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Trade and Rising Wage Inequality in the UK: Results from a CGE Analysis

By D. Greenaway, G.V. Reed and N. Winchester

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Leverhulme Centre for Research on Globalisation and Economic Policy

The Authors

David Greenaway is Professor of Economics and Director of the Leverhulme Research Centre for Research on Globalisation and Economic Policy; Geoffrey Reed is a Reader in Economics and Internal Fellow of the Leverhulme Research Centre for Research on Globalisation and Economic Policy, University of Nottingham; Niven Winchester is a Lecturer at the University of Otago.

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Abstract

The phenomenon of rising wage inequality has been extensively documented in OECD countries. In the final quarter of the last century it appears to have been particularly marked in the US and UK. The drivers of rising inequality have been subject to econometric analysis and the relative roles of trade and skill-biased technical change evaluated. In this paper, we take an alternative approach, namely computable general equilibrium (CGE) modelling. The contribution of the paper is twofold: first, it constructs the first purpose built model of the UK economy specifically geared to evaluating the drivers of rising wage inequality; second, it incorporates new and more disaggregated measures of labour types. The model's output identifies clearly the role of trade in the process over the period 1980 to 1998.

JEL classification: D58, F16

Keywords: Trade and Wages, CGE Modelling

Outline

1. *Introduction*
2. *Model Structure*
3. *Augmentation of the GTAP database and determination of labour types*
4. Descriptive analysis of the database
5. *Model Parameterisation and Simulation*
6. *Conclusions*

Non-Technical Summary *(500 words)*

The phenomenon of rising wage inequality in OECD economies has been widely documented and appears to have been most marked in the US and UK over the last quarter of the twentieth century. One explanation which has been advanced to explain this trend is growing trade between North and South, where these are perceived as skilled and unskilled labour abundant respectively. An alternative explanation is growing demand for skilled labour, driven by skill-biased technical change. Most, but not all, analyses of the skill premium have concluded that it is skill-biased technical change which is largely responsible, with trade only having a minor role to play.

Almost all empirical work has been econometric. In this paper we adopt a different approach, namely computable general equilibrium (CGE) analysis. We construct a purpose built model of the UK economy, the first of its kind, and simulate this with a range of alternative classifications of labour types. We build a model on the Global Trade Analysis (GTAP) database, with considerable refinement and extension to the UK 'region'. We have five trading regions, five product categories (built on 37 sectors of economic activity) and of course primary factors. With respect to the last, in order to enrich the analysis we identify up to four labour types using cluster analysis. Using model backcasts from 1998 to 1980, we identify changes in real wages across labour types and employment shares. We then parameterise and simulate the model to isolate the role of trade in explaining rising wage inequality. Our results suggest that trade has had a relatively minor role to play in explaining wage inequality and this finding is robust to variations in substitution elasticities.

1. INTRODUCTION

The coincidence of rising wage inequality in the North and increased North-South trade over the final quarter of last century generated renewed interest in the Stolper-Samuelson theorem. If the global economy is Heckscher-Ohlin, with skilled and unskilled labour as the only factors of production, the North can be expected to export the skilled-labour-intensive (SLI) good and the South the unskilled-labour-intensive (ULI) good. When barriers / trade frictions are reduced, trade increases and the relative price of the SLI good rises in the North. Following Stolper-Samuelson, this results in the relative return to skilled labour increasing. This posited link between trade and relative wages has motivated a large empirical literature targeted at evaluating the role of trade, generally relative to technology shocks, (see for example Slaughter 2000 and Greenaway and Nelson 2000). The consensus from this seems to be that trade has a relatively modest role to play in explaining rising wage inequality.

Most, but not all, of the literature is econometric, often, like Haskell and Slaughter (2001), using a mandated wage framework. A few studies, including Tyers and Yang (2000), use computable general equilibrium (CGE) analysis to investigate the issue. This study deploys a purpose-built CGE model, based on the GTAP database and focusing on the UK. The UK is an important case to investigate since, as well as being a relatively open economy, after the US it is the OECD economy that has recorded the largest increase in wage inequality over the latter part of the twentieth century. This is the first study to investigate the issue for the UK, using CGE technology.

One of the limitations of much of the work on trade and wages is the modest disaggregation between labour types in most studies. For example, the GTAP database only distinguishes between two broad labour types: skilled and unskilled labour. One of the innovations of this paper is to augment the basic GTAP dataset for the UK by distinguishing four labour types. Patterns in the augmented database imply that the observed increase in wage inequality in the UK has probably been driven by a large increase in the relative demand for highly skilled labour.

Because we make extensive use of the GTAP database, Section 2 begins with a description of its main features, and the structure of our base CGE model, GTAP5inGAMS. Section 3 describes our new measures of labour and how they are used in the augmentation of the UK part of the database. Section 4 contains a descriptive analysis of our data and reports on the values assumed for key model elasticities. The form and outcomes of a number of simulations are detailed in Section 5 together with the outcomes of a number of sensitivity analyses. Section 6 summarises the results and offers some conclusions.

2 MODEL STRUCTURE

The most recent version of the GTAP database, Version V, is a representation of the world economy in 1997. The database "*contains detailed bilateral trade, transport and protection data characterising economic linkages among regions, together with individual country input-output databases which account for inter-sectoral linkages within regions*" (Hertel 1998, p.2). Flows of goods and services are measured in money values. No price or quantity data are recorded. The database distinguishes 66 regions, 57 sectors and five primary factors. All developed countries, except for a few in the European Free Trade Area, enter as separate regions, as do a number of South East Asian and South American countries. Remaining countries are included in composite regions.[1] GTAP sectors can be grouped into five product categories: 12 agricultural sectors, six resource-based sectors, eight food manufacturing sectors, 16 non-food manufacturing sectors, three utility sectors, and 12 service sectors.

Four of the five factors of productions, skilled and unskilled labour, land, and natural resources, are endowed. The remaining factor, capital, is produced. Land and natural resources are exclusively used to produce agricultural and natural resources based products respectively. Skilled and unskilled labour are utilised in all sectors except dwellings, which are produced entirely from capital. The latter is employed in all sectors.

Parameters explicitly represented by the GTAP database are displayed in the top portion of Table 1. Commodities are identified by both i and j and regions by r and s. Parameters beginning with `t` are tax rates whereas `v` denotes a base year value.[2] The second section of Table 1 lists parameters assigned as part of the modelling procedure. A new identifier, d, is used here to distinguish three sub-markets for imports, namely government consumption,

[1] The composition of each region is detailed in Betina and McDougall (2002).
[2] Tax rates are included in the GAMS version of the database but not in the dataset suitable for use with GEMPACK. As a result, values of transactions gross of tax stored in the GEMPACK version of the database are not present in the GAMS version.

Table 1
Parameters in the GTAP database

EXPLICITLY REPRESENTED	
`ty(i,r)`	Output tax
`ti(j,i,r)`	Intermediate input tax
`tf(f,i,r)`	Factor tax
`tx(i,s,r)`	Export tax rate (defined on a net basis)
`tm(i,s,r)`	Import tariff rate
`tg(i,r,)`	Tax rate on government demand
`tp(i,r)`	Tax rate on private demand
`vafm(j,i,r)`	Aggregate intermediate inputs
`vfm(f,i,r)`	Value of factor inputs, net of tax
`vxmd(i,r,s)`	Value of commodity trade (*fob*, net export tax)
`vtwr(i,r,s)`	Transport services
`vst(i,r)`	Value of international transport sales
`vdgm(i,r)`	Government demand (domestic)
`vigm(i,r,)`	Government demand (imported)
`vdpm(i,r)`	Aggregate private demand (domestic)
`vipm(i,r)`	Aggregate private demand (imported)
ASSIGNED	
`vim(i,r)`	Total value of imports (gross of tariff)
`vxm(i,r)`	Value of exports (including transport services)
`vdm(i,r)`	Value of domestic output (gross of taxes)
`vdfm(i,r)`	Aggregate intermediate demand (domestic)
`vifm(i,r)`	Aggregate intermediate demand (imported)
`vom(i,r)`	Aggregate output value (gross of tax)
`vgm(i,r)`	Public expenditures
`vpm(i,r)`	Private expenditures
`vg(r)`	Total value of public expenditure
`vp(r)`	Total value of private expenditure
`vi(r)`	Total value of investment
`vt`	Value of international trade margins
`vb(r)`	Net capital inflows
`evoa(f,r)`	Value of factor income
`va(d,i,r)`	Armington Supply
`vd(d,i,r)`	Domestic Supply
`vm(d,i,r)`	Imported supply
BENCHMARK PRICES	
`pc0(I,r)`	Reference price for private consumption
`pf0(f,i,r)`	Reference price for factor inputs
`pg0(I,r)`	Reference price for government consumption
`pi0(j,i,r)`	Reference price for intermediate inputs
`pt0(I,s,r)`	Reference price index for transport services
`px0(I,s,r)`	Reference price for imports

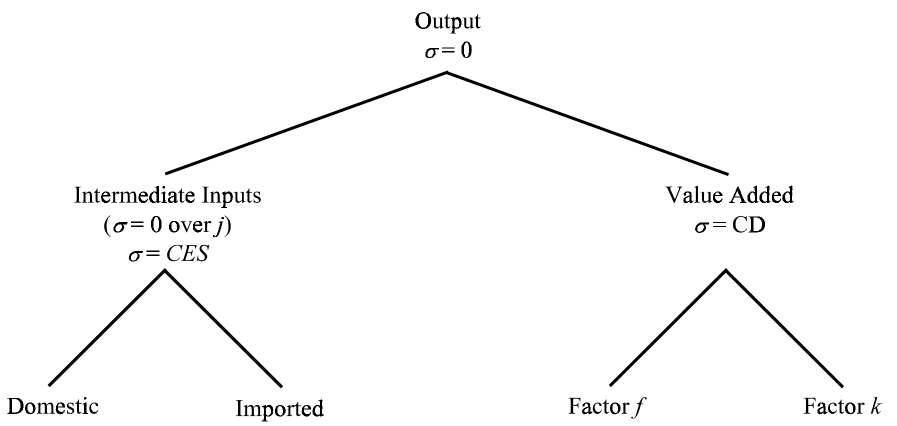
Source: Rutherford and Paltsev (2000).

intermediate input demand, and private consumption. Assigned parameters are generated from parameters explicitly represented. A number of base year prices also need to be assigned. Base prices subject to taxes are imputed from explicitly included tax rates and are presented in the bottom segment of Table 1.

GTAP5inGAMS is a static, multi-regional model of the global economy that determines the production and allocation of goods.[3] Sectors are perfectly competitive and outputs produced by linear homogenous production functions. Factors of production are perfectly mobile between sectors in each region but immobile internationally. There is a representative consumer in each region who maximises utility over private consumption subject to fixed levels of public expenditure and investment demand. Interactions between regions are captured by a full set of bilateral trade flows. Transport costs, export taxes/subsidies and protection data, expressed in the form of *ad valorem* equivalents, tariff and non-tariff barriers are also included.

Production: Production technology is characterised by a multilevel nest of intermediate inputs and primary factors, as depicted in Figure 1. A Leontief nest of primary factors and intermediate inputs composites produces output. Intermediate inputs by product type are combined using a further Leontief nest and the value-added composite is derived from a Cobb-Douglas aggregation of primary factors. Following Armington (1969), intermediate inputs are defined by a constant elasticity of substitution (CES) aggregation of the domestic variety and a composite of imported varieties. A further Armington aggregation, of imports from different regions, is employed to generate the import composite.

Figure 1
Production in the GTAP5inGAMS model

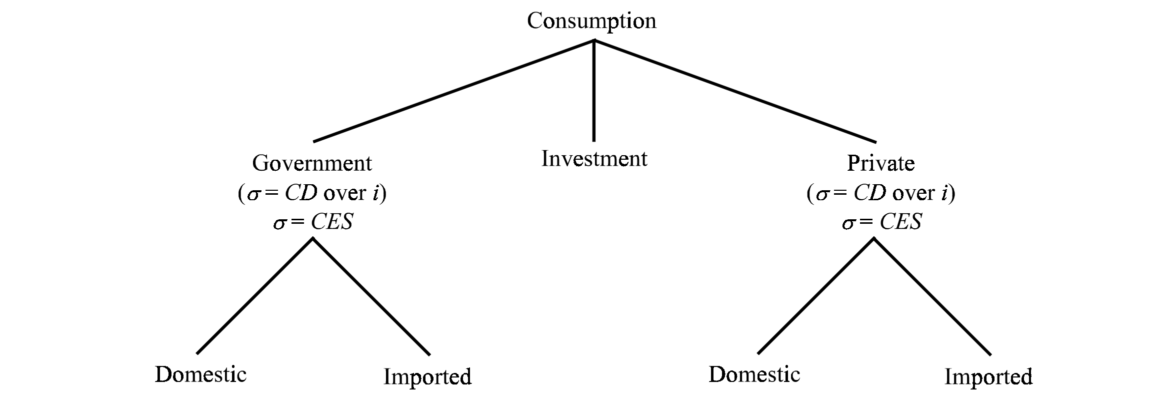


Consumption: Consumption is each region is determined by a representative agent, who allocates expenditure across public[4] and private demand in order to maximise utility.

[3] Rutherford and Paltsev (2000) outline the model in detail.
[4] Public demand refers to demand by the public sector. There are no publicly produced goods in model.

Expenditure is equal to the aggregate of factor income, tax revenue and an exogenous net transfer from other regions. The structure of consumption demand is illustrated in Figure 2.

Figure 2
Consumption in the GTAP5inGAMS model

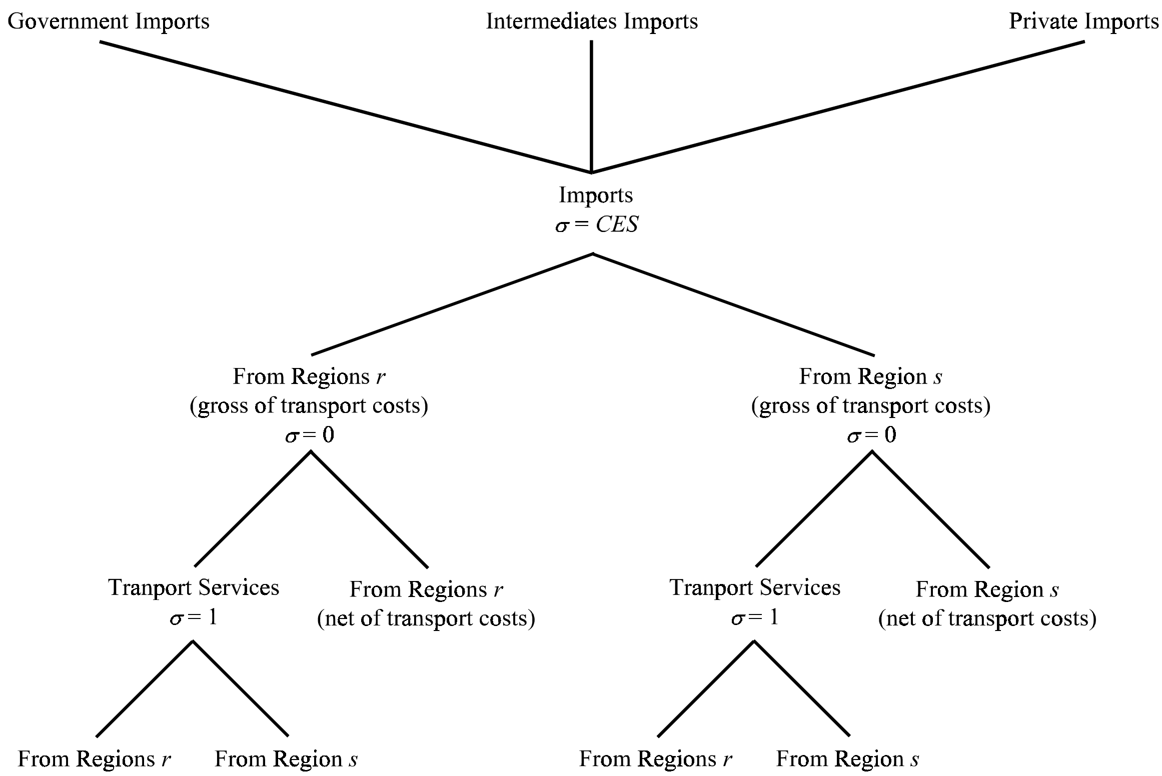


Private and public demands are determined by utility-maximising behaviour, subject to the constraint that public expenditure is fixed in absolute value. Private demand is nested in several levels. At the top level, preferences are defined by a Cobb-Douglas aggregation of composite commodities, derived from Armington aggregations of domestic and imported varieties. Public sector preferences are modelled in an identical fashion to private tastes, which allows the composition of public expenditure to respond to changes in relative prices, even though the level of public expenditure is exogenous. Investment demand is also exogenous. New capital is produced in the same way as tradable commodities, except that primary factor services are not required.[5]

Imports: There are three sources of demand for intermediate inputs: producers; the public sector; and the private sector. It is assumed that import shares have the same regional composition in all three, but the aggregate share of imports may differ across sources. Imports are differentiated by region of origin and incur transport costs which are proportional to trade values and therefore enter in a Leontief nest. Transport services are produced by a Cobb-Douglas aggregation of international transport inputs from different countries. The aggregation of imports and transport costs is set out in Figure 3. The domestic price of imports arriving at region r from region s is equal to the summation of the *fob* export price in region s, per-unit export tax revenue accruing to region s, transport costs, and the import tariff levied by r.

[5] Primary factor services are embodied in the intermediate inputs assembled by the investment sector.

Figure 3
Imports in the GTAP5inGAMS model



Closures: The model is global so one region's imports are sourced from other regions' production, which negates the need to specify an external closure rule. The model uses what Dewatripont and Michel (1987) classify as a non-neoclassical macroeconomic closure. This can best be illustrated by equating national expenditure from the sources and uses sides. This implies that savings (S) minus investment (I) is equal to exports (X) minus imports (M)[6]

$$S - I = X - M \tag{1}$$

In the GTAP5inGAMS model, the current account balance is exogenous, which, with rigid investment, fixes regional savings. Since both investment and savings in each region are exogenous, the imposition of equilibrium between global savings and global investment in

[6] Strictly speaking, the right-hand side of equation (1) should include international transfer receipts. In the GTAP database, due to data constraints, however, international transfer receipts are set equal to zero and savings are derived residually.

the benchmark equilibrium ensures that such equilibria are present in counterfactual simulations.

3. AUGMENTATION OF THE GTAP DATABASE AND DETERMINATION OF LABOUR TYPES

Aggregations in our model are summarised in Table 2. There are five regions and five sectors. Five factors of production are identified in the UK and three in other regions. The starting point for aggregation **a** is the summation of UK factors. Combining highly-skilled with skilled labour and semi-skilled with unskilled workers generates two labour types. These composite factors are labelled skilled labour and unskilled labour respectively. (Such an aggregation has been used in previous CGE studies, for example Abrego and Whalley, 2000.) Appropriately averaging the labour data reveals that the real wage of skilled labour increased by 34.4 percent over the sample period, while that of unskilled rose by 14.4 percent which suggests that the skill premium increased by 17.5 percent between 1980 and 1997. Aggregation **b** maintains the four separate labour types in the UK. Two labour types are identified in other regions in both aggregations. Although similarly labelled, labour inputs in other regions differ from those employed in the UK.

Table 2
Model Aggregation

REGIONS	SECTORS
1. United Kingdom	1. Agriculture, mineral and energy
2. Western Europe [a]	2. Skilled-intensive manufacturing
3. Other Developed [b]	3. Unskilled-intensive manufacturing
4. Rapidly Developing [c]	4. Skilled-intensive services
5. Rest of World [d]	5. Unskilled-intensive services
PRIMARY FACTORS [e, f]	
(a)	**(b)**
1. Skilled labour	1. Highly-skilled labour
2. Unskilled labour	2. Skilled labour
3. Capital (including land and resources)	3. Semi-skilled labour
	4. Unskilled labour
	5. Capital (including land and resources)

Notes:- a: The EU-15 and the European Free Trade Area. b: Japan, The United States, Canada, Australia, and New Zealand. c: China, Hong Kong, Taiwan, Korea (Rep.), Indonesia, Malaysia, Philippines, Thailand, Vietnam. d: All other countries. e: Labour types for the UK defined using the method described in the text. F: Skilled labour, unskilled labour, and capital are identified in regions other than the UK in both aggregations.

Labour types in regions other than the UK are taken from the GTAP database and classified according to occupational characteristics as in Lui *et al.* (1998), whereas labour types in the

UK are identified by observing educational and wage characteristics. There is only one capital asset in both the UK and other regions, which includes land and natural resources.

Sectoral aggregation follows a two-stage process. First, using broad definitions, agriculture, manufacturing and service sectors are identified. Manufacturing and service sectors are then classified as skill-intensive or unskilled-intensive. The process creates five sectors. The composition of each is detailed in Table 3. Five regions are identified, the UK enters as a separate region and four others are identified by reference to relative labour endowments: Western Europe and Other Developed, which are relatively abundant in skilled labour; Rapidly Developing and Rest of World, which are relatively abundant in unskilled labour.

As noted earlier, one of the innovations in this paper is our disaggregation of labour types. Hence we spend a little time elaborating on what has been done. Two methods are commonly used to distinguish different types of labour. One involves using job classifications to create proxies for skilled and unskilled labour. The job classification technique most frequently employed uses non-production and production workers to approximate skilled and unskilled labour respectively,[7] although white collar/blue-collar and non-manual/manual classifications are occasionally adopted.[8] The other commonly used technique employs educational characteristics to measure skills. For example, Bound and Johnson (1992) identify four groups based on educational attainment (high school dropouts, high school graduates, some college, and college graduates). Baldwin and Cain (1997), on the other hand, classify employees with 1-12 years of education as unskilled labour and workers with more than 13 years of education as skilled.[9] In another approach, Leamer (1996) differentiates between skilled and unskilled labour by assuming that differences in average wages across sectors are due to differences in the mix of skilled and unskilled labour. He assumes that the lowest wage sector consists entirely of unskilled labour and the highest wage sector entirely of skilled labour. The proportions of skilled and unskilled labour in other sectors are then determined by linearly interpolating from the level of each industry's wage.

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[7] Lawrence and Slaughter (1993), Berman, Bound, and Griliches (1994), Sachs and Shatz (1994), Feenstra and Hanson (1995), Leamer (1996), Tyers and Yang (1997), and Francois and Nelson (1998) use a production-non-production classification.

[8] Neven and Wyplosz (1996) make a distinction between white collar and blue-collar workers, while Haskel and Slaughter (2001) use a non-manual/manual classification.

[9] Mincer (1991), Cline (1997), and Krueger (1994), are other authors who establish skill classifications based on educational characteristics.

Table 3
Sectoral Aggregation

Aggregated Sector		GTAP Sector		
1	Agriculture, minerals and energy	1	pdr	Paddy rice
		2	wht	Wheat
		3	gro	Cereal grains nec
		4	v_f	Vegetables, fruit, nuts
		5	osd	Oil seeds
		6	c_b	Sugar cane, sugar beet
		7	pfb	Plant-based fibers
		8	ocr	Crops nec
		9	ctl	Bovine cattle, sheep meat etc
		10	oap	Animal products nec
		11	rmk	Raw milk
		12	wol	Wool, silk-worm cocoons
		13	frs	Forestry
		14	fsh	Fishing
		15	col	Coal
		16	oil	Oil
		17	gas	Gas
		18	omn	Minerals nec
		19	cmt	Bovine cattle, sheep meat etc
		20	omt	Meat products nec
		21	vol	Vegetable oils and fats
		22	mil	Dairy products
		23	pcr	Processed rice
		24	sgr	Sugar
		25	ofd	Food products nec
		26	b_t	Beverages and tobacco products
2	Skilled-intensive manufacturing	31	ppp	Paper products, publishing
		32	p_c	Petroleum, coal products
		33	crp	Chemical, rubber, plastic products
		38	mvh	Motor vehicles and parts
		39	otn	Transport equipment nec
		40	ele	Electronic equipment
		41	ome	Machinery and equipment nec
3	Unskilled-intensive manufacturing	27	tex	Textiles
		28	wap	Wearing apparel
		29	lea	Leather products
		30	lum	Wood products
		34	nmm	Mineral products nec
		35	i_s	Ferrous metals
		36	nfm	Metals nec
		37	fmp	Metal products
		42	omf	Manufactures nec
5	Skilled-intensive services	43	ely	Electricity
		44	gdt	Gas manufacture, distribution
		45	wtr	Water
		49	wtp	Water transport
		50	atp	Air transport
		51	cmn	Communication
		52	ofi	Financial services nec
		54	obs	Business services nec
		55	ros	Recreational and other services
		56	osg	Public Admin., Defence, Education
4	Unskilled-intensive services	46	cns	Construction
		47	trd	Trade
		48	otp	Transport nec
		53	isr	Insurance
		57	dwe	Dwellings

While Berman, Bound, and Griliches (1994) have shown that the identifications of skilled and unskilled labour on the basis of job classification and educational attainment are quite similar,[10] it is generally acknowledged that the latter is superior. First, classifications based on educational data can easily be extended to incorporate several types of labour. As Hall (1993) observes, job classification procedures misclassify too many workers: "*many non-production workers are clerical workers, janitors, security guards, and the like, not the elite of the labour force. Many production workers have significant problem-solving roles*". Additionally, Leamer (1996) notes that "*there is a very substantial amount of wage inequality across sectors within the production and non-production categories*". Leamer (1996) also suggests that a proficient method for determining different types of labour should identify subcategories of workers with skill levels that are fairly uniform within groups and substantially different across groups. This approach is adopted here by: (a) segregating employees into one of seventy-seven minor group occupations identified by the Standard Occupational Classification (SOC), (b) collecting data on average wages and educational characteristics by occupational category, and (c) employing cluster analysis to group together similarly skilled employees.

We start with seventy-seven minor-group occupations identified by the Standard Occupational Classification (SOC). Occupations are described by two characteristics: each occupation's average wage and its average educational attainment. The 1995 Labour Force Users' Guide converts all qualifications to their National Vocational Qualification (NVQ) equivalents, which comprises six levels. These, with summaries of qualifications at each level in parentheses, are: Level 5 (higher degree), Level 4 (undergraduate degree or other post-high-school qualification), Level 3 (high school graduate or trade apprenticeship), Level 2 (GCSE or equivalent vocational training), Level 1 (high school qualifications below GCSE or equivalent vocational training), and Level 0 (no qualification). In cases where employees hold more than one qualification, individuals are classified according to the qualification that awards them the highest NVQ level.[11] The sample size is restricted to full-time employees on adult rates whose pay was not affected by absence, and wage

[10] The authors show that there is a tight fit between non-production/production and white collar/blue collar classifications and that the white collar/blue collar classification closely reflects an educational classification of college graduates/non-college graduates.

[11] Employment weighted averages of NVQ scores are calculated for each occupation to characterise educational attainment. NVQ data are collected from the 1995 Labour Force Survey (LFS) and the 1995 New Earnings Survey (NES) is used to calculate the hourly wage for each occupation.

calculations include overtime pay. Finally, as units of measurement differ across variables, the data are standardised in the interval zero to one.

The results are presented in the Appendix, which lists occupational groups, hourly wages and NVQ scores by occupation, and flags whether each occupation is manual or non-manual. The optimal number of labour types is determined following Everitt's (1993) suggestion of examining differences between fusion levels in the dendrogram.[12] When Ward's method is employed, this decision rule indicates that four distinct groups are identifiable: highly-skilled (employment share of 14.0 percent and wage bill share of 24.9 percent), skilled (21.3 and 26.9), semi-skilled (34.3 and 28.3), and unskilled (30.3 and 19.9). Using *group-average* clustering, however, the dendrogram does not identify any fusion level as being optimal; consequently, occupations in Table 4 are categorised using Ward's method.

Table 4
UK labour cost shares by sector, 1997, percent

	Highly skilled	Skilled	Semi-skilled	Unskilled
Agriculture	17.2	19.0	21.2	42.6
Skilled manufacturing	13.8	27.4	27.5	31.3
Unskilled manufacturing	8.4	17.0	30.8	43.8
Skilled services	34.8	32.9	21.8	10.5
Unskilled services	14.3	15.4	45.0	25.5

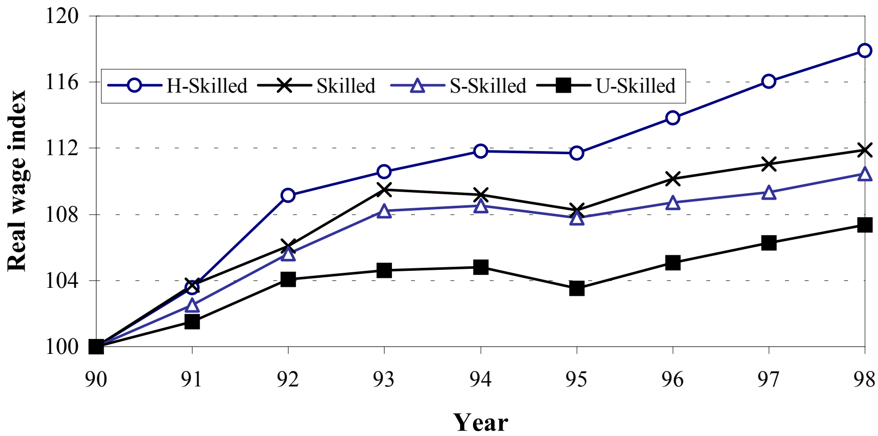
Source: New Earnings Survey (1998).

The closest existing classification to the one outlined here is that of Bound and Johnson (1992). College graduate, some college, high school graduate, and high school dropout labour categories mirror, respectively, our highly-skilled, skilled, semi-skilled, and unskilled classifications. There is, however, one exception, namely that the skilled labour category adopted here contains many individuals with college degrees. Consequently, rather than making a distinction between employees with college degrees and those with partial credit towards such qualifications, the highly-skilled and skilled classifications differentiate high achieving graduates from standard graduates.

Examining the manual/non-manual classification of each occupation across labour types (see appendix) illustrates that the two more highly skilled labour types almost exclusively consist of non-manual occupations. Mixtures of manual and non-manual occupations, however, are present in the two lesser skilled labour types. This illustrates the inadequate nature of using job classification techniques to classify skill levels, the root of which is the misclassification of several non-manual occupations, such as sales assistants and checkout operators, as skilled vocations.

Wage inequality is examined in the context of the four labour types identified by plotting the pattern of real wages by labour type over time in Figure 4. Each series is normalised so that the real wage of each labour type in 1990 is equal to 100. 1990 is the earliest year for which the series can be generated as this is the first year that the NES recorded occupations using SOC codes. Figure 4 illustrates that all labour types have experienced increases in real unit rewards and, strikingly, there is a positive relationship between skill levels and the growth of real wages. The real wage of highly-skilled labour has increased by 17.9 percent and the real unit returns to skilled, semi-skilled and unskilled labour by 11.9, 10.5 and 7.4 percent respectively. This pattern suggests that wage inequality between any pair of labour types has increased. Changes in wage inequality over the period 1980-98 are examined by employing simple regression techniques to generate 1980 backcasts for real wages by labour type.

Figure 4
Real wages by labour type, 1990-98



Source: Real wages are constructed from the *New Earnings Survey* (various years) as described in the text.

Table 5 displays proportional changes in wage ratios between 1980 and 1998. The observations suggest that there has been a substantial increase in wage inequality between

[12] A dendrogram is a two-dimensional diagram that shows which clusters are being combined and the value of the distant coefficients at each stage of the analysis. Large changes in distant coefficients are taken to indicate a particular number of clusters.

highly-skilled and all other types of labour and the rise in inequality is most severe between highly-skilled and unskilled labour, 24.6 percent. The smallest increase in relative wage ratios, just over 2.5 percent, is between skilled and semi-skilled labour, both of which experienced non-negligible growth in unit returns relative to that of unskilled labour.[13]

Table 5
Changes in wage ratios, 1980-98, percent

Numerator \ Denominator	Skilled	Semi-skilled	Unskilled
Highly-skilled	14.6	17.6	24.6
Skilled		2.6	8.7
Semi-skilled			5.9

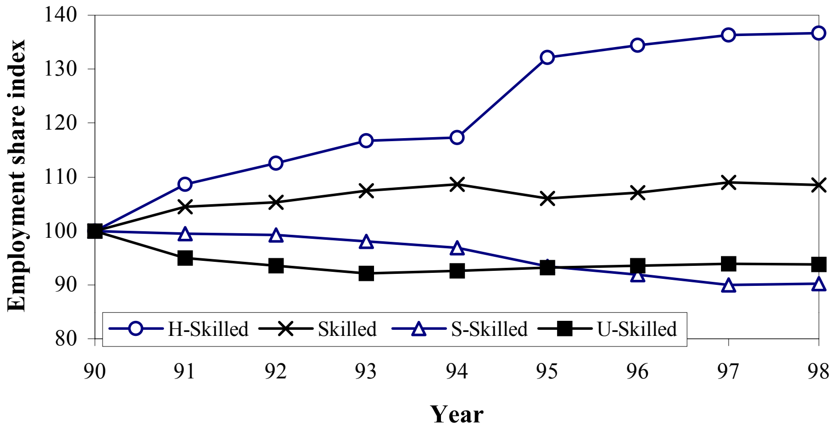
Source: Real wages in 1998 are taken from the *New Earnings Survey* and real wages in 1980 are calculated from linear backcasts.

Changes in employment shares are examined in Figure 5. The stylised fact of rising relative supplies of more skilled labour is present. What is striking, however, is the significant increase in the employment share of highly-skilled labour, 36.8 percent, compared to the modest increase in skilled labour, 8.5 percent. In contrast, employment shares for semi-skilled and unskilled have fallen by 9.8 and 6.2 percent respectively. Combined with the observations on movements in real wages, labour supply changes have profound implications for demand side influences. In the presence of relative supply changes which would, *ceteris paribus*, decease the relative return to more skilled labour, demand side influences must have favoured such workers and have been large, particularly so for highly-skilled labour.

Table 6 further summarises supply side changes by listing employment shares in 1980 and 1998. Again 1980 values are generated using regression techniques. The results indicate that the employment share of highly-skilled workers has increased by 150.9 percent, albeit from a low base. This increase has largely come at the expense of the employment share of semi-skilled labour, which has decreased by 22.2 percent.

[13] The increase in the ratio of non-manual to manual wages over the same time period is 20.4 percent (*New Earnings Survey* 1980, 1998).

Figure 5
Employment shares by labour type, 1990-98



Source: Employment shares are taken from the *New Earnings Survey* (various years) as described in the text.

Table 6
Employment shares by labour type, 1980 & 1998, percent

	1980	1998	Change (%)
Highly-skilled	5.8	14.5	150.9
Skilled	19.1	21.8	14.4
Semi-skilled	42.6	33.1	-22.2
Unskilled	32.5	30.5	-6.2

Source: Employment shares in 1998 are taken from the *New Earnings Survey* and shares in 1980 are calculated from linear backcasts.

4 DESCRIPTIVE ANALYSIS OF THE DATABASE

Sectors are summarised according to UK cost shares in Table 7, which lists factor cost shares for aggregate capital and labour, and provides the proportional contribution to each composite factor share by labour types identified in aggregation **a**. Composite shares indicate that unskilled manufacturing and skilled services are relatively intensive in aggregate labour. Analysis by labour type suggests that as a whole services are more skill-intensive than manufacturing.

Table 7
UK factor cost shares in manufacturing and services, 1997, percent

	Composite factors		**Labour**	
	Labour	Capital	Skilled	Unskilled
Agriculture	67.2	31.5	36.2	63.8
Skilled manufacturing	58.8	41.2	41.2	58.8
Unskilled manufacturing	69.5	30.5	25.4	74.6
Skilled services	78.2	21.8	67.7	32.3
Unskilled services	53.1	46.9	29.7	70.5
All sectors	65.6	33.4	52.5	47.5

Source: Aggregate capital and labour shares are calculated from the GTAP V database (Betina and McDougall, 2002).

Table 8 presents an overview of the global database and summarises production, factor endowments, trade, and GDP growth in each region. The first section indicates that the UK is a relatively small region in the world economy and that the majority of global production, approximately 72 percent, is concentrated in services and that skill-intensive production is greater than unskilled-intensive production. The relative importance of service sectors, however, varies across regions. In developed regions the GDP contribution of services is around 75 percent, whereas services account for a much smaller share of GDP in developing regions. Also, unskilled manufacturing is a larger contributor to GDP in developing economies (Rapidly Developing and Rest of World) than in developed regions (UK, Western Europe and Other Developed).

Table 8
GDP, factor cost shares, and measures of growth, percent

	United Kingdom	Western Europe	Other Developed	Rapidly Developing	Rest of World	All Regions
GDP Shares						
Agriculture	6.2	6.5	4.8	19.2	23.1	9.5
Skilled manufact.	12.7	12.9	12.4	16.0	9.4	12.3
Unskilled manufact.	5.9	7.0	5.0	11.5	9.1	6.7
Skilled services	42.1	46.2	42.5	25.1	29.5	39.8
Unskilled services	33.1	27.4	35.3	28.2	28.9	31.7
Global Share	4.5	23.6	47.2	8.0	16.8	100.0
Factor cost shares[a]						
Skilled Labour	26.1	21.6	24.3	13.4	13.3	21.1
Unskilled Labour	37.7	32.6	36.6	36.2	34.0	35.2
Capital	36.2	45.8	39.1	50.4	52.7	43.7
Trade relative to GDP[b]						
Agriculture	103.8	135.9	80.2	56.7	60.4	78.1
Skilled manufact.	246.7	278.0	124.1	335.9	216.9	202.2
Unskilled manufact.	181.9	200.4	93.3	212.3	127.8	147.3
Skilled services	20.6	18.1	8.0	31.6	21.5	14.2
Unskilled services	9.1	15.8	4.6	18.4	9.9	8.7
All sectors	60.3	71.6	28.9	102.3	55.2	50.1
GDP growth						
(1980-97)	55.0	37.8	64.3	347.0	59.3	77.5

Notes:- a: Factor cost shares are relative to value added. b: Trade is defined as the sum of exports and imports.
Source: Shares for GDP, factor costs and trade are calculated from the GTAP Version V Database (Betina and McDougall, 2002). Real GDP growth rates are GDP weighted averages from the World Bank's *World Tables* database.

The second section displays factor shares as proportions of value added. To enable comparisons across countries, unskilled and skilled labour shares are calculated using GTAP's classification of labour types (Lui *et al.*, 1998). Again, two regions are identifiable in the data. Developed regions are relatively abundant in aggregate labour while developing economies are relatively abundant in capital.[14] Moreover, approximately 40 percent of labour payments are made to skilled labour in developed regions while the corresponding figure in developing regions is less than 30 percent. Combined with the data on GDP shares, this indicates that, broadly speaking, global production follows a Heckscher-Ohlin pattern. Specifically, production in developed regions is skewed towards skilled services, and that in unskilled-labour-abundant developing regions is relatively concentrated in agriculture and unskilled manufacturing. The distribution of skilled manufacturing and unskilled services across the global economy does not follow a Heckscher-Ohlin pattern

[14] Payments to land and natural resources total one percent of value added payments in the developed region and six percent in the developing region; consequently, the figures are only slightly distorted by classifying land and natural resources as capital.

according to relative endowments of different types of labour, but is consistent with the developing regions being relatively abundant in capital.

The value of trade relative to sectoral GDP is presented in the third section of Table 8. Trade is defined as the sum of exports plus imports. Regional aggregates indicate that the Rapidly Developing economies are the most open. Sectoral aggregates show that the two manufacturing sectors are heavily traded, particularly skilled manufacturing. The final section presents changes in GDP. The figures highlight the dramatic increase in the economic size of the Rapidly Developing region.

Table 9 analyses UK trade by trading partner and sector and displays trade values, expressed as proportions of total UK trade, and proportions of trade values as net exports. Regional aggregates reveal that the majority of UK trade, around three-quarters, is with the Other Developed regions. Sectoral aggregates indicate that nearly all UK trade in skilled-manufacturing is intra-industry trade. Inter-industry trade is much larger in unskilled-manufacturing and services, where Heckscher-Ohlin production patterns are present (see above). Other evidence that trade is partially driven by factor endowments is that 20.7 percent of UK trade with developing regions is in the form of inter-industry trade compared to 8.6 percent of UK trade with other developed economies.

Table 9

UK trade shares and proportions of trade as net exports (NE)[a, b]

Sector	Western Europe		Other Developed		Rapidly Developing		Rest of World		All Regions	
	Trade	NE	Trade	NE	Trade	NE	Trade	NE	Trade	NE
Agr.	6.1	-12.6	1.5	0.7	0.6	39.4	2.5	-28.9	10.7	-11.9
S. man.	30.0	-6.9	11.5	-13.7	4.9	-16.6	5.7	56.7	52.1	-2.4
U.man.	9.3	-12.1	2.4	-3.3	2.5	-31.5	3.6	-15.5	3.6	-14.3
S. Ser.	5.7	15.7	4.7	1.7	1.5	11.2	2.5	13.1	2.5	10.2
U. Ser.	1.7	15.7	1.9	7.8	0.5	14.7	0.9	21.1	0.9	13.6
All	52.8	-5.4	22.0	-6.4	10.0	-11.4	15.2	16.2	100.0	-

Notes:- a: Trade values calculated as the summation of import plus exports, relative to total UK trade. b: Net exports are defined as exports minus imports and are expressed relative to trade values.
Source: GTAP Version V Database (Betina and McDougall, 2002).

5 MODEL PARAMETERISATION AND SIMULATION

The core GTAP5inGAMS model is modified in respect of the allocation of consumer expenditure, with a Cobb-Douglas function being used in the top level of the expenditure nest. This allows the value of government purchases and savings, which are fixed in the

GTAP5inGAMS model, to vary with income and is necessary to allow large changes in economic size to be examined.

To parameterise the model, the elasticity values describing substitution possibilities between imports and domestic commodities, and substitution between imported goods from different regions need to be specified. Elasticity parameters are calculated as commodity-weighted averages of those in the GTAP V database and are assumed to be identical in both direct and derived demand; those used are presented in Table 10.

Table 10
Elasticities of substitution in final and intermediate demand for traded goods

Sector	Between domestic goods and imports	Between imported goods by region
Agriculture	2.5	5.0
Skilled manufacturing	2.8	6.0
Unskilled manufacturing	2.9	6.0
Skilled services	2.0	3.9
Unskilled services	1.9	3.8

Source: GTAP Version V Database (Betina and McDougall, 2002).

Elasticity values indicate that substitution between products by source is greatest in manufacturing. Elasticity parameters governing substitution between imports from different regions are twice as large as those dictating substitution between aggregate imports and domestic production, which reflects the assumption that imports are more substitutable between themselves than with domestic production.

The shock applied to the two models simulates both the decrease in the UK's trade barriers and the increase in the economic size of (unskilled-labour-abundant) developing regions. This is achieved by removing observed changes in regional GDPs and controlling the value of UK imports. Regional GDPs are returned to their 1980 values, as documented in Table 8, by introducing regional-generic factor endowment multipliers, which are determined endogenously.[15] Non-tariff barriers and transport costs are subsumed into tariffs, and those and actual tariffs are then determined endogenously so as to fix UK imports at their 1980 values. This is an indirect approach to modelling the effect of reduced trade distortions. However, data on the above characteristics are scarce, whereas trade volumes are more

[15] GDP growth over the sample period is most likely a result of increased factor supplies and total factor productivity growth. From the perspective of the UK, however, the consequences of more prosperous trading partners are the same regardless of whether an increase in factor endowments or technical change is the cause of growth, as noted by Cortes and Jean (1999).

readily accessible. Disaggregated data on trade in services are also rare. In response to this constraint, and the small proportion of services trade in total UK trade, only trade in manufactured commodities is controlled in the simulation. The imposed changes in import volumes are detailed in Table 11.

Table 11
Changes in UK imports, 1980-97, percent

Sector	Western Europe	Other Developed	Rapidly Developing	Rest of World	All Regions
Agriculture	35.4	-23.2	-4.3	-48.9	-2.9
Skilled manufacturing	259.8	297.0	1624.4	317.2	303.5
Unskilled manufacturing	155.0	66.9	318.7	442.3	181.7

Source: GTAP Version V Database (Betina and McDougall, 2002).

Changes in output and trade volumes, product prices, and unit factor rewards are reported in Table 12. The domestic output price of agriculture is chosen as the *numeraire* in the model and factor prices are deflated by a consumer price index. Differences in the percentage changes between 1980 and 1997 in sectoral outputs and relative prices in the two aggregations are minimal.

Product price changes are the starting point for the Stolper-Samuelson correlation, "*there is a tendency for changes in relative commodity prices to be accompanied by increases in the rewards of factors employed most intensively by those goods whose prices have relatively risen the most and employed least intensively by those goods whose prices have fallen the most*" (Ethier, 1984, p.164). In both experiments manufacturing prices fall relative to service prices, which are more skill-intensive. In accordance with the Stolper-Samuelson correlation this results in an increase in the skill premium of 0.6 percent in the aggregation **a** simulation. Given the changes in factor supplies documented in Table 6 and the observed large increase in the skill premium, the result indicates that the effect of other demand-side influences (e.g. skill-biased technical change) on wage inequality was many times greater than the impact of trade.

Table 12
Simulated changes in UK output and trade volumes, product prices and unit factor rewards, 1980-97, percent

Change in:	Aggregation (a)	(b)
Sectoral output		
Agriculture	80.7	80.6
Skilled manufacturing	43.2	43.3

Unskilled manufacturing	41.4		41.4
Skilled services	52.7		52.6
Unskilled services	51.0		51.0
Sectoral imports			
Agriculture	-2.9		-2.9
Skilled manufacturing	303.5		303.5
Unskilled manufacturing	181.7		181.7
Skilled services	27.7		27.7
Unskilled services	26.4		26.4
Sectoral prices[a]			
Agriculture	0.0		0.0
Skilled manufacturing	-8.5		-8.5
Unskilled manufacturing	-6.0		-6.0
Skilled services	-0.1		-0.1
Unskilled services	-1.7		-1.7
Wages[b]			
w_s	1.9	w_h	2.2
w_u	1.2	w_s	1.6
w_s / w_u	0.6	w_m	1.2
		w_u	1.2
		w_h / w_u	1.0
		w_s / w_u	0.4
		w_m / w_u	0.0

Notes:- a: The domestic output price of agriculture is chosen as the *numeraire*. b: the unit return to labour type *i* (h denotes highly-skilled, s skilled, m semi-skilled, and u unskilled labour).

In the aggregation **b** simulations we find that the wage premia of highly skilled and skilled labour types relative to unskilled labour increase by 1.0 and 0.4 percent respectively, while there is little change in the semi-skilled/skilled ratio. Skilled services are highly intensive in their use of highly-skilled labour relative to all other sectors, including skilled manufacturing, and are also the most intensive user of skilled labour. Skilled and unskilled manufacturing are relatively intensive employers of unskilled labour, and are moderately intensive in their use of semi-skilled labour (see Table 4). The fall in the output prices of both manufacturing sectors should therefore, in accordance with the Stolper-Samuelson correlation, have depressed the relative wages of the unskilled and semi-skilled, while the rise in the relative price of skilled services should have increased the wage of highly skilled labour relative to all other types. Again the estimated changes in wage inequality due to trade are small relative to observed changes. We take this as further evidence exonerating trade as the main driver of increased wage inequality.

Sensitivity Analysis

In CGE simulations it is essential to examine the sensitivity of results to key parameter values. The only assumed parameter values are those for the elasticities of substitution in the Armington aggregations of imports from different sources and of imports with domestic products. Table 13 reports the effects on the wage premia of changing all Armington substitution elasticities by a common proportion.

Table 13
Simulated changes in relative wages for scaled Armington elasticities, percent

	Armington elasticities multiplier						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0
				Aggregation (a)			
w_s/w_u	0.637	0.896	1.003	1.059	1.091	1.112	1.124
				Aggregation (b)			
w_h/w_u	0.954	1.449	1.639	1.731	1.780	1.806	1.820
w_s/w_u	0.350	0.638	0.741	0.787	0.809	0.819	0.822
w_m/w_u	0.004	0.223	0.290	0.316	0.326	0.327	0.327

Note: See notes to Table 9.

In aggregation **a**, where only two types of labour are distinguished, decreasing the elasticities decreases the skilled-unskilled premium. The results are consistent with the expectation that the less substitutable are imports for each other, and the less substitutable are imports with domestic output, the lower will be the premium. Figure 6 illustrates this.

The equivalent sensitivity for aggregation **b** shows a broadly similar pattern in that the premia of the wages of other labour types relative to the unskilled wage decrease as the Armington elasticities decrease. However, as Figure 7 shows, the impact is most marked for the highly-skilled premium. Both sets of simulations indicate that our conclusions are robust to alternative elasticities of substitution in the Armington aggregations.

Figure 6
Changes in the relative wage of skilled labour in aggregation (a)

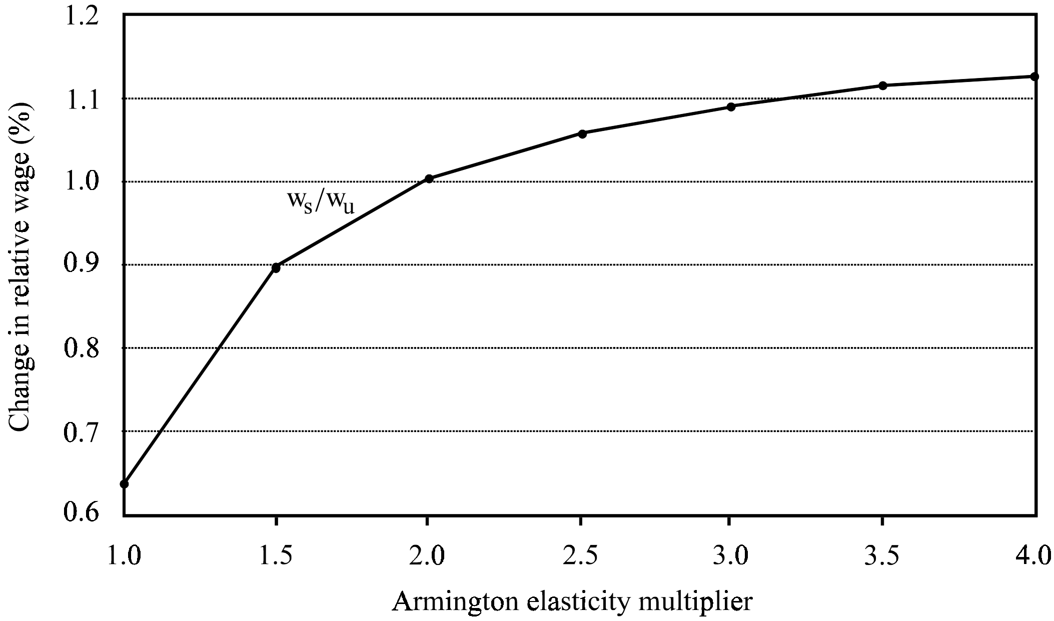
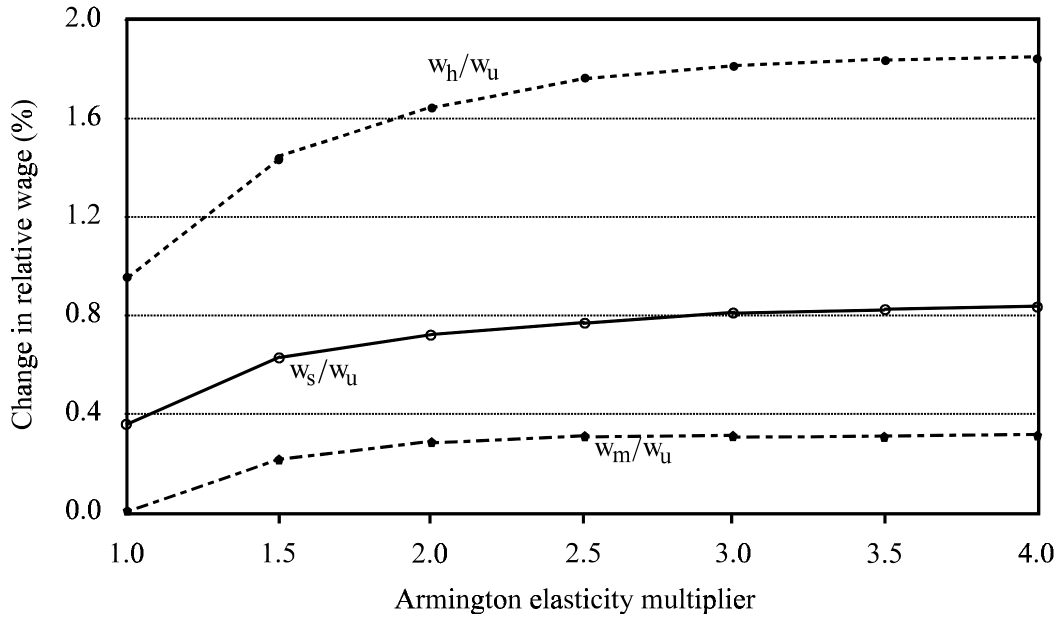


Figure 7
Changes in the relative wages in aggregation (b)



6 CONCLUSIONS

This paper has outlined the construction of a global, small-scale CGE model with two different labour-type aggregations. The simpler aggregation was a skilled-unskilled division, such as has commonly been used in analyses of the link between trade and wages.

This was, for the UK data, itself an aggregation of four labour types (highly skilled, skilled, semi-skilled and unskilled). Both variants of the model were subjected to a shock that backcast the model to 1980 values of regional GDPs and UK imports.

Results from our simulations with the smaller labour aggregation are consistent with econometric results that trade has played a relatively minor role in driving the observed increase in the skilled wage premium. The simulation with the larger aggregation is also consistent with this conclusion in that all wages increase relative to the wage of the least skilled workers. Moreover, there is a consistent pattern, with the wage of the highly-skilled rising relative to that of the skilled, as does that of the skilled relative to that of the semi-skilled, and the wage of the semi-skilled to that of the unskilled. In all simulations we were able to reconcile changes in wages with Stolper-Samuelson predictions. Neither set of results casts doubt on the consensus that trade has had a relatively modest role to play in explaining increasing wage inequality in the UK over the last two decades of the twentieth century.

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Appendix

Classification of Occupations

SOC code	Occupation	Manual/ Non-Manual	Wage (£ / hour)	NVQ score
	Highly-skilled		15.07	3.67
10	General managers in government & large companies	NM	16.73	3.30
12	Specialist managers	NM	19.93	3.28
15	Protective service officers	NM	14.97	3.35
20	Natural scientists	NM	12.58	4.18
22	Health professionals	NM	16.95	4.19
23	Teaching professionals	NM	14.04	4.18
24	Legal professionals	NM	15.41	4.07
25	Business & financial professionals	NM	13.76	3.61
33	Ship & aircraft officers, air traffic controllers	NM	15.08	3.08
36	Business & financial associate professionals	NM	15.70	3.15
	Skilled		10.69	3.30
11	Production managers in manufacturing etc	NM	12.67	3.15
13	Financial institution & office managers etc	NM	12.16	2.90
19	Managers & administrators nec	NM	12.74	2.99
21	Engineers & technologists	NM	12.14	3.59
26	Architects, town planners & surveyors	NM	11.86	3.85
27	Librarians & related professionals	NM	10.31	4.14
29	Professional occupations nec	NM	9.21	3.57
30	Scientific technicians	NM	8.46	3.16
31	Draughtspersons, quantity & other surveyors	NM	9.29	3.50
32	Computer analysts/programmers	NM	11.52	3.48
34	Health associate professionals	NM	8.82	3.84
35	Legal associate professionals	NM	11.64	3.26
37	Social welfare associate professionals	NM	7.81	3.26
38	Literary, artistic & sports professionals	NM	11.11	3.32
39	Associate professional & technical occupations	NM	9.30	3.13
61	Security & protective service occupations	M	8.83	3.11
	Semi-skilled		7.01	2.67
14	Managers in transport & storing	NM	10.12	2.59
17	Managers & proprietors in service industries	NM	8.42	2.49
40	Administrative/clerical officers & assistants	NM	6.15	2.67
41	Numerical clerks & cashiers	NM	6.87	2.64
42	Filing & records clerks	NM	6.21	2.75
43	Clerks (not otherwise specified)	NM	5.91	2.68
45	Secretaries, personal assistants etc	NM	6.88	2.85
49	Clerical & secretarial occupations nec	NM	7.12	2.73
51	Metal machining & instrument making trades	M	7.83	2.52
52	Electrical/electronic trades	M	7.93	2.76
53	Metal forming, welding & related trades	M	7.11	2.45
54	Vehicle trades	M	6.16	2.54
57	Woodworking trades	M	6.12	2.53
63	Travel attendants & related occupations	M	7.05	2.82
70	Buyers, brokers & related agents	NM	9.90	2.82
71	Sales representatives	NM	9.26	2.75
87	Road transport operatives	M	5.48	2.82
88	Other transport & machinery operatives	M	6.73	2.76

Continued

Classification of Occupations (continued)

SOC code	Occupation	Manual/ Non-Manual	Wage (£ / hour)	NVQ score
	Unskilled		5.75	2.14
16	Managers in farming, forestry & fishing	NM	7.83	1.82
44	Stores & despatch clerks, storekeepers	NM	5.75	2.36
46	Receptionists, telephonists and related occupations	NM	5.42	2.46
50	Construction trades	M	6.14	2.17
55	Textiles, garments and related trades	M	4.90	1.52
56	Printing and related trades	M	7.40	2.31
58	Food preparation trades	M	4.92	2.33
59	Other craft and related occupations	M	5.84	2.28
62	Catering occupations	M	4.48	2.41
64	Health and related occupations	M	5.13	2.46
65	Childcare and related occupations	M	4.13	2.77
66	Hairdressers, beauticians and related occupations	M	3.83	2.53
67	Domestic staff and related occupations	M	4.94	1.54
69	Personal and protective service occupations nec	M	5.28	2.45
72	Sales assistants and checkout operators	NM	4.44	2.33
73	Mobile, market and door-to-door salespersons	NM	6.41	2.29
79	Sales occupations nec	NM	5.95	2.26
80	Food, drink and tobacco process operatives	M	5.86	2.09
81	Textiles and tannery process operatives	M	5.33	1.81
82	Chemicals, paper, plastics and related operatives	M	7.16	2.20
83	Metal making and treating process operatives	M	7.10	1.95
84	Metal working process operatives	M	6.23	1.99
85	Assemblers/line workers	M	5.82	1.93
86	Other routine process operatives	M	5.71	2.03
89	Plant and machine operatives nec	M	7.01	2.30
90	Other occupations in agriculture, forestry and fishing	M	4.78	2.15
91	Other occupations in mining and manufacturing	M	5.69	2.17
92	Other occupations in construction	M	5.77	1.88
93	Other occupations in transport	M	5.84	2.15
94	Other occupations communications	M	6.25	1.98
95	Other occupations in sales and services	M	4.32	1.75
99	Other occupations nec	M	5.09	1.84

Source: Wages are calculated from the New Earnings survey and NVQ scores are taken from the Labour Force Survey, both in 1995.