FRAGMENTATION, PRODUCTIVITY AND RELATIVE WAGES IN THE UK: A GENERAL EQUILIBRIUM APPROACH*

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Abstract

Feenstra and Hanson (1999) propose a two-stop method to analyse the role of outsourcing and skill-biased technological change (SBTC) in the rise in wage inequality. This paper applies their methodology to UK manufacturing using data for the 1990s and extends it in order to obtain additional insight in the relative importance of the sector bias and the factor bias of outsourcing and SBTC. The results indicate that outsourcing has significantly contributed to the rise in the domestic wage inequality accounting for approximately 12% of the increase in the UK in the 1990s. Factor-biased outsourcing was about 2.5 times as important as sector-biased outsourcing in explaining the increase in wage inequality.

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One of the main consequences of the process of globalisation is the increasing international fragmentation of production, that is, the splitting up of production processes into separate components so that they can be produced in different locations (Jones and Kierzkowski, 2001). International fragmentation of production leads to the establishment of international production networks, which are associated with trade in intermediates.

In this paper fragmentation (or outsourcing) is related to the debate on trade and wages. In a previous study Görg, Hijzen, and Hine (2001) use a partial equilibrium framework, which focuses on the factor bias by estimating the relative demand for labour. The paper presents mixed results with respect to the role of trade on domestic wage inequality. Obviously, a partial equilibrium framework employed does not pick up the expansion and decline of industries in response to foreign competition. General equilibrium effects similarly apply to the impact of technological change and outsourcing. Haskel and Slaughter (2002b) find evidence indicating that the sector-bias of skill-biased technological change is important. That is, the factor bias of technological change or outsourcing matters to relative factor prices to the extent that relative industry prices are affected. This can only be the case when those developments are unequally distributed across industries. Thus, a general equilibrium framework is necessary in order to account for both factor and sector bias of various structural forces.

The theoretical framework to assess the impact of trade and outsourcing on wages is provided by the Stolper-Samuelson theorem, which relates relative industry prices to relative factor prices through the zero-profit conditions. Empirical studies that employ a general equilibrium approach by directly applying the Stolper-Samuelson theorem, generally take the form of so-called mandated wage regressions in which the change in industry prices is regressed on the factor-cost shares in that industry. The coefficients reflect the implied factor price changes following the change in industry prices.[1]

However, Feenstra and Hanson (1999) in their study of the effect of outsourcing on US wages argue that if fully specified the regression becomes an identity and can no longer be used to make inferences about the implied factor price changes. In order to solve this problem they propose to endogenise prices and total factor productivity (TFP) in a two-stage procedure. In the first stage industry prices and TFP are regressed on expenditure on computers and outsourcing.[2] In the second stage the estimated coefficients from the first stage regressions are inserted as the dependent variables in the mandated wage regressions.

In fact Feenstra and Hanson estimate a reduced-form in which they jointly estimate the direct and indirect effect of their structural variables on value-added prices and TFP. The indirect effect is the impact of the structural variables on productivity that is passed-through on value-added prices. This specification is interesting as it includes the indirect effect of outsourcing and SBTC on factor prices, but does not require a consistent pass-through coefficient for TFP on prices (TFP and value added prices are correlated by construction).

[1] See Slaughter (2000) for a survey.
[2] By including productivity in the price regression they effectively impose the 'large country assumption'.

Haskel and Slaughter (2001) adopt a similar methodology using UK data for the 1970s and 1980s, but do only consider trade in final goods. They do not allow for pass-through from TFP on prices as the UK is considered to be small relative to the world economy. As a result they have a separate set of structural variables for both prices and TFP. Most importantly, they find that price effects (and not technology) were the main force behind the increase in relative wages during the 1980s. However, they do not consider the impact of foreign competition on productivity, or the impact of productivity on prices.

The contribution of the present paper is to provide a detailed analysis of the effects of outsourcing and technology on wages in the UK using 3-digit manufacturing data for the period 1993-1998. The use of recent data is thought to be crucial as fragmentation is considered to be primarily a phenomenon of the last decade. The empirical analysis applies and extends the method introduced by Feenstra and Hanson (1999).

An important innovation is that this paper explicitly addresses the relative importance of factor and sector bias (or the direct and indirect effect) of skill-biased technological change and outsourcing. The sector bias captures the relative cost-saving effect, while the factor bias captures changes in total factor-use. Decomposing the total effect of technological change or outsourcing in its factor bias and sector bias is interesting for three reasons.

First, the relative importance of those effects has been the topic of an intensive debate in the theoretical literature. Leamer (1995) emphasises that in small-open economy the sector bias is all that matters. Krugman (2000) argues that it is justified to emphasise the factor bias of technological change when technological change is global. However, no study seems to have addressed the issue empirically. This paper is the first to empirically address this question. Second, the reduced-form specification developed by Feenstra and Hanson (1999) is only sensible when the factor bias and the sector bias affect effective prices in the same direction. In other words it could be risky to interpret the obtained results without further knowledge on the factor bias and the sector bias. Third, decomposing the aggregate effect of structural variables allows one to investigate the role of outsourcing and foreign competition on productivity growth.

The paper is structured as follows. Section 1 presents a discussion of the theory linking trade and fragmentation to relative wages. Special emphasis is given to the issue of sector versus factor bias. Section 2 sets out the methodology employed in the econometric analysis while highlighting the key differences in the methodology used in Feenstra and Hanson (1999) and Haskel and Slaughter (2001). Section 3 discusses the data and presents some descriptive statistics. Section 4 applies the two-stage method proposed by Feenstra and Hanson, which involves estimating the impact of SBTC and outsourcing on the sum of productivity and value-added prices while controlling for foreign competition and market concentration. Section 5 extends the methodology to gain additional insight in the factor and the sector bias, which requires the estimation of the two first-stage regressions for productivity and prices (including TFP growth). In order to account for the endogeneity of TFP the regressions are estimated simultaneously using three-stage least squares. Finally, Section 6 concludes.

1. Theory

The theoretical foundation for empirical studies analysing the impact of trade on wages is provided by the Stolper-Samuelson theorem. With many goods and factors the most appropriate version states that 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. Allowing for productivity growth and accounting for the use of intermediate inputs yields:

$$(1.1) \qquad \hat{p}_i - \sum_k \theta_{ik} \hat{p}_k = \sum_j \theta_{ij} \hat{w}_j - T\hat{F}P_i$$

Equation (1.1) is derived from the zero-profit conditions equating prices to average costs resulting from the assumption of perfect competition.[3] The term on the left-hand side reflects value-added prices which equal final good prices, p_i, minus the sum of the cost shares, θ_{ik}, of intermediate inputs $k=1,...,K$ times p_k. In equilibrium value-added prices equal the sum of the primary cost shares, θ_{ij}, times factor prices, w_j with $j=1,...J$. Hats indicate proportional changes. Note that for factor prices the industry subscript is omitted as factor prices are equalised throughout the economy due to the assumption of perfect factor mobility across industries. As such an assumption is only warranted over a sufficiently large time horizon this should be reflected in the empirical analysis.

In a small-open economy factor price changes can only result from a change in the relative profitability (short-run) across sectors. From (1.1) it follows that the relative profitability can change as a result of either a change in relative prices or productivity growth. In a small-open price-taking economy domestic price changes are solely due to changes in world prices. By the factor-price insensitivity theorem (Leamer, 1995) changes in relative factor endowments leave relative factor prices unaffected. The change in factor endowments will instead be accommodated by a magnified change in output quantities. The implications of this theorem are far-reaching. Any change affecting the relative demand or relative supply for primary factors, whether due to skill-biased technological change, fragmentation of production or an increase in the relative supply of skilled labour, also leave relative factor prices unaffected as long as those changes do not affect the relative profitability across sectors. The fact that even within a small open economy SBTC and fragmentation are generally not neutral in their effect on relative factor prices comes entirely from their sector bias of the associated saving in production costs (reflected by higher productivity growth).

At this point it is useful to clarify some of the terminology that will be used throughout this paper. It was stated that in a small-open economy everything that matters is the relative profitability across sectors. Technological change (whatever its

[3] In the presence of imperfect competition the Stolper-Samuelson theorem remains valid in two cases. First, when the market is characterised by monopolistic competition the zero-profit conditions are still satisfied. Second, even when the zero-profit condition are no longer satisfied the Stolper-Samuelson theorem remains valid as long as mark-ups are constant over time. Haskel and Slaughter (2002a) find suggestive evidence that changes in industry-specific rents account for 15% of the changes in wages.

source) only matters to the extent that it changes total factor costs between sectors (cost-saving effect). This will be referred to as the sector bias of technological change. In Jones (1965) this was called the 'differential sector effect'. In the 2x2 case the cost change, γ_i in industry $i=1,2$ as a result of technological change can be represented as in equation (1.2) where l stands for labour, k for capital and θ reflects the respective factor cost shares.

$$\gamma_i = \theta_{li}\hat{c}_{li} + \theta_{ki}\hat{c}_{ki} \tag{1.2}$$

However technological change may also, as does a change in endowments, alter factor market equilibrium. Jones referred to this as the 'differential factor effect' and in this paper it will be referred to as the factor bias of technological change. Formally for factors $j=L, K,$ equation (1.3) gives the total change in factor use.

$$\gamma_j = \lambda_{j1}\hat{c}_{j1} + \lambda_{j2}\hat{c}_{j2} \tag{1.3}$$

Equation (1.3) is derived by fully differentiating the full-employment conditions equating total endowments of factor j to the sum of its use across all sectors (unit input requirements times output). Changes in factor endowments or technological change can only be accommodated by adjustments in the relative size of industries. In the small-open diversified economy any change in relative demand will leave relative factor prices unaffected. Changes in relative outputs do not affect goods prices as those are exogenously determined by world prices. The relative factor demand curve is therefore infinitely elastic.

The relative importance of the factor bias versus sector bias is subject to considerable. disagreement. Leamer (1995, 1998) emphasises that in small-open economy the sector bias is all that matters. Krugman (2000) argues that it is justified to emphasise the factor bias of technological change when technological change is global. Several issues matter for the importance of factor bias. First of all, it depends on the relative size of the country compared to world markets. Related is the argument presented by Krugman (2000) that technological change (or any other structural force) at home *and* abroad has a similar effect as technological change in a closed economy. In a closed economy it is solely the factor bias of technological change that determines what happens to relative factor prices. In addition, the relevance of factor bias depends on the production technology (Xu, 2001), and the relative size of the non-tradables sector where goods prices are endogenous by definition. Second-order effects may be important whenever technological change is finite (Leamer, 1998; Findlay and Jones, 2000). Finally, the factor bias matters whenever countries are completely specialised.

The focus of the present paper however is on trade in intermediates resulting from the increasing international fragmentation of production processes rather than trade in final goods. The literature on international fragmentation is predominantly characterised by perfect competition. Fragmentation in those models is generally driven by the presence of cross-border differences in relative factor prices. Fragmentation takes the form of moving unskilled intensive manufacturing processes

from a developed country to a developing country. It is argued that fragmentation has a similar effect as skill-biased technological change.

Arndt (1997) analyses the impact of fragmentation in a small open developed economy in a standard 2x2x2 Heckscher-Ohlin model. Consequently, Arndt emphasises the sector bias of outsourcing. He concludes that outsourcing of labour-intensive components in the labour-intensive industry actually reduces wage inequality whereas outsourcing of labour-intensive components in the capital/skill-intensive industry increases wage inequality.[4]

Deardorff (2001) analyses fragmentation across cones, i.e. in the absence of factor price equalisation. He argues that the impact of fragmentation on relative factor prices depends crucially on the relative factor-intensity of the fragment being moved abroad and the average factor intensity in the economy. The adjustment of the economy depending on the relative factor-intensity of the fragment and the average factor-intensity of the economy is reflected in a change in relative factor prices. The difference with Arndt resides in the fact that Arndt considers an open-diversified economy, while Deardorff considers a completely specialised economy. [5]

One can conclude that the debate on the relevance of factor bias extends to trade in intermediates. However, it should be noted that the case for an important role for the factor bias is stronger when trade in intermediates is concerned. Fragmentation is only viable if it brings sufficient savings in factor costs to cover the cost of fragmentation. Thus it requires the persistence of factor price differentials (the lack of international factor price equalisation). Furthermore, the impact of outsourcing on the production technologies is unlikely to be marginal but instead is expected to be quite radical. Therefore it seems that in order to assess the impact of fragmentation on relative wages one has to account both for its factor and its sector bias.[6]

2. Methodology

In order to investigate more formally the link between fragmentation, productivity and factor prices a two-stage methodology based on Feenstra and Hanson (1999) and Haskel and Slaughter (2001) is employed.

Feenstra and Hanson (1999) argue that estimating equation (1.1) in a fully specified regression yields an identity and cannot be used to make inferences about the implied factor price changes. In order to solve this problem Feenstra and Hanson propose to endogenise prices and total factor productivity (TFP). They therefore develop a two-stage procedure. In the first stage industry prices and TFP are regressed on expenditure on computers and outsourcing. In the second stage the estimated

[4] Jones and Kierzkowski (2001) confirm these possibilities, but also stress the radical nature of outsourcing for which the Heckscher-Ohlin framework may be ill equipped. A priori, therefore, it is very difficult to predict how fragmentation will actually affect relative wages.
[5] Consequently, in the analysis conducted by Arndt relative factor demand is infinitely elastic and only the sector bias matters. In Deardorff's analysis the relative demand curve is downward-sloping.
[6] The net cost saving effect appears in the data as productivity growth. In all likelihood this productivity growth has often been attributed to domestic SBTC instead of outsourcing.

coefficients from the first stage regressions are inserted as the dependent variables in the mandated wage regressions.

Haskel and Slaughter (2001) adopt a similar methodology using UK data for the 1970s and 1980s. The essential difference resides in the scope of pass-through from TFP to prices in the first stage of the regression analysis. Feenstra and Hanson allow for such a pass-through whereas Haskel and Slaughter do not. The idea of pass-through is plausible whenever the factor bias plays a role.[7]

Haskel and Slaughter (2001) separately estimate a price and a TFP-regression in the first-stage.

(2.1a) $$\Delta \ln p_i^{VA} = \delta' \Delta z_i + \omega_i$$

(2.1b) $$\Delta \ln TFP_i = \alpha' \Delta z_i + \varepsilon_i$$

When productivity pass-through is allowed for this is reflected in the price regression where the change in value-added prices is regressed on TFP plus a vector of structural variables. Feenstra and Hanson (1999) therefore start off with the following set of equations in the first stage:

(2.2a) $$\Delta \ln p_i^{VA} = \lambda \Delta \ln TFP_i + \beta' \Delta z_i + \upsilon_i$$

(2.2b) $$\Delta \ln TFP_i = \alpha' \Delta z_i + \varepsilon_i$$

Whenever λ is negative one should allow for pass-through from TFP to prices.[8] Including TFP in the price regression (2.2a) accounts for the pass-through of the sector-biased technological change. Its effect on goods prices equals $\lambda\alpha$, while its effect on factor prices equals $(1+\lambda)\alpha$. The factor bias comes into play when output affects goods prices. If one believes in pass-through one should also account for the factor bias. The factor bias is given by β. Thus, the total effect of technological change and outsourcing (factor and sector bias) on goods prices equals $\lambda\alpha+\beta$, while its effect on factor prices equals $(1+\lambda)\alpha+\beta$. Note that the factor bias only matters to the extent that technological change directly affects prices! Note that price effects may also be due to exogenous forces affecting prices without affecting TFP (such as reductions in tariff and transportation costs).

[7] When allowing for price-effects (large country assumption, pass-through and factor bias) sector-biased TFP only has an impact on factor prices when pass-through is incomplete. In the presence of complete pass-through sector-biased TFP growth leaves relative factor prices unaffected.

[8] Both Feenstra and Hanson (1999) and Haskel and Slaughter (2001, 2002a) estimate that the pass-through rate is significantly different from zero. Applying the F-test for $\lambda=0$ in (2.2a) is rejected, whereas the F-test of λ= -1 cannot be rejected (95% confidence interval). However as Baldwin and Cain (2000) note the empirical measurement of TFP is endogenous to the price setting process.

In fact Feenstra and Hanson estimate a reduced-form in which they jointly estimate the direct and indirect effect of the structural variables on value-added prices and TFP reflected by (2.3), which is obtained by adding TFP to both sides of (2.2a). The indirect effect is the impact of the structural variables on productivity that is passed-through on value-added prices.

$$\Delta \ln p_i^{VA} + \Delta \ln TFP_i = \gamma' \Delta z_i + \eta_i \tag{2.3}$$

where $\gamma=(1+\lambda)\alpha+\beta$ and $\eta_i=(1+\lambda)\varepsilon_i+\upsilon_i$. Feenstra and Hanson thus regress several structural variables on effective prices, i.e. the sum of price changes and TFP growth. The advantage of their specification is that they only have to estimate a single parameter, γ. Adding TFP to both sides of the equation singles out the net effect of technological change on relative factor prices.

However, it would be interesting to decompose the direct effect (factor bias) and indirect effect (sector bias) of factors such as outsourcing and SBTC on wage inequality. Not only does this contribute to the academic debate, but it may also have some interesting policy implications.

Decomposing direct and indirect effects involves the estimation of the three parameters α, λ and β in equations (2.2a) and (2.2b). The inclusion of TFP as an explanatory variable in equation (2.4b) implies that OLS estimates would suffer from simultaneity bias. One has to simultaneously estimate both equations in order to deal with the endogeneity problem associated with TFP (TFP and error term will be correlated) in (2.2b). The problem can be overcome by using three-stage least squares (3SLS).

In the second-stage the components explained by each structural variable, k, in the first-stage are regressed on the average factor shares, V_{ji}. Note that γ in equation (2.4) either reflects γ in (2.3) or the combination of α, λ and β from (2.4a) and (2.4b) as discussed above.

$$\gamma_k' \Delta z_{ik} = \delta_k' V_i + \nu_i \tag{2.4}$$

3. Data and Descriptive Statistics

The labour market data are obtained from Labour Force Survey (LFS). The LFS allows one to construct numerous skill measures. In this paper skill is defined on the basis of the Standard Occupational Classification (SOC), which allows one to construct a more accurate measure of skill than the one based on the distinction between manual/non-manual workers generally used in the literature. In the QLFS workers are classified according to 9 Major Groups. The SOC Major Groups are based on qualifications, training, skills, and experience. Therefore, distinguishing skill groups on the basis of their Major Group Codes allows one to construct a very accurate measure of skill. For the determination of skill groups the approach taken by Gregory, Zissimos and Greenhalgh (2001) is adopted. Apart from providing a more

accurate measure of skill, this approach allows one to distinguish three skill groups: skilled, intermediate, and unskilled.[9]

Production data are obtained directly from the ONS. Data on R&D intensity and outsourcing are obtained from the Input-Output Tables. The trade data are obtained from EUROSTAT. The period under consideration is limited to 1993-1998. The year 1993 is the first for which data are classified according to SIC92 is 1993.

Following Feenstra and Hanson (1999) two measures of outsourcing will be used: narrow (to the same industry) and differential outsourcing (to other industries). In order to emphasise outsourcing of low-skill fragments driven by the persistence of factor cost differentials, outsourcing is weighted by imports from developing countries. SBTC is measured by R&D intensity. Foreign competition is measured by import prices based on unit values. Finally, concentration ratios are used to control for industry characteristics such as market concentration.[10]

Table 3.1 represents summary statistics with respect to factor prices and factor cost shares. Changes in factor prices are measured as the average annual change in the log of factor earnings. Factor cost shares reflect the average of the start and end of period factor cost shares. The data confirm the increase in wage inequality. Skilled labour wages increased at an annual average of 4.2% over the period 1993-1998, while unskilled labour wages only increased by 2.9% a year. A recurrent element is that it is actually semi-skilled labour that experienced the lowest wage increases. Concerning the factor cost shares one should note that factor cost shares are relatively stable over time. The factor cost share of intermediates seems to be an exception, which might indicate the increasing importance of outsourcing.

Table 3.1: Summary Statistics, 1993-1998

	Average (%)	Annual change
Change in log factor prices (based on quantities)[11]		
- Skilled labour		4.211
- Semi-skilled labour		2.200
- Unskilled labour		2.884
- Intermediates		5.030
- Capital		3.012
Factor cost shares		
- Skilled labour	6.99	-0.002
- Semi-skilled labour	6.22	-0.127
- Unskilled labour	3.78	-0.051
- Intermediates	55.88	0.438
- Capital	27.14	-0.257

Averages are computed over 1993 and 1998. Changes in factor prices are measured as the average annual change in the log of factor earnings. Factor cost shares reflect the average of the start and end of period factor cost shares.

[9] Skilled workers are those classified as Managers and Administrators, Professional Occupations, Associate Professional and Technical Occupations; semi-skilled workers as Clerical and Secretarial Occupations, Craft and Related Occupations, Personal and Protective Service Occupations; and unskilled workers as Plant and Machine Occupations, Other Occupations.

[10] See the data appendix for more detailed information on the construction of the variables.

[11] The annual change in the earnings of semi-skilled and unskilled workers together amounts 2.459. The annual increase in wage inequality was then 1.71%.

Table 3.2 depicts the trends in prices and TFP by low and high skill-intensity as well as their relative change. Skill-intensity is defined as the skilled labour cost share in value-added. Value-added prices in skill-extensive industries increased by 1.9% a year while value-added prices decreased by 2.7% a year in skill-intensive industries. The relative value-added price of skill-intensive industries thus fell by 4.6% a year. Price effects *cannot* explain the increase in wage inequality in the UK, although it is possible that value-added prices reflect productivity pass-through. TFP growth was considerably higher in skill-intensive industries amounting to 5.5% a year compared to 0.7% in skill-extensive industries. One should therefore focus on the price effect net of productivity pass-through to see whether the trade-based explanation can be rejected. Import prices may clarify this puzzle. From Table 3.2 it follows that import prices rose faster in skill-extensive industries. Note that the relative price rise of skill-extensive imports is driven by the rise in the price of imports from developed countries as the relative price of skill-extensive imports from developing countries fell significantly.

In sum, price effects can reflect two complementary developments. First, productivity pass-through may be responsible for a large part of the observed price effects. The part of TFP growth that is not transmitted through lower prices affects relative factor prices. Second, prices of imports from developed countries had a positive effect on the relative price of skill-intensive products, whereas prices of imports from developing countries had a negative impact. Overall Stolper-Samuelson effects should have induced a reduction in wage inequality. The remaining explanation for the increase in wage inequality should therefore come from TFP growth not passed through onto prices.

Table 3.2: Summary Statistics by Use of Skilled Labour, 1993-1998

Skill-intensity	Δlnp^{VA}	$\Delta ln\ TFP$	$\Delta ln\ p^{M}$ (all imports)	$\Delta ln\ p^{M}$ (developing countries)	$\Delta \ln p^{M}$ (developed countries)
Low	1.88	0.72	9.14	12.47	4.79
High	-2.74	5.45	4.37	18.79	-1.69
Relative Δ	4.62	-4.73	4.37	-6.32	6.48

4. Empirical Results

Table 6.1 reports the results obtained from estimating (2.3) with OLS. It is important to note that a priori the expected sign on outsourcing or technological change is not clear. However, meaningful results may be expected when the processes are regular, i.e. its sector bias and factor bias effect affect the sum of prices and TFP in the same direction. By definition outsourcing should have a positive impact on TFP as outsourcing is only profitable when it is cost-saving. The question therefore is under what circumstances a positive relationship between the factor-biased outsourcing and prices becomes plausible. By assumption outsourcing leads to an excess supply of unskilled workers (as it is assumed that the low skill-intensive fragments move abroad). As the economy as a whole becomes more skill-intensive the full employment conditions require that on average unskilled intensive industries expand and skill-intensive industries contract. This will be associated with a relative fall in the price of unskilled-intensive industries if prices are determined endogenously (at least partly). Thus a positive relationship between outsourcing and prices in the price

regression can only occur when outsourcing is concentrated in the skill-intensive industries.[12]

Outsourcing of fragments within the same industry to developing countries is positive and statistically significant, whereas outsourcing to other industries in developing countries is insignificant. R&D intensity is also positive and significant. Thus both processes seem indeed to be concentrated in the skill-intensive industries.

Import prices are found to exert a positive and significant effect on effective prices. In column (2) imports prices are split into import prices based on imports from developing countries and import prices based on imports from developed countries. The results indicate that competition from other developed countries drives the relationship between import prices and effective prices, which corresponds to the descriptive statistics in Table 3.2. The coefficient on the concentration ratio is negative and significant. Although its coefficients are extremely small the concentration ratio seems to play an important role by controlling for industry characteristics such as market concentration.

Table 4.1: Stage-I-Regressions with OLS

Dependent Variable: $\Delta p^{VA}+TFP$	(1)		(2)	
Outsourcing (narrow)	0.115	(4.29) ***	0.084	(1.87) *
Outsourcing (difference)	-0.012	(-1.00)	0.017	(1.02)
R&D Intensity	2.058	(2.05) **	2.862	(2.80) ***
Import prices	0.033	(2.04) **		
Import prices (developing countries)			0.010	(0.47)
Import prices (developed countries)			0.034	(2.13) **
Concentration Ratio	-0.0	(-2.14) **	-0.0	(-2.49) **
Constant	0.023	(3.18) ***	0.020	(2.85) ***
N	55		52	
R-squared	0.26		0.30	

Robust T-statistics in parentheses, *, **, *** indicate significance levels of 10%, 5% and 1% respectively. Observations are weighted by sales.

The second stage involves estimating equation (2.4), i.e., the impact of each structural force on relative factor prices. The component explained by each structural variable serves as the dependent variable of the mandated wage regressions. On the right-hand side the average cost share over 1993-1998 of skilled and unskilled labour are included. The estimated coefficients are interpreted as the implied average annual factor price changes resulting from the structural variable under consideration. The difference between the coefficients on skilled and unskilled labour is interpreted as the total mandated change in domestic wage inequality. The results in Table 4.2 relate to the results in regression (1) of Table 4.1.

[12] Note that the regression does not imply a direct causal relationship between outsourcing and prices but the correlation between two variables reflecting the outcome of the implied general equilibrium dynamics.

Table 4.2: Stage-II-Regressions - Mandated wage changes, 1993-1998

	R&D Intensity		Outsourcing (N)		Outsourcing (D)		Import Prices	
Skilled	-0.003	(-0.08)	0.022	(-0.87)	0.006	(0.46)	-0.106	(-3.54) ***
Unskilled	-0.059	(-3.82) ***	-0.059	(-1.96) *	0.013	(1.77) *	0.014	(1.13)
Constant	0.019	(7.51) ***	0.009	(1.84) *	-0.002	(-1.45)	0.004	(2.27) **
R-squared	0.23		0.14		0.02		0.37	
N	64		62		62		63	
Mandated change	0.06		0.06		-0.01		-0.11	

Robust T-statistics in parentheses, *, **, *** indicate significance levels of 10%, 5% and 1% respectively. Observations are weighted by employment.

Outsourcing to developing countries is estimated to have reduced the wage of unskilled workers by on average 0.06% a year over the period 1993-1998, while no significant impact is found for skilled wages. The total mandated change in domestic wage inequality as a result of outsourcing therefore was 0.06 percent a year. R&D had no significant effect on skilled wages, while it had a negative significant impact on unskilled wages. R&D reduced unskilled wages by 0.0.6 percent a year. Thus, from regression (1) it follows that both outsourcing and SBTC have contributed to the increase in wage inequality. With the actual annual increase in wage inequality around 1.7% (see Table 3.1), the proportion explained by outsourcing amounts to 4% as does the proportion explained by SBTC. Feenstra and Hanson find that outsourcing accounts for 15% of the annual increase in wage inequality in the US.

5. The sector bias and factor bias of outsourcing and SBTC

Table 5.1 represents the results of estimating (2.2a) and (2.2b) simultaneously using 3SLS. Results for system (1) indicate that both narrow outsourcing and R&D intensity are positively and significantly related to TFP. Outsourcing to other industries in developing countries is found to have a negative impact but its impact is extremely small. Import prices and the concentration ratio both are insignificant. If anything the signs of the coefficients suggest that competition encourages technological progress. Foreign competition is associated with a positive sign, while the lack of domestic competition is associated with a negative sign.

In the first set of results value-added prices are regressed on overall import prices in addition to TFP. Foreign prices have a positive but insignificant impact on value-added prices. In the second set of results a distinction is made between the price of imports from developing countries and developed countries. Both are positive, but insignificant.

The coefficients for both measures of outsourcing and R&D are all insignificant. It might be the case that the impact of outsourcing is not the same across sectors. As a matter of fact the econometric framework relates outsourcing within a particular industry to prices changes in that industry. However, in theory there is no such direct relationship. Instead it is the excess supply of unskilled workers that has to be absorbed by relative output adjustments. Thus, one would expect relative prices to go

down in low skill-intensive industries independent of the level of outsourcing in those specific-industries but as a result of the total increase of outsourcing of fragments of low skill-intensity. One way to capture this is to use an interaction term for narrow outsourcing with skill-intensity.

In the second specification the interaction term is included in the price regression. Including the interaction term in the price regression renders both outsourcing and R&D intensity positive and significant. The interaction term is negative which indicates that the effect of outsourcing on prices is less the higher the skill intensity in the industry. The negative sign might reflect that outsourcing in unskilled-intensive industries tends to result in more job losses for unskilled workers (because for instance the fragments moved abroad are even less skill-intensive) and therefore requires a more radical adjustment of output quantities.[13]

Table 5.1: First-Stage Regressions with 3SLS

	(1)				(2)			
Dependent variable	p^{VA}		*TFP*		p^{VA}		*TFP*	
TFP	-0.679	(-2.18) **			-0.700	(-2.30) **		
Outsourcing (N)	-0.001	(-0.01)	0.362	(5.86) ***	0.294	(2.26) **	0.362	(5.86) ***
Outsourcing (D)	-0.004	(-0.33)	-0.026	(-1.75) *	-0.009	(-0.84)	-0.026	(-1.75) *
R&D intensity	1.393	(1.37)	2.151	(1.66) *	1.631	(1.83) *	2.151	(1.66) *
Import prices	0.029	(1.76) *	0.013	(0.47)	0.025	(1.46)	0.013	(0.47)
Concentration ratio	-0.0	(-2.78) ***	-0.0	(-1.01)	-0.0	(-3.40) ***	-0.0	(-1.01)
Factor intensity *O(N)					-0.498	(-1.36)		
Constant	0.024	(3.77) ***	-0.003	(-0.28)	0.024	(4.00) ***	-0.003	(-0.28)
R	0.63		0.50		0.63		0.50	
N	55		55		55		55	

T-statistics in parentheses, *, **, *** indicate significance levels of 10%, 5% and 1% respectively. Observations are weighted by sales.

Table 5.2 reports the results for the mandated wage regressions for specification (2) of the First-Stage Regressions. The total increase in the relative wage of skilled workers mandated by outsourcing amounted to 0.21% a year (considerably higher than the role attributed to outsourcing in the OLS regressions) which amounts to 12% of the increase in domestic wage inequality over the period 1993-1998 in the UK. SBTC induced an increase 0.07% in wage inequality, which is the equivalent of 4% of the total. Import prices induced a reduction in the relative wage of skilled labour of 0.09% a year (5% of total). Nevertheless, the net effect of globalisation defined as the sum of foreign price competition and outsourcing, points at a significant role for globalisation in explaining the rise in domestic wage inequality accounting for an annual increase in the relative wage of skilled workers of 0.12% (still larger than SBTC).

[13] Including the interaction term also in the TFP regression yields similar results. However the interaction term in the TFP regression is positive and significant indicating that the higher the skill-intensity the higher the cost-reducing effect of outsourcing.

Table 5.2: Second-Stage Regressions for Specification (3)

	TFP	O(N) total	R&D total	PM total	R&D FB	R&D SB	O(N) FB	O(N) SB
Skilled	-0.185	-0.079	-0.004	-0.090	-0.003	-0.001	-0.057	-0.021
	(-1.14)	(-0.87)	(-0.08)	(-3.54)	(-0.08)	(-0.08)	(-0.87)	(-0.87)
				***				
Unskilled	0.074	-0.207	-0.066	0.012	-0.047	-0.019	-0.151	-0.056
	(0.63)	(-1.96)	(-3.82)	(1.13)	(-3.82)	(-3.82)	(-1.96)	(-1.96)
		*	***		***	***	*	*
Constant	-0.001	0.035	0.021	0.003	0.015	0.006	0.026	0.009
	(-0.02)	(2.20)	(7.51)	(2.27)	(7.51)	(7.51)	(2.20)	(2.20)
		**	***	**	***	***	**	**
Mandated change	-	0.21	0.07	-0.09	0.05	0.02	0.15	0.06
R	0.02	0.10	0.23	0.37	0.23	0.23	0.12	0.12
n	62	62	64	63	64	64	62	62

Robust t-statistics in parentheses, *, **, *** indicate significance levels of 10%, 5% and 1% respectively. Observations are weighted by employment. The dependent variable for the sector bias outsourcing and R&D is based on $(1+\lambda)\alpha$ thus accounting for productivity pass-through, the factor bias is based on β. Their total effect therefore is based on the sum of the factor and sector bias, $(1+\lambda)\alpha+\beta$.

With 3SLS it is possible to decompose the total effect of outsourcing into the effect due to the factor and sector bias respectively. The results are reported in the last two columns of Table 5.2. Results attribute a 0.15% annual increase in wage inequality to the factor bias of outsourcing, while the sector-bias of outsourcing accounts for 0.06%. Thus it is suggested that the factor bias of outsourcing has been about 2.5 times as important as the sector bias of outsourcing for the rise in domestic wage inequality.

However these results should be interpreted with caution as they results critically depend on the estimate of the pass-through rate. The estimated coefficient on TFP in the price regression in Table 5.3 equals -.7. For different specifications the pass-through estimate was typically found to be in the range of –0.7 and -1. This is broadly in line with findings by Feenstra and Hanson (1999) and Haskel and Slaughter (2001). However, it is not clear to what extent this finding reflects the actual TFP pass-through or is driven by the empirical measurement of TFP. It seems likely that the estimated pass-through seriously overestimates the actual pass-through rate as a result of the construction of TFP. It is therefore interesting to see how the relative importance of the factor and sector bias changes with λ. The results are summarised in Table 5.3.

Table 5.3: Summary results outsourcing by constrained 3SLS

λ	Sector bias	Factor bias	Total mandated change
0	0.19	0.10	0.29
-0.50	0.09	0.16	0.26
-1	0	0.23	0.23

The first column reflects the imposed values on the pass-through rate. With zero pass-through as is the case for a small open economy the mandated change in relative wages is almost dominated by the sector bias. For the intermediate case with $\lambda=-0.5$ both sector bias and the factor bias matter, the latter being the dominant force. For the extreme case where pass-through is complete only the factor bias that matters. Thus in order to assess the relative importance of factor and sector bias the estimate of the pass-through rate is critical.

The result that TFP is highly significant in explaining prices without inducing any change in relative factor prices is consistent with Haskel and Slaughter (2001). It may not be appropriate to conclude, however, that sector-biased TFP growth did not affect relative factor prices. As a matter of fact the total impact of sector-biased TFP growth is estimated to have reduced relative wages by 0.08% a year (the sum of R&D and outsourcing). The coefficient on TFP in the first-stage regressions reflects to what extent sector-biased productivity growth is neutralised by a sector-biased price change. It should therefore not come as a surprise that TFP pass-through did not induce any change in relative factor prices.

6. Conclusion

This paper analyses the impact of trade and in particular the impact of trade in intermediate goods resulting from the increasing international fragmentation of production processes on the increase in wage inequality in UK manufacturing for the period 1993-1998.

Theoretically relative factor prices can be affected by the factor bias and the sector bias of structural change. The factor bias captures the impact of changes in the relative demand and supply for factors on relative factor prices through the impact of restructuring on relative goods prices. The sector bias reflects changes in the relative profitability across sectors due to foreign price competition or productivity growth.

In order to account for both the factor and the sector bias a general equilibrium approach is adopted following Feenstra and Hanson (1999). The results obtained in the present study using this approach indicate that outsourcing and SBTC have significantly contributed to the rise in the domestic wage inequality in the UK in the 1990s. Both processes explain about 4% of the increase in wage inequality.

In order to get additional information on the relative importance of sector bias and factor bias the TFP and prices regressions are simultaneously estimated using three-stage least squares. With this extended method it is possible to evaluate the impact of structural variables such as outsourcing and technological change in cases where these processes are not regular, i.e. the two effects do not affect prices and TFP in the same direction.

The analysis yields qualitatively similar results to the OLS regressions. Outsourcing is estimated to have mandated an annual increase in the relative wage of skilled labour of 0.21%, which amounts to about 12% of the actual increase in domestic wage inequality.

Decomposing the total effect of outsourcing in the effect of factor-biased outsourcing and sector-biased outsourcing yields that the factor bias of outsourcing mandated of an increase in the relative wage of skilled workers of 0.15% a year, while the sector bias of outsourcing mandated an increase of 0.06% a year. The factor bias is thus found to be about 2.5 times as important as its sector bias. However in assessing the relative importance of the two effects the estimate of the productivity pass-through coefficient is crucial. Further research is needed to look into the actual level of the pass-through rate.

In contrast to what is generally assumed import prices turn out to have reduced domestic wage inequality. Import prices mandated a reduction in the relative wage of skilled labour of 0.09% a year. Nevertheless, the net effect of globalisation defined as the sum of foreign price competition and outsourcing points at a significant role for globalisation in explaining the rise in domestic wage inequality accounting for an annual increase in the relative wage of skilled workers of 0.12%.

I Data Appendix

Value-added prices are constructed as follows:

$$\text{(A.1)} \qquad \Delta \ln p_i^{VA} = \Delta \ln p_i - \sum_j (x_{ij97} / X_{i97}) * 1/2(X_{it} / Y_{ti} + X_{it-1} / Y_{ti-1}) \Delta \ln p_j^I$$

Value added prices are obtained by subtracting the value of the sum of intermediate purchases. The weights are obtained from the combined-use matrix for 1997. The weights sum up to unity across manufacturing industries excluding services.

Total factor productivity is measured by the primal Tornqvist Index:

$$\text{(A.2)} \qquad \begin{aligned} &\Delta \ln TFP_i = \Delta \ln VA_i - (\Delta \ln E_{1i} * V_{1i}) - (\Delta \ln E_{2i} * V_{2i}) - (\Delta \ln E_{3i} * V_{3i}) \\ &- (\Delta \ln K_i * V_{ki}) \end{aligned}$$

The factor cost shares are based on sales. The capital cost share is defined as the residual after subtracting the labour cost share and the intermediate cost share from unity. Capital payments are defined as the capital cost share times sales.

Narrow outsourcing is defined as follows total intermediate purchases (C) times the ratio of imported intermediate inputs (O) over total intermediate purchases in 1995 weighted by the proportional change in import penetration by developing countries over value added:

$$\text{(A.3)} \qquad O_{it}^{N} = \frac{\frac{O_{i95}}{C_{i95}} \times C_{it} \times \frac{M_{it}/VA_{it} - M_{i95}/VA_{i95}}{M_{i95}/VA_{i95}}}{VA_{it}}$$

Differential outsourcing in turn:

$$\text{(A.4)} \qquad O_{it}^{N} = \frac{\sum_j \frac{O_{ij95}}{C_{ij95}} \times C_{ijt} \times \frac{M_{jt}/VA_{jt} - M_{j95}/VA_{j95}}{M_{j95}/VA_{j95}}}{VA_{it}}$$

R&D intensity is measured by the relative importance of spending on external R&D as a share of total intermediate purchases. The concentration ratios reflect the share in sales of enterprises with more than 500 employees.

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