

The Trade and Labour Approaches to Wage Inequality^{*}

Jonathan E. Haskel

Queen Mary and Westfield College, University of London and CEPR

July 1999

JEL Classification: F16, J31, O33

Keywords: wage inequality, technical change, Stolper-Samuelson effects

Abstract

We compare the trade and labour approaches to wage inequality. We first look at the theoretical differences, stressing the different roles ascribed to sector and factor bias, labour supply and the theory of technical change in trade models with endogenous prices. We then briefly review some of the evidence on the sector bias of prices and technology.

^{*}Contact address: Jonathan Haskel, Economics, QMW, Mile End Rd, London E1 4NS, England; <j.e.haskel@qmw.ac.uk>, <www.qmw.ac.uk/~ugte153/>. This paper reports some of the empirical results contained in Haskel and Slaughter (1999a). For financial support I thank the U.K. Economic and Social Research Council for grants #R000236653 and R000222730. Many of the ideas in this paper are the result of long discussions with Matt Slaughter and are therefore as much his as are mine. My thanks also to Nick Oulton and Ian Steedman for useful suggestions. Errors are my own.

1. Introduction

Research on changes in wage inequality has been undertaken by two groups who can loosely be identified, by training and/or recent research as labour economists or trade economists. The research methods adopted by these two groups has been quite different. Much of the work by labour economists has documented evidence of skill-biased technical change (SBTC) within many industries (see e.g. Berman, Bound and Griliches, 1994). Much of the work of trade economists has focused on total factor productivity growth and product price changes across industries (see e.g. Leamer, 1998, Deardorff, 1998).

The purpose of this paper is to try to set out a common framework to understand reasons for the different empirical strategies. We shall argue that most labour economists organise their data analysis, either explicitly or implicitly, from a one-sector model. But most trade economists organise their work, again either explicitly or implicitly, from a multi-sector model. As we set out below, these different models give rise to a very different empirical approach. Labour economists tend to focus on the factor-biased of technical change whereas trade economists look for the sector bias of technical change and/or of price changes.

The next section of this paper sets out two different models as simply as possible. In section three we provide a short review of the evidence on sector bias and section four concludes.

2. Understanding the trade and labour approaches: a simple framework¹

A standard empirical labour approach is to use industry data to estimate relative labour demand functions and see if there is evidence that technical progress is skill biased. Typically such skill-biased technical change (SBTC) is found in many industries. With the supply/demand intuition the presence of SBTC in many sectors seems strong evidence that technology has caused a rise in the skill premium.

Standard trade theory suggests this reasoning is not conclusive. Consider an industry where there is no skill-biased or any other type of technical progress (or price change). At first pass, this sector would seem to have no change in relative wages since there is no SBTC occurring. But suppose another industry releases workers, perhaps due to falling prices from increased trade competition or technical change. This creates a flow of potential workers willing to work at the first industry and so potentially drives down wages. Relative wages therefore depend on whether technical progress and output prices are changing by more in one sector *relative* to another. It is these *differences across* sectors, their “sector bias”, that potentially cause wage adjustments. Put another way, the finding that there is technical progress *occurring within* many sectors, driven perhaps by computers, may not be informative about changes in wages, for it does not establish whether technical

¹ See Slaughter (1999) for a similar perspective.

progress is changing more in some sectors than in others. This type of logic is a feature of the Heckscher-Ohlin model and so explains why trade economists typically look for sector bias.²

To see this formally, suppose there are two sectors in the economy producing goods i and j . Following Johnson (1997), suppose that output (Y) is produced by skilled and unskilled labour (N_s and N_u) according to a constant returns CES production function $Y = [(\alpha(\lambda_s N_s)^{1-1/\sigma} + (1-\alpha)(\lambda_u N_u)^{1-1/\sigma})]^{\sigma/(\sigma-1)} A$ where A is neutral technical progress, λ_s and λ_u are intensive skilled and unskilled labour biased technical progress respectively, α is extensive skill-biased technical progress and σ is the elasticity of substitution. Ignoring the λ s for the moment, the cost functions for each sector are

$$\begin{aligned} C^i &= \left((\alpha^i)^\sigma w_s^{1-\sigma} + (1-\alpha^i)^\sigma w_u^{1-\sigma} \right)^{1/(1-\sigma)} (A^i)^{-1} Y^i \\ C^j &= \left((\alpha^j)^\sigma w_s^{1-\sigma} + (1-\alpha^j)^\sigma w_u^{1-\sigma} \right)^{1/(1-\sigma)} (A^j)^{-1} Y^j \end{aligned} \quad (1)$$

where skilled and unskilled labour receive wages w_s and w_u . Without loss of generality, assume further that sector i is skill-intensive, defined by the wage bill share of skilled workers in total costs C being higher in sector i than in sector j . Using Shephard's lemma, the relative demand for skilled and unskilled labour in sector i is

$$\frac{N_s^i}{N_u^i} = \left(\frac{\alpha^i}{1-\alpha^i} \right)^\sigma \left(\frac{w_s^i}{w_u^i} \right)^{-\sigma} \quad (2)$$

where N_s and N_u are skilled and unskilled labour.

Equation (2), the relative demand for labour curve, is uncontroversial. Only α , skill-biased TC, appears in these first order conditions. A number of papers have estimated (2) (or more general translog versions of it, see e.g. Berman et al (1994) for the US, Haskel and Heden (1999) for the UK and Machin and van Reenen (1998) for many countries) and found that α , or an assumed correlate such as computers, is skill-biased. Machin and van Reenen (1998) further add import penetration to (2) and find no relation, thereby arguing that imports have not contributed changes in the relative demand for skilled labour.

What are the implications for wage inequality that follow from this? Assuming one sector, or that workers cannot move between sectors, each sector faces its own upward-sloping supply curve. Equating relative supply denoted $(N_s^i/N_u^i)^S$, and demand, totally differentiating (2) and rearranging gives the change in relative wages as

² Leamer (1998) for example emphasises that an important message of the Heckscher-Ohlin model is that wages

$$\Delta \ln(w_s / w_u)^i = \Delta \ln(\alpha / 1 - \alpha)^i - \frac{1}{\sigma} \Delta \ln(N_s^i / N_u^i)^s \quad (3)$$

Hence increases in relative wages occur due to increases in demand from SBTC (net of changes in supply).³ Since there is evidence for SBTC from the estimation of (2) this suggests that technology has raised the wage premium. Further, since imports are insignificant when added to (2), it is argued that trade has had no effect.

The alternative, favoured by trade economists, is to assume that workers are mobile across sectors. Thus each sector faces a flat relative labour supply curve and so another condition is required to close the model. This then is the production side of the HO model and it is conventionally assumed that each sector is competitive so that revenue equals costs

$$\begin{aligned} p^i Y^i &= C^i \\ p^j Y^j &= C^j \end{aligned} \quad (4)$$

where p^i and p^j are prices in each sector. Changes in (log) relative wages can be written⁴

$$\Delta \ln(w_s / w_u) = \frac{1}{V_s^i - V_s^j} (\Delta \ln(p^i / p^j) + \Delta \ln(TFP^i / TFP^j)) \quad (5)$$

where V_s^i and V_s^j are the shares of skilled labour in the total wage bill in each sector, w_s and w_u are not indexed by i since free mobility ensures workers can move across sectors, and TFP is total factor productivity. Recall too that by assumption, $V_s^i > V_s^j$.

Equation (5) is standard in the trade literature. First, it shows Stolper-Samuelson type effects of changes in p^i/p^j on w_s/w_u . The effects depends on the sector bias of changes in prices. If prices fall in the skill-intensive sector ($\Delta \ln p^i < 0$) then w_s/w_u falls and if prices fall in the unskilled-intensive sector ($\Delta \ln p^j < 0$) then w_s/w_u rises. The mechanism works via the zero profit conditions in (4). If prices fall in any sector then that sector is now unprofitable. Relative wages must adjust to restore zero-profit equilibrium. Hence if prices fall in the skill-intensive sector, w_s/w_u must fall (if they rose that would

are determined on the margin.

³ Indeed Johnson (1997) and Katz and Autor (1999) use aggregate data on changes in supply and relative wages to infer from (3) the change in aggregate relative demand. As both stress, when applied to aggregate data, changes in α can arise from SBTC but also from shifts in product demand from domestic or international sources.

⁴ This totally differentiates (3) with respect to time, uses Shephard's Lemma and $\partial \log C / \partial t = \Delta \ln TFP$. See Leamer (1999).

further render the skill-intensive sector unprofitable). If prices fall in the unskilled-intensive sector, w_s/w_u must rise.⁵

Second, equation (5) also shows that the effect of technology depends on sector bias of changes in $\Delta \ln TFP$. The mechanism also works via the zero profit conditions in (4) and has the same intuition as changes in prices. Technical progress reduces a sector's costs and so makes it relatively profitable. Hence, technical progress in a skilled-intensive sector ($\Delta \ln TFP^i > 0$) makes the that sector more profitable and hence w_s/w_u must rise; progress in an unskilled-intensive sector ($\Delta \ln TFP^j > 0$) means that w_s/w_u must fall. See Findlay and Grubert (1958) for a classic early theoretical analysis of this.

The following points are worth noting.

a. *Sector bias and factor bias.* Concerning technology, (3) suggests that only factor-biased TC affects wages since it changes the relative productivity of factors *within* a sector. Equation (5) suggests that *all* types of technical change, as summarised in $\Delta \ln TFP$, and price changes, are important. The reason is that they change the *relative profitability of sectors*. This is why the typical labour focus is on factor bias and the trade focus on sector bias.

b. *SBTC.* In (3), SBTC is of course essential. In (5), SBTC does not appear directly. So what is the role of SBTC in the multi-sector model? Note that SBTC is of course part of $\Delta \ln TFP$; since $\Delta \ln TFP$ is increases in output net of measured inputs it includes any form of technical progress, be it biased in favour of any factor of production or neutral (see e.g. Berndt and Wood, 1982). The focus on TFP is appropriate in a multi-sector model since *any* type of technical change, as long as it reduces costs, potentially raises sectoral profitability and so necessitates wage changes.

This argument suggests that SBTC affects relative wages in this model under two conditions: first, that it should have the appropriate sector bias and second, that it should reduce costs. The latter effect depends on the form of SBTC. In (1), SBTC is represented by a rise in α , which raises the productivity of the skilled relative to the unskilled. This type of SBTC is what Johnson (1997) terms extensive SBTC, whereby the skilled become better at performing the tasks previously done by the unskilled (typing this paper for example) which from (2) raises the relative demand for the skilled regardless of σ . From (1) however, a rise in α does not necessarily lower unit cost. Differentiation of (1) shows that it only does so as long as $\alpha < V_s$ (and $\sigma > 1$). This is not surprising since this type of

⁵ In terms of flows of workers across sectors, a fall in prices in the skill-intensive sector (i) causes firms to move to the unskilled-intensive sector (j). Sector i contracts and since it is skill-intensive, it releases comparatively more skilled workers. Hence w_s/w_u has to fall to re-employ them. See Deardorff (1994) for a statement of a number of different versions of the Stolper-Samuelson theorem. Note finally that (5) shows the Jones magnification effect (Jones, 1965) namely that $(\partial \ln(w_s/w_u)/\partial \ln(p^i/p^j)) > 1$ (since $[1/(V_s^i - V_s^j)] > 1$).

technical change is a productivity gain by one factor and a loss by another. Intensive SBTC, that makes each factor more productive at the tasks it already performs, by contrast will lower costs.⁶

In the light of this, it is worth noting that it is perfectly possible, in multi-sector models, for SBTC to *lower* relative skilled wages if it occurs in unskilled-intensive sectors and lowers costs there. In one-sector models, SBTC raises relative skilled wages (with certain conditions on technology) to “absorb” the unskilled by pricing them back into work when the skilled become more productive. In multi-sector models, changes in wages have to be consistent with zero profits in all sectors; if SBTC in the unskilled-intensive sector were to raise skilled/unskilled relative wages the relative profitability of the unskilled-intensive sector would raise further. How then are these unskilled “absorbed”? The answer is that in a multi-sector model output is endogenous. Hence output rises in unskilled-intensive sectors and this absorbs the “extra” unskilled workers.

In the light of this argument, consider the finding that many industries in many countries have had rising relative wages and rising relative skill levels (see e.g. Machin and Van Reenen, 1998).⁷ This has led many to argue that this shows evidence of SBTC and that such SBTC has raised relative wages. It is clear from (2) that the evidence is consistent with SBTC⁸. But without knowing the sector bias of SBTC one cannot say whether SBTC has raised relative wages. Indeed it is theoretically possible that SBTC has tended to lower wages, if for example it occurred in the unskilled-intensive sectors, and that skilled sector biased price changes are responsible for the growth in relative wages.⁹ So the multi-sector perspective suggests one should treat the finding of widespread SBTC with caution.

c. *Labour supply.* To see the impact of labour supply, Figure 1 draws (3) and (5) in $[w_s/w_u, N_s/N_u]$ space. Panel (a) shows the downward-sloping relative demand (RD) curve (2) and an assumed upward-sloping relative labour supply curve (RS). Increases in w_s/w_u arising from SBTC i.e. increase in α shift RD to RD¹. Panel (b) shows (5), labelled as an economy-wide relative labour demand curve and relative supply. The curve is horizontal since w_s/w_u is determined by (p^i/p^j) and TFP^i/TFP^j .

⁶ The cost function corresponding to the production function immediately above equation (1) is $C=[(\alpha^\sigma(w_s/\lambda_s)^{1-\sigma} + (1-\alpha)^\sigma(w_u/\lambda_u)^{1-\sigma})]^{1/(1-\sigma)} A^{-1}$ Y differentiation of which with respect to λ shows that $\partial C/\partial \lambda < 0$.

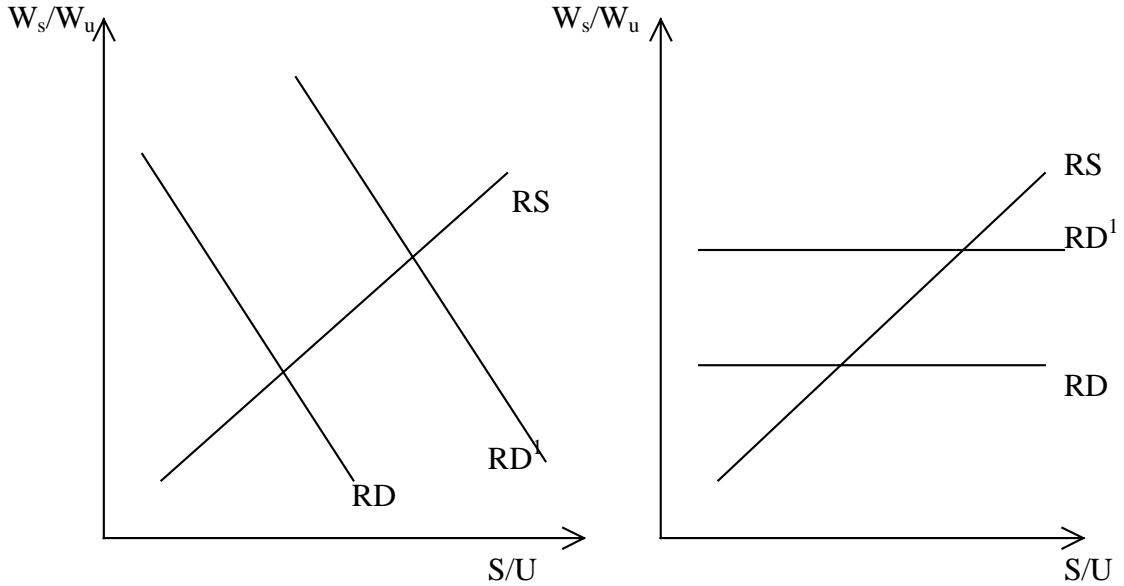
⁷ A related finding is that much of the changes in skill-upgrading is “within” industry rather than “between”, see e.g. Berman et al (1994).

⁸ Depending on the extent to which the industry rises in skill-intensity are caused by between-firm averaging effects within-industries. Bernard and Jensen (1997) examine this using plant data for the US.

⁹ Using the cost function in note 6 above we can write $\Delta \ln TFP^i = \Delta \ln A^i + V_s^i \Delta \ln \lambda_s^i + [\sigma/(\sigma-1)] \{[(V_s^i - \alpha^i)/(1-\alpha^i)] \Delta \ln \alpha^i\}$ which shows that TFP rises if A rises, λ_s rises and if α rises, the latter as long as $\sigma > 1$ and $V_s^i > \alpha^i$ which is the same condition for a rise in α to reduce total costs. Substituting this into the last term of (5) gives that $\Delta \ln(TFP^i/TFP^j) = \Delta \ln(A^i/A^j) + (V_s^i \Delta \ln \lambda_s^i - V_s^j \Delta \ln \lambda_s^j) + [\sigma/(\sigma-1)] \{[(V_s^i - \alpha^i)/(1-\alpha^i)] \Delta \ln \alpha^i - [(V_s^j - \alpha^j)/(1-\alpha^j)] \Delta \ln \alpha^j\}$. So, for example intensive SBTC mostly in the unskilled-intensive sector ($\lambda^i > \lambda^j$) might raise or lower relative wages. Note that with this functional form equally intensive SBTC throughout all sectors ($\lambda^i = \lambda^j$) would raise relative TFP in the i sector. The intuition is that although SBTC is equal, the assumption there are more skilled workers in the i sector means the cost reduction is greater in that sector and hence relative skilled wages rise. Haskel and

Hence increases w_s/w_u arise from skilled-sector biased rises in prices or tfp ($\Delta \ln p^i > 0$, or $\Delta \ln tfp^i > 0$) which shift the curve upwards from RD to RD^1 .

Figure 1
Demand and Supply of Labour under the one-sector and the two-sector models



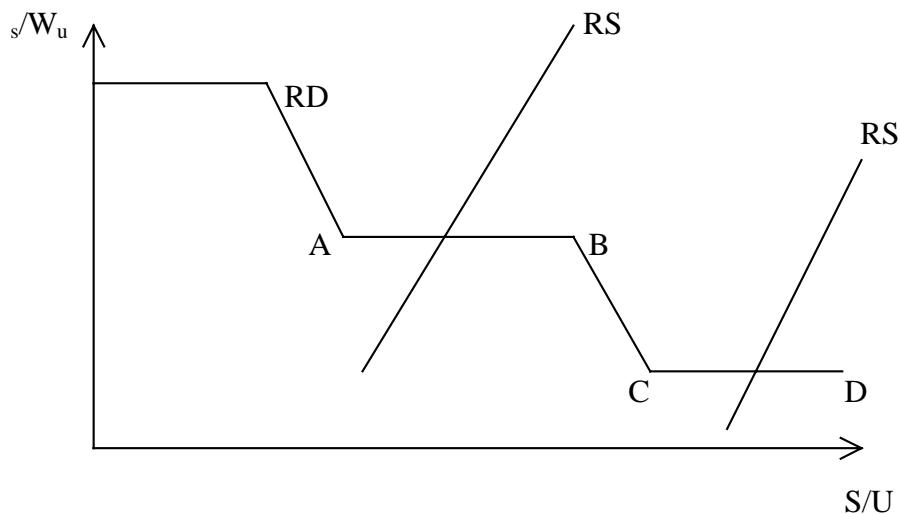
To see the intuition for the “flat” shape of the curve, consider a rise in relative skilled supply to traces out relative demand. In panel (a) relative wages must fall to absorb the extra skilled workers, and so RD slopes downwards. Panel (b) is the aggregate relative demand curve in a multi-sector model. With many sectors the extra skilled workers can potentially be absorbed by a rise in output in the skilled-intensive sector. The flat shape shows that in the 2x2 model this absorption is done entirely by changes in these output mixes with no change in relative wages; this is the so-called Rybczynski effect (Rybczynski, 1955). Davis (1998) criticises HO theory on the empirical grounds that estimated labour demand curves are not flat. Note however that a downward-sloping *single sector* relative demand curve such as (2) still holds; it is the *economy-wide* curve that is flat, as is clear algebraically from (5). Note too that although the aggregate RD curve is, in an accounting sense, a weighted average of the individual sectoral demand curves, in a multi-sector model the weights are endogenous. The above exercise of varying RS to trace out RD shows that the employment/output weights adjust rather than relative wages, giving a flat RD curve.

How then might labour supply affect relative wages in this model? First, it depends on the number of factors and products. In the above model with 2 products there are 2 zero profit conditions and with 2 factors of production relative wages are completely determined. In general, if there are N

Slaughter (1998) look at the sector-bias of SBTC and find that over the 1970s (1980s) SBTC was concentrated in unskilled-intensive (skill-intensive) sectors.

traded goods being produced and M factors, as long as $N \geq M$, there are enough zero-profit conditions to determine factor prices without any effect from labour supply. However, if there is insufficient diversification in the economy such that there are more products than factors then labour supply matters for relative wages since relative wages are not completely determined.¹⁰ Second, as RS increases the economy might shift from producing N goods to N' goods. This gives a new set of zero-profit conditions in (4) and hence a new flat segment of the national relative demand curve. This is shown in figure 2, where the increases in skilled labour supply mean the economy ceases to produce the most unskilled-intensive products and starts producing new, more skill-intensive products than before. Hence changes in supply affect relative wages as the economy moves from segment AB to CD. Third, if factors are immobile across sectors then each sector is a local labour market, in which case relative supply and demand will determine relative wages.

Figure 2
The aggregate labour demand curve in a multi-sector model with changes in the range of goods



d. *Prices.* To say anything about trade, a convenient additional assumption is that the economy is small. Hence prices are determined exogenously on world markets and price changes can only be due to changes in world trading conditions. A number of recent papers have reconsidered the effects of technical progress when prices are endogenous, either because a country is large or because trading partners share the same technology and technical change is global.

When (p^j/p^i) is endogenous we have to add an equation to (5) whereby p^j/p^i is determined by goods relative supply and relative demand. With homothetic preferences, relative demand does not depend on income, but solely on relative prices (and preference parameters).¹¹ Relative supply

¹⁰ Freeman (1995) criticises the knife-edge property of this model.

¹¹ Krugman (1995) discusses the case where relative demand depends on income effects.

depends on relative wages and, crucially, technology. In this case then, the effect of technology on relative wages depends on what one might call the “direct” effect of sector bias described by (5) at given p^i/p^j and the “indirect” effects working through changes in p^i/p^j due to changes in relative goods supply.

A number of recent papers, summarised in Haskel and Slaughter (1998) have considered the endogenous price case and reached different conclusions. Krugman (1995) and Davis (1997) consider the case of technical change (TC) in a single sector with endogenous prices. Krugman (1995) asserts that in this case the economy is analytically equivalent to being closed and that SBTC in either sector raises w_s/w_u . However, the above algebra suggests that the importance of sector bias arises from the assumption of two sectors, rather than the assumption that the economy is closed or open; (5) still holds regardless of whether prices are endogenous or not. As Haskel and Slaughter (1998) show Krugman’s assertion is correct if one assumes Leontief technologies and ignores the direct effect. With general production functions, the direct and indirect effects offset each other and hence the overall impact of TC in one sector on w_s/w_u is ambiguous. If the direct effect exceeds the indirect effect, the results depend unambiguously on sector bias.

Berman, Bound and Machin (1998) consider SBTC in *both* sectors when product prices are endogenous. They claim that relative wages rise in this case. Their model is a special case in two regards however. They assume that SBTC lowers costs in both the skill-intensive and unskilled-intensive sectors and that these reductions in costs are exactly equal. Hence relative profitability does not change and so there is no direct effect on wages. The impact on relative wages comes entirely from the indirect effect of SBTC on relative supply and hence prices. Relative wages rise in this case however only if technology is Leontief. If there is any substitutability in production, relative wages depend on the sector bias of SBTC, see Haskel and Slaughter (1998) for more details.

e. Other points. The effect of sector bias on relative wages is derived here for a 2x2 model. In even models of higher dimensions the effect of sector bias holds “on average”: factors employed intensively in rising price industries will experience relative price increases. See Ethier (1984).¹² Non-traded sectors can be added to the model but as long as traded prices are exogenous the 2x2 traded sector determines relative wages which are the same throughout the economy due to labour mobility (TC in the non-traded sector changes non-traded prices).

3. Empirical analysis of the HO model

One statistical approach to examining the HO model (Lawrence and Slaughter, 1993, Sachs and Shatz, 1994, Desjonques, Machin and van Reenen, 1998) has been to estimate

¹² Deardorff (1994), quoted in Slaughter (1999) states the correlation version of the Stolper-Samuelson theorem “For any vector of goods price changes, the accompanying vector of factor price changes will be positively correlated with the factor-intensity-weighted averages of the goods price changes”.

$$\Delta \ln p_{kt} = \alpha + \beta \left(\frac{N_s}{N_u} \right)_{kt} + \varepsilon_{kt} \quad (6)$$

where ε_{kt} is a random error and (6) is estimated across k industries. However this is only for two factors and hence it is not clear how additional factors can be admitted. In addition, Stolper-Samuelson price effects arise from the assumption that each sector in the economy makes zero profits, so that when prices change, relative wages have to change to restore zero-profit equilibrium. The zero profit relation links the level of prices and levels of factor inputs. Yet (6) regresses the *change* in prices on the level of factor inputs.

Since the HO model is based on zero-profit conditions, Leamer (1998) proposes to estimate the n zero-profit conditions in (4) directly. Taking logs, totally differentiating with respect to time and using the definition of TFP above gives that for each sector k

$$\Delta \ln p^k + \Delta \ln TFP^k = (\Delta \ln w_s) V_s^k + (\Delta \ln w_u) V_u^k \quad (7)$$

(where note that (5) is simply the difference between (7) for two sectors). This equation says that changes in p or TFP can be accompanied by changes in w_s and w_u and still be consistent with zero profits (note the changes in w_s and w_u are weighted by factor cost shares which gives the effect on profitability). In (7), we can use data on prices and outputs and inputs to construct Δp^k , ΔTFP^k , V_s^k and V_u^k . The terms Δw_s and Δw_u are unknown since they are the changes in economy-wide factor prices required to maintain zero profits. To find them, Leamer (1998) suggests running the regressions

$$\begin{aligned} \Delta \ln TFP^k &= \beta_s V_s^k + \beta_u V_u^k + \varepsilon_1^k \\ \Delta \ln p^k &= \gamma_s V_s^k + \gamma_u V_u^k + \varepsilon_2^k \end{aligned} \quad (8)$$

where ε_1 and ε_2 are errors arising from measurement error, the failure of zero profits to hold exactly and the like (and the capital share of total costs can be added into (7)). Comparing (7) and (8), β_s , β_u , γ_s and γ_u are the changes in skilled and unskilled wages consistent with zero profits in response to changes in TFP when prices are unchanging and changes in prices when TFP is constant. These coefficients can be regarded as summarising the sector bias of Δp and $\Delta \ln TFP$. If $\beta_s > \beta_u$ or $\gamma_s > \gamma_u$ then TFP or price changes are concentrated in skill-intensive sectors, in which case relative skilled wages rise. If $\beta_u > \beta_s$ or $\gamma_u > \gamma_s$ then TFP and price changes are concentrated in unskilled-intensive sectors and

relative skilled wages fall. Finally, the estimates of $\Delta \ln w_s = \beta_s + \gamma_s$ and $\Delta \ln w_u = \beta_u + \gamma_u$ can of course be compared with actual changes to gauge the accuracy of the model.¹³

Table 1 reports Leamer's findings for the US in the 1980s using the NBER Panel of 444 industries, 1981-91. Consider the top cell in column 1. The figure of -2.11 shows that skilled wages would have had to have fallen 211% to maintain zero profits in the face of changes in US TFP from 1981-91. The cell beneath that shows the unskilled wage would have had to have fallen -337%. So sector bias of $\Delta \ln TFP_{it}$ in the US over this period was in the skill-intensive sector, which would have tended to raise wage inequality. Column 5 shows analogous results for $\Delta \ln p_{it}$ and suggests that price changes were skilled sector biased; again this would have tended to raise wage inequality.

Table 1
The sector bias of prices and technology for the US and UK in the 1980s: estimates of (8)
(but dependent variables: $\Delta \log p_{it}$ and $\Delta \log TFP_{it}$ for each indicated year interval)

<i>Column</i>	<i>$\Delta \ln TFP_{it}$</i>				<i>$\Delta \ln p_{it}$</i>			
	(1) <i>L</i>	(2) <i>HS</i>	(3) <i>HS</i>	(4) <i>GZ</i>	(5) <i>L</i>	(6) <i>HS</i>	(7) <i>HS</i>	(8) <i>GZ</i>
<i>Study</i>								
<i>Years</i>	1981-91	1979-86,	1980-1989	1981-91	1981-91	1979-86	1980-1989	1981-91
<i>Data</i>	4 digit	3-digit	3-digit	IO	4 digit	3-digit	3-digit	IO
<i>Country</i>	US	UK	UK	UK	US	UK	UK	UK
V_s^k	-2.11 (1.65)	0.06 (0.19)	0.22 (0.41)	-0.47 (0.16)	5.82 (4.61)	0.92 (3.31)	0.77 (1.40)	2.50 (5.38)
V_u^k	-3.37 (3.00)	0.49 (3.64)	0.29 (1.47)	3.65 (1.37)	4.89 (4.45)	-0.16 (1.35)	0.08 (0.40)	-0.31 (0.74)
# Obs.	450	123	67	87	450	123	67	87

Notes: Absolute t statistics in parentheses. Capital share of total costs included as a regressor: coefficients not reported. Studies are L (Leamer, 1998, for the US), HS (Haskel and Slaughter, 1999a, for the UK), GZ (Gregory and Zissimos, 1998, for the UK) using, respectively, 4 digit, 3 digit industry and input/output data. V_s and V_u are shares in total costs of: non-production and production workers (L), non-manual and manuals (HS) and high and medium educated workers (GZ). GZ also include the share of low educated workers (not reported).

Sources: Leamer (1998, table 24), Gregory and Zissimos (1998, table 3), Haskel and Slaughter (1999a, table 2).

The rest of the table sets out the results for the UK reported in Haskel and Slaughter (1999a) and Gregory and Zissimos (1998). Columns 2 and 6 use 123 three-digit manufacturing industries 1979-86 drawn from the UK Census of Production. Columns 3 and 7 use 67 three-digit industries 1980-89 also drawn from the UK Census.¹⁴ Both these data use non-manuals/manuals as a measure of skill. Columns 4 and 8 use 87 sectors from the UK input/output tables, including the service sector and

¹³ Leamer also considers the case where $\Delta \ln TFP$ passes through to prices in which case the sum ($\Delta \ln TFP + \Delta \ln p$) are regressed on the cost shares. See also Feenstra and Hanson (1999).

¹⁴ There was a major change in the Standard Industrial Classification in 1980. The 1979 and 1986 data are matched to the 1968 Standard Industrial Classification, necessitating substantial adjustment to the 1986 data. The 1980-89 data is based on the 1980 SIC and so are unadjusted.

using fractions of high, medium and low educated workers (measured by matching educational attainment data to their industry categories) as skill measures.

Comparing the co-efficients on V_s and V_u reveals a consistent picture for the UK. Growth in TFP is *not* concentrated in the skill-intensive sector. By this method then, technology cannot have caused the rise in wage inequality. By contrast, relative price rises are concentrated in the skill-intensive sector. This then is consistent with the idea that price changes have contributed to rising wage inequality.

The question this work raises is what causes $\Delta \log TFP_{it}$ and $\Delta \log p_{it}$. This is taken up in three studies. For the US, Feenstra and Hanson (1999) assume 100% pass-through of $\Delta \ln TFP$ to prices. Hence wage premia respond to the sum ($\Delta \ln TFP + \Delta \ln p$). To investigate what causes ($\Delta \ln TFP + \Delta \ln p$) Feenstra and Hanson (1999) regress $(\Delta \ln TFP + \Delta \ln p)_{it}$ on computers and outsourcing. They find significant effects of computers and outsourcing in this regression and significant effects on wage inequality based on regressing the estimated contributions of computers and outsourcing on the factor shares. For the UK, Haskel and Slaughter (1999a) look at $\Delta \ln p_{it}$ and $\Delta \ln TFP_{it}$ separately. They regress $\Delta \log p_{it}$ on foreign prices but find a rather small impact (they have no data on trade barriers however). $\Delta \ln TFP_{it}$ is significantly influenced by innovations and changes in domestic and foreign market competition and union power. By examining the sector bias of the induced change in TFP due to foreign competition, for example, Haskel and Slaughter (1999a) show that although foreign competition raised UK TFP it did not do so in the skilled-intensive sectors in which case it did not contribute (statistically significantly) to wage inequality. Finally, Haskel and Slaughter (1999b) regress changes in US product prices on changes in trade barriers and find some effect, suggesting that changes in trade barriers may well be part of the explanation of changes in prices.

4. Conclusion

This paper has tried to compare the “trade” and “labour” approaches to estimating the contributions of trade and technology to wage inequality. The labour approach looks for factor-biased technical change whilst the trade approach looks for sector-biased technical change and price change. We have presented a model to highlight why and argued that the trade approach derives from an explicit model of aggregating relative demand curves across sectors. In the 1980s data, the US saw a skilled-sector bias to both prices and technology. The UK saw quite well defined skilled-sector biased changes in prices with no strong sector bias for technology.

These issues raise two particular questions for future work. On the theory side, developing the HO model to incorporate further the effects of labour supply would seem desirable. On the empirical side, we need a better understanding of what drives prices and technology and what explains the different sector bias of prices across countries.

References

- Bernard, Andrew B., and J. Bradford Jensen, (1997), "Exporters, Skill Upgrading and the Wage Gap", *Journal of International Economics*, 42, pp.3-31.
- Berndt, Ernst R. and David O. Wood, (1982) "The Specification and Measurement of Technical Change in U.S. Manufacturing," in *Advances in the Economics of Energy and Resources*, Volume 4, JAI Press, pp. 199-221.
- Berman, Eli, John Bound, and Zvi Griliches, (1994), "Changes in the Demand for Skilled Labour within U.S. Manufacturing: Evidence from the Annual Survey of Manufactures," *Quarterly Journal of Economics*, May, pp. 367-397.
- Berman, Eli, John Bound, and Stephen Machin, (1998), "Implications of Skill-Biased Technological Change: International Evidence," *Quarterly Journal of Economics*, November, pp. 1245-1280.
- Davis, Donald R., (1997), "Technology, Unemployment and Relative Wages in a Global Economy", *European Economic Review*, 1997.
- Davis, Stephen, J., (1998), "Comment on Leamer" in Susan Collins (ed), *Imports, Exports and the American Worker*, Washington, D.C.: The Brookings Institution.
- Deardorff, Alan V., (1994), "Overview of the Stolper-Samuelson Theorem," in Alan V. Deardorff and Robert M. Stern (eds) *The Stolper-Samuelson Theorem: A Golden Jubilee*, Ann Arbor: The University of Michigan Press, 1994, pp.
- Deardorff, A., (1999), "Technology, Trade and Increasing Inequality: Does the Case Matter for the Cure?", University of Michigan Working Paper, <www.spp.umich.edu/rsie/workingpapers/papers426-450/r428.pdf>.
- Desjonquieres, Thibaut, Stephen Machin, and John Van Reenen, (1997), "Another Nail in the Coffin? Or Can the Trade Based Explanation of Changing Skill Structures Be Resurrected?" mimeograph, December 1997.
- Ethier, Wilfred J., (1984), "Higher Dimensional Issues in Trade Theory" in R. Jones and P. Kenen (eds), *Handbook of International Economics*, Volume 1, pp. 131-184, Amsterdam: Elsevier Science Publishers BV.
- Feenstra, Robert C. and Gordon H. Hanson, (1999), "Productivity Measurement and the Impact of Trade and Technology on Wages: Estimates For the U.S., 1972-1990," National Bureau of Economic Research Working Paper #6052, June 1997, *Quarterly Journal of Economics*, forthcoming.
- Findlay, Ronald and Harry Grubert, (1959), "Factor Intensities, Technological Progress, and the Terms of Trade," *Oxford Economic Papers*, 1959, Volume 11, pp. 111-121.
- Freeman, Richard, B., (1995), "Are Your Wages Set in Beijing", *Journal of Economic Perspectives*, Summer pp. 15-32.
- Gregory, Mary and Zissimos, Ben, (1998), "In Search of Stolper-Samuelson Effects: A Review of Methodological Issues and some Illustrative Results using UK Wages", mimeo.
- Haskel, Jonathan, E., and Heden, Ylva, (1999), "Computers and the Demand for Skilled Labour: Evidence from Establishment and Industry Panels", *Economic Journal*, Conference Volume.

Haskel, Jonathan E. and Matthew J. Slaughter, (1998), "Does the Sector Bias of Skill-Biased Technical Change Explain Changing Wage Inequality?" National Bureau of Economic Research Working Paper #6565, May 1998, revised version available from <www.qmw.ac.uk/~ugte153/>.

Haskel, Jonathan E. and Matthew J. Slaughter, (1999a), "Trade, Technology and UK Wage Inequality", National Bureau of Economic Research Working Paper #6978, March.

Haskel, Jonathan E. and Matthew J. Slaughter, (1999b), "How Much Have Changing Trade Barriers Raised US Wage Inequality?" draft paper.

Johnson, George, (1997), "Changes in Earnings Inequality: The Role of Demand Shifts," *Journal of Economic Perspectives*, 11, 2, Spring, pp. 41-54

Jones, Ronald, (1965), "The Structure of Simple General Equilibrium Models", *Journal of Political Economy*.

Katz, Lawrence, and Autor, David, (1999), "Wage Inequality", forthcoming in O. Ashenfelter and A. D. Card, eds, Handbook of Labour Economics, North Holland.

Katz, Lawrence F. and Lawrence H. Summers, (1989), "Industry Rents: Evidence and Implications," *Brookings Papers on Economic Activity*, 1989, pp. 209-275.

Krugman, Paul R., (1995), "Technology, Trade, and Factor Prices," National Bureau of Economic Research Working Paper #5355, November.

Lawrence, Robert Z. and Matthew J. Slaughter, (1993), "International Trade and American Wages in the 1980s: Giant Sucking Sound or Small Hiccup?" in Martin Neil Baily and Clifford Winston (eds) *Brookings Papers on Economic Activity: Microeconomics* 2, 161-211.

Leamer, Edward E., (1998), "In Search of Stolper-Samuelson Effects On U.S. Wages," in Susan Collins (ed), *Imports, Exports and the American Worker*, Washington, D.C.: The Brookings Institution.

Leamer, Edward E., (1998), "Linking The Theory with the Data: That's the Core Problem of International Economics", paper prepared for Handbook of Econometrics Conference, London, December 1998.

Machin, Stephen and Van Reenen, John, (1998) "Technology and the Skill Structure: Evidence from Seven Countries", *Quarterly Journal of Economics*, 113, 4, November, pp. 1215-1244.

Rybczynski, T. M. 1955. "Factor Endowments and Relative Commodity Prices." *Economica*, 22: 336-341.

Sachs, Jeffery D., and Shatz, Howard (1994), "Trade and Jobs in US Manufacturing", *Brookings Papers on Economic Activity*, pp. 1-84.

Slaughter, Matthew, (1999), "What Are the Results of Product Price Studies and What can we Learn from their Differences?", forthcoming in Robert C. Feenstra (ed) *International Trade and Wages*, Cambridge, MA: National Bureau of Economic Research.

Slaughter, Matthew J., (1999), "Globalisation and Wages: A Tale of Two Perspectives" *World Economy*, forthcoming.