changed to their 1995 model values. We then compare these computed model equilibria to the actual 1995 data in which all these changes jointly appear.

Previous studies (eg Abrego and Whalley (2000)) have decomposed the causes of increased inequality by carrying out simulations, first altering prices, then technological parameters (or vice-versa). Due to model nonlinearities, the order of decomposition can make a difference to how much change is attributed to which cause. For this reason, we follow a method (similar to that in Kose and Riezman's (1999) study of customs unions), in which endowments, trade and technology are changed in a series of small steps (first 1/10 of the total change in endowments, then 1/10 of the total change in prices and 1/10 of the total change in technology, then repeating the cycle):

the smaller the steps, the less order matters.

### 3.1 Data

We use data for the UK for 1979 and 1995 for our model analyses, similar to those used by Abrego and Whalley (1999). They use data on skilled and unskilled employment and wages for two broad categories of industry, taken from the UK Labour Force Survey. We use an estimate of a 7.9 per cent fall in the relative price of unskilled imports between 1979 and 1995 based on an estimate derived by Abrego and Whalley (1999) from Neven and Wyplosz (1999)<sup>4</sup>.

As two of our models have only two factors, against the three in Abrego and Whalley (1999a), we reallocate income accruing to the fixed factor in each sector between skilled and unskilled labour in the proportions used in that sector. Following Abrego and Whalley value added is rounded to equal gross output.

The 1979 and 1995 UK data we use are shown in Table 1 below. Price and wage data are in real terms. The rise in the average real wage of unskilled labour was approximately 23 per cent between 1979 and 1995<sup>5</sup>, reflecting an increase in the premium for skilled over unskilled wage rates from 22% in

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<sup>4</sup>Although Neven and Wyplosz find that prices of imports from OECD countries or from developing countries do not vary much by sector skill-intensity, imports from developing countries fall relatively in price to those from OECD countries, and these weigh more heavily in total UK imports in the skill-intensive sectors.

<sup>5</sup>This is calibrated to UK GNP growth – see the UK national accounts 1996 Table 1.3.

1979 to over 59% in 1995. This occurs despite the ratio of skilled/unskilled labour inputs rising in both sectors. While there is an increase in the share of skilled intensive exportables in total production, both sectors show rising output. The change in industrial structure in the data is therefore a relatively minor factor compared with what a Heckscher-Ohlin model would usually be expected to produce in response to the assumed 7.9% fall in the relative goods prices<sup>6</sup>.

The unskilled labour mobility cost,  $\lambda_u$ , reflects studies which tend to indicate that unskilled labour may be less mobile between sectors than skilled. Kruse (1988) suggest unemployment periods in the US are generally longer for unskilled rather than skilled workers, which, in terms of our model might suggest a higher threshold wage differential for the unskilled before they start to move between sectors. This is borne out by Haynes, Upward and Wright's (2000) UK study, which suggest that those with lower skills experience longer unemployment duration.

We have chosen, for simplicity, to assume that only unskilled labour, factor  $U$ , is affected by mobility costs (ie  $\lambda_s = 0; \lambda_u \geq 0$ ) and we use a

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<sup>6</sup>With an elasticity of substitution of 1.25 between the two fully-mobile factors, and starting with output and employment as in our database for 1979, we show complete specialisation in good X after a price fall of just 6.3% in good M. This corresponds to a change of nearly 40% in relative skilled wages. Details of this calculation are available on request from the authors.

figure of 13.7 % for 1995<sup>7</sup>, an ‘upper end’ estimate of mobility costs. In later sensitivity analysis, we also evaluate models with lower values.

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<sup>7</sup>This assumes that the  $7\frac{3}{4}$  % difference in wages between sectors reported by Greenaway *et al.* (1999) for the UK in 1990 is explained entirely by lower unskilled wages in the declining sectors, in turn reflecting an unwillingness to move due to mobility costs. We assume the  $7\frac{3}{4}$  % difference in average wages comprises no differential for skilled workers and a 13.7 % differential for unskilled.

#### 4. MODEL RESULTS

We use three calibrations to the 1979 and 1995 data: one involving a long-run two-factor model in which all factors are able to move freely in response to price and technology shocks; a second short-run model in which unskilled labour is only partially mobile, if intersectoral wage differentials exceed a threshold, assumed to be 13.7% of wages; and a third using a three-factor Ricardo-Viner model with sectorally fixed capital. We concentrate initially on the case where the elasticity of substitution between factors of production is 1.25 in both sectors.

Table 2 outlines our decomposition results for observed than actually observed changes in relative wages of skilled and unskilled labour between 1979 and 1995 using these three calibrated models. The contribution of various causal factors to the observed change in the average skilled to unskilled wage ratio, which Table 1 indicates increased from 1.22 to 1.59, and is expressed by the contribution of each causal factor as a percentage of the total change.

In the long-run Heckscher-Ohlin factors mobile model (first column of numbers), the increase in skilled and fall in unskilled factor endowments has no effect, as the factor price insensitivity result (due to Leamer and Levinsohn (1995)) suggests. However, the model shows substantial sensitivity to the change in world prices, which alone accounts for 152 % of the total observed wage change. There is also substantial factor bias in favour of the skilled



factor (skill bias +184% and factor quality +255%), and rise in the skilled share of output. These results fit the observed wage and output changes due to a sizeable sector-biased technical change in the opposite direction (-491%), favouring the unskilled intensive sector  $M$ .

In the second column, the partial mobility model shows different results. The change of endowments has a large effect on relative wages narrowing the gap between skilled and unskilled wage rates (-92% of the total net observed change). The effect of world prices is reduced to around 83% of the observed total wage change, while sector bias, which still favours the unskilled-intensive good, is also smaller in this model compared to the factors mobile model (-228% of the observed change against -491%). The main factor in this model behind the increased inequality is the change in the skill share within industries (187% of the observed change), with a slightly smaller contribution from factor quality.

The final column of Table 2 reports results for the Ricardo-Viner fixed factors model sectoral output and employment are less sensitive to price or sector-biased technical changes. World price changes account for just 19% of the total observed change in relative wages, 1/10 of the change in the Heckscher-Ohlin model. Sector-biased technical change has a moderate damping effect on inequality (-43%). The main picture conveyed by this model is strong factor-biased change within industries (+256% of the ob-

served net change) in favor of skilled labour, offset partially by large effects of endowment changes (-191%).

Table 3a reports the sensitivity results for the partial mobility model to changes in the assumed mobility cost. Moving rightward the columns show adjustment costs for labour increasing from zero (Long-run model) to our maximum 13.7 %, and shows that the effect of trade in explaining wage changes falls markedly as the adjustment cost rises, from 152% of total observed changes in the Heckscher-Ohlin case to 83% in our maximum adjustment cost case. The latter is still, however, somewhat larger than estimated by most other empirical studies of the contribution of trade. But it is worth noting that even a relatively modest adjustment cost, such as the 5% cost in our second column, significantly changes the decomposition results compared to Heckscher-Ohlin: the effect of trade is reduced from 152% of the observed change to 126%. The roles of factor-biased technology changes, in the opposite direction: the role of endowment changes rises rapidly as factor mobility costs are introduced.

Table 3b summarizes the sensitivity of the Ricardo-Viner fixed factor model to different assumptions about the share of fixed factors in value added. The higher the assumed share of fixed factors in value added, the less role for trade or sector bias and the greater the role of endowment changes. However, the most revealing column is that where we have assumed just 2% of value

added consists of fixed factor payments. Even with this low share, the model behaves very differently to the Heckscher-Ohlin model: the effect of traded prices, for example, is cut from 152% of observed changes to 101%. For a 5% factor share, the price effect is just 65% of total wage changes. This indicates that the magnitude of Stolper-Samuelson trade effects is not at all robust in the face of even small amounts of fixed factors.

Table 4 explores the sensitivity of our decomposition results in the three models to the elasticity of substitution between unskilled and skilled labour in production, which we set at 0.5 and 2 instead of our central case value of 1.25.

Comparing estimates of the contribution of various factors when the assumed elasticity of substitution between skilled and unskilled labour is changed shows that the relationship between elasticity and decomposition estimates is neither simple or monotonic. In most cases the effects of skill bias (positive) and endowments change (negative) on relative wages are higher when the elasticity of substitution between factors is lower. Factor quality is more important in explaining relative wage changes with higher substitution elasticities. The relationship with price changes and sector bias seems to be non-monotonic.

## 5. CONCLUSIONS

In this paper, we compare the use of short-run and long-run trade models to decompose changes in observed wage inequalities between skilled and unskilled labour over the period 1979-95 for the UK into trade and technology, and endowment change components. Results of these decompositions are very different depending upon whether a short-run model, with limited mobility of unskilled labour, or a long-run model is used to explain the observed changes. This emphasises that assumed model structure applied to the same data in decomposition will substantially affect the perception of the role of trade in wage inequality change.

In the long-run model, the usual Heckscher-Ohlin result of factor price insensitivity holds, so that the rise in relative supply of skilled labour has no effect on skill premia. The factor-bias of technical change has no effect (except insofar as the relative quality of skilled labour has risen). In contrast, the effects of observed world price increases are very large: on its own this price increase would cause a larger shift in output towards the skill-intensive goods, and a larger rise in skill premia than actually observed. The long-run model can only be made consistent with the observed output and income changes if the sector-bias of technical change (the residual category of the decomposition) is in the opposite direction: for UK total factor productivity in the unskilled-intensive sector to have risen faster than in the skill-intensive

sector, so damping the tendency of output to switch.

By contrast, when we use a short-run model for these decompositions, one in which, unskilled labour is only partially mobile, the decomposition results are quite different. The rise in the relative supply of unskilled labour now has a sizeable damping effect on inequality. Factor-biased technical change (leading to a rise in skilled/unskilled input ratios in both sectors) despite rising skill premia will raise relative skilled wages in a short-run model. The effect of trade is less marked in the short-run model, though still quite substantial. The sector-bias in technical progress (which had been large and favoured the unskilled-intensive sector in the long-run model) is relatively minor in our short-run model.

The other short-run model specification we examine is a Ricardo-Viner model, where capital is assumed to be fixed. The effects of this are even more marked than in the partial mobility case - prices and sector-biased technical change move only a small effect, while factor-biased change is the main cause of insensitivity in inequality, offset by endowment changes. Sensitivity analysis shows that, even when only a small proportion of valued added is linked to fixed factors; the model is greatly changed compared to the Hecksher-Ohlin formulation.

There are a number of reasons we believe for the short-run model decomposition to be the more plausible. First, the sign of the sector bias in

our calibrated long-run model is contrary to what comparisons the effects of computerisation on wage inequality (eg by Haskel and Slaughter would indicate. Second, the effects of labour upskilling and of factor-biased technical change in the short-term models are more consistent with what studies by labour economists would indicate (eg Borjas *et al.*, 1992; Murphy and Welch, 1991; and Katz and Murphy, 1992)

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## SUMMARY TABLES

**Table 1**      **1979 and 1995 UK data used in calibrating short-run models**

			<b>1979</b>	<b>1995</b>
<b>Labour input (billions of hours)</b>	<b>Good M</b>	<i>Unskilled</i>	36.0	24.3
		<i>Skilled</i>	19.0	33.4
		<i>Total</i>	55.0	57.7
	<b>Good E</b>	<i>Unskilled</i>	24.3	60.3
		<i>Skilled</i>	33.4	52.4
		<i>Total</i>	57.7	112.7
	<b>Total</b>	<i>Unskilled</i>	60.3	84.6
		<i>Skilled</i>	52.4	85.8
		<i>Total</i>	112.7	170.3
<b>Hourly wage pounds per week 1995 prices</b>	<b>Average</b>	<i>Unskilled</i>	5.47	6.45
		<i>Skilled</i>	6.67	10.23
<b>Average wage ratio</b>			1.22	1.59
<b>Output index (1979 volume = 100)</b>	<b>Good M</b>		100.0	134.0
	<b>Good E</b>		100.0	138.1
<b>Goods prices (1979 = 1)</b>	<b>Good M</b>		1	0.921
	<b>Good E</b>		1	1
<b>Importables (good M) as % of total value added</b>			47.49%	44.70%

**Table 2 Model Decompositions of Wage Inequality: Change for Central Case Specifications.**

<b>Component Factors Behind Inequality Change</b>	<b>Factors Mobile Long Run Model</b>	<b>Short Run Adjustment Cost Model</b>	<b>Ricardo Viner Short Run Fixed Factors Model</b>
<b>World Price Change (Trade)</b>	152%	83%	19%
<b>Technology</b>			
<b>Sector bias</b>	-491%	-228%	-43%
<b>Skill bias</b>	184%	187%	256%
<b>Capital bias</b>	0%	0%	-8%
<b>Factor quality</b>	255%	151%	67%
<b>Endowments change</b>	0%	-92%	-191%
<b>Total</b>	100%	100%	100%

**Table 3a Sensitivity of Model Based Decompositions in Short Run Models to Key Parameters**

Percent of total change in ratio of skilled/unskilled earnings.

Component	Long-run	Short-Run Adjustment Cost Model		
		Adjustment cost coefficient		
Factors Behind Inequality Change		5%	10%	14%
World Price Change	152%	126%	99%	83%
<b>Technology</b>				
Sector bias	-491%	-387%	-288%	-228%
Skill bias	184%	186%	186%	187%
Capital bias	0%	0%	0%	0%
Factor quality	255%	212%	173%	151%
<b>Endowments change</b>	0%	-37%	-70%	-92%
<b>Total</b>	100%	100%	100%	100%



**Table 4 Elasticity Sensitivity of Model Based Decompositions**

<b>Component Factors Behind Inequality Change</b>		<b>Factors Mobile Long-run Model</b>	<b>Short-Run Adjustment Cost Model</b>	<b>Ricardo-Viner Short-Run Fixed Factors Model</b>
<b>Substitution elasticity between skilled and unskilled set at 0.5</b>				
	<b>World Price Change (Trade)</b>	86%	41%	34%
<b>Technology</b>	<b>Sector bias</b>	-330%	-137%	-106%
	<b>Skill bias</b>	310%	315%	631%
	<b>Capital bias</b>	0%	0%	-8%
	<b>Factor quality</b>	54%	-6%	-83%
	<b>Endowments change</b>	0%	-113%	-369%
<b>Total</b>	120%	100%	100%	
<b>Substitution elasticity between skilled and unskilled set at 1.25</b>				
	<b>World Price Change (Trade)</b>	152%	83%	19%
<b>Technology</b>	<b>Sector bias</b>	-491%	-228%	-43%
	<b>Skill bias</b>	184%	187%	256%
	<b>Capital bias</b>	0%	0%	-8%
	<b>Factor quality</b>	255%	151%	67%
	<b>Endowments change</b>	0%	-92%	-191%
<b>Total</b>	100%	100%	100%	
<b>Substitution elasticity between skilled and unskilled set at 2</b>				
	<b>World Price Change (Trade)</b>	<b>155%</b>	67%	12%
<b>Technology</b>	<b>Sector bias</b>	-400%	-132%	-22%
	<b>Skill bias</b>	42%	19%	64%
	<b>Capital bias</b>	0%	0%	-5%
	<b>Factor quality</b>	303%	221%	171%
	<b>Endowments change</b>	0%	-75%	-120%
<b>Total</b>	100%	100%	100%	