Trade in Intermediates and the Rise in Wage Inequality in the UK: A GNP Function Approach

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Abstract

This paper contributes to the debate on trade and wages by estimating a GNP function for the United Kingdom using data for the period 1975-1999. Consistent with standard trade theory the GNP function treats factor supplies and output prices as exogenous and factor prices and output supplies as endogenous. Moreover, the GNP function explicitly distinguishes between different sectors and is therefore in principle consistent with general equilibrium trade theory. The signs of the estimated elasticities were mostly in line with theoretical predictions. The main findings of this paper are the following. Firstly, the skill bias of technological change is found to be the predominant source of the increase in wage inequality. Secondly, while the paper provides mixed results for the role of all trade, the results provide some evidence in support of the outsourcing-hypothesis which asserts that international outsourcing constitutes an important contributing factor to the widening wage gap. Finally, the factor-price insensitivity theorem does not seem to hold for the UK.

JEL Classification: F14, J31

Keywords: trade, factor supplies, wage inequality, GNP function

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1 Introduction

An extensive literature has developed explaining the rise in wage inequality in many developed countries during the last two decades. While a consensus is emerging on the relative importance of the different causes no consensus seems to exist regarding the appropriate methodology. Product price studies concentrate on the impact of the price effects of international trade on factor prices as implied by the Heckscher-Ohlin-Samuelson framework (see Slaughter, 2000, for an excellent survey). The factor content approach, in contrast, focuses on the impact of the volume of international trade on the effective supply of factors of production (Borjas, Freeman, and Katz, 1991; Sachs and Shatz, 1994). The present paper employs a methodology that is relatively novel to the trade and wages debate to analyse the impact of globalisation on domestic wage inequality. This methodology is referred to as the GNP function approach and is based on the work by Burgess (1974, 1976) and Kohli (1991) and was recently introduced to the wage inequality debate by Harrigan and Balaban (1999), Harrigan (2000) and Tombazos (1999, 2003).[1]

The GNP function approach employs duality theory to specify a function for the economy as a whole that reflects the assumptions of standard trade theory for a small open economy. Consistent with standard trade theory, the GNP function is defined as a function of factor supplies and output prices, whilst factor prices and output supplies are determined endogenously. Moreover, in contrast to the early work by for example Burgess (1974b) and studies on immigration and labour markets, which are typically based on a single sector, the GNP function explicitly distinguishes between different sectors. The GNP function approach is therefore in principle consistent with general equilibrium trade theory characterised by non-joint production. Any change in the composition of output will directly affect aggregate factor demands at given output prices (factor prices).

The GNP function approach has two main features. Its first feature is its generality. Compared to the other main empirical methodologies the GNP function approach is more general in three ways: i) the width of the data used; ii) the variety of channels allowed to affect factor prices; and iii) the restrictiveness of its underlying assumptions.

Firstly, the GNP approach is typically more general in terms of its coverage both across time and across economic activities. Whilst the literature on trade and wages focuses almost exclusively on manufacturing the GNP function approach requires one to account for the economy as a whole, i.e. to include services and agriculture. From a general equilibrium perspective accounting for only a quarter of the economy seems highly unsatisfactory.[2]

Secondly, by taking a macro perspective the methodology allows one to evaluate within a single framework to what extent changes in relative factor returns are due to sector bias effects in the form of relative price changes and productivity growth, factor bias effects, which derive from factor-biased technological change (FBTC), which includes the volume effect of trade, and changes in factor supplies. Whilst, factor content studies multiply the estimated change in 'effective factor supplies' due to international trade by a pre-specified elasticity, the GNP function approach directly estimates the relevant elasticities.

Finally, the GNP function is less restrictive in terms of its assumptions since it does not impose any restrictions on the number of goods and factors and the way domestic output prices are determined. The most important implication being that, in contrast to trade economists, who have typically ruled out any role for FBTC and factor supplies in accordance to the predictions of the factor-price insensitivity theorem (Leamer, 1995), FBTC and changes in factor supplies are allowed to affect factor prices. At constant output prices factor bias effects can play a role in the presence of more

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[1] Burgess (1974a, 1976), Aw and Roberts (1985), and Tombazos (1998) analyse the impact of trade on the distribution of earnings by estimating a joint cost function rather than a GNP function.
[2] On the basis of trade theory one might justify ignoring the non-tradable sector when the number of traded goods is larger or equal than the number of immobile factors. In this case factor demand will be perfectly elastic (as will normally be the case in a small open diversified economy) and the vector of tradable output prices uniquely determines the vector of factor prices.

factors than goods. To the extent that domestic output prices are endogenous, changes in relative output prices may also be due to FBTC and changes in factor supplies.[3]

The second main feature of the GNP function approach is that all imports are treated as imported intermediate inputs. In order to capture the fact that, unlike domestic inputs, imports do not have a fixed supply, the GNP function approach takes the form of a variable profit function where domestic inputs are exogenous and foreign inputs endogenous (Samuelson, 1953).

By assuming that all imports are intermediate inputs this paper differs importantly in the treatment of outsourcing from previous papers. Treating all imports as imported intermediate inputs has been justified in the literature on the basis that most trade concerns trade in intermediates and increasingly so (see for example Hummels et al, 2001). Moreover, even goods that are classified as final goods will generally require some degree of processing before they can be marketed to consumers. Another justification not present in the literature is that at the country level the conceptual difference between trade in intermediates and trade in final goods disappears. Whether the factor-intensity of the economy as a whole changes due to changes in the factor-intensity of industries or due to changes in the composition of output does not matter for the impact of trade on factor prices. [4]

The present paper aims to analyse the impact of trade on wage inequality by estimating a GNP function for the United Kingdom using data for the period 1975-1999. It will be the first such study not to focus on the United States. A trend term is included in order to account for the factor bias of technological change so that the estimable model, in principle, provides a complete characterisation of the determination of factor prices.

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[3] Unfortunately, FBTC and changes in factor supplies that affect factor prices due to their impact on the diversification cone (the set of goods produced), cannot be analysed within GNP function framework (or any other methodology that has been employed in the literature). In this case the GNP function will be characterised by kinks and factor prices become indeterminate.

[4] Rather than assuming that all imports are intermediate inputs a number of studies have analysed the impact of outsourcing on wage inequality by explicitly focusing on imported intermediate inputs. See, for example, Feenstra and Hanson (1996, 1999) for the United States and Hijzen (2003), Hijzen, Görg, and Hine (2003) for the United Kingdom.

The estimated model of the GNP function is kept as parsimonious and as realistic as possible. GNP is assumed to be a function of two domestic outputs (skilled and unskilled), three intermediate imports (durable, non-durable and oil), and three factors of production (unskilled and skilled labour and capital). The main aim of this model is to see to what extent imported intermediates act as substitutes to domestic labour.

The remainder of this paper will be structured as follows. Section 2 discusses the theory. Section 3 discusses the methodology. Section 4 provides details on data sources and presents some stylised facts for the UK. Section 5 discusses the econometric results. Finally, Section 6 concludes.

2 Theory

This section shortly discusses the theory whilst emphasising the issue of dimensionality. Throughout it is assumed that markets are perfectly competitive and that firms produce under constant returns to scale.[5]

Suppose that for a small open economy GNP can be represented by $G(\theta, p, p^M, \lambda, v)$ where θ refers to the vector of Hicks-neutral technological change (TFP), p to output prices, p^M to the vector of imported intermediate input prices, λ to the factor bias of technological change (FBTC), and v to factor supplies for sectors $i=1,...,N$ and factors $k=1,...,M$. Since all imports are considered to be imported intermediate inputs, imports are considered negative outputs, i.e. total production equals total factor income plus expenditure on imported intermediate inputs:

$$G(\theta, p, \lambda, v) = py - p^M m = wv \qquad (1)$$

Changes in exogenous output prices and TFP

The impact of trade in final goods on factor prices is given by the change in output prices that occurs when a small country opens up to trade (and the impact of outsourcing is given by the cost-saving effect across sectors due to outsourcing). In equilibrium the requirement of zero-profits implies that the vector of factor prices w has to adjust in response to a change in the vector of prices or TFP:

$$(dp + d\theta)dw = (dp + d\theta)G_{VP}(dp + d\theta) \approx (dp + d\theta)A(w)^{-1}(dp + d\theta) > 0 \qquad (2)$$

The last part of (2) gives the 'correlation version' of the Stolper-Samuelson theorem originally due to Ethier (1984), which states that there is a positive "correlation" between the factor-intensity (technology matrix of unit input requirements *A(w)*) weighted vector of price changes and TFP growth on the one hand, and the vector of factor price changes on the other.[6] A change in the price of imported intermediate inputs will affect factor prices in the opposite direction as do final output prices and productivity growth. An increase in imported intermediate input prices will tend to squeeze (short-run) profits and therefore lead to an average reduction in factor prices ($dp^M A(w)dw < 0$).

Changes in factor endowments and factor-biased technological change

It is well known that under the assumption that M equals N a small change in the vector of factor supplies v or FBTC λ will change the pattern of trade, but does not affect the vector of goods and factor prices. As long as home remains in the same cone of diversification, factor price equalisation continues to hold and G_{VV} is a zero matrix. This was appropriately coined the factor price insensitivity theorem (Leamer, 1995) and is formally represented by:

$$dw = G_{VV}(d\lambda + dv) = 0 \qquad (3)$$

[5] For more details on the theory see Dixit and Norman (1980).

[6] Whilst in a Heckscher-Ohlin world the impact of a change in world prices on real factors is similar to that for nominal returns in a specific factors context the impact of a change in world prices on real factor prices is ambiguous due to the effect of price changes on the cost of living. In a specific factor context the impact on real factor prices depends on the size of the terms of trade effect (which affects nominal factor prices) relative to the cost of living or production bias effect (Jones and Ruffin, 2002).

FPI fails when one relaxes some of the underlying assumptions. Jones and Scheinkman (1977) have shown that when the number of factors exceeds the number of traded goods (*M*>*N*) factor endowments do matter. In this case (3) becomes:

$$(d\lambda + dv)dw = (d\lambda + dv)G_{VV}(d\lambda + dv) < 0 \tag{4}$$

G_{VV} will be negative semi-definite, so that a change in relative factor endowments is associated with a negative "correlation" between the change in relative factor endowments and the change in relative factor prices.

3 Methodology

It is assumed that the economy's GNP function in can be approximated by a translog function. The translog GNP function can be represented formally as:

$$\begin{aligned} G(p,v,t) &= \alpha_0 + \sum_{i=1}^{N}\alpha_i \ln p_i + \sum_{k=1}^{M}\beta_k \ln v_k + \frac{1}{2}\sum_{j=1}^{M}\sum_{i=1}^{N}\alpha_{ij} \ln p_i \ln p_j \\ &+ \frac{1}{2}\sum_{k=1}^{K}\sum_{l=1}^{K}\beta_{kl} \ln v_k \ln v_l + \frac{1}{2}\sum_{i=1}^{N}\sum_{k=1}^{K}\gamma_{ik} \ln p_i \ln v_k + t\sum_{i=1}^{N}\delta_i \ln p_i \\ &+ t\sum_{l=1}^{K}\delta_k \ln v_k + \delta_1 t + \delta_2{}^2 t \end{aligned} \tag{5}$$

where *p* refers to the sum of value-added prices and total factor productivity in industry *i* (or *j*) *=1,…,N* (effective prices) and *v* to factor utilisation of factor *k* (or *l*) *=1,…,M* and *t* to non-neutral technological change (in addition to Hicks neutral technological change included in *p*) which is assumed to be a function of the time index.[7] It is assumed that the GNP function is twice differentiable in prices and factor endowments, increasing and convex in prices, increasing and concave in factor endowments.

[7] Note that simply adding up prices and TFP gives their joint impact on factor prices net of productivity pass-through (Feenstra and Hanson, 1999).

The assumption of profit maximisation implies linear homogeneity in prices and the assumption of constant returns to scale in line with perfect competition implies linear homogeneity in factor endowments:

$$\sum_{i=1}^{N}\alpha_i = \sum_{k=1}^{M}\beta_k = 1 \text{ and } \sum_{i=1}^{N}\alpha_{ik} = \sum_{k=1}^{M}\alpha_{ik} = \sum_{i=1}^{N}\beta_{ik} = \sum_{k=1}^{M}\beta_{ik} = \sum_{i}^{N}\delta_i = \sum_{k=1}^{M}\delta_k = 0 \qquad (6)$$

Without loss of generality imposing symmetry restrictions following Young's Theorem yields:

$$\alpha_{ij} = \alpha_{ji} \text{ and } \beta_{kl} = \beta_{lk} \text{ and also } \gamma_{ik} = \gamma_{ki} \qquad (7)$$

Differentiation of the revenue function (5) with respect to lnv_k gives the share of factor k in GNP:

$$s_k = \beta_{0k} + \sum_{j=2}^{N}\gamma_{kj}\ln\frac{p_j}{p_1} + \sum_{l=2}^{K}\beta_{kl}\ln\frac{v_l}{v_1} + \delta_k t \qquad (8)$$

where $s_k = \frac{w_k v_k}{Y}$. Since linear homogeneity is imposed on the aggregate production function one can rewrite the regressors of the share equations in relative terms (Berndt and Wood, 1975).

Differentiation of the revenue function (5) with respect to lnp_i yields the share of final output i in GNP:

$$s_{i,-j} = \alpha_{0i} + \sum_{j=2}^{N}\alpha_{ij}\ln\frac{p_i}{p_1} + \sum_{l=2}^{K}\gamma_{il}\ln\frac{v_k}{v_1} + \delta_i t, \qquad (9)$$

where $s_{i,-j} = \frac{p_i x_i}{Y}$ is the combined vector of final output share in GNP and the negative vector of positive import shares in GNP.

The complete system of share equations (8 and 9) will be estimated simultaneously. Although our prime interest goes out to the cost share equations, including the output share equations should lead to greater efficiency due to the correlation of the disturbances and the cross equation restrictions, $\gamma_{ik} = \gamma_{ki}$. Since the output and cost share equations add up to unity the disturbance covariance matrix will be singular. Consequently, one should drop one equation from each system. Estimates will normally not be invariant to the equation deleted. Fortunately, invariance can be obtained by iterating the system's estimation procedure so that the parameter estimates and the residual covariance matrix converge (Berndt and Wood, 1975).

The GNP function is estimated using three alternative econometric techniques. The first specification uses the iterative Zellner or iterated seemingly unrelated regression estimator (ISUR). The second specification uses iterated GMM in order to account for the endogeneity of domestic prices. In the present case where the estimable model is linear in its parameters iterated GMM and iterated 3SLS yield identical results. However, Wooldridge (2002) recommends using the GMM estimator as it is more general. In principle, the GMM estimator produces consistent results even in the presence of serial correlation or heteroskedasticity. The third method is also GMM, but accounts for the presence of first-order autocorrelation. Unfortunately, the present sample is too small to account for heteroskedasticity. However, accounting for serial correlation when constructing the estimator seems an improvement to the literature where one usually adjusts for serial correlation after estimation (Kohli, 1991; Tombazos, 2003). Tombazos (2003), for instance, observes that the adjustment procedure for serial correlation may be in conflict with instrumenting procedures to account for endogeneity. He therefore reports results for all possible combinations. Note, however, that the GMM estimator like the 3SLS estimator relies on its large sample properties. It is therefore a priori not clear whether using GMM-AR1 improves estimates relative to the SUR estimates.[8]

[8] The R^2 measure for the goodness of fit reported by most statistical packages applies only to single equation regressions. In a system the R^2 is no longer constrained between zero and one as system estimators do not share the same objective function (min. e'e). This paper therefore presents the generalised R^2 as suggested by Berndt (1991).

The results will be discussed on the basis of the estimated elasticities rather than the direct regression estimates as their interpretation is not straightforward due to the fact that the explanatory variables are in natural logarithms while the dependent variables are not. Instead of using the Hicksian elasticities of complementarity (Allen-Uzawa elasticities of substitution in a cost function context) the direct price and quantity elasticities are reported.[9]

The elasticity of supply *i* with respect to a change in the sum of price *j* and total factor productivity *j* is given by:

$$\varepsilon_{ij} = \frac{\partial \ln y_i}{\partial \ln p_j} = \frac{\alpha_{ij}}{s_i} + s_j - \phi_{ij}\,, \qquad \sum_{j=1}^{N} \varepsilon_{ij} = 0 \tag{10a}$$

where $\phi = 1$ if $i = j$. The elasticity of nominal return to factor *k* with respect to a change in the utilisation of factor *l* is given by:

$$\varepsilon_{kl} = \frac{\partial \ln w_k}{\partial \ln v_l} = \frac{\beta_{kl}}{s_k} + s_l - \phi_{kl}\,, \qquad \sum_{l=1}^{M} \varepsilon_{kl} = 0 \tag{10b}$$

where $\phi = 1$ if $l = k$.

The quantity elasticities of output supply (Rybczynski elasticities) are given by:

$$\varepsilon_{ik} = \frac{\partial \ln y_i}{\partial \ln v_k} = \frac{\gamma_{ik}}{s_i} + s_k\,, \qquad \sum_{k=1}^{M} \varepsilon_{ik} = 1 \tag{10c}$$

[9] There are two reasons for doing so. Firstly, Berndt and Wood (1981) recommend this as the partial elasticities of complementarity can become quite volatile in the presence of small cost or output shares. Secondly, Blackorby and Russell (1989) argue that the Allen-Uzawa generalisation to more than two inputs has no meaning as a quantitative measure. The same argument applies to the elasticities of complementarity.

The elasticities of inverse factor demand with respect to the sum of output prices and total factor productivity (Stolper-Samuelson elasticities) is given by:

$$\varepsilon_{ki} = \frac{\partial \ln w_k}{\partial \ln p_i} = \frac{\gamma_{ki}}{s_k} + s_i \,, \qquad \sum_{i=1}^{N} \varepsilon_{ki} = 1 \qquad (10.d)$$

The command ANALYZ in TSP can used to obtain approximate standard errors (Kohli, 1991).

4 Data

The GNP function is estimated using annual country-level data for the United Kingdom over the period 1975-1999. Note that in spite of estimating the model at the country level disaggregated are required as the GNP function explicitly distinguishes between different sectors. A core dataset is therefore constructed for 20 sectors (see Table 1A in the Appendix) from which the data are aggregated for the econometric analysis. Labour market data are obtained from the New Earnings Survey Panel Data Set (NESPD). In order to analyse the increase in wage inequality workers are classified skilled and unskilled on the basis of their Standard Occupational Classification (SOC) similar to Gregory, Zissimos, and Greenhalgh (2001). Since the SOC ranks occupations according to their qualifications, training, skills, and experience this allows one to construct a more accurate measure of skill than the one based on manual/non-manual workers generally used in the literature (Machin and Van Reenen, 1998; Feenstra and Hanson, 1999). Data on producer price indices, TFP and most of the production data are obtained from the National Institute Sectoral Productivity Database (NISPD). See the appendix for more details.

GNP is represented as a function of a six-input, two-output technology. There are three domestic inputs: skilled labour (V_s), unskilled labour (V_u) and capital (V_k) and three types of imported intermediate inputs: non-durables (M_1), oil (M_2) and durables (M_3). The two domestic outputs are skilled-intensive (Y_1), and unskilled-intensive (Y_2) respectively. The measure of skill-intensity used to classify sectors is based on the cost share of skilled labour in value-added for the year 1987.

Table 1 represents the average output shares and cost shares for the period 1975-1999 as well as their average annual changes. It can be seen that skill-intensive activities have grown in importance at the expense of unskilled-intensive activities. The increased importance of imported intermediate inputs in production is entirely driven by the growth in durable imports as the importance of imported non-durables and oil has declined. The growth in the sum of output prices and TFP was, if only slightly, biased towards unskilled-intensive activities indicating that Stolper-Samuelson type of reasoning would, if anything, have reduced wage inequality over the sample period. Finally, the price of imported durables rose slightly more quickly than the price of non-durables and oil.

[insert Table 1 here]

5 Results

The GNP function is well behaved if it is convex in prices and concave in factor endowments. If curvature conditions are not satisfied the results are inconsistent with economic theory and therefore meaningless. Convexity (concavity) implies that the matrix of second-order derivatives with respect to prices (factor endowments) is positive (negative) semi-definite which implies that all the principal minors should be positive (negative).[10] The translog GNP function does not satisfy these properties globally. One should therefore check whether the curvature conditions are satisfied at each observation. One can do so by using the characteristic root test for sign definiteness. Table 2 reports the respective eigenvalues for the relevant substitution matrices for a number of years. The characteristic root test yields that curvature conditions, i.e. convexity in output and import prices and concavity in factor endowments, are violated in most years. In principle, it is possible to impose curvature conditions as proposed by Kohli (1991) and Ryan and Wales (2000). However, when curvature violations are frequent imposing curvature conditions might

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[10] Harrigan and Balaban (1999) and Harrigan (2000) simply impose the necessary but not sufficient condition that all own price-output elasticities are positive and all own supply-factor price elasticities negative. More serious is though that they impose the restrictions globally which severely damages the flexibility of the translog function (Diewert and Wales, 1987)

render convergence impossible. Convergence is necessary in order to achieve invariance with respect to the equation dropped from the singular system. Curvature conditions could therefore not be imposed.

[insert Table 2 here]

The results are still meaningful for a number of reasons. Firstly, curvature violations only relate to the relationship between import prices and import demands. The remainder of the model continues to satisfy curvature conditions naturally without imposing any curvature conditions. Secondly, the output share equations are only included to improve the efficiency of the estimation. The results do not significantly change when concentrating on the cost share equations. Thirdly, the necessary but insufficient conditions imposed on the own price elasticities of import demand by Harrigan and Balaban (1999) and Harrigan (2000) are satisfied naturally or insignificant. Fourthly, the demand for imported intermediate inputs is presented as a function of prices (and factor supplies and time). However, it may not be appropriate to endogenise the demand for imported intermediate inputs in such a way. Instead, the timing of international outsourcing is likely to be driven by exogenous developments in transportation and communication technology. Finally, the main reason for using a flexible functional form is that elasticities can vary over the sample and need not be parametric. Flexible functional forms put much less restrictions prior to estimation than more traditional functional forms. The limitation of flexible functional forms to approximate true but unknown structures and ensure global curvature properties should be considered secondary (Chambers, 1988).

Table 3 reports the results of estimating a system of 8 share equations (two of which are dropped due to singularity of the covariance matrix of the disturbances). The GNP function is estimated using three alternative econometric techniques. Specification 1 uses the seeming unrelated regression estimator (ISUR). Specification 2 accounts for the endogeneity of output prices by using iterated GMM. Specification 3 uses IGMM whilst taking account of first-order serial correlation. The instruments that are used are: lagged population, the lagged total population of the United States, Japan and France, lagged GDP, the lagged real effective exchange rate, the savings ratio, lagged the discount rate, the lagged government's budget deficit as a share of GNP, the lagged capital stock and the squared time trend.[11]

The Sargan-test on the validity of overidentifying restrictions is rejected for IGMM, but cannot be rejected once serial correlation is taken into account for the construction of the optimal weighting matrix (IGMM-AR1). Accounting for first-order serial correlation seems to substantially improve the validity of the instruments. The Hausman-test on the equality of the coefficients across the restricted model (GMM and GMM-AR1) and the unrestricted model (SUR) indicates that the coefficients are significantly different ($\chi^2(2)$~191.13 and 215.99 respectively). As it is not obvious which specification should be preferred the results are discussed on the basis of both the ISUR and the IGMM-AR1 results

[insert Table 3 here]

The interpretation of the results is not straightforward due to the fact that the right-hand side variables are in natural logarithms whereas the dependent variables are not. We will therefore concentrate on the estimated elasticities. Table 4a and 4b represent the full set of price, quantity and time elasticities based on the SUR and GMM-AR1 estimates respectively. The discussion, however, will be limited to the price, quantity and time elasticities of inverse factor demand.

The quantity elasticities of inverse factor demand are all significantly different from zero, which might suggest that the factor price insensitivity theorem (FPI) does not hold for the UK. In principle, this could be due to, amongst others, the presence of more factors than tradable goods. The failure of FPI is presented as the main result in Harrigan and Balaban (1999) and Harrigan (2000).

Furthermore, it can be seen from the table that, whilst skilled and unskilled labour are substitutes, both types of labour are complemented by capital. All own quantity elasticities of inverse factor demand are negative as implied by economic theory. The

[11] Rather than estimating a complete general equilibrium model to determine output prices we use a number of exogenous variables as proxies for consumer demand, investment, government expenditure and foreign demand following Kohli (1991).

results with respect to the role of capital-intensity on wage inequality are mixed. The SUR estimates indicate a small favourable effect for skilled workers relative to unskilled workers (0.423-0.417), whereas the GMM results suggest a small favourable effect for unskilled workers relative to skilled workers (0.475-0.526). Harrigan (2000) also finds ambiguous results with respect to the role of capital accumulation. Tombazos (2003) finds a large positive effect of capital accumulation on wage inequality when using a narrow measure of skill, but only small effects when using a broad measure of skill.

In order to assess the impact of relative price changes on factor prices one should compare the relative price elasticities of inverse factor demand (Stolper-Samuelson elasticities) across factors. The impact of changes in domestic prices seems broadly consistent with Stolper-Samuelson reasoning. An increase in the relative price of skilled-intensive commodities has a large positive effect on skilled workers and a much smaller positive impact on unskilled workers. The SUR results for skilled workers even suggest the presence of magnification effects. Its absence for unskilled labour and capital could be related to the issue of aggregation or be due to the presence of more goods than factors in which case only the ‘extreme’ factors are expected to be associated with magnification effects.

The impact of trade on wages seems to be rather limited. This may be due to the fact that the impact of trade is already incorporated in domestic price changes. However, given the present framework there does not seem a way to disentangle the impact of international trade on domestic prices from purely domestic developments. The results for trade should therefore be considered as lower bound estimates since part of its impact might be captured by domestic prices.

The import price elasticities of inverse factor demand suggest that all imported intermediate inputs act as substitutes to domestic labour while durable and non-durable imports act as complements to capital. The impact of oil imports on domestic factor prices is very small. The negative impact of non-durable imports on wages ranges from -0.081 to -0.153. The impact of non-durables on relative wages is ambiguous. Finally, durable imports have the strongest negative effect on labour. Moreover, an increase in the price of durable imports seems to have a significantly more negative impact on the wage of unskilled workers compared to that of skilled workers.

Finally, the time elasticities of inverse factor demand imply that the factor bias of technological change (non-neutral technological change) might account for a significant part of the increase in wage inequality.

[insert Table 4a and 4b here]

6 Conclusions

The aim of this paper was to estimate a GNP function for the United Kingdom using data for the period 1975-1999. Consistent with standard trade theory the GNP function treats factor supplies and output prices as exogenous and factor prices and output supplies as endogenous. Moreover, the GNP function explicitly distinguishes between different sectors and is therefore in principle consistent with general equilibrium trade theory. The signs of the estimated elasticities were mostly in line with theoretical predictions. The main findings of this paper are the following.

Firstly, in line with the consensus in the literature the skill bias of technological change is found to be the predominant source of the increase in wage inequality. However, the skill bias of technological change was simply reflected in the estimable model by the inclusion of a trend term. It is therefore not clear to what extent the skill bias of technological change is attributable to globalisation-related developments such as the volume effect of international trade, international outsourcing, trade-induced upgrading or to purely domestic factors. It seems worthwhile extending the present framework to account explicitly for the sources of skill-biased technological change.

Secondly, while the paper provides mixed results for the role of all trade, the results provide some evidence in support of the outsourcing-hypothesis (Feenstra and Hanson, 1996, 1999), which asserts that international outsourcing constitutes an important contributing factor to the widening wage gap. This is reflected in the analysis by the positive albeit fairly small mandated change in the relative wage of skilled workers due to trade in durable goods. That the impact of trade in intermediates on factor prices is generally small should not come as a surprise given that most of the impact of trade on factor prices is likely to be reflected by changes in domestic prices also included in the analysis.

Finally, the conclusion by Balaban and Harrigan (1999) and Harrigan (2000) that the factor-price insensitivity theorem does not hold for the US carries over for the UK. All the quantity elasticities of inverse factor demand are found to be statistically significant

Concluding, the analysis suggests that output price changes and productivity growth do not account for the majority of the increase in wage inequality as most trade economists would assert. Instead, the factor bias of technological change (at constant output prices appears to be the main source). This could be due to the presence of more factors than goods.

Although the results seem sensible a word of caution is in place. The analysis is subject to two important drawbacks. Due to aggregation issues ‘true’ relationships may be obscured by unobserved heterogeneity. Moreover, the presence of non-stationary variables renders it impossible to make explicit statements on the basis of the preceding analysis. However, it is felt that by taking appropriate caution and interpreting results in the context of the existing literature this type of exercise certainly constitutes a valuable contribution to the ongoing debate.

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Data Appendix

Labour market data are obtained from the New Earnings Survey Panel Data Set (NESPD). The NESPD is based on a series of surveys carried out by the Office for National Statistics that covers approximately one percent of the working population. The survey is directed to employers who complete it on the basis of payroll records for the employee for a specific week in April. As the employer and employee are linked via an employee's income tax records the NESPD tends to underrepresent employees whose income falls below the income tax threshold. The most recent version of the NESPD covers the period 1975-2001. The present study only takes into account male workers aged between 18-65 that work full-time, are not self-employed, and whose earnings are not affected by absence.

Data on producer price indices, TFP and most of the production data are obtained from the National Institute Sectoral Productivity Database (NISPD). The database contains annual data for five major industrial economies on, amongst others, real output, employment, labour productivity, capital stocks, and TFP for about 25 sectors for the period 1950-1999.

Disaggregated producer price indices for the UK are only available for the 1990s for the UK and only for manufacturing industries. However, Indices of Production are available at the sectoral level for both services and manufacturing. Such indices should reflect the growth in output by sector in real terms. This index has been compiled on a more or less consistent basis since the 1940s. The construction of these indices is based on turnover data deflated using weighted combinations of producer price indices and export price indices. Without having data on price indices one could retrieve the 'producer price indices' by combining data on value added at current prices with the index of production, that is, to convert nominal value-added into an index (1995=100) and subsequently divide the index of value added (current prices) by the index of production (constant prices). Obviously constructing producer price indices for services is subject to many problems. In particular, output indices might not just reflect real growth of output in services due to the difficulty to disentangle cost-price effects from volume effects. Data on output indices and nominal value added are obtained from the ONS.

Capital stock and TFP estimates are obtained from the NISPD, which is publicly available from the NIESR. For more information on the sources and the construction of these variables the reader is referred to O'Mahony (1999).

Table A1: Industry classification with skilled labour cost share in value-added

Unskilled	1975	1999	Skilled	1975	1999
Agriculture and Forestry	0.029	0.112	Paper and printing	0.294	0.418
Mining and extraction	0.227	0.208	Chemicals	0.399	0.667
Food, drink and tobacco	0.167	0.319	Total machinery & equipment	0.318	0.712
Textiles, clothing and leather	0.095	0.259	Electricity, gas and water	0.217	0.425
Wood products	0.077	0.291	Retail	0.374	0.623
Rubber & Plastics	0.245	0.373	Financial & business services	0.218	0.511
Non-metallic mineral products	0.187	0.639	Communications	0.191	0.413
Basic metals & fabricated metal products	0.315	0.289	Personal services	0.149	0.385
Furniture and miscellaneous	0.233	0.276			
Construction	0.158	0.354			
Hotels and catering	0.050	0.193			
Transport	0.182	0.260			

Table 1: Descriptive statistics, 1975-1999

	Average	%Δ		%Δ
Output/Import shares			Output/Import prices	
Y_s	0.898	0.005	p_s	0.074
Y_u	0.396	-0.012	p_u	0.081
M_1	-0.053	-0.025	p_{m1}	0.035
M_2	-0.026	-0.036	p_{m2}	0.032
M_3	-0.130	0.041	p_{m3}	0.043
Cost shares			Input quantities	
V_s	0.237	0.025	v_s	0.013
V_u	0.331	-0.019	v_u	-0.022
V_k	0.432	0.012	v_k	0.012

The measure of skill-intensity used to classify sectors is based on the cost share of skilled labour in value-added the year 1987.

Table 2: Eigenvalues SUR estimates

	Convexity in prices (matrix A)					**Concavity in factor supplies (matrix B)**		
1976	3.3535	0.4563	0.0073	**-3.7276**	0.6465	-0.0345	-0.0775	-0.0378
1987	3.3123	0.3854	**-0.0166**	0.2211	1.2654	-0.0602	-0.0631	-0.0365
1999	3.4279	0.3769	**-0.0248**	0.0306	2.0268	-0.0878	-0.0518	-0.0332

Table 3: Regression results GNP function with three types of imports for UK, 1975-1999

	ISUR			IGMM-3SLS			IGMM-AR1		
α_1	1.164	(10.41)	***	1.050	(7.28)	***	0.969	(6.88)	***
α_2	0.336	(3.45)	***	0.464	(3.17)	***	0.544	(3.79)	***
α_3	-0.180	(-6.14)	***	-0.130	(-3.32)	***	-0.101	(-2.68)	***
α_4	-0.125	(-6.68)	***	-0.129	(-6.81)	***	-0.130	(-6.62)	***
β_1	0.369	(8.60)	***	0.383	(8.08)	***	0.412	(8.92)	***
β_2	0.351	(9.28)	***	0.353	(8.30)	***	0.341	(8.05)	***
α_{11}	3.441	(17.07)	***	2.744	(7.88)	***	2.876	(8.44)	***
α_{12}	-3.363	(-16.31)	***	-2.714	(-7.51)	***	-2.856	(-8.04)	***
α_{13}	-0.141	(-3.08)	***	0.202	(2.67)	***	0.189	(2.64)	***
α_{14}	-0.032	(-2.92)	***	-0.049	(-4.09)	***	-0.042	(-3.55)	***
α_{22}	3.329	(15.43)	***	2.733	(7.26)	***	2.884	(7.77)	***
α_{23}	0.117	(2.48)	**	-0.200	(-2.60)	***	-0.184	(-2.51)	**
α_{24}	-0.006	(-0.73)		0.011	(0.91)		0.005	(0.44)	
α_{33}	-0.046	(-2.86)	**	-0.218	(-8.77)	***	-0.221	(-9.54)	***
α_{34}	0.020	(7.84)	***	0.029	(8.78)	***	0.028	(9.02)	***
α_{44}	-0.007	(-2.11)	**	-0.008	(-2.25)	**	-0.008	(-2.13)	**
β_{11}	0.117	(6.03)	***	0.121	(5.32)	***	0.136	(6.15)	***
β_{12}	-0.131	(-7.53)	***	-0.131	(-6.31)	***	-0.141	(-6.82)	***
β_{22}	0.099	(6.04)	***	0.102	(5.14)	***	0.117	(5.91)	***
γ_{11}	0.129	(2.67)	***	0.117	(1.58)		0.074	(1.05)	
γ_{12}	-0.064	(-1.41)		-0.043	(-0.61)		0.002	(0.03)	
γ_{21}	-0.104	(-2.10)	**	-0.088	(-1.14)		-0.042	(-0.58)	
γ_{22}	0.126	(2.71)	***	0.106	(1.44)		0.060	(0.87)	
γ_{31}	-0.024	(-1.79)	*	-0.025	(-1.32)		-0.010	(-0.58)	
γ_{32}	-0.010	(-0.83)		-0.013	(-0.76)		-0.026	(-1.54)	
γ_{41}	-0.007	(-1.71)	*	-0.007	(-1.60)		-0.010	(-2.27)	**
γ_{42}	-0.001	(-0.36)		-0.001	(-0.29)		0.000	(0.07)	
δ_{11}	0.007	(3.78)	***	0.007	(3.25)	***	0.009	(4.13)	***
δ_{12}	-0.005	(-3.23)	***	-0.005	(-2.24)	**	-0.007	(-3.13)	***
δ_{13}	0.001	(1.96)	**	0.001	(1.48)		0.001	(0.97)	
δ_{14}	0.001	(2.17)	**	0.001	(2.06)	**	0.001	(2.21)	**
δ_{21}	0.001	(1.61)		0.001	(1.57)		0.001	(1.17)	
δ_{22}	-0.003	(-5.69)	***	-0.003	(-4.81)	***	-0.003	(-3.95)	***
N	25			25			25		
$\tilde{R}^2$	1.0000			1.0000			1.0000		
Sargan $-\chi^2$				92.4(63)	[0.009]		76.1(63)	[0.123]	

Table 4a: Price, quantity and time elasticities based on ISUR estimates

	$\partial n y_1$	$\partial n y_2$	$\partial n m_1$	$\partial n m_2$	$\partial n m_3$
<u>Price elasticity of output supply</u>					
$\partial n p_1$	**3.783**	-7.147	2.608	1.478	-0.256
	(16.550)	(-14.516)	(4.654)	(7.252)	(-0.434)
	***	***	***	***	
$\partial n p_2$	-3.394	**7.368**	-1.016	0.524	1.360
	(-14.516)	(14.305)	(-1.758)	(3.626)	(2.569)
	***	***	*	***	***
$\partial n p_{M1}$	-0.241	0.198	**-0.521**	-0.457	-0.680
	(-4.654)	(1.758)	(-2.656)	(-9.542)	(-4.279)
	***	*	***	***	***
$\partial n p_{M2}$	-0.089	-0.066	-0.297	**-0.918**	-0.348
	(-7.252)	(-3.626)	(-9.542)	(-14.342)	(-4.714)
	***	***	***	***	***
$\partial n p_{M3}$	0.024	-0.269	-0.691	-0.544	***0.007***
	(0.434)	(-2.569)	(-4.279)	(-4.714)	(0.027)
		***	***	***	
<u>Quantity elasticity of output supply (Rybczinsky)</u>					
$\partial n v_s$	0.331	-0.062	0.480	0.312	0.113
	(6.070)	(-0.528)	(2.920)	(4.199)	(0.697)
	***		***	***	
$\partial n v_u$	0.393	0.766	0.593	0.493	1.072
	(7.670)	(6.899)	(3.876)	(6.472)	(7.046)
	***	***	***	***	***
$\partial n v_k$	0.276	0.296	-0.073	0.195	-0.186
	(12.402)	(10.010)	(-1.319)	(1.675)	(-0.210)
	***	***			
<u>Time elasticity of output supply</u>					
∂t	0.008	-0.012	-0.011	-0.011	0.027
	(3.780)	(-3.225)	(-1.964)	(-2.169)	(-1.976)
	***	***	**	**	**

	$\partial n w_s$	$\partial n w_u$	$\partial n w_k$
<u>Quantity elasticity of inverse factor demand</u>			
$\partial n v_s$	**-0.182**	-0.096	0.224
	(-1.731)	(-2.568)	(8.428)
	*	***	***
$\partial n v_u$	-0.241	**-0.321**	0.555
	(-2.568)	(-9.096)	(22.147)
	***	***	***
$\partial n v_k$	0.423	0.417	**-0.779**
	(8.423)	(22.147)	(-17.288)
	***	***	***
<u>Price elasticity of inverse factor demand (Stolper-Samuelson)</u>			
$\partial n p_1$	1.576	0.745	0.697
	(6.070)	(7.670)	(12.402)
	***	***	***
$\partial n p_2$	-0.141	0.690	0.355
	(-0.528)	(6.890)	(10.010)
		***	***
$\partial n p_{M1}$	-0.211	-0.104	0.017
	(-2.920)	(-3.876)	(1.318)
	***	**	
$\partial n p_{M2}$	-0.089	-0.056	-0.030
	(-4.199)	(-6.472)	(-1.675)
	***	***	*
$\partial n p_{M3}$	-0.051	-0.191	0.044
	(-0.697)	(-7.047)	(1.210)
	*	***	
<u>Time elasticity of inverse factor demand</u>			
∂t	0.005	-0.007	-0.012
	(1.613)	(-5.693)	(4.167)
		***	***

The elasticities correspond to the regression results reported in Table 3. All variables are in logs. T-statistics in parentheses, ***, **, *, refer to 10%, 5% and 1% significance levels. The t-statistics are computed with the command ANALYZ in TSP. Black elements refer to the own price elasticities of output supply and own quantity elasticities of inverse factor demand. The bold italic elements highlight the own price and quantity elasticities that are inconsistent with economic theory.

Table 4b: Price, quantity and time elasticities based on IGMM-AR1 estimates

	∂ny_1	∂ny_2	∂nm_1	∂nm_2	∂nm_3
Price elasticity of output supply					
∂np_1	**3.244**	-5.611	-3.043	3.087	2.075
	(8.056)	(-6.987)	(-2.068)	(4.893)	(3.746)
	***	***	**	***	***
∂np_2	-2.932	**5.962**	4.234	0.174	-0.678
	(-6.987)	(7.107)	(2.801)	(0.288)	(-1.223)
	***	***	***		
∂np_{M1}	0.175	-0.465	***3.496***	-1.562	-1.435
	(2.068)	(-2.801)	(7.341)	(-9.312)	(-9.637)
	**	***	***	***	***
∂np_{M2}	-0.068	-0.007	-0.602	**-0.587**	-0.142
	(-4.893)	(-0.288)	(-9.312)	(-2.901)	(-2.417)
	***		***	***	**
∂np_{M3}	-0.332	0.207	-3.998	-1.026	***0.266***
	(-3.746)	(1.223)	(-9.637)	(-2.417)	(1.002)
	***		***	**	
Quantity elasticity of output supply (Rybczinsky)					
∂nv_s	0.318	0.135	0.443	0.754	0.314
	(3.827)	(0.819)	(1.214)	(3.273)	(2.296)
	***			***	**
∂nv_u	0.321	0.455	0.845	0.302	0.591
	(4.073)	(2.908)	(2.470)	(1.229)	(4.682)
	***	***	**		***
∂nv_k	0.362	0.410	-0.288	-0.056	0.095
	(17.446)	(11.831)	(-2.362)	(-0.160)	(0.812)
	***	***	**		
Time elasticity of output supply					
∂t	0.010	-0.015	-0.011	-0.038	0.015
	(4.130)	(-3.126)	(-0.967)	(-2.211)	(1.372)
	***	***		**	

	∂nw_s	∂nw_u	∂nw_k
Quantity elasticity of inverse factor demand			
∂nv_s	**-0.181**	-0.213	0.243
	(-1.887)	(-3.272)	(11.639)
	*	***	***
∂nv_u	-0.294	**-0.313**	0.372
	(-3.272)	(-5.032)	(18.378)
	***	***	***
∂nv_k	0.475	0.526	**-0.614**
	(11.639)	(18.378)	(-16.776)
	***	***	***
Price elasticity of inverse factor demand (Stolper-Samuelson)			
∂np_1	1.166	0.852	0.679
	(3.827)	(4.073)	(17.446)
	***	***	***
∂np_2	0.259	0.632	0.402
	(0.819)	(2.908)	(11.831)
		***	***
∂np_{M1}	-0.093	-0.129	0.031
	(-1.214)	(-2.470)	(2.362)
		**	**
∂np_{M2}	-0.061	-0.018	0.002
	(-3.273)	(-1.229)	(0.160)
	***		
∂np_{M3}	-0.184	-0.251	-0.029
	(-2.296)	(-4.682)	(-0.812)
	**	***	
Time elasticity of inverse factor demand			
∂t	0.004	-0.009	-0.008
	(1.169)	(-3.951)	(-2.856)
		***	***

The elasticities correspond to the regression results reported in Table 3. All variables are in logs. T-statistics in parentheses, ***, **, *, refer to 10%, 5% and 1% significance levels. The t-statistics are computed with the command ANALYZ in TSP. Black elements refer to the own price elasticities of output supply and own quantity elasticities of inverse factor demand. The bold italic elements highlight the own price and quantity elasticities that are inconsistent with economic theory.