FEATURE

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Multi-factor productivity: estimates for 1997 to 2006

SUMMARY

This article presents multi-factor productivity (sometimes referred to as total factor productivity or growth accounting), results for 1997 to 2006, using an experimental quality-adjusted labour input measure and experimental estimates of capital services growth as inputs. The analysis has been produced for the whole economy, some broad industry groupings and, for the first time, the market sector, with the aim of better understanding the UK's productivity performance over this period and of using the results as a diagnostic check on the consistency of output and input data.

Annual publication of multi-factor productivity (MFP) estimates is an important development for productivity analysis in the Office for National Statistics (ONS) since the framework applied – the growth accounting framework – provides a better understanding of the contributions to output growth (gross value added – GVA[1]) by showing how much is due to growth in labour, in terms of hours actually worked or its quality, and how much is due to growth in capital, for example, by increased use of plant and machinery, information and communication technology (ICT) or any other form of capital. The residual of output growth that cannot be explained by growth in these inputs is referred to as MFP.

Traditionally, this residual is thought to capture technical change, but in practice it also captures a number of other effects including improvements in management techniques and processes, improvements in the skill level of the workforce not captured by the quality adjustment of labour, and returns from intangibles such as research and development (R&D) knowledge or organisational know-how. The MFP term will also include the contributions of omitted inputs over and above their cost of purchase (such as energy, materials and services), adjustment costs, economies of scale, cyclical effects, inefficiencies and errors in the measurement of output.

The measures of labour and capital used in these MFP calculations attempt to more accurately measure the contributions of labour and capital to production by using data on their user costs (wages and rental prices, respectively) to adjust their input, giving a more accurate picture of what has been driving GVA growth over this period. Also, the quality adjustment process applied to the labour measure means some insight can be gained into the contribution of labour composition or skills. Skills are listed as one of the five key drivers of productivity by the Department for Business, Enterprise and Regulatory Reform and HM Treasury, and is part of the Government's policy to improve the skill level of the UK workforce and thus help reduce the productivity gap with the USA and other industrialised nations. The results in this article not only estimate MFP, but go on to estimate the contribution of skills by splitting out the contribution of labour productivity into the contribution of the volume of hours plus the contribution of labour composition.

Another reason analysts are interested in MFP lies in the increased use of ICT and its effects, which are frequently cited as an explanation for the acceleration in the productivity performance of the USA in the 1990s. Observers of this phenomenon are interested to know whether the UK has experienced any such surge in productivity growth as a result of increased use of ICT. As well as hardware – physical ICT capital – there has been considerable growth in investment in software, both purchased and own-account (developed in-house by the firm), which can assist both product and process innovation, particularly in the service sector.

Software is an intangible asset, that is, one that does not have a physical, material existence. It is one of the few intangible assets included in National Accounts investment figures, although it will soon be joined by R&D, provisionally recorded in a satellite account (Galindo-Rueda 2007). Other intangible assets that are not included in the estimates of capital, mainly because of their nature and the difficulty in measuring them, are brand equity, firm-specific human capital, organisational capital and other forms of innovative expenditure such as design. Since expenditure in these categories is not measured in the official National Accounts investment series, its contribution will also be present in the MFP residual. However, there is now a body of work attempting to measure such investments and investigate their productivity effects (see for example Giorgio Marrano, Haskel, and Wallis 2007).

MFP analysis is also a useful tool for checking the consistency of output and input data and identifying measurement issues in these areas. For instance, a persistent decline in MFP growth is not compatible with a sector that is consistently growing in terms of its output. This is particularly relevant to service sector industries, especially financial intermediation and business services, and also public services, where output is believed to be underestimated due to inherent measurement difficulties in these sectors. It is these sectors where quality improvement in output is most prevalent, but also most difficult to capture in official output data. The analysis suggests negative MFP growth in, among others, the public and personal services sectors. This may be due to the failure to capture changes in quality in these sectors.

This article presents MFP results for the period 1997 to 2006. The work is a result of the ONS strategy on productivity first published in April 2002 (Lau 2002) and revised in August 2006 (Camus and Lau 2006). For the first time, market sector estimates have also been produced due to developments in the input measures. However, due to the short back-series on labour input specifically for the market sector, its estimates only refer to 2001 to 2006.

Growth accounting

Growth accounting apportions growth in output to growth in the factor inputs, capital and labour, and growth in a residual. Therefore, if the growth rate of output is greater than the growth in contributions of the factor inputs, then the residual can be interpreted as an approximation of growth in 'disembodied technical change', that is, advances in technology not specifically embodied in either input. This represents an increase in MFP. Examples of such a change are increased knowledge through R&D or improvements in organisational structure or management. In general, it captures any improvement in output that is not driven by the factor inputs, capital and labour. It should be noted that the MFP term does not include 'embodied technical change', that is, advances in the quality of capital or other inputs, which are already captured when calculating their contribution. An example of this would be the rapid improvement in the quality of ICT over the last 20 years.

In a sense, MFP growth can be thought of as increased efficiency. This can be achieved in a number of different ways. For instance, if a firm changes its organisational structure and this results in increased efficiency, then this can be thought of as MFP. The increase in productivity is not due to an increase in the quantity or quality of capital or labour but instead an improvement in how they are employed. Another potentially important source of MFP growth is the extent of unobserved differences in the use of ICT. For instance, consider two firms that invest equally in ICT, but one employs it better to link its business processes so that sales, stock replenishment, customer service resources and marketing are all automatically linked with no need for manual intervention. Although they have made the same investment in ICT capital, the way it has been used means one firm enjoys a much greater boost in productivity. This also illustrates that MFP can be the result of the combination of capital and the skill level of the workforce or management.

Methodology

The inputs used for this analysis are the experimental quality-adjusted labour input measure (QALI) and the volume index of capital services (VICS). Detail on the methodology and calculation of the input data can be found in Dey-Chowdhury and Goodridge (2007) for QALI, and Wallis and Dey-Chowdhury (2007) for VICS.

A standard Cobb-Douglas production function, as shown in equation (1), states that output is a function of capital (K), labour (L) and a generic term (A) which represents disembodied technical change (MFP) and some other factors discussed previously:

$$Y(t) = A(t)K^{\alpha K}(t)L^{\alpha L}(t) \qquad (1)$$

Therefore, in continuous time, growth in output can be represented as a share-weighted sum of growth in capital, labour and the Solow residual (A) (Solow 1957), as shown in equation (2):

$$\frac{\dot{Y}(t)}{Y(t)} = \frac{\dot{A}(t)}{A(t)} + \alpha_K \frac{\dot{K}(t)}{K(t)} + \alpha_L \frac{\dot{L}(t)}{L(t)} \qquad (2)$$

where αK and αL are the output elasticities for capital and labour, respectively. Since a Cobb-Douglas production function has been used with the assumption of constant returns to scale, αK and αL sum to one. Under the assumptions of perfect competition, firms will hire labour and invest in capital up to the point where its rental price or wage equals its marginal product (that is, the marginal value of what it produces). Therefore the coefficient for capital, αK, is equal to the share of income that accrues to capital, captured by 'gross operating surplus' (GOS) in the National Accounts, and the corresponding coefficient for labour equals its share as captured by 'compensation of employees' (CoE). A slight adjustment is made for self-employed income as it is contained in the series 'mixed income', but this issue is discussed later in the article in the section Output and factor income shares.

More generally, in discrete time, we can approximate GVA growth between two periods, t-1 and t, as follows:

$$\begin{aligned}\Delta \ln Y(t) &= [1 - \bar{s}_L(t)]\Delta \ln K(t) \\ &+ \bar{s}_L(t)\Delta \ln L(t) + \Delta \ln A(t)\end{aligned} \qquad (3)$$

This states that growth in log GVA is equal to an average of growth in log capital input weighted by the capital income share and growth in log labour input weighted by the labour income share plus growth of disembodied technical change – the MFP residual.

More specifically, $\bar{s}_{L(t)}$ is the average of the labour share of total income in the current and previous period, and the weight for capital is simply one minus the share for labour. So:

$$\bar{s}_L(t) = [s_L(t) + s_L(t-1)]/2 \qquad (4)$$

Therefore the actual calculation is simply a rearrangement of equation (3):

$$\begin{aligned}&MFP\ growth = \Delta \ln Y(t) \\ &-[1 - \bar{s}_L(t)]\Delta \ln K(t) - \bar{s}_L(t)\Delta \ln L(t)\end{aligned} \qquad (5)$$

The advantage of using QALI over a standard labour input measure is that the contribution of skills is captured, at least partially, and is not attributed to a change in MFP. In practice, some of the quality changes in labour and capital will still be present in the MFP term. Also, if the factor income shares are inaccurate approximations of the elasticities in the production function, then there will be errors in the estimation of the factor contributions and therefore MFP.

The same technique can be used to decompose labour productivity growth into the contributions of physical capital deepening (capital income share multiplied by growth in physical capital per hour worked), labour composition (skills or the 'quality adjustment' made during the production of QALI) and MFP growth, as shown in equation (6):

$$\Delta \ln\left[\frac{Y(t)}{H(t)}\right] = [1-\bar{s}_L(t)]\Delta \ln\left[\frac{K(t)}{H(t)}\right] + \bar{s}_L(t)[\Delta \ln L(t) - \Delta \ln H(t)] + \Delta \ln A(1) \qquad (6)$$

where H(t) and L(t) represent standard and quality-adjusted hours respectively. A standard aggregation of hours treats labour as a homogenous input, whereas the use of a quality-adjusted measure explicitly recognises the heterogeneity of labour and uses its profile in terms of education, experience, sex and industry to measure the added value it generates. This is done by weighting hours growth according to the share of different worker types in the overall wage bill, relying on the assumption of competitive markets where workers are paid according to their marginal product.

Source data

Labour input

The data source for the labour input measure, QALI, is the Labour Force Survey (LFS) which is a continuous household-based survey that covers approximately 53,000 households every quarter. It contains information on educational attainment, industry, sex and age. Under the assumption that different worker types have differing levels of marginal productivity, labour hours are adjusted with regard to these characteristics. For detail on the quality adjustment process and why these characteristics have been chosen please see Dey-Chowdhury and Goodridge (2007). The labour input data used is the same as that contained in Dey-Chowdhury and Goodridge (2007), and is available in more detail at www.statistics.gov.uk/statbase/product.asp?vlnk=14206

Capital services

Details on the calculation of capital services (VICS) and the latest estimates can be found in Wallis and Dey-Chowdhury (2007). It should be noted that VICS differs from growth in the net capital stock measure in the National Accounts because VICS uses rental costs rather than asset prices to weight together assets. The main asset types are buildings, plant and machinery, vehicles and intangibles. Computers, and now both purchased and own-account software (Wallis and Dey-Chowdhury 2007), are separated out of plant and machinery and intangibles and given shorter life-lengths, and hence higher depreciation rates, to ensure their productivity input is more accuratly captured.

Output and factor income shares

The output measure used in this article is GVA at basic prices, an annually chain-linked volume measure, last rebased in 2003 and consistent with that published in *Blue Book* 2007, but without the adjustments made as part of the National Accounts balancing process. Actual and imputed rents of owner-occupied dwellings are removed from GVA as they are not a true measure of output, and dwellings are not part of the productive capital stock. Therefore they are removed to ensure consistency with the capital input data.

Since balancing and coherence adjustments are applied at divisional level, and in some cases the market sector is made up of parts of different divisions rather than totals, the market sector GVA measure used contains adjustments made as part of National Accounts balancing.

Issues surrounding the calculation of labour's income share

In calculating the labour (and therefore the capital) share of total income, the numerator is equal to CoE from National Accounts plus the labour compensation of the self-employed. Since there is no National Accounts series for labour income of the self-employed, this has to be estimated – the National Accounts series for self-employed earnings is 'mixed income', which includes both the returns to capital and labour in the self-employed sector. There are two principle ways of splitting 'mixed income' to derive a labour income series for self-employed. The first is to use data from the LFS on the average hourly wage rate for the employed sector and multiply this by the total self-employed hours in each relevant sector, to generate a proxy for the compensation of the self-employed. The conceptual justification for this is that the result is based on the opportunity cost of their labour. Alternatively, mixed income can be split using the relative proportions of CoE and GOS in the employed sector, assuming that capital and labour generate the same returns in the self-employed sector as they do in the employed sector.

The initial choice was to estimate labour income of the self-employed using microdata from the LFS. However, examination of the results showed that virtually all of mixed income was being allocated to labour, which would imply that capital generated zero returns – a nonsensical result. One possible explanation for this may be that self-employed income is under-reported for tax purposes and that much self-employed activity takes place in the hidden economy, so is not picked up in official figures. In addition, there does not appear to be any good reason to believe that capital would generate a lower return in the self-employed sector than in the employed sector. Because of these inconsistencies in the imputed returns to capital and labour in the self-employed sector, the method of using the proportions from the employed sector is used.

In the last publication, for quality assurance, and to reassure the user, the analysis was also produced using the alternative methodology and in practice it makes little difference to the final results, since mixed income is such a small component of total income. The results of this exercise are presented in the appendix at the end of the previous article (Goodridge 2007).

There are further issues with some of the data used to calculate income shares for 2005 and 2006. Industry breakdowns of GOS and mixed income are produced as part of the Input-Output analyses, and will not be published this year due to the National Accounts modernisation programme. Therefore, some breakdowns have been imputed based on the profile of the back series. This issue will be resolved in time for the next MFP publication.

Results

For the time period examined (1997 to 2006), approximately one-quarter of the output growth in the UK economy was due to growth in multi-factor productivity. In the market sector, for 2001 to 2006, the proportion was over one-third.

Figure 1 shows the decomposition of output growth into contributions from the factor inputs, capital and labour, and MFP growth. The contribution of labour has been split into two components, growth in hours and growth in labour composition, namely the growth of QALI not accounted for by

Figure 1
Decomposition of annual average output growth, 1997 to 2006 (2001 to 2006 for the market sector)

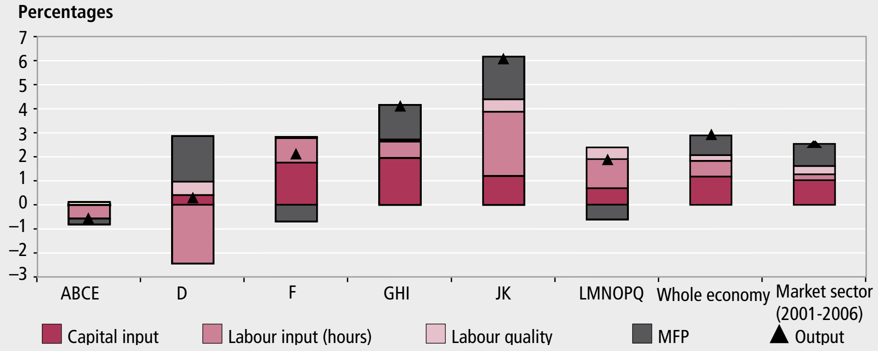


Table 1
Industry description

Industry	Industry description
ABCE	Agriculture, hunting, forestry, fishing, mining and quarrying, utilities
D	Manufacturing
F	Construction
GHI	Wholesale and retail trade, hotels and restaurants, transport storage and communications
JK	Financial intermediation, real estate, renting and business activities
LMNOPQ	Public administration and defence, education, health and social work, other social and personal services, and extra-territorial activities

growth in hours. For the whole economy, MFP growth is estimated to have been 0.8 per cent per annum between 1997 and 2006 compared with 0.9 per cent in the market sector (2001 to 2006). This partially reflects the way public sector GVA is measured in the National Accounts, which is still largely based on measures of labour input plus capital depreciation. For measures of public sector output based on outcomes that contain adjustments for quality, users should consult analysis produced by the UK Centre for the Measurement of Government Activity (UKCeMGA) at www.statistics.gov.uk/ukcemga

Table 1 provides a description of the sectors used in this analysis.

Looking at individual sectors, the strongest growth in MFP has occurred in manufacturing (D), though this is set against a contraction in labour input. There has also been strong growth in financial intermediation and business services (JK) and the combined sector of the distributive trades, transport and communications (GHI). The negative result for construction (F) was expected and is consistent with other studies over similar periods in both the UK and the US (Lau and Vaze 2002).

The contributions of labour composition suggest skilled labour has been more widely utilised in the market sector than the whole economy. Specifically, there has not been growth in the utilisation of skilled labour in agriculture, construction or the distributive trades, but the utilisation of skilled labour has grown significantly in other parts of the service sector, notably financial and business services, as well as public and personal services.

Figure 2 presents a similar analysis to the above, but this time on the decomposition of growth in labour productivity, rather than output growth.

This chart shows that the contribution of growth in labour composition for the whole economy was just 0.2 per cent per annum, 11.7 per cent of labour productivity growth, with capital deepening and MFP making much larger contributions. Labour composition reflects the quality of labour input, taking account of contributing factors such as skills and experience. At an industrial level, labour composition made its largest contribution in manufacturing (D), making up 15 per cent of growth in labour productivity. Labour composition also made significant contributions to labour productivity growth in financial intermediation and business services (JK) and in public and personal services (LMNOPQ).

As can be seen, labour productivity tends to be slightly lower in service sector industries compared with manufacturing. This is in good part a reflection of the nature of the service sector, as in many cases the service offered is the product of labour itself, so it is often very labour-intensive, for example, hairdressing or financial advice. Because of the relative intensity of labour input compared with capital (or technological) input, the scope for capital deepening is limited and so productivity gains are necessarily constrained. In addition, it is hard to conceive how there could be significant productivity improvements in sectors where technology has hardly changed in years, and the technological input is relatively limited or low. However, for many service sector industries, this appears to be changing, with developments in ICT which have resulted in considerable innovation to both products and processes in much of the service sector, particularly in finance and business services. However, although labour productivity growth in services is behind manufacturing, the share contributed by MFP growth is fairly similar, possibly reflecting the increased use of ICT in these industries.

Table 2 shows the growth in labour composition, by sector, between 1997 and 2006.

Labour composition is the adjustment made for quality of labour input, that is, to take account of skills and work experience:

Figure 2
Decomposition of annual average labour productivity growth, 1997 to 2006 (2001 to 2006 for the market sector)

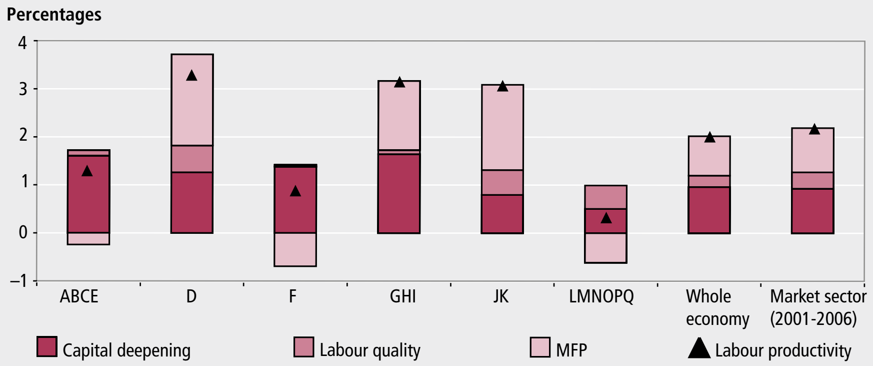


Table 2
Annual growth in labour composition

Percentages

	ABCE	D	F	GHI	JK	LMNOPQ	Whole economy	Market sector
1997	–1.25	0.88	1.46	–0.53	3.12	–0.24	0.43	
1998	1.66	0.09	0.02	–0.03	0.77	1.43	0.64	
1999	0.99	1.15	–0.01	0.31	0.60	0.78	0.49	
2000	–0.80	1.40	–0.05	0.30	–0.38	0.84	0.45	
2001	2.58	0.56	0.50	0.60	–0.10	–0.52	–0.18	0.62
2002	–2.26	0.54	–1.15	–0.13	0.75	0.80	0.00	0.04
2003	5.48	0.94	–0.26	0.27	0.64	0.04	0.37	1.08
2004	–2.14	0.15	0.97	–1.36	0.20	1.03	–0.22	0.09
2005	–0.87	0.60	–0.28	–0.14	–0.20	0.70	0.04	0.06
2006	1.08	1.34	–0.62	1.67	0.71	0.80	1.10	0.93
Average	0.45	0.77	0.06	0.10	0.61	0.57	0.31	0.47

Figure 3
Decomposition of annual average output growth, 1997 to 2000

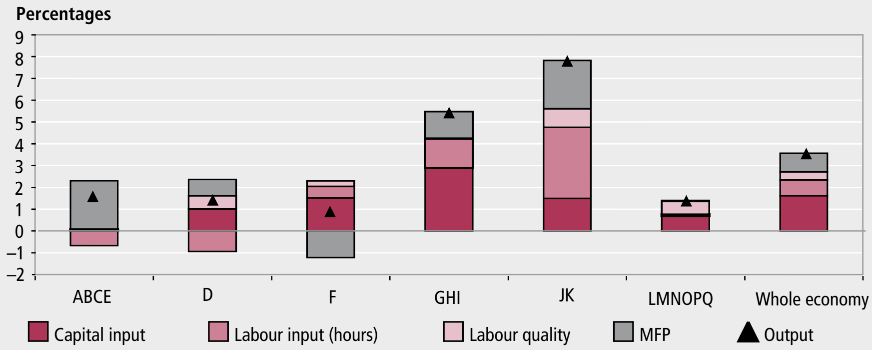
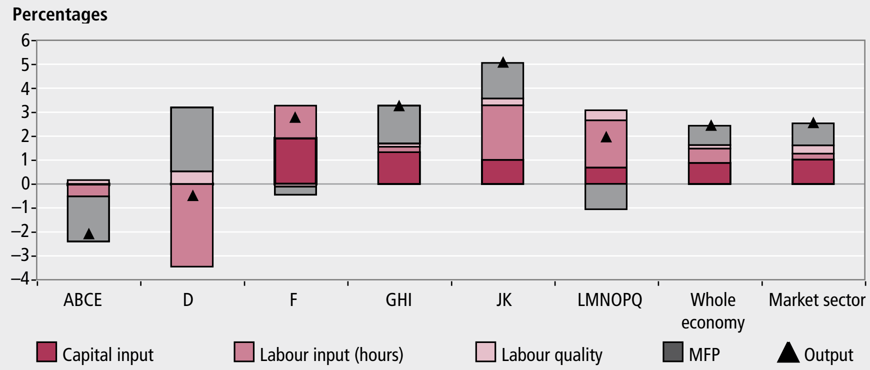


Figure 4
Decomposition of annual average output growth, 2001 to 2006



its growth is a measure of the improvement in the composition of the workforce. The table illustrates that at the whole economy level, labour composition grew on average by 0.3 per cent a year, with the highest growth occurring in manufacturing (D), financial intermediation and business services (JK) and public and other services (LMNOPQ). However, few definitive conclusions can be drawn on the change in labour composition due to the relatively short time period studied and the relative volatility of the data. The labour measure is based on hours worked, which is a far more cyclical measure than workers or jobs, with firms responding to changing demand conditions by increasing or reducing hours in the short term rather than hiring or dismissing workers. Therefore, if such changes affect different worker types differently, there will be a change in labour composition. In general, it would be expected that labour composition would rise during a 'slump' when the less skilled and experienced workers are the first to be laid off, and fall during a 'boom' when less productive workers are drawn back into the labour market due to increased demand. Therefore, the seemingly slow growth in labour composition since 1997 may reflect the strength of the UK economy and therefore labour demand over this period.

As a final piece of analysis, the period studied has been split into two separate parts: up to 2000, and after 2000, for two reasons. This is to compare the whole economy more directly with the market sector over the same time period (2001 to 2006), and to reflect the difference in capital investments made before and after 2000. Before 2000, firms made larger, possibly unnecessarily large, investments in ICT in attempts to avert the 'millennium bug'. This, in turn, often resulted in much lower investment just after 2000 as capital had already recently been replaced. This is reflected in the capital services growth estimates presented in Wallis and Dey-Chowdhury (2007). A decomposition of output growth for the two periods is presented in **Figure 3** and **Figure 4**.

The results show that the contribution of capital in the latter period was indeed lower although so was growth in output. Capital contributed 45.5 per cent to output growth between 1997 and 2000, compared with 36.1 per cent after 2000. Results by sector tell a similar story. The difference is particularly stark in manufacturing where, in the latter period, the contribution of capital was zero, although output did decline over the period. Conversely, capital deepening increased in the construction sector in the period 2001 to 2006. Comparing the market sector with the whole economy (2001 to 2006), the contribution of capital to output growth was slightly stronger in the market sector than for the whole economy.

The contribution of growth in labour composition has also declined between the two periods and is again stronger in the market sector than in the whole economy.

Looking specifically at MFP growth, the latter period shows a significant decline in agriculture, mining and utilities, and in the public and personal services sector, but strong improvement in manufacturing.

Figure 5 decomposes labour productivity growth for each period.

The results show that the decline in labour productivity growth between the two periods is partly due to a fall in the contribution of capital deepening, reflecting the impact of the millennium bug, and partly due to a slowdown in labour

Figure 5
Decomposition of annual average labour productivity growth

composition growth, reflecting the view that with employment at historically high levels, less productive workers are being drawn into the workforce due to favourable demand conditions, although this does vary between sectors. The contribution of MFP growth is broadly similar.

The contribution of labour composition in the market sector made up 15 per cent of labour productivity growth compared with 8 per cent in the whole economy (see second part of Figure 5). Again it should be borne in mind, however, that the output measure is affected by the use of employment and earnings indicators as proxies for output in the public sector.

Future developments

The growth accounting framework presented here is based on the decomposition of growth in GVA into growth in labour and capital inputs. An alternative growth accounting framework exists where intermediate inputs to production are also modelled – energy, materials and services. These other inputs to production, usually defined as intermediate inputs, could be included in MFP analysis for gross output, as opposed to GVA. Although such inputs are not included in this particular analysis, as they are netted out of gross output to derive the GVA measure, they have been included in the EUKLEMS project (Van Ark *et al* 2007). The development of the KLEMS database for the UK, and the future publication of constant price Input-Output tables will mean that future MFP publications can be broadened to include a wider range of inputs, and therefore a deeper analysis of productivity.

Conclusion

This article has presented analysis of MFP growth using the quality-adjusted input measures of labour and capital, QALI and VICS, developed by ONS, resulting in a more accurate estimate of MFP. However, the short time period examined, particularly for the market sector, constrains the depth of analysis of MFP growth, particularly given its volatility in the short term. Consequently, estimates, and therefore analysis, will improve as the series is lengthened. Unfortunately it is not possible to extend the series further back due to breaks in the qualification variable on which QALI is partially based. The results suggest that the UK is still not experiencing a surge in productivity growth as seen in other countries, possibly driven by increased investment in ICT, most notably the USA, but also in its application and wider utilisation.

Notes

1 There are two possible approaches to accounting for growth in output. The approach taken here is to calculate the contributions to growth in GVA made by factor inputs, that is, the added value generated in the production process after removing the costs of intermediate consumption. The other possible approach is to calculate the contributions to growth in gross output but to include input factors – energy, materials and services. An example of this is the ongoing EUKLEMS project.

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