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by T. Huw Edward and Matthias Lücke

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JEL classification: C68, F16, O4
Keywords: general equilibrium, wage inequality, trade, growth

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Abstract

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1 Introduction

In this paper, we set out to integrate the economic analysis of growth and wage decomposition, by use of a double-calibrated computable general equilibrium (CGE) model. In particular, we focus on the developments in the United Kingdom over the period 1979-2000: a time during which, perhaps more than any other advanced economy barring the United States, the UK experienced a radical economic liberalisation and deregulation in the face of advancing globalisation, seemingly trading off a substantial rise in inequality in return for an improved relative growth performance, compared to her European neighbours (Crafts, 2011).

We wish to examine to what extent this trade-off was real - at least, within the limits of what a neoclassically-based analysis can tell us. To this end, the layout of the paper is as follows: Section 2 provides a brief review and comparison of decomposition techniques for economic growth and for inequality. Section 3 outlines the general equilibrium decomposition approach, and the use of double calibration in decomposition analysis. In Section 4 we outline the decomposition procedure. Section 5 summarises and compares the decompositions of growth and inequality, based upon the same model and dataset. In Section 6 we conclude.

2 Traditions of Decomposition analysis

Decomposition analysis is where an observed change in a variable (or set of variables) is broken down according to the contributions of a number of putative causal factors. Usually such a decomposition is expected to be additive - in other words, either the contributions of all the various factors are determined in such a way as to sum to unity, or the residual term is attributed to an interaction of the various factors. The decomposition can be carried out either by non-parametric or by parametric means. Non-parametric decomposition is a method of index calculation, such as devising related indices of output, productivity, inputs and inflation in an economy over a period of time. Such methods do not require the assumption of any particular functional forms (other than some very broad assumptions, as will be shown in section 2.2 below). However, there are well-known index number problems (De Boer, 2008), in which the order of calculation affects the decomposition. These are usually reduced, though rarely totally eliminated, by rebasing indices at regular, short intervals.

Parametric decompositions involve the assumption of a model form. These can often be multi-equation models, either estimated econometrically or using calibrated parameters derived from the literature. Parametric decompositions can handle more complex chains of causality (for example, the ‘explanation’ of changing wage inequality in an open economy), but are clearly dependent upon the accuracy of the assumed model and the validity of the assumed or estimated functional forms. Decompositions with calibrated models usually carry a series of sensitivity analyses, in order to test robustness to parameter values. We should also add: while carrying out a decomposition of a change over time using a parametric model does not require regular rebasing (and so can be carried out with just starting and end-year datasets), there is still an index number problem, in the sense that the order of calculation will affect the estimated decomposition. For this reason, some general equilibrium analyses (Kose and Reizman, 2000, Edwards and Whalley, 2007) carry out decompositions breaking down the changes in causal factor values into small steps, and simulating counterfactuals in a series of loops, from the starting to the end year values.

2.1 Decomposing economic growth by nonparametric and parametric means

We turn first to the traditional use of decomposition analysis to 'explain' observed growth of output and productivity. Such analysis is usually carried out on an aggregate level for a whole economy (or alternatively for a single industry within an economy) and, as such, is relatively amenable to the parametric, growth accounting methodology. Although this has its origins in Solow's (1957) analysis, there is an important difference when it comes to decomposition, which will be instructive for our subsequent discussion. Solow treats aggregate output as the product of an aggregate production function

$$Y = Y(U, S, K, \tau), \tag{1}$$

where U, S and K are unskilled and skilled labour and capital inputs respectively and τ represents total factor productivity. Assuming perfect competition and constant returns to scale, and abstracting from distortions such as taxation, externalities and spillovers, we can assume factors are paid the value of their marginal products. With this assumption, and totally differentiating (1), we find

$$P\partial Y = Wu\partial U + Ws\partial S + r\partial K + \partial\tau, \tag{2}$$

where Wu and Ws are unskilled and skilled wages, and r is the profit rate, which should be equated to interest rates after account is taken of risk.

Data for estimating (2) are available for many countries over many years. $\partial U, \partial S$ and ∂K can be approximated by differencing appropriately discounted factor stock estimates from the national income accounts. For example, Bank of England estimates suggest TFP growth of around 2% per annum in the early 1990s, falling to perhaps 1.5% in the late 1990s (Groth et al, 2004). One advantage of this method is that no assumption (other than homogeneity of degree one) is required for the aggregate production function.[1] It provides us, critically, with an estimate of the Solow residual, τ, and decompositions of growth into the contributions from changes in the quantities employed of each factor.

An objection is that growth accounting treats factor accumulation as exogenous, in direct contrast to Solow's (1957) original approach, in which capital stock per head is a dynamic function of the savings and depreciation

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[1] There is, however, an issue of measurement of capital - see Jorgenson and Griliches (1967) and Oulton (2007). Capital stock weights older capital too highly: a capital services measure is more appropriate.

rates and technological progress. For example, if we assume (1) is of Cobb-Douglas form, so that

$$Y_t = \tau_t U_t^{\alpha u} S_t^{\alpha s} K_t^{1-\alpha u-\alpha s}, \tag{3}$$

then in equilibrium, equating depreciation to savings yields

$$\delta K_t^* = sY_t^* \Longrightarrow Y_t^* = \tau_t^{\frac{1}{\alpha u+\alpha s}} U_t^{\frac{\alpha u}{\alpha u+\alpha s}} S_t^{\frac{\alpha s}{\alpha u+\alpha s}} (\frac{s}{\delta})^{\frac{1-\alpha u-\alpha s}{\alpha u+\alpha s}}. \tag{4}$$

Taking logs and assuming exogenous growth rates for τ, U_t and S_t, it is not difficult to derive an equilibrium time-path for Y_t. One can also endogenise skills acquisition and savings rates by applying a life-cycle model. If the functional form assumed is correct, then the Solow residual, τ_t, should be the same as that calculated by growth accounting: however, its contribution to growth is larger than in the growth accounting model by a factor of $\frac{1}{\alpha u+\alpha s}$. In many ways this latter model is more economically meaningful: however,it does require a parametric estimation (or calibration), and is therefore sensitive to accuracy of assumed functional forms.

2.2 Decompositions of changing wage inequality

Wage inequality has increased greatly in the Anglo-Saxon economies since the end of the 1970s, triggering a debate on causal factors. Data for the UK, for example, show a 30% widening in the pay differential between the highest and lowest deciles. The situation for the USA is, in some ways, even more serious, since living standards for the middle classes have stagnated and those for the poor have fallen since the 1970s (c.f. Krugman, 2007, for discussion of the US case). The literature on this is sizeable, and has generated considerable controversy, with blame being attributed solely or partly, variously, to rising import volumes from developing countries (Wood,1994), falling trade prices (Leamer, 1998), skill-biased technical change (numerous studies), unskilled migration, sector-biased technical change favouring skill-intensive industries (Haskel and Slaughter, 2001, 2002), falling capital prices combined with capital-skill complementarity (Krusell et al, 2000, Winchester and Greenaway, 2007) and outsourcing (Anderton and Brenton, 1999, Feenstra and Hanson, 2001).

Decomposition analysis in this case is reliant upon parametric models, though these vary considerably, with some being single-equation estimated models, while studies utilise multi-equation calibrated models. There are three main decomposition methodologies. First, a number of studies (Borjas et al., 1991; Murphy and Welch, 1991; Katz and Murphy, 1992; Wood, 1994) have simply fallen back on an aggregate macroeconomic production function with fairly *ad hoc* adjustments for job displacement. This factor contents approach involves, first, deriving the changes in net imports by sector, secondly weighting these by skilled and unskilled employment. Thirdly, these are then combined with a single sector aggregate production function to estimate aggregate skilled and unskilled labour demand curves and then derive the changes in market clearing wages. Having made these estimates for the contribution of 'trade', the contribution of the other major factor, 'technology', is usually derived by residual (reflecting a lack of specific data), although some studies have also paid attention to demographics and immigration.

The second major approach has, at first sight, a stronger theoretical foundation, based upon Stolper and Samuelson (1941). Given the correct information on the structure of an economy, it is in principle possible to develop a reduced form equation for the relationship between relative prices and relative wages. This makes possible the estimation of a 'mandated wages' equation (e.g. Lawrence and Slaughter, 1993; Baldwin and Cain, 2000; Leamer, 1998; Harrigan and Baliban, 1999). This typically assumes a two-sector (skill-intensive and unskilled-intensive) economy. Goods are homogeneous, so prices are set on World markets. Technology is common across countries. Factors (and we typically assume there are just two) are perfectly mobile within national borders, but fixed at a national level. In these circumstances, as long as the economy lies within its cone of diversification, then factor prices are simply a function of World traded prices. For example, in a two-factor CES model, where output of sector i,

$$Y_i = A_i(\beta_i U_i^{\frac{\sigma-1}{\sigma}} + (1-\beta_i) S_i^{\frac{\sigma-1}{\sigma}})^{\frac{1-\sigma}{\sigma}}, \tag{5}$$

then we can derive a mandated labour demand equation. This is most easily evaluated at the point where the price of the unskilled-intensive good (labelled P_M, as we are concentrating on advanced countries where unskilled-intensive goods are net imports), $P_M = P_X = 1$, in which case

$$\frac{\partial \ln \phi}{\partial \ln P_M} = \frac{{\beta_X}^{\sigma}}{{\beta_X}^{\sigma} - {\beta_M}^{\sigma}} - \frac{(1-\beta_X)^{\sigma}}{(1-\beta_X)^{\sigma} - (1-\beta_M)^{\sigma}}, \tag{6}$$

where $\phi = \frac{W_s}{W_u}$. Since $\beta_M > \beta_X$, $\frac{\partial \ln \phi}{\partial \ln P_M}$ is negative. If initial factor intensities are very close together ($\beta_M - \beta_X \longrightarrow 0$), the elasticity will tend towards infinity. As σ tends to zero, $\frac{\partial \ln \phi}{\partial \ln P_M}$ tends to infinity.

The mandated wages equation can be estimated by time-series or panel methods. Since most published data on traded goods prices shows relatively little movement over time, the conclusion of most of these studies has been that mandated wages could not have changed, so that technological factors were primarily responsible for rising inequality. Mandated wages studies by Haskel and Slaughter (2001 and 2002) which, interestingly, used different rates of computerisation by sector rather than traded prices as drivers, found similar results.

2.3 The rationale for multi-equation methods

The third method for trade-wages decomposition is to use a multi-equation model - either estimated or calibrated. To understand why such models have become popular, it is worth reviewing the reduced form, mandated wages model in (5) and (6). When $\ln \phi$ is regressed upon $\ln P_M$, we derive a coefficient for the mandated wages model, which can then be used in attributing some of the change in wages to World traded prices. The first problem is that share parameters.β_X and β_X are very likely changing over time, so that regression techniques may find it difficult to distinguish between the effects of a steady change in terms of trade or biased technical progress. Hence there is an identification problem. There may also be a specification problem, in the sense that the assumed Heckscher-Ohlin formulation may not accurately reflect the open economy. In fact, we know this must be the case, since we can observe the presence of non-tradable goods, two-way trade within industries and differences in goods prices from different source countries. Prices are typically much lower for goods in the same class coming from poorer nations. This implies goods are differentiated. And while there is little evidence of import prices for a particular class of goods from a particular country changing greatly in relative terms (Neven and Wyplosz, 1996), the share of these unskilled-intensive goods from poorer countries has risen sharply over the years. When correction is made for this, the assumption that prices of unskilled-intensive imports have been constant has to be abandoned or modified.

Ironically, once the use of near-constant prices is removed, a second problem emerges for Heckscher-Ohlin-based models: they are very difficult to reconcile simultaneously with both price/wage and output data. This problem is illustrated in *Figure 1, below*, which compares the effect of a global price shock in a Heckscher-Ohlin economy, based on alternative elasticity assumptions.

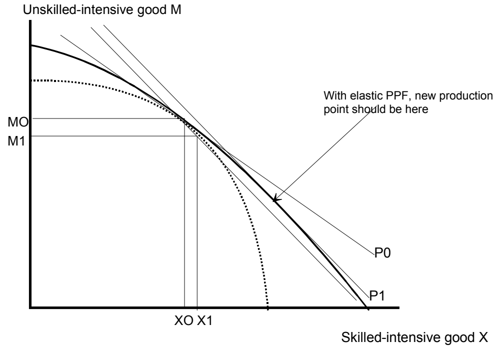


Figure 1: observed output response to price shock

The solid PPF is based upon a relatively high assumed elasticity of substitution between factors in production, σ. In this case, following equation (6), the response of wages to a price shock is relatively modest. However, since factor intensities can change easily in this flexible economy, we would expect to see a large shift in production across sectors. This is not consistent with what we observe in reality, which is a move from (X_0, M_0) to (X_1, M_1). By only examining the wage/price relationship, single equation studies usually miss this important cross-check: whether the implied changes in other variables are actually consistent with the model.

The dashed PPF is more consistent with the relatively modest changes in the structure of output seen in most advanced economies. However, in this case, the implied value of σ must be low, implying that relative wages should be more responsive to prices than single-equation estimated models indicate. The apparent contradiction could, in theory, be resolved if some other factor were changing: for example, if the change in unskilled-intensive goods prices were offset by faster technical progress in that sector. The trouble is, studies such as Haskel and Slaughter (2001 and 2002) indicate that technical progress is faster in the other, skilled-intensive sector. Hence the model again does not seem to fit.

The implications of this rather brief discussion are that the supposed theoretical advantages of the single-equation, mandated wages models are illusory. Two important modifications are needed for a general-equilibrium based analysis to be plausible: first, the abandonment of the assumption of homogeneity of domestic and imported goods (Abrego and Whalley, 2003), and, secondly, the restriction of factor mobility (Edwards and Whalley, 2007). Both of these approaches dilute the impact of a price shock: in the first case, because a fall in the traded price of a good need not be fully reflected in domestic prices. In the second case, Jones' (1967) factor price magnification effect is damped by factor specificity (Neary, 1978). Both modifications require more explicit, multisectoral models.

3 Calibrated Computable General Equilibrium Approaches to Decomposition Analysis

As an alternative to the single reduced-form estimation techniques discussed above, computable general equilibrium (CGE) techniques set out a much more disaggregated, multi-equation model, usually calibrated rather than estimated. The use of calibrated models is discussed in detail in Dawkins *et al* (2001). Calibration is a limited technique, in that it is reliant upon the use of 'plausible' parameter estimates pooled from elsewhere in the literature. The simulations of such models are rarely testable statistically, but their qualitative properties and stability are testable by sensitivity analysis. The other side is that calibrated models can be larger than econometrically-estimated models, and can ensure consistency and be restricted to ensure plausibility across a variety of properties - something which avoids the problem of single-equation mandated wages equations, discussed in the preceding section, which may fit well with observed wage changes, but have implausible implications for output and employment changes. The use of a CGE framework cannot necessarily rule out structures which behave implausibly - but this kind of problem is more likely to become apparent during the processes of calibration and simulation. The calibration technique also allows for the use of estimated parameters from a variety of studies (macro- or microeconometric and others). However, the fact that a CGE model has to be calibrated to data on employment, prices, trade, wages, output and incomes, for several sectors and factors, means that data requirements are large (and simplifications and data adjustments need to be made to the Social Accounting Matrix (SAM), in order to ensure consistency with the assumed model structure.

3.1 Double-calibrated models for decomposition analysis

Most CGE studies are calibrated to a single year's social accounting matrix. The normal procedure is to make sufficient restrictions to the model (in the form of key parameter assumptions, such as elasticities) to ensure that there is the same number of unidentified parameters as data points in the model, which in turn equal the number of independent equations to be solved. We then have an invertible matrix, which yields exact calibration of the parameters for that year. Such parameters include technological efficiency and share parameters for each sector in the database.

It is not difficult to extend this procedure to cover a start and an end year. In this case, social accounting matrices are constructed for both years, using consistent data definitions. The same model can be calibrated separately to each year, yielding a set of parameters in each case. This will give exact identification of scale and share parameters in production and consumption for all sectors, as before, subject to the assumed model structure and elasticity assumptions being 'correct'. Alternatively, one might wish to trade off restrictions across the two years for fewer assumptions about elasticity or other parameters within each year: for example, one could hypothetically fix the share parameters in one industry, in return for making a substitution elasticity endogenous. Either approach is possible.

Decomposition then consists of running counterfactual simulations of the model, gradually changing calibrated technological and other parameters one by one from their starting to their end values. Since, when we have changed all parameters from their starting to their final values, the CGE will replicate the final year dataset (to which it was calibrated), we have a useful tool for simultaneously decomposing the changes in all the variables in the microconsistent dataset. This includes distribution, sectoral composition of output, trade volumes, GDP growth, employment and many more variables. Hence we have an integrated decomposition model covering a wide variety of economic variables.

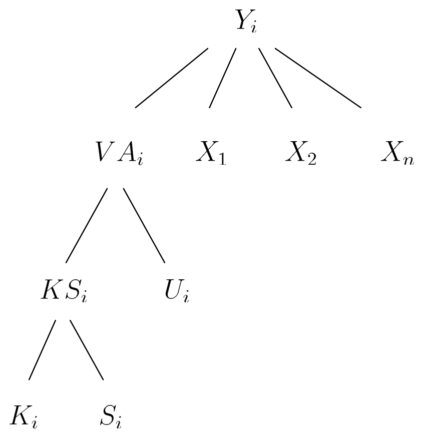
3.2 The Model

Having established the principles of a double-calibrated CGE model, we now wish to extend these to a more general model, particularly focused on separating out the effects of technological progress, capital cheapening and increasing unskilled-intensive exports upon wage inequality and growth. As explained above, this type of analysis properly requires an explicitly multi-sectoral model. Given the increasing emphasis on the role of imported intermediates (Feenstra and Hanson, 1996), a SAM incorporating intermediates is important. In addition, due to the potential 'over-flexibility' of the Heckscher-Ohlin model (as discussed in Section 2.2 above), we modify this approach, using relatively 'conservative' assumptions on trade structure - for example, the Armington assumption of imperfect substitution between national products (following Abrego and Whalley, 2003) and imperfect intersectoral mobility of labour (Edwards and Whalley, 2007). These seem more consistent with observed data (Edwards and Whalley, 2007), avoiding the extreme sensitivity of the trade price/factor price magnification effect observed in other models.

We examine the change in wage inequality between skilled (white-collar) and unskilled workers in the United Kingdom between 1979 and 2000: a period in which the skilled/unskilled wage differential jumped from 48.5% to over 60%. To carry out this decomposition, we set up a relatively schematic general equilibrium model, employing two types of labour, S and U, capital, K, and land, D. No factors are internationally mobile. S and K are fully mobile between sectors (given the gap of 21 years over which the calibration is being carried out). U is only partially mobile between sectors, as in Edwards and Whalley (2007). Land, D, is only employed in one sector, and is sectorally immobile and permanently fixed.

The model has four production sectors, E, which is the exportable goods sector, and is relatively skill-intensive, M, the import-competing sector, which is unskilled-intensive, N, the (relatively) nontradable parts of the services sector, which tend in the UK to be relatively skilled-intensive, and F, a sector covering farming and fuels, which employs relatively little labour, but which was disaggregated from the other sectors due to the large fall in its relative price over the period.

As in Krusell et al's (2000) econometric study, we assume that skilled labour and capital are complements in production (an assumption justified by many econometric studies, following Griliches, 1969), but that they are substitutes for the other factors (unskilled labour and land). This is achieved by employing a nested CES production function structure, with the lower level of the nest (elasticity of substitution < 1) aggregating capital and skill, and the higher level then (elasticity of substitution > 1) combining them with the other factors. Intermediate inputs are also incorporated into the production function structure, using Leontief fixed input-output coefficients.



$$Y_i = VA_i/\alpha_{va_i}$$

$$VA_i = A_{va,i}(\beta_{ks_i} KS_i^{\rho_{va}} + \beta_{u_i} U_i^{\rho_{va}})^{1/\rho_{va}}$$

$$KS_i = A_{ks,i}(\beta_{s_i} S_i^{\rho_{ks}} + \beta_{k_i} K_i^{\rho_{ks}})^{1/\rho_{ks}}$$

$$\rho = (\sigma - 1)/\sigma$$

Figure 2: production structure of the nested CES model.

Trade conforms to the Armington (1969) assumption, where domestic goods are combined with imports from a variety of sources in a CES aggregation. Elasticities are subject to sensitivity analysis.

3.3 The microconsistent database

Sectors with a stronger relative employment of manual workers are classified as unskilled sectors. Data for these calculations stems from the monthly publication Labour Market Trends by UK statistics (2003). 14 out of 48 sectors have been identified as non-tradable, because their import-export to output ratios are less than or equal to 11 per cent in 2000. Note that this boundary of 11 per cent is arbitrarily chosen, though other authors have used similar cut-off points (Pavcnik (2002) uses 15%). Due to price volatility, we aggregate primary sectors (i.e. agriculture, mining and quarrying of energy-generating resources, and electricity, gas, and water supply) separately.

For **wage calculations**, we take into account possible differences in the hours worked by the two groups of workers, U and S[2].

Price indices for each sector are calculated from OECD STAN database, using a chain Laspeyres weighting. Setting 1982=100, our calculated indices for 2000 are: M=97.9, E=91.0, N=117.6, F=60.4. Note that we cannot obtain good-quality price series for years prior to 1982, due to changes in puiblished data series.

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[2] Note that we use non-manual and manual as proxies for skilled and unskilled labour, respectively. We are well aware that usage of these crude types is imperfect as it does not necessarily reflect the actual skills of a worker. In fact, non-manual workers usually the type of workers found in the service sectors, while it is hard to believe that all of them are skilled (think e.g. of cleaning personnel). The principal problem here is data availability for the early years.

3.4 Share and scale parameters.

In calibrating the production function, an important aspect is to allow an accurate decomposition between factor- and sector-bias effects. We define these as follows.

Definition 1 *Pure factor bias is a change in parameters such that, for a given set of factor input prices, the relative inputs of some factors increase while others decrease, in such a way that the overall unit production cost of output is unchanged.*

Definition 2 *Pure sector bias is a change in parameters which changes the relative production costs of different sectors without altering the ratio of inputs (at given input prices) within any sector.*

These definitions raise some important issues in the case of a CES production function. As an illustration, the CES zero profit condition yields a price

$$Pi = (\frac{1}{A_i})[\beta u_i^{\frac{1}{1-\rho}} wu_i^{\frac{\rho}{\rho-1}} + (1-\beta u_i)^{\frac{1}{1-\rho}} ws_i^{\frac{\rho}{\rho-1}}]^{\frac{\rho-1}{\rho}}. \tag{7}$$

Also that the ratio of factor inputs

$$\frac{U_i}{S_i} = (\frac{\beta u_i}{1-\beta u_i})^{\frac{1}{1-\rho}} [\frac{ws_i}{wu_i}]^{\frac{1}{1-\rho}}, \tag{8}$$

which is the constant elasticity of substitution property. Straightaway, from inspecting (7) and (8), we can see that a change in A_i affects sector prices, but does not affect the ratio of inputs: hence A_i has a sector-bias, but not a factor-biased effect, and is Hicks-neutral.

By contrast, from inspecting (8), βu_i clearly has a factor-biased effect. However, differentiating (8) with respect to βu_i, it can be shown[3] that $\frac{\partial Pi}{\partial \beta u_i} = 0$ if and only if $U_i = S_i$.Otherwise, the change in βu_i will have both sector- and factor-biased effects, and if the rise in βu_i increases the input (per unit output) of the more intensively-used factor, then it will be cost-increasing.

Over a 21 year period, share parameter shifts are sufficiently large that they can significantly affect distribution, causing a significant overestimate of the effect of factor bias on increasing inequality in the UK, offset by an essentially spurious 'sector-bias' effect in the opposite direction. This is corrected using a two-step procedure.[4]

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[3] Proof available from the authors on request.

[4] Details available on request.

4 The Decompositions

We carry out our decompositions, based upon a number of elasticity scenarios, utilising two main decompositional methods. The first is that used by Edwards and Whalley (2007), which is, in turn, based upon Kose and Riezman (1999). This is a looping procedure, designed to address the 'index-number' problem which bedevils decomposition analysis: since there are potentially sizeable interaction effects between the various causal factors.

We compare decompositions carried out in three elasticity 'scenarios':

Scenario/elasticities	capital/skill	capital-skill/other factors	Armington trade
Low elasticity	0.5	1.1	2.5
High elasticity	0.67	1.5	5
Mixed elasticity	0.5	1.1	5

4.1 The various explanatory factors

1. Capital cheapening, combined with capital-skill complementarity. Capital goods in the UK have become much cheaper since the late 1970s: in fact, Bank of England studies (Bakhshi and Thompson (2002), Baumann and Price (2007)) indicate a near halving of the business investment deflator compared to the GDP deflator, and a share rise, starting around 1983, in the business investment/GDP ratio in constant 1995 prices. The causes of this can be split about equally into a fall in the relative price of investment goods - reflecting both technical progress in producing investment goods and the effects of a strong pound in the later part of our period - and a reduction in real interest rates and equity risk premia (as well as some benefits from credit market liberalisation). As a rough proxy for this, we have assumed a 50% fall in the real cost of capital goods to industry over the period concerned, consisting of a 30% fall in the cost of producing investment goods and a roughly similar drop in the financial cost of capital.

2. Trade. While ideally we would like to model trade in terms of international trade prices (as Abrego and Whalley (1999) and Edwards and Whalley (2007) did, using data from Neven and Wyplosz (1996)), in practice there are difficulties, both in obtaining reliable price data and of adjusting for differences in quality and changes in trading costs and potential product variety across countries. For this reason, in this study we have used made use of the Armington approach to modelling trade, so that changes in price, quality, variety and search costs for trade partners are effectively incorporated as shifts in the trade share parameter. Changes in net exports by sector are shown below:

per cent	**Year**	**M**	**E**	**N**	**F**
Net exports/GDP	**1979**	-1.47	1.68	1.36	-2.04
	2000	-1.87	0.50	-0.01	0.25

The observed trade patterns are probably not consistent with a Heckscher-Ohlin trade model, where specialisation would be expected to be much more dramatic. In an Armington setup the sensitivity of local incomes to World traded prices is more damped. One other point to mention on trade: the UK moved from a trade surplus in 1979 to a deficit in 2000, which may have benefited wages.

3. Changes in consumer preferences

We have modelled consumer preferences with a Cobb-Douglas utility function, so that changes in expenditure shares over time will be reflected in changes in share parameters. Over time, nontradables (which in the UK are relatively skill-intensive) have been increasing, while import-competing goods have declined.

per cent	**Year**	**M**	**E**	**N**	**F**
Consumer expenditure shares	**1979**	28.32	22.84	48.23	0.62
	2000	19.18	21.51	57.11	1.59

4. Factor-biased technical progress.

The scale and share parameters are calibrated to ensure the production functions ‘fit’ after all the other causal factors (such as changes in demand and prices) have been taken into account. It should be noted that technology is still being treated as a residual in this calibration. The main advantages over residuals derived from reduced form econometric estimation are i) that we are able to consider more complicated (and realistic) functional formulations and ii) we are testing the consistency of the entire model against data, not just the few variables which appear in a reduced form equation.

The following table shows the shifts in calibrated share parameters at the lower level ($\beta s/\beta kg$) and the higher level ($\beta ks/\beta u$) in our low elasticity case. In all sectors, there has been a shift in share parameters towards using more of the capital/skill aggregate (ks) rather than unskilled labour, but that, within that aggregate, there has been a shift towards using more capital relative to skilled labour, so the net effect on skilled/unskilled demand is not immediately apparent.

Factor shares	**per cent**	**M**	**E**	**N**	**F**
$\frac{\beta s}{\beta kg}$ (low elas)	1979	1.87	2.15	3.04	0.21
	2000	1.80	1.48	1.08	0.07
	Shift favours skilled?	N	N	N	N
$\frac{\beta ks}{\beta u}$	1979	66.35	68.35	217.55	138.11
	2000	117.79	248.43	415.76	394.10
	Shift favours skilled	Y	Y	Y	Y

5. Sector-biased technical progress.

The shift in consumer spending towards nontradable goods, and the rising share of imports among import-competing sectors both favour skilled rather than unskilled labour. So does the cheapening of capital, since skill-intensive sectors also tend to be more capital-intensive. Nevertheless, there is relatively little evidence of any extra sector-bias coming from technical progress.

Changes in calibrated scale parameters		**M**	**E**	**N**	**F**
Lower level	**1979**	0.54	0.58	0.69	0.25
	2000	0.49	0.44	0.37	0.12
	Change	-0.05	-0.14	-0.32	-0.12
Higher level	**1979**	4.94	2.93	2.90	4.55
	2000	4.34	2.94	2.20	3.33
	Change	-0.60	-0.02	-0.70	-1.22

Concentrating on the higher-level scale parameter, there seems to have been considerable TFP growth in fuels, nontradables and (perhaps surprisingly) import-competing sectors, but none in the exportable sector. The progress in the importable sector may reflect firm-selection effects: as the sector has declined, inefficient firms or plants have been weeded out, raising overal TFP. Importables, fuels nontradable sectors may all have gained in productivity from the removal of subsidies during the 1980s. By contrast, the growth in labour productivity in our exportable sector seems to be explained in terms of rising capital inputs, rather than TFP.

6. Labour supply changes

Using our blue-collar/white-collar definitions, the unskilled labour force in the UK declined by 23.5 per cent between 1979 and 2000, while the skilled labour force rose by 41.2 per cent. This reflects, in part, an improvement in overall educational levels. However, the change may not be entirely exogenous, since workers may retrain or spend longer in education in response to changing job opportunities. In addition, our current dataset has a deficiency, in that it does not distinguish between unskilled and semi-skilled blue-collar workers, or between professional/managerial and other white-collar workers.

In the low and high elasticity cases, our calibrated labour demand elasticities in 2000 are between -1.46 and -2.16 for unskilled labour, and between -1.21 and -1.88 for skilled. Nevertheless, even with the high case elasticities, the observed fall in the unskilled labour force would have been expected to raise unskilled wages by about 13% between 1979 and 2000, while the observed rise in the skilled labour force would have lowered skilled wages by about 17%. These relative changes far outweigh the changes actually observed.

5 Decomposition Results

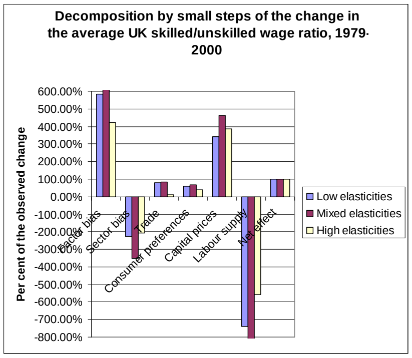
The results of the decompositions by small steps are shown in Figure 2 below. These are fitted integrals of the components of the change in the wage ratio, had all the causative factors been steadily changing. Many conclusions seem to be quite robust to elasticity changes, at least over the ranges under consideration.

The two primary contributors to widening inequality are factor bias and the fall in capital prices (the latter being further decomposible into technical progress in capital goods production and a cheapening of finance). Both factors are far more than enough, even taken separately, to explain the rise in observed inequality.

No other single factor can explain, on its own, the increase in inequality. However, at least in the low and mixed elasticity scenarios, a combination of trade and changing consumer preferences is enough to explain the change. Even in the high elasticities case, these two factors together account for 84% of the observed rise in inequality.

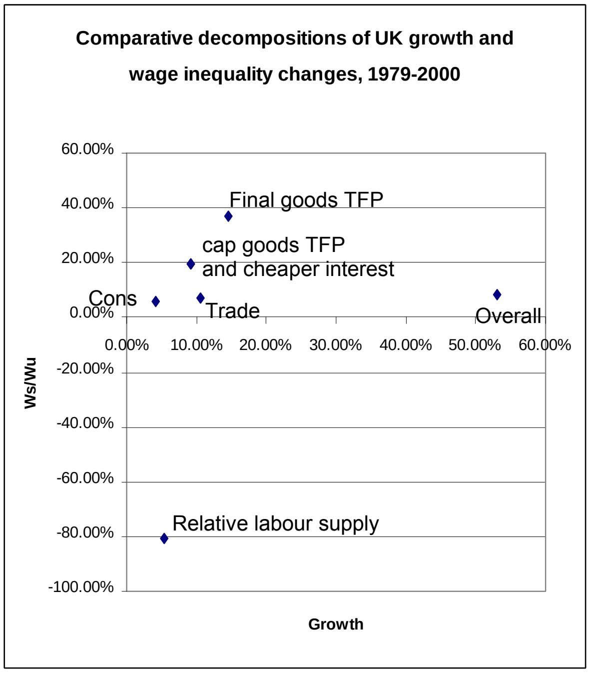
Sector bias appears to have a negative effect, which is large in the low elasticity case and small in the other cases. This reflects rising productivity in the export-competing sectors.

In all cases, an upskilling of the workforce has greatly reduced the combined effects of the other factors upon wage inequality.



5.1 Comparative decompositions on UK growth and wage inequality

Since our general equilibrium model decomposes the move from a start year social accounting matrix and table of factor and goods prices to an end year, it produces a consistent set of decompositions of a wide range of economic variables. Hence we can also plot the comparative effects of the various causal factors upon both growth and inequality. This is done in *Figure 3* below.



We should note that the effects upon inequality and upon growth are qualitatively very different. The UK economy grew at around 3 per cent per annum over the period concerned, because the contribution of technological progress in final goods production was supplemented by technological progress in capital production, human capital accumulation and falling risk premia. The effect of trade liberalisation may have been positive, but perhaps offset by terms of trade and balance of payments effects, so the net contribution from trade is small and uncertain. We are treating technological progress as exogenous, rather than linking it to the pro-competitive and selection effects of trade, as some sources do.

Decomposition of wage inequality is qualitatively quite different, at least when using these comparative static models. Counterfactual simulations suggest that the small net increase in inequality was the result of a number of offsetting factors - technological progress (itself the net effect of oppositely-signed effects of factor- and sector-bias) and capital cheapening, both of which worsen inequality, are offset by labour force upskilling. Trade appears to be a small bit-player, yet it may well have been enough to tip the balance in favour of widening inequality.

6 Conclusions

The numerical analysis is subject to all the usual caveats concerning model structure and elasticity assumptions. Nevertheless, we can draw a number of conclusions, some of which broadly support the literature to date, others of which qualify the findings of previous studies.

Concerning results which support the broad findings of previous literature: it is true that capital price falls and factor biased technology have widened the gulf between the skilled and unskilled. Also that changes in trade flows have tended to increase inequality, but to a much lesser degree.

The main lesson of this study, however, is to underline that, while comparative static decomposition in models of growth and convergence is well-established and seems robust, the same cannot be said for the development of related counterfactual models to explain rising wage inequality. Numerous studies - both trade-derived (Heckscher-Ohlin-Samuelson, or Armington or Ricardo-Viner) and otherwise (factor content models) - have appealed to general equilibrium to explain rising wage inequality - yet when general equilibrium models are laid out and calibrated, and the results simulated, the overwhelming conclusion must be that the models concerned are unstable. Above all, if these models are to be believed, then decomposition has been problematic, since small changes in various of the explanatory variables can lead to vast changes in relative inequality. Since wage inequality over time (and here we are looking back a century or more) has changed far more modestly than most counterfactuals on these models would indicate - the fundamental starting-point should be to ask why there has been relative stability in wage differentials. Such an answer should surely exclude the coincidental effects of sizeable offsetting shifts.

Worrying also is the complete contrast between the (unstable) factor-contents approach of the labour economists and the (equally unstable but in different ways) Heckscher-Ohlin model of many trade theorists. In the former, factor biased technology and changing factor endowments produce huge effects on relative wages, at least based on the elasticities which we use, while in the latter they have no effect, with sector-bias and traded prices having magnified effects, also, in practice, enormous. Moreover, as Abrego and Whalley (1999. 2003) and Edwards and Whalley (2007) have pointed out, these conclusions of the HOS model are not, in practice, robust to even small changes in model structure. Our larger, Armington model in Section 4 includes a case with quite high trade elasticities, and yet its behaviour is very close to that of the simple, Cobb-Douglas, factor contents model, rather than the HOS model.

So where does this leave us? Maybe the starting-point is that decomposition depends upon the fairly arbitrary decision of which variables to class as exogenous, and which as endogenous. The debates on technology and wages and (particularly) trade and wages have tended to treat factor supply as given. Yet we are talking about trying to explain changes over two decades or more - when perhaps half the workforce would have retired and been replaced. Skill acquisition and allocation decisions are much more likely to be price-sensitive over this kind of period - so damping the effects of other factors.

This effectively suggests analysis should proceed towards a different kind of explanation: that maybe a mixture of price-sensitivity and careful policymaking has generally maintained relative wage stability over long periods. This would then suggest that the shocks since 1980 (in some countries only) have produced a mismatch, since policy in the UK and USA (but not Continental Europe) shifted sufficiently to catch workers out, allowing a rise in skill premia. This suggests that future decomposition work should be done using dynamic models, with explicit focus on policy and expectations formation.

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