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Fragmentation, Productivity and Relative Wages in the UK: A Mandated Wage Approach

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Fragmentation, Productivity and Relative Wages in the UK:

A Mandated Wage Approach

by

Alexander Hijzen

Abstract

Feenstra and Hanson (1999) propose a two-step method to analyse the role of outsourcing and skill-biased technological change (SBTC) in the rise of wage inequality. This paper applies their methodology to UK manufacturing using data for the 1990s and extends it in order to obtain additional insight into the relative importance of the sector bias and the factor bias of outsourcing and SBTC. The results indicate that SBTC is the predominant force behind the increase in wage inequality accounting for 10% of the total increase in the UK in the 1990s. Outsourcing also significantly contributed to the rise in the domestic wage inequality accounting for about 6% of the total increase. In explaining the increase in wage inequality the factor bias of SBTC was slightly larger than its sector bias, while for outsourcing the sector bias was about 2.5 times as important as its factor bias.

JEL Classification: F14, J31

Keywords: fragmentation, outsourcing, productivity, mandated wage regressions

Outline

Non-Technical Summary

A key feature that distinguishes the current wave of globalisation from previous periods of relative openness is the increasing international fragmentation of production. Fragmentation refers to the splitting up of production processes into separate components so that they can be produced in different locations around the world (Jones and Kierzkowski, 1990). International fragmentation of production leads to the establishment of international production networks, which are associated with an increasing importance of trade in intermediates in world trade. It is assumed throughout that fragmentation is driven by the persistence of factor price differentials across countries, which creates incentives for firms in developed economies to move unskilled intensive manufacturing processes to low wage countries.

In this paper fragmentation (or outsourcing) is related to the debate on trade and wages. Most empirical work indicates that skill-biased technological change (SBTC) is the predominant source of the increase in wage inequality in developed countries, although trade appears to play a significant role as well. However, outsourcing or trade in intermediates differs importantly from trade in final goods in the sense that it explicitly takes into account the extent to which firms move production activities abroad. Moreover, relative labour demand is not only affected in import-competing industries, but in all industries that use foreign inputs. Hence, the impact of outsourcing may not be limited to changing labour demands between industries, but also affects the relative demand for labour within industries.

Feenstra and Hanson (1999) propose a two-step method to analyse the role of outsourcing and SBTC in the rise of wage inequality. This paper applies and extending their methodology to UK manufacturing using data for the 1990s.

An important innovation is that this paper explicitly addresses the relative importance of factor and sector bias of outsourcing and SBTC. The sector bias captures the relative cost-saving effect, while the factor bias captures changes in factor-use for the economy as a whole. Decomposing the total effect of technological change or outsourcing to its factor bias and sector bias is interesting for at least two reasons.

First, the relative importance of factor bias and sector bias has been subject to intensive debate in the theoretical literature. Second, decomposing the aggregate effect of structural variables allows one to investigate the role of increased foreign competition and outsourcing on productivity growth.

The results indicate that SBTC is the predominant force behind the increase in wage inequality accounting for 10% of the total increase in the UK in the 1990s. Outsourcing also significantly contributed to the rise in the domestic wage inequality accounting for about 6% of the total increase. In explaining the increase in wage inequality the factor bias of SBTC was slightly larger than its sector bias, while for outsourcing the sector bias was about 2.5 times as important as its factor bias.

1. Introduction

A key feature that distinguishes the current wave of globalisation from previous periods of relative openness is the increasing international fragmentation of production. Fragmentation refers to the splitting up of production processes into separate components so that they can be conducted in different locations around the world (Jones and Kierzkowski, 1990).[1] International fragmentation of production leads to the establishment of international production networks, which are associated with an increasing importance of trade in intermediates in world trade (Hummels, Ishii and Yi, 2001). It is assumed throughout that fragmentation is driven by the persistence of factor price differentials across countries, which creates incentives for firms in developed economies to move unskilled intensive manufacturing processes to low wage countries.

In this paper fragmentation (or outsourcing) is related to the debate on trade and wages. Most empirical work indicates that skill-biased technological change (SBTC) is the predominant source of the increase in wage inequality in developed countries, although trade appears to play a significant role as well. Berman, Bound and Griliches (1994) show that the increase in the relative demand for skilled labour occurred *within* rather than *across* industries. Consequently they conclude that trade cannot be the predominant source of wage inequality. In addition the Stolper-Samuelson theorem implies that if trade were to induce wage inequality through its impact on domestic goods prices, the price of skilled-intensive goods relative to unskilled-intensive goods should have increased. Lawrence and Slaughter (1993) however show that in the US relative price changes during the 1980s were not consistent with the trade-based explanation.

However, outsourcing or trade in intermediates differs importantly from trade in final goods in the sense that it explicitly takes into account the extent to which firms move production activities abroad. Moreover, relative labour demand is not only affected in

[1] Other terms that are used to describe a similar phenomenon are vertical specialisation (Hummels, Ishii and Yi, 2001), intra-product specialisation (Arndt, 1997), delocalization (Leamer, 1998), outsourcing

import-competing industries, but in all industries that use foreign inputs. Hence, the impact of outsourcing may not be limited to changing labour demands between industries, but also affects the relative demand for labour within industries.

Previous studies based on a partial equilibrium framework evaluating alternative explanations for the increase in wage inequality sometimes found mixed results with respect to the qualitative impact of international trade on relative wages.[2] Obviously, a partial equilibrium framework is not appropriate to addressing the general equilibrium effects underlying the trade-based explanation of increased wage inequality. Foreign competition is likely to induce industrial restructuring by changing the relative size of different industries. As industries differ in their relative use of inputs, increased foreign competition will affect the relative demand for labour. General equilibrium effects similarly apply to the impact of technological change and outsourcing. Haskel and Slaughter (2002a) for example find evidence indicating that the sector bias of skill-biased technological change is important. Thus, a general equilibrium framework is necessary in order to properly account for the labour market effects of various structural forces.

The most commonly used 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.[3]

However, Feenstra and Hanson (1999) in their study on the impact 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

(Feenstra and Hanson), disintegration (Feenstra, 1998). Throughout this paper these terms will be used interchangeably.

[2] See for example Machin and Van Reenen (1998).

(TFP) in a two-stage procedure. In the first stage, industry prices and TFP are regressed on expenditure on computers and outsourcing.[4] In the second stage, the estimated coefficients from the first stage regressions are inserted as the dependent variables in the mandated wage regressions.

In practice Feenstra and Hanson employed a reduced-form in which they jointly estimate the direct and indirect effects of their structural variables on the sum of 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 estimate of the pass-through rate for TFP on prices (TFP and value added prices are correlated by construction).

Haskel and Slaughter (2001) adopt a similar methodology to assess the impact of foreign prices, trade costs and technological change on relative wages using UK data for the 1970s and 1980s. They do not allow for pass-through from TFP on prices as the UK is considered to be small relative to the world economy. Interestingly, they find that price effects - and not technology - were the main force behind the increase in relative wages during the 1980s.

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. Hijzen, Görg, and Hine (2003) use a partial equilibrium framework to examine the impact of outsourcing on the increase in wage inequality using data for the UK for the period 1982-1997. Outsourcing is measured as the share of imported intermediate inputs in value added using input-output data. They show that the outsourcing within the same industry (narrow outsourcing) could account for about half of the increase in wage inequality. The descriptive statistics indicate that narrow outsourcing increased dramatically in the first half of the 1990s in relatively skill-intensive industries. As fragmentation seems to be primarily a phenomenon of the last decade the use of recent data is crucial. The present paper concentrates on the

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

general equilibrium effects of fragmentation and SBTC by applying and extending the mandated wage methodology 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 effects) 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 to its factor bias and sector bias is interesting for at least two reasons.

First, the relative importance of factor bias and sector bias has been subject to intensive debate in the theoretical literature. Leamer (1995) emphasises that in a 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. This paper is the first to address this question empirically.[5]

Second, decomposing the aggregate effect of structural variables allows one to investigate the role of increased foreign competition and outsourcing on productivity growth. Although the empirical evidence suggests that the direct effect of foreign competition on wage inequality is limited recently researchers have become interested in the indirect effect of international trade on wage inequality. The indirect effect refers to the impact of trade and outsourcing on relative wages through its impact on sector-biased productivity growth. Wood (1995) suggests the possibility that increased foreign competition might induce 'defensive innovation.[6] Falvey and Reed (2000) present an example of a theoretical model linking trade to technological progress. Glass and Saggi (2001) develop a dynamic model in which they explicitly focus on the effect of outsourcing on innovation and wages. No empirical study seems

[5] It is worth noting that whatever effect dominates this should not be used to either put more or less confidence in studies using a partial equilibrium framework. Sometimes it is argued that factor bias is associated with within-industry changes in the relative demand for labour and therefore could be appropriately evaluated with a partial equilibrium framework along the lines of Berman, Bound and Griliches (1994). Although this could in principle be the case this is not necessarily true. Factor bias reflects the economy wide change in the relative demand for labour. Consequently, it cannot be properly captured in a partial equilibrium framework.

[6] A recent paper that assesses the importance of defensive innovation is provided by Anderton and Oscarsson (2002).

to exist for the UK that explicitly analyses the relationship between outsourcing towards unskilled-abundant low wage countries and total factor productivity.

This paper is structured as follows. Section 2 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 3 sets out the methodology employed in the econometric analysis while highlighting the key differences between the approaches used in Feenstra and Hanson (1999) and Haskel and Slaughter (2001). Section 4 discusses the data and presents some descriptive statistics. Section 5 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 6 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 7 concludes.

2. Theory

The theoretical literature on international fragmentation is predominantly characterised by the assumption of 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. Jones and Kierzkowski (2001) confirm these possibilities.

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, which depends on the relative factor-intensity of the fragment and the average factor-intensity of the economy, is reflected by 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.[7]

This section presents a simple theoretical model that serves two main purposes. First it should clarify the concepts of factor and sector bias and the debate on their relative importance. Second, the model illustrates how the factor and sector bias of international fragmentation could affect the wage of skilled workers relative to unskilled workers. It should become clear why this debate is particularly relevant in the context of international fragmentation of production. The model draws heavily on Jones (1965, 2000).

Following Deardorff (2001) we account for the absence of FPE by assuming complete specialisation. Consider an economy which is specialised in the production of subset of goods X_1 and $X_2 \in X_i$ where $X_i=1,..,N$, with price p_i and two factors of production skilled labour L_S and unskilled labour L_U with wages w_s and w_u respectively. Assuming perfect competition implies that in equilibrium the zero-profit conditions and full-employment conditions are satisfied. The zero-profit conditions equate prices to average costs and are given by (2.1). The full-employment conditions are given in (2.2). Unit input requirements of factor j in industry X_i are represented by a_{ij}.[8]

(2.1a) $$p_1 = a_{s1}w_s + a_{u1}w_u$$

(2.1b) $$p_2 = a_{s2}w_s + a_{s2}w_u$$

[7] 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.

(2.2a) $$L_s = a_{s1}X_1 + a_{s2}X_2$$

(2.2b) $$L_u = a_{u1}X_1 + a_{u2}X_2$$

Fully differentiating (2.1) and (2.2) and dividing by prices and factor endowments respectively yields (2.3) and (2.4) where θ reflects the respective factor cost shares and λ the respective factor use shares. 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.

(2.3a) $$\hat{p}_1 = \theta_{s1}\hat{w}_s + \theta_{u1}\hat{w}_u$$

(2.3b) $$\hat{p}_2 = \theta_{s2}\hat{w}_s + \theta_{u2}\hat{w}_u$$

(2.4a) $$\lambda_{s1}\hat{X}_1 + \lambda_{s2}\hat{X}_2 = \hat{L}_s + \delta_s(\hat{w}_s - \hat{w}_u)$$

(2.4b) $$\lambda_{u1}\hat{X}_1 + \lambda_{u2}\hat{X}_2 = \hat{L}_u + \delta_u(\hat{w}_s - \hat{w}_u)$$

The second term on the right-hand side of the full employment conditions is necessary to allow for factor substitution, i.e. movements along the unit isoquant as a result of changes in relative factor prices. In particular, $\delta_s = \lambda_{s1}\theta_{s1}\sigma_1 + \lambda_{s2}\theta_{s2}\sigma_2$ and $\delta_u = \lambda_{u1}\theta_{u1}\sigma_1 + \lambda_{u2}\theta_{u2}\sigma_2$ where σ_i reflects the elasticity of substitution between factors in each industry. See Jones (1965) for details.

The theoretical foundation analysing the impact of trade on wages is provided by the Stolper-Samuelson theorem which is obtained by solving system (2.3) with respect to relative wages. It states that an increase in the relative price of the skill-intensive commodity will increase the real return to skilled labour and reduce the real return to unskilled labour.

(2.5) $$(\hat{w}_s - \hat{w}_u) = \frac{1}{|\theta|}(\hat{p}_1 - \hat{p}_2)$$

[8] Without loss of generality one could include internationally mobile capital as a third factor.

where $|\theta| = \theta_{s1} - \theta_{s2} = \theta_{u2} - \theta_{u1}$ which is assumed to be positive. In a small-open economy where goods prices are exogenous, factor prices can only change in response to exogenous changes in relative goods prices, i.e. changes in relative world prices.

Primary input requirements are a function of relative factor prices and international fragmentation of production $a_{ij} = a_{ij}(\frac{w_s}{w_u}, F)$.

(2.6) $\hat{a}_{ij} = \hat{b}_{ij} - \hat{c}_{ij}$ where $\hat{c}_{ij} = -\frac{1}{a_{ij}} \frac{\partial a_{ij}}{\partial F}$.

where $\hat{b}$ refers to a change in the input technology as a result of relative factor price changes and $\hat{c}$ refers to the proportional reduction in input requirements (at constant factor prices) due to fragmentation which equals the domestic unit input requirements of the components whose production is moved abroad. Thus, technological change is assumed to result from international fragmentation rather than from the adoption of superior technologies.

International fragmentation of production could affect relative factor prices through two channels. First, fragmentation matters for relative factor prices to the extent that it affects the relative profitability (short-run) across sectors, or, in other words, the relative unit costs across sectors (cost-saving effect).[9] This will be referred to as the sector bias of fragmentation. In Jones (1965) this was called the 'differential sector effect'. The sector bias of fragmentation γ in industry X can be represented as in equation (2.7) where p^M stands for the price of the sector-specific fragment that is imported from abroad.

(2.7a) $\gamma_1 = \theta_{s1}\hat{c}_{s1} + \theta_{u1}\hat{c}_{u1} - p_1^M$

(2.7b) $\gamma_2 = \theta_{s2}\hat{c}_{s2} + \theta_{u2}\hat{c}_{u2} - p_2^M$

[9] Only temporarily because in equilibrium unit costs equal output prices which are determined on world markets.

Obviously fragmentation will only occur when $p^M < \theta_s \hat{c}_s + \theta_u \hat{c}_u$. Equation (2.7) essentially generalises equation (2.3) to allow for TFP growth.

Second, fragmentation or 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 fragmentation. Given the full-employment conditions in (2.4) the total change in factor use for the economy as a whole at constant output quantities is given by (2.8):

(2.8a) $\gamma_s = \lambda_{s1}\hat{c}_{s1} + \lambda_{s2}\hat{c}_{s2}$

(2.8b) $\gamma_u = \lambda_{u1}\hat{c}_{u1} + \lambda_{u2}\hat{c}_{u2}$

The value of international fragmentation in terms of home production can then be represented by:

(2.10) $F = (\gamma_1 + p_1^M)X_1 + (\gamma_2 + p_2^M)X_2 = \gamma_s w_s + \gamma_u w_u$

In terms of the foreign country, the value of fragmentation would be $F^* = p_1^M X_1 + p_2^M X_2$. It is assumed that international fragmentation of production does not affect domestic specialisation.[10] Adding fragmentation to equations (2.3) and (2.4) while assuming constant factor supplies gives:

(2.3a') $\theta_{s1}\hat{w}_s + \theta_{u1}\hat{w}_u = \hat{p}_1 + \gamma_1$

(2.3b') $\theta_{s2}\hat{w}_s + \theta_{u2}\hat{w}_u = \hat{p}_2 + \gamma_2$

(2.4a') $\lambda_{s1}\hat{X}_1 + \lambda_{s2}\hat{X}_2 = \gamma_s + \delta_s(\hat{w}_s - \hat{w}_u)$

(2.4b') $\lambda_{u1}\hat{X}_1 + \lambda_{u2}\hat{X}_2 = \gamma_u + \delta_u(\hat{w}_s - \hat{w}_u)$

If prices are exogenous the impact of technological change on relative factor prices is obtained by solving (2.3').

[10] This assumption could be plausible when for example the country under consideration is at the extreme end of the spectrum and that fragmentation reinforces this position.

$$(2.11) \qquad (\hat{w}_s - \hat{w}_u) = \frac{1}{|\theta|}\{(\hat{p}_1 - \hat{p}_2) + (\gamma_1 - \gamma_2)\}$$

From (2.11) it follows that the relative (short-run) profitability can change as a result of either a change in relative goods prices or fragmentation-induced productivity growth. If prices remain constant (2.11) reduces to:

$$(2.11') \qquad (\hat{w}_s - \hat{w}_u) = \frac{1}{|\theta|}(\gamma_1 - \gamma_2)$$

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 labour, also leave relative factor prices unaffected as long as those changes do not affect the relative profitability across sectors.[11] More generally in the small-open diversified economy any change in relative factor demand will leave relative factor prices unaffected. The relative factor demand curve is therefore infinitely elastic. Changes in factor endowments or technological change can only be accommodated by adjustments in the relative size of industries. Changes in relative outputs do not affect goods prices as those are exogenously determined on world markets.

If goods prices are determined endogenously as is the case when the economy is completely specialised, one should take into account the price changes as a result of sector-biased technological change (in the empirical part this is referred to as productivity pass-through) and the factor bias of technological change. In order to

[11] Accordingly 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. The net cost saving effect of outsourcing and SBTC appears in the data as productivity growth.

obtain the indirect effect of fragmentation on relative wages via its impact on relative goods prices one solves (2.4') with respect to outputs which gives:

$$(\hat{X}_1 - \hat{X}_2) = \frac{1}{|\lambda|}(\gamma_s - \gamma_u) + (\delta_s + \delta_u)(w_s - w_u) \tag{2.12}$$

where $|\lambda| = \lambda_{s1} - \lambda_{u1} = \lambda_{u2} - \lambda_{s2}$ which is assumed to be positive. Assuming identical homothetic preferences at home and abroad implies that the elasticity of substitution in demand between goods σ_D is also identical across countries.

$$(\hat{D}_1 + \hat{D}_1^*) - (\hat{D}_2 + \hat{D}_2^*) = -\sigma_D(\hat{p}_1 - \hat{p}_2) \tag{2.13}$$

where *D* and *D** reflect domestic and foreign demand respectively. In line with the assumption of complete specialisation equating world demand (2.13) to domestic supply (2.12) gives the change in relative prices as a function of the factor bias and the sector bias of technological change.

$$(\hat{p}_1 - \hat{p}_2) = -\frac{|\theta|}{\sigma}\{(\gamma_s - \gamma_u) + |\lambda|\sigma_S(\gamma_1 - \gamma_2)\} \tag{2.14}$$

$$-1 \le -\frac{|\theta|}{\sigma}|\lambda|\sigma_S \le 0$$

where σ_S refers to the elasticity of substitution between goods on the supply side $\sigma_S = \frac{(\delta_s + \delta_u)}{|\lambda||\theta|}$, and where σ refers to the economy-wide elasticity of substitution between factors of production, $\sigma \equiv |\lambda||\theta|(\sigma_S + \sigma_D)$. See Jones (1965) for details.

Substituting (2.14) into (2.11) gives:

$$(\hat{w}_s - \hat{w}_u) = -\frac{1}{\sigma}\{(\gamma_s - \gamma_u) - |\lambda|\sigma_D(\gamma_1 - \gamma_2)\} \tag{2.15}$$

Equation (2.15) describes relative wage as a function of the factor bias and the sector bias of fragmentation.

Assume that X_1 is the relatively skill-intensive sector (as a result the determinants of λ and θ will be a positive number between zero and unity). If fragmentation is concentrated in sector 1 than $(\gamma_1-\gamma_2)$ will be positive. Thus the sector bias effect of fragmentation will normally induce an increase in wage inequality.[12] It is assumed throughout that the factor bias of outsourcing reduces the relative demand for unskilled labour so that $(\gamma_s-\gamma_u)$ will be negative. The factor bias of outsourcing is therefore expected to increase the relative wage of skilled workers. The factor and sector bias of fragmentation both tend to increase relative skilled wages when $|\lambda|(\gamma_1-\gamma_2)$ is positive. The relative importance of both effects depends crucially on the slope of the relative demand for labour curve and the degree of substitutability of goods in final demand.

The relative importance of the factor bias versus sector bias is subject to considerable disagreement in the theoretical literature. Leamer (1995, 1998) emphasises that in a 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.

[12] The cost-saving effect is completely neutralised by a reduction in prices when $\sigma_S/(\sigma_S+\sigma_D)=1$, i.e. when the elasticity of demand for goods is zero and the elasticity of the relative demand for labour is non-zero.

The debate on the relative of importance of factor bias is particularly relevant when analysing trade in intermediates. 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 in order to assess the impact of fragmentation on relative wages one has to account for its factor and its sector biases.

The application of the Stolper-Samuelson theorem to analyse the impact of international fragmentation on relative factor prices may be subject to several criticisms. First of all, concerns might be raised with respect to the dimension of the model. However the Stolper-Samuelson theorem is not fundamentally altered in the presence of many goods and only few factors (Ethier, 1984). 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.[13]

More serious is the feature of the HOS framework that it only deals with marginal changes in technology. As argued above fragmentation does not represent marginal change, but instead represents radical technological change. The HOS model is based on the assumption of a fixed set of industries and factors of production. Outsourcing, however, is likely to lead to the destruction of some industries and the creation of others, that is, to change the existing cone structure. The analysis of comparative statics in the HOS framework therefore becomes unclear (see Findlay and Jones, 2000). Unfortunately, no framework exists to assess the question at hand that is flexible enough to account for the true nature of outsourcing.

[13] 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.

3. Empirical 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.

Until recently applied trade economists analysed the impact of trade on relative wages by implementing equation (2.11'). However, Feenstra and Hanson (1999) argue that estimating (2.11') 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 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 presence of pass-through is plausible whenever the factor bias plays a role.[14]

Haskel and Slaughter (2001) separately estimate a price and a TFP-regression on a vector of exogenous variables *z* in the first-stage.

(3.1a) $$\Delta \ln p_i^{VA} = \delta' \Delta z_i + \omega_i$$

(3.1b) $$\Delta \ln TFP_i = \alpha' \Delta z_i + \varepsilon_i$$

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

[14] 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.

variables. Feenstra and Hanson (1999) therefore start off with the following set of equations in the first stage:

(3.2a) $\Delta \ln p_i^{VA} = \lambda \Delta \ln TFP_i + \beta' \Delta z_i + \upsilon_i$

(3.2b) $\Delta \ln TFP_i = \alpha' \Delta z_i + \varepsilon_i$

Whenever productivity growth tends to result in lower goods prices, i.e. λ is negative, one should allow for pass-through from TFP to prices.[15] Including TFP in the price regression (3.2a) 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 changes affect 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! Of course price effects may also be due to exogenous forces affecting prices without affecting TFP (such as reductions in tariff and transportation costs).

In practice Feenstra and Hanson employ 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 (3.3), which is obtained by adding TFP to both sides of (3.2a).[16] The indirect effect is the impact of the structural variables on productivity that is passed-through on value-added prices. Note that (3.3) is the empirical equivalent of (2.14').

(3.3) $\Delta \ln p_i^{VA} + \Delta \ln TFP_i = \gamma' \Delta z_i + \eta_i$

[15] 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.

[16] This method relies on having the same vector of structural variables in the prices and the TFP regression.

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. It would be interesting, however, to decompose the direct effect (factor bias) and indirect effect (sector bias) of factors such as outsourcing and SBTC on wage inequality.

Decomposing direct and indirect effects involves the estimation of the three parameters α, λ and β in equations (3.2a) and (3.2b). The inclusion of TFP as an explanatory variable in equation (3.4b) implies that OLS estimates would suffer from simultaneity bias. Therefore one has to simultaneously estimate both equations in order to deal with the endogeneity problem associated with TFP (TFP and the error term will be correlated) in (3.2b). The problem can be overcome by using three-stage least squares (3SLS).[17]

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 (3.4) either reflects γ in (3.3) or the combination of α, λ and β from (3.4a) and (3.4b) as discussed above.

$$(3.4) \quad \gamma_k' \Delta z_{ik} = \delta_k' V_i + \nu_i$$

4. Data and Descriptive Statistics

The labour market data are obtained from the 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

[17] Two-stage least squares would also yield consistent estimates, but 3SLS is more efficient as it takes into account the information embedded in the correlation of the disturbances across equations.

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.[18]

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

Following Feenstra and Hanson (1999) two measures of outsourcing will be used: narrow (to the same industry) and differential outsourcing (to other industries). Outsourcing is defined as total intermediate purchases times the openness in that industry. Openness is measured by import penetration based on trade with developing countries in order to emphasise outsourcing of low-skill fragments driven by the persistence of factor cost differentials. 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.[19]

Table 4.1 represents summary statistics for 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

[18] 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.
[19] See the data appendix for more detailed information on the construction of the variables.

time. The factor cost share of intermediates seems to be an exception, which might indicate the increasing importance of outsourcing.

Table 4.1: Summary Statistics, 1993-1998

	Average (%)	Annual change
Change in log factor prices (based on quantities)		
- 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. The annual change in the earnings of semi-skilled and unskilled workers together amounts to 2.459. The annual increase in wage inequality was then 1.71%.

Table 4.2 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 rose on average more quickly in the relatively more skill-extensive industries.

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 negative effect on the relative price of skill-intensive products. Standard Stolper-Samuelson effects should have induced a reduction in wage inequality. The remaining explanation for

the increase in wage inequality should therefore comes from TFP growth not passed through onto prices. Thus the descriptive statistics suggest a larger role for the sector bias of outsourcing and SBTC than their factor bias.

Table 4.2: Summary Statistics by Use of Skilled Labour, 1993-1998

Skill-intensity	Δlnp^{VA}	$\Delta ln\ TFP$	$\Delta ln\ p^{M}$
Low	1.88	0.72	0.04
High	-2.74	5.45	-0.21
Relative Δ	-4.62	4.73	-0.25

5. Empirical Results

Table 5.1 reports the results obtained from estimating (3.3) with OLS. It is important to note that a priori the expected sign on outsourcing or technological change is not clear. First, only when the processes are 'regular', i.e. the sector bias and factor bias effect affect the sum of prices and TFP in the same direction, or if one effect dominates the other, can one expect significant results (positive or negative). Second, whilst the impact of outsourcing on TFP should be positive by definition - outsourcing is only profitable when it is cost-saving -, the impact of outsourcing on final goods prices is ambiguous. The impact of structural change on value-added prices is ambiguous because there does not exist a linear relationship between the structural variables and value-added prices. It is the aggregate change in relative factor demand as a result of structural change that affects relative goods prices.

In order to deal with absence of a linear relationship between structural change and prices Feenstra and Hanson (1999) run an additional set of first-stage regressions with interaction terms which interact the variables of structural change with the average factor quantities employed in each sector. Given the small sample size in the present case we account for heterogeneous price changes in response to structural change by including interaction terms which interact the outsourcing and technology variables with a measure of skill intensity. In order to emphasise the idea that outsourcing is likely to affect unskilled workers disproportionately relative to skilled workers, skill intensity is defined as the share of semi- and unskilled labour in value-added.

In the linear case, represented by specifications (1) and (2), outsourcing of fragments within the same industry to developing countries is positive although not statistically significant, whereas outsourcing to other industries in developing countries is negative and insignificant. The positive sign on narrow outsourcing could either indicate the dominance of the cost-saving effect of outsourcing relative to its relative factor demand effect or that narrow outsourcing has both a positive impact on TFP and prices. A positive relationship between outsourcing and prices in the linear case without interaction terms could mean that outsourcing is concentrated in the skill-intensive industries. As it is assumed that only unskilled-intensive fragments are moved abroad, outsourcing creates an excess supply of unskilled workers. As production becomes more skill-intensive overall the full employment conditions require that on average unskilled intensive industries have to expand and skill-intensive industries have to contract in order to restore labour market equilibrium. To the extent that prices are determined endogenously this will be associated with a relative fall in the price of unskilled-intensive industries. Thus a positive relationship could arise when outsourcing is concentrated in the skill-intensive industries. If outsourcing is concentrated in the unskilled-intensive industries the impact of outsourcing on final goods prices is negative and its impact on factor prices ambiguous.[20] Thus, the regression does not imply a direct causal relationship between outsourcing and prices but the correlation between two variables reflects the outcome of the implied general equilibrium dynamics.

R&D intensity is associated with a positive sign and is statistically significant. Similar to the case of outsourcing this could either indicate that the productivity-enhancing effect of R&D dominates or that R&D is concentrated in relatively 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 prices of imports from developing countries and from developed countries. The results indicate that if anything competition from other developing countries drives the relationship between import prices and effective prices. The coefficient on the concentration ratio is negative and insignificant.

[20] According to descriptive statistics similar to those in Table 4.2 not reported outsourcing is concentrated in skilled-intensive industries.

Nevertheless including the concentration ratio improves the overall regression considerably suggesting that is important to control for industry characteristics such as market concentration.

Table 5.1: Stage-I-Regressions with OLS

Dependent Variable: $\Delta p^{VA}+TFP$	(1)	(2)	(3)
Outsourcing (narrow)	0.092 (1.59)	0.081 (1.41)	1.866 (2.98) ***
Outsourcing (difference)	-0.059 (-0.39)	-0.073 (-0.46)	-0.233 (-1.98) *
R&D Intensity	3.210 (2.87) ***	2.873 (2.30) **	5.505 (2.24) **
Import prices	0.011 (1.88) *		0.011 (1.97) *
Import prices (developing countries)		0.007 (1.58)	
Import prices (developed countries)		0.005 (0.88)	
Concentration Ratio	-0.0 (-1.20)	-0.0 (-1.16)	-0.0 (-0.77)
Interaction terms			
Skill-intensity * narrow outsourcing			-2.337 (-2.83) ***
Skill-intensity * differential outsourcing			-0.086 (-1.51)
Skill-intensity * R&D intensity			-6.620 (-1.36)
Constant	0.014 (1.56)	0.015 (1.64)	0.020 (2.16) **
N	67	67	64
R-squared	0.16	0.17	0.27

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

Column (3) reports the results obtained when including interaction terms for the two outsourcing measures and R&D intensity. The regression with interaction terms yields qualitatively similar results as the linear case, but results are generally stronger. The positive and significant sign on narrow outsourcing and R&D intensity and the negative sign on the interaction terms indicate that prices do not respond in a uniform

manner to changes in relative factor demand. More in particular, the impact of narrow outsourcing and R&D intensity on prices is more positive the higher the skill-intensity in the industry, which is consistent with the reasoning above that narrow outsourcing and R&D intensity tend to be concentrated in the relatively skill-intensive industries. For differential outsourcing the results indicate that its impact on effective prices is more negative the higher the skill-intensity of that industry. Foreign price competition continues to exert a positive influence on effective prices.

The second stage involves estimating equation (3.4), i.e., the impact of each structural force on relative factor prices. The component explained by each structural variable in stage one serves as the dependent variable of the mandated wage regressions. On the right-hand side the average cost shares over 1993-1998 of skilled labour, unskilled labour and capital 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. T-statistics are adjusted to account for the presence of generated regressands.[21]

Table 5.2: Stage-II-Regressions - Mandated wage changes, 1993-1998 (specification 3 of 5.1)

	R&D Intensity		Outsourcing (N)		Outsourcing (D)		Import Prices	
Skilled	-0.033	(-0.49)	-0.033	(-0.50)	0.002	(0.04)	-0.091	(-3.64) ***
Unskilled	-0.174	(-4.92) ***	-0.099	(-2.92) ***	0.027	(0.98)	0.008	(0.67)
Capital	0.004	(0.29)	-0.037	(-3.13) ***	0.008	(0.81)	-0.005	(-1.22)
Constant	0.052	(7.13) ***	0.028	(4.04) ***	-0.007	(-1.28)	0.004	(1.41)
R-squared	0.36		0.16		0.04		0.29	
N	58		58		58		58	
Mandated change	0.17		0.10		-		-0.09	

*, **, *** indicate significance levels of 10%, 5% and 1% respectively. Observations are weighted by sales. Outlier industries were purged from the sample except the computer industry, which is considered a 'true' outlier. T-statistics in parentheses corrected using procedure proposed by Feenstra and Hanson (1999). The mandated change in relative wages equals the difference between the coefficients on the cost shares of skilled and unskilled labour taking into account significant coefficients only.

[21] Feenstra and Hanson (1999) note that the dependent variable does not reflect the *actual* part of effective prices accounted for by each structural variables but its *estimated* part. The variance-covariance matrix of the estimated coefficients in the second stage reflects a combination of the errors of the *true* second stage regression and those from the first stage regression. They therefore propose to correct the standard errors in the second stage in order to obtain the *true* standard errors by subtracting by that part of the variance that results from the first regression.

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 0.17% a year. With the actual annual increase in wage inequality around 1.7% (see Table 4.1), the proportion explained by SBTC amounts to about 10%. Outsourcing to developing countries is estimated to have reduced the wage of unskilled workers by on average 0.10% 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 corresponds to about 6% of the total increase in wage inequality.[22] Thus, from regression (3) it follows that both outsourcing and SBTC have contributed to the increase in wage inequality. The impact of differential outsourcing on relative wages is insignificant. Foreign price competition seems to have played an important role in dampening the increase in wage inequality mandated annual reduction of 0.09% of relative wages.

6. The factor and sector bias of outsourcing and SBTC

Table 6.1 represents the results of estimating (3.2a) and (3.2b) simultaneously using 3SLS. As such one might be able to obtain some insight in the importance of the factor bias of outsourcing and SBTC relative to their sector bias as debated in the theoretical literature. In addition it might offer some suggestive evidence on the importance of globalisation (in the form of either trade in intermediates or foreign price competition) on relative wages via its impact on productivity.

The system is estimated in three alternative specifications. Specification (1) reflects the linear case without interaction terms. Specification (2) accounts for non-linear price changes in response to changes in outsourcing and SBTC. The inclusion of the interaction terms is primarily motivated by general equilibrium trade theory. Specification (3) accounts for non-linearities by including interaction terms in both the price and the TFP regression. Including interaction terms allows one to account

[22] Feenstra and Hanson (1999) find that outsourcing accounts for 15% of the annual increase in wage inequality in the US in the linear case and up to 40% in the specification with interaction terms.

for heterogeneous pass-through rates from the structural variables to effective prices (and subsequently relative wages). Note, however, that from a theoretical perspective there is no justification for including interaction terms in the TFP regression.

Table 6.1: First-Stage Regressions with 3SLS

	(1)		(2)		(3)	
Dependent Variable	p^{VA}	*TFP*	p^{VA}	*TFP*	p^{VA}	*TFP*
TFP	-0.669 (-4.19) ***		-0.652 (4.73) ***		-0.679 (-4.96) ***	
Outsourcing (narrow)	0.071 (1.60)	0.060 (0.58)	-0.089 (-0.11)	0.057 (0.53)	0.395 (0.49)	4.485 (4.10) ***
Outsourcing (difference)	-0.149 (-1.71) *	-0.350 (-2.17) **	-0.145 (-1.68) *	-0.360 (-2.19) **	-0.189 (-2.18) **	-0.133 (-0.75)
R&D Intensity	1.638 (1.65) *	4.600 (2.96) ***	2.565 (1.59)	4.584 (2.90) ***	3.089 (1.91) *	8.259 (3.38) ***
Import prices	0.010 (2.31) **	0.007 (0.69)	0.010 (2.40) **	0.006 (0.63)	0.010 (2.40) **	0.005 (0.53)
Concentration ratio	-0.0 (-3.05) ***	0.0 (0.28)	-0.0 (-2.86) ***	0.0 (0.27)	-0.0 (-2.68) ***	0.0 (1.01)
Interaction terms						
Skill-intensity * narrow outsourcing			0.253 (0.24)		-0.386 (-0.36)	-5.810 (-4.01) ***
Skill-intensity * differential outsourcing			-0.035 (-0.46)		-0.055 (-0.72)	-0.188 (-1.23)
Skill-intensity * R&D intensity			-2.891 (-0.98)		-4.036 (-1.35)	-10.427 (-1.86) *
Constant	0.024 (4.04) ***	-0.020 (-1.59)	0.028 (4.87) ***	-0.020 (-1.57)	0.027 (4.62) ***	-0.009 (-0.73)
N	64	64	61	61	61	61
R-squared	0.65	0.25	0.68	0.26	0.67	0.46

Z-statistics in parentheses, *, **, *** indicate significance levels of 10%, 5% and 1% respectively. Observations are weighted by sales. Outlier industries were purged from the sample except the computer industry, which is considered a 'true' outlier.

Comparing the results obtained with the three alternative specifications suggests that in contrast to what was expected accounting for non-linearities does not seem to be very effective in picking up the general equilibrium dynamics set into motion by outsourcing and SBTC. However the interaction terms do play an important role in the TFP regression. The impact of narrow outsourcing and R&D intensity on TFP is

more positive the higher the skill-intensity in the industry suggesting that effectiveness of outsourcing and R&D is higher in the relatively more skill-intensive industries.

Results for system (3) 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 and insignificant. Import prices and the concentration ratio both are positive, but insignificant. If anything the signs of the coefficients suggest that competition reduces technological progress.

Value-added prices are considered to be a function of the pass-through of TFP, outsourcing, SBTC, foreign competition and market structure. The results indicate that allowing for productivity pass-through is indeed important. The estimated pass-through rate amounts to about -0.7 and is statistically significant. Narrow outsourcing is positive and insignificant suggesting that its direct impact on the labour market might be limited. Differential outsourcing is negative and significant. R&D intensity and foreign prices are both found to be positive and significant. It is perhaps disappointing that the interaction terms do not pick up the general equilibrium dynamics more strongly.

Table 6.2 reports the results for the mandated wage regressions for specification (3) of the first-stage regressions. The total increase in the relative wage of skilled workers mandated by narrow outsourcing amounted to 0.09% a year which amounts to 5% of the increase in domestic wage inequality over the period 1993-1998 in the UK. SBTC induced an increase 0.17% in wage inequality, which is the equivalent of 10% of the total. Import prices induced a reduction in the relative wage of skilled labour of 0.1% a year (6% of total). Globalisation - defined as the sum of outsourcing and foreign price competition - did not exert any significant change on the distribution of earnings between skilled and unskilled workers. Thus, the aggregate results obtained with the 3SLS regressions are almost identical to the OLS regressions.

With 3SLS it is possible to decompose the total effect of outsourcing and SBTC into their factor and sector bias respectively. The sector bias of narrow outsourcing is

estimated to have induced an annual increase in wage inequality of 0.07%, while its factor bias account for an 0.02% annual increase. Thus, it is suggested that the sector bias effect of outsourcing has been about 2.5 times as important as its factor bias effect for the rise in domestic wage inequality. However, it not clear how to interpret this result given the insignificant estimate for outsourcing in the price regression. It might therefore be more informative to focus on SBTC which is significantly estimated in both the price and the TFP regression. Results attribute a 0.08% annual increase in wage inequality to the sector bias of SBTC,[23] while the factor bias of SBTC accounts for 0.09%. Thus, for SBTC the results suggest a slightly larger role for the factor bias than the sector bias. This result is broadly consistent with results found using the between-and-within decomposition by Berman, Bound and Griliches (1994) for the US and Machin and Van Reenen (1998) for seven of OECD countries including the UK. With the within-and-between decomposition it was shown that the increase in wage inequality is largely due to shifts in the relative demand for labour *within* industries (factor bias) rather than *between* industries (sector bias).

Table 6.2: Second-Stage Regressions for Specification (3)

	Total				**Sector bias**		**Factor bias**	
	O(N)	*O(D)*	*R&D*	P^M	*O(N)*	*R&D*	*O(N)*	*R&D*
Skilled	-0.034	0.002	-0.077	-0.096	-0.026	-0.056	-0.007	-0.021
	(-0.57)	(0.08)	(-0.64)	(-4.79) ***	(-0.57)	(-0.64)	(-0.57)	(-0.64)
Unskilled	-0.091	0.027	-0.335	0.010	-0.072	-0.244	-0.020	-0.091
	(-2.20) **	(1.26)	(-4.01) ***	(0.68)	(-2.02) **	(-4.01) ***	(-2.20) **	(-4.01) ***
Capital	-0.035	0.008	0.008	-0.005	-0.028	0.006	-0.008	0.002
	(-3.23) ***	(1.42)	(0.37)	(-1.47)	(-3.23) ***	(0.37)	(-3.23) ***	(0.37)
Constant	0.026	-0.007	0.104	0.004	0.021	0.076	0.006	0.028
	(3.74) ***	(-2.02) **	(7.23) ***	(1.52)	(3.74) ***	(7.25) ***	(3.74) ***	(7.25) ***
Mandated change	0.09	-	0.17	-0.10	0.07	0.08	0.02	0.09
R^2	0.16	0.04	0.35	0.28	0.16	0.23	0.16	0.35
N	64	58	64	64	64	64	64	64

Uncorrected T-statistics in parentheses, *, **, *** indicate significance levels of 10%, 5% and 1% respectively. Observations are weighted by sales. Outlier industries were purged from the sample except the computer industry, which is considered a 'true' outlier. 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, $(1+\lambda)\alpha+\beta$. The mandated change in relative wages equals the difference between the coefficients on the cost shares of skilled and unskilled labour taking into account significant coefficients only.

[23] The large role for R&D in explaining TFP growth confirms previous findings by Haskel and Slaughter (2002a) that the sector bias of SBTC could be important.

The total impact of sector-biased TFP growth is estimated to have reduced the relative wage of skilled workers by 0.15% a year (the sum of the sector bias of R&D and outsourcing), while price effects do not seem to have exerted a strong influence (the sum of the factor bias of R&D and outsourcing plus foreign prices). This result for the 1990s is the opposite of findings by Haskel and Slaughter (2001) for the 1980s.

These results however should be interpreted with caution as they rely critically on the estimate of the pass-through rate. The estimated coefficient on TFP in the price regression equals -0.7 (Table 6.1). For different specifications the pass-through estimate was typically found to be in the range of –0.6 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 rate or instead is driven by the empirical measurement of TFP. It seems likely that the estimated pass-through rate 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 6.3.

Table 6.3: Summary results outsourcing and SBTC by constrained 3SLS

	Skill-biased technological change			Outsourcing		
λ	*Sector bias*	*Factor bias*	*Total mandated change*	*Sector bias*	*Factor bias*	*Total mandated change*
0	0.24	-0.07	0.17	0.22	-0.13	0.09
-0.25	0.18	-0.01	0.17	0.17	-0.08	0.09
-0.5	0.12	0.05	0.17	0.11	-0.02	0.09
-0.75	0.06	0.11	0.17	0.06	0.03	0.09
-1	0	0.17	0.17	0	0.09	0.09

The first column reflects the imposed values on the pass-through rate. Note that in the 3SLS regressions no significant effect was found for the factor bias of outsourcing (outsourcing in the price regression). The discussion below will therefore concentrate on SBTC. With zero pass-through as is the case for a small open economy the sector and factor bias are estimated to work in opposite directions. The total mandated change in relative wages is entirely due to the dominance of the sector bias. For pass-through rates of –0.25 the factor bias is virtually zero and the sector bias is all that matters. For pass-through rates in the range of –0.25 and –1 both the factor bias and

the sector matter. However, as the actual level of the pass-through rate converges to -1 the factor bias gains in importance at the expense of the sector bias. When productivity pass-through is complete (λ=-*1*) the factor bias is all that matters. It is clear that in order to assess the relative importance of the factor and the sector bias the estimate of the pass-through rate is critical.

7. Conclusions

This paper analyses 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.

Theory suggests that 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 SBTC is the predominant force behind the increase in wage inequality in the UK during the 1990s accounting for 10% of the total increase, while outsourcing also played a significant albeit more limited role accounting for about 6% of the total increase in wage inequality.

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 0.1% a year. Indeed, globalisation - defined as the sum of foreign price competition and outsourcing – is not found to have any significant impact on the distribution of earnings between skilled and unskilled workers.

In order to get additional information on the relative importance of sector bias and factor bias, the TFP and price regressions are simultaneously estimated using three-stage least squares. The results are very similar to those obtained with the OLS regressions.

Decomposing the total effect of outsourcing into its respective factor and sector bias components indicates that the sector bias of outsourcing is about 2.5 times as important as its factor bias. However, it not clear how to interpret this result given the insignificant estimate for outsourcing in the price regression. Instead, it might be more informative to focus on SBTC which is significantly estimated in both the price and the TFP regression. The results for SBTC suggest a slightly larger role for the factor bias than the sector bias. This result is broadly consistent with results in the literature based on the between-and-within decomposition introduced by Berman, Bound and Griliches (1994). With the within-and-between decomposition it was shown that the increase in wage inequality is largely due to shifts in the relative demand for labour *within* industries (factor bias) rather than *between* industries (sector bias). However, in assessing the relative importance of the two effects, the estimate of the productivity pass-through rate is crucial. Further research is needed to look into the actual level of the pass-through rate.

Finally the results contribute to the debate on the indirect effect of globalisation on the economy via its impact on productivity. Imported intermediates inputs are found to have an important productivity-enhancing effect. Most likely the positive effect of outsourcing on productivity reflects its cost-saving effect. No evidence was found in favour of the 'defensive innovation' hypothesis which asserts that foreign competition enhances productivity as it constitutes an incentive for firms to adopt more innovative production techniques. If anything, increased (foreign) competition appeared to have reduced productivity growth.

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. 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 total intermediate purchases (C) times import penetration by developing countries over value added:

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

Differential outsourcing in turn is defined as:

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

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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