FEATURE

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Multi-factor productivity: estimates for 1998 to 2007

SUMMARY

Multi-factor productivity (MFP), sometimes referred to as 'total-factor productivity' or 'growth accounting', is a method of analysing productivity which allows for a more in-depth assessment of performance at a whole economy or sectoral level. It apportions growth in output to contributions from capital, from labour and a residual MFP which represents the 'productivity change' not explained by the growth in either labour or capital inputs. This approach permits more detailed analysis of what is driving output growth compared with the traditional 'headline' measures of productivity, which use only labour as their factor input. This article presents multi-factor productivity results for 1998 to 2007 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, the market sector and some broad industry groupings.

Annual publication of multi-factor productivity (MFP) estimates is an important development for productivity analysis by the Office for National Statistics (ONS), as the framework applied – the growth-accounting framework – provides a better understanding of the contributions to output growth. This is achieved 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. The use of a growth-accounting framework provides a much more incisive and detailed assessment of what is driving growth in output and productivity, particularly in comparison with the more conventional, but simpler, labour input-based productivity measures.

Traditionally, the MFP residual is thought to have principally captured technical change, but in practice it also captures a number of other effects. These include 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), brand equity, firm-specific human capital, organisational capital and design. These are not currently measured in National Accounts investment series, although R&D has been provisionally recorded in a satellite account by Galindo-Rueda (2007) and work is ongoing to fully integrate R&D and other intangibles into the National Accounts in the near future (see, for example, Giorgio Marrano *et al* 2007). The MFP term will also include adjustment costs, economies of scale, cyclical effects, inefficiencies and errors in the measurement of output or inputs.

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 marginal user costs (wages and rental prices, respectively) to adjust their input, giving a more accurate picture of what has been driving output growth. 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 HM Treasury and the Department for Business, Enterprise & Regulatory Reform (BERR); it is part of government policy to improve the skill level of the UK workforce in order to reduce the productivity gap with the US and other industrialised nations. The results in this article estimate the contribution of skills by splitting the impact of labour into contributions from the volume of hours and labour composition.

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 inherently difficult to measure. It is in these sectors where quality improvement in output is most prevalent, but also most difficult to capture in official output data.

This article presents MFP results for the period 1998 to 2007 for the whole economy and six broad industry groupings. Due to the short back series for labour input in the market sector, estimates for MFP in this sector cover only the period 2001 to 2007.

Growth accounting

Growth accounting apportions growth in output to growth in the factor inputs and growth in a residual, MFP. This analysis uses gross value added (GVA) as its output measure, and capital and labour as inputs. However, there is more than one way to account for growth in output. **Box 1** outlines the different approaches to growth accounting, focusing on the ongoing EU KLEMS project.

Regardless of the particular method of growth accounting used, the meaning of the MFP residual is the same: it can be interpreted as an approximation of growth in 'disembodied technical change', that is, advances in technology not embodied in capital. 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 data on factor inputs. 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, it can be thought of as growth in 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 utilised.

Another important source of MFP growth is the use of ICT. For example, 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 the capital has been utilised means that one firm enjoys a much greater boost to productivity. This also illustrates that MFP growth can be the result of the combination of capital and the skill level of the workforce or management.

Methodology

A standard Cobb-Douglas production function, as shown below 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 α_K and α_L 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, α_K and α_L sum to one. Under the assumption of perfect competition, firms will hire labour and invest in capital up to the point where its price or wage equals its marginal product (that is, the value of what it produces). Therefore, the coefficient for capital, α_K, is equal to the share of total income that accrues to capital, captured by gross operating surplus (GOS) in the National Accounts, and the corresponding coefficient for labour equals its share of income, as measured by compensation of employees (CoE). A slight adjustment is made for the self-employed, as all self-employed income is contained in the series mixed income – this issue is discussed later in the article.

More generally, in discrete time, output growth can be approximated as follows:

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

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 the disembodied technical change parameter (the MFP residual).

Box 1
Methods of growth accounting

There are two approaches to accounting for growth in output that may be used for productivity analysis. The approach taken here is to calculate the contributions to growth in GVA, that is, the added value generated in the production process after removing the costs of intermediate consumption. This method is able to apportion GVA growth to growth in capital and labour, by far the most important inputs into the production process, with relatively minor data requirements – all the data needed to compile the quality-adjusted labour input (QALI) and capital services input are readily available to ONS in the National Accounts and Labour Force Survey (LFS).

The other possible approach is to calculate the contributions to growth in gross output, including from those intermediate inputs which are omitted from the GVA-based method of growth accounting. An example of this is the ongoing EU KLEMS project, which apportions output growth to growth in capital, labour, energy, materials and services. Conceptually, this approach is superior to the one used in this article, as it explains the causes of output growth to a greater degree of detail, leaving a smaller MFP residual (see, for example, Van Ark *et al* 2007).

However, the data requirements of KLEMS growth accounting are commensurately higher, which present some barriers to implementation in the short term. In particular, the National Accounts data requirements are much greater, particularly of constant price Supply and Use tables, which are not currently published by ONS. Once constant price Supply and Use tables are available, ONS will be able to calculate the contribution of intermediate inputs to growth in gross output within, or in a similar framework to, KLEMS growth accounting.[1]

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:

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

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

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

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 (the quality adjustment made during the production of QALI) and MFP growth, as shown in equation (6):

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

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 generated by accounting for the differing skill levels of workers.

Source data

Labour input

The labour input used for MFP analysis is the experimental QALI measure. The main data source for QALI is the 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, and are paid as such, labour hours are adjusted with regard to these characteristics according to the share of the different worker types in total labour income. Further detail on the QALI methodology, as well as the latest estimates, can be found in Goodridge (2009).

The advantage of QALI over a standard measure of labour is that the contribution of skills is captured, at least partially, and is not attributed to a change in MFP. In practice, however, some of the quality changes in labour will still be present in the MFP term. A significant drawback to using QALI is the relatively short time period covered: due to breaks in the qualification variable, the series can only be produced from 1997 onwards. As a result, this constrains the time series for MFP analysis.

Capital services

Capital services estimates are used as the capital input for this analysis. Capital services are the flow of services into the production of output that are generated by the capital stock, as opposed to the capital stock itself. They differ from National Accounts measures of capital stock in that they use rental prices instead of purchase prices to weight together growth in the net stock of assets. The use of rental prices better reflects the user cost of a particular asset in a given period and, assuming competitive markets, the relative productivity of the asset. Another advantage of capital services is the greater asset detail compared with the National Accounts net stock measures, in particular, the separate treatment of short-lived, productive ICT assets such as computers, purchased and own-account software. Further information about capital services, and the latest estimates, can be found in Wallis and Turvey (2009).

Output and factor income shares

The output measure used in this article is an annually chain-linked volume measure (last rebased in 2003) of GVA at basic prices, consistent with that published in *Blue Book 2008*. The measure does not contain any adjustments made as part of the National Accounts balancing process, as these adjustments do not reflect the production of goods and services and so should not be included when measuring productivity. 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 excluded 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.

The labour share of total income is equal to CoE from the National Accounts plus the labour compensation of the self-employed, as a proportion of GVA. The capital share is simply one minus the labour share. Since there is no National Accounts series for the labour income of the self-employed (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), this is estimated by splitting mixed income using the relative proportions of CoE and GOS in the employed sector, assuming labour and capital generate the same proportional returns in the self-employed sector. For more detail on the issues surrounding the calculation of factor income shares, please consult Goodridge (2008).

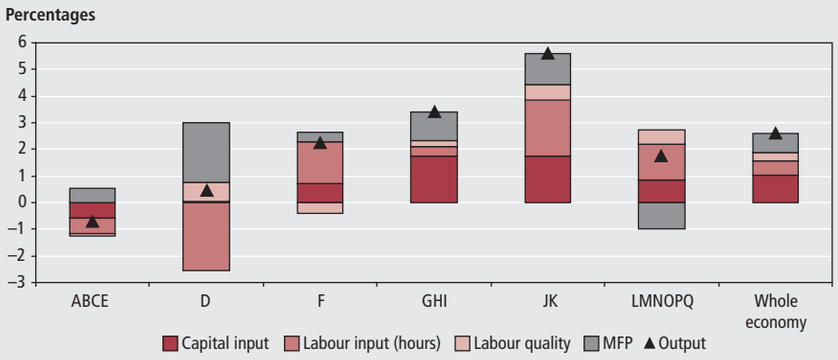
Results

This section presents growth accounting results for 1998 to 2007 for the whole economy and six broad industry groupings. Estimates for the market sector refer to the period 2001 to 2007, due to the shorter back series of labour input data. Due to the volatility of year-on-year MFP growth, it is difficult to assess the contribution of MFP to output growth from year to year. As such, the results are presented as averages over the period studied.

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, which represents the change in quality of labour input, taking account of factors such as skills and experience. For the whole economy, MFP growth is estimated to have been 0.7 per cent per annum between 1998 and 2007, a contribution to average output growth over the period of approximately one-quarter. The greatest contribution to growth in GVA (of almost two-fifths) came from capital input, which is likely due to rapid growth in capital services, particularly from ICT assets, which peaked in the late-1990s and has remained strong throughout the period. Growth in labour composition contributed around 13 per cent of output growth between 1998 and 2007.

Looking at broad industry groups, which are described in **Table 1**, the strongest MFP growth has occurred in manufacturing (D), while 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). All industry groups besides agriculture and utilities

Figure 1
Decomposition of annual average output growth, 1998 to 2007



Source: Office for National Statistics

experienced positive contributions from capital services, while the positive contributions from labour composition in many sectors, especially in the service industries, show an increased utilisation of skilled labour in these sectors.

The negative MFP result for the public and personal services industry group (LMNOPQ) may be due to the fact that the majority of these industries are in the non-market sector. They do not face the same degree of competitive pressure as firms in the market sector to better utilise factor inputs to deliver efficiency improvements over and above those arising from capital investments. Alternatively, measures of government output, produced by the UK Centre for the Measurement of Government Activity, may not yet be fully capturing changes in quality; work is ongoing to further develop these measures.[2]

To ensure consistency with the time series for the market sector, **Figure 2** shows the decomposition of output growth over the period 2001 to 2007. In the market sector, average MFP growth during these years was approximately 1.1 per cent, compared with 0.8 per cent for the whole economy. This difference was driven by the public and personal services industry, which contains non-market sector output. As during the period 1998 to 2007, the industry had negative MFP growth.

Between 2001 and 2007, the contribution of capital services to output growth was greater in the market sector than for the whole economy, while the contribution of labour composition was approximately equal. Again, these are due to the performance of the non-market sector, which had a lower contribution from capital and similar contribution from labour composition compared with the market sector.

Figure 3 presents the decomposition of labour productivity growth into contributions from capital deepening (the amount of capital available for use in production per worker hour), labour composition and MFP. While similar to the above analysis, it additionally shows what has been driving growth in headline productivity measures over the period. The chart shows that growth in labour composition contributed 0.3 percentage points (or 18 per cent) to labour productivity growth at the whole economy level. While this contribution is smaller than those from capital deepening and MFP, it represents an increase from the previously published estimate in Goodridge (2008).

At the industry level, labour productivity growth between 1998 and 2007 was strongest in manufacturing, driven by the largest contributions of any industry from MFP and labour composition. There were also significant contributions from labour composition in financial and business services and in public and personal services. The strong labour productivity growth in manufacturing likely reflects the industry's relatively high degree of capital intensity and shrinking workforce – a relatively large, and increasing, proportion of output can be produced with fewer workers as capital substitutes for labour in the production process. In contrast, many service industries are very labour intensive, in that labour is required to deliver the service itself: examples include hairdressing and legal services.

Nonetheless, the industries with the greatest contributions to labour productivity growth from capital deepening over the period are both in the service sector – distributive trades, transport and communications, and financial intermediation and business services. This is probably due to large investments in ICT over the period, which have spurred product and process innovation. Investment in ICT is also likely to be driving the strong growth in MFP in distributive trades, transport and communications and financial intermediation and business services, as well as in manufacturing, for example, by enabling firms to organise and structure themselves in more efficient ways.

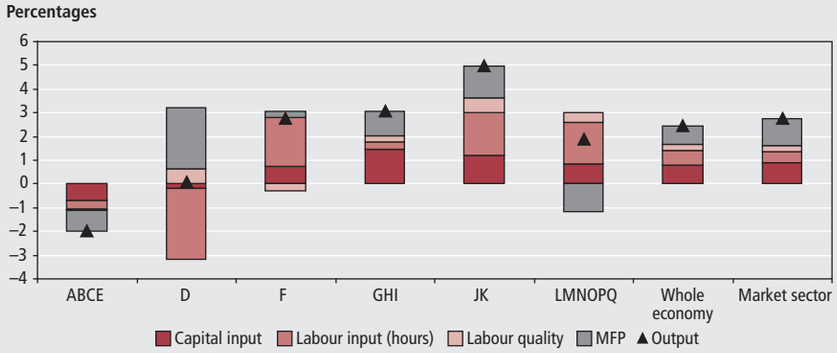
Figure 4 shows the decomposition of labour productivity growth for 2001 to 2007, to enable comparisons between the whole economy, industry and market sector estimates. The results are very similar to those for the decomposition of output

Table 1
Industry description

Industry	Industry description
ABCE	Agriculture, hunting, forestry, fishing, mining 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

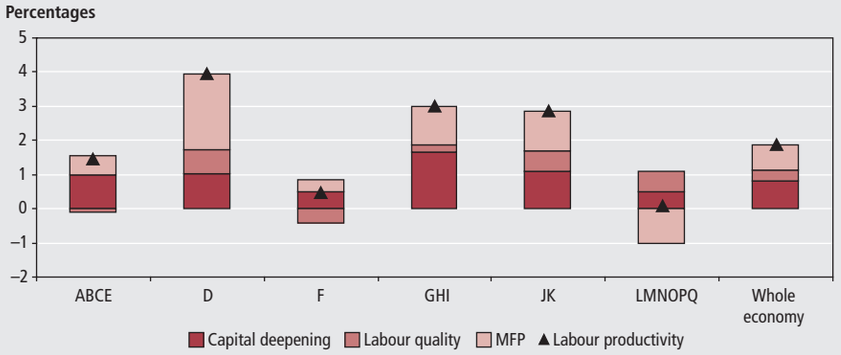
Source: Office for National Statistics

Figure 2
Decomposition of annual average output growth, 2001 to 2007



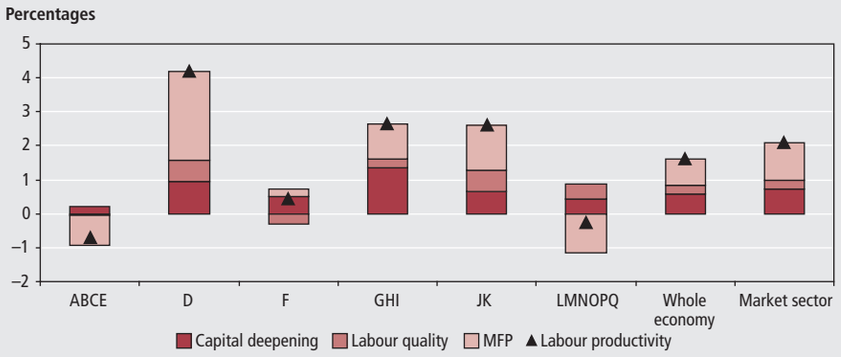
Source: Office for National Statistics

Figure 3
Decomposition of annual average labour productivity growth, 1998 to 2007



Source: Office for National Statistics

Figure 4
Decomposition of annual average labour productivity growth, 2001 to 2007



Source: Office for National Statistics

growth between 2001 and 2007 presented in Figure 2. The main difference between labour productivity growth in the whole economy and the market sector is the contribution from MFP, which again is smaller for the whole economy due to the inclusion of the non-market sector. The difference between the whole economy and market sector measures is also greater when comparing labour productivity as opposed to output growth. This is because the contribution of hours worked to output growth is greater for the whole economy than the market sector, possibly due to non-market services being particularly labour intensive.

Table 2 shows yearly growth in labour composition, by sector, over the period 1998 to 2007. For the whole economy, labour composition grew on average by just under 0.5 per cent a year, with the highest growth occurring in manufacturing, financial intermediation and business services, and public and other services. However, few conclusions can be drawn on the change in labour composition due to the short time period studied. 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 particular 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. Thus, the seemingly slow growth in labour composition between 1998 and 2007 may reflect the strength of the UK economy over this period. This question can begin to be addressed in the next MFP publication, which will include output data for 2008 expected to be much weaker than any of the years covered in this article.

Revisions since previous release

Revisions to MFP results since Goodridge (2008) are caused by revisions to numerous component series, which can be divided into:

- revisions to capital services estimates
- revisions to QALI estimates, and
- revisions to National Accounts data in *Blue Book 2008*

The revisions to labour and capital input have a clear impact on MFP, which is calculated as the residual of GVA growth not explained by the contributions from labour and capital. Revisions to capital services estimates, described in detail in Wallis and Turvey (2009), are primarily driven by the adoption of new methodologies for deflating investment in purchased software and plant and machinery (excluding computers). An important source of revisions to QALI estimates is the regrossing of LFS microdata to 2007 population estimates (Goodridge 2009).

Revisions to National Accounts data in *Blue Book 2008* affect MFP results in many ways. GVA has been revised throughout

Table 2
Annual growth in labour composition

Percentages

	ABCE	D	F	GHI	JK	LMNOPQ	Whole economy	Market sector
1998	*–1.37*	*0.64*	*–0.31*	*0.16*	*0.83*	*1.64*	*0.86*	*..*
1999	*–0.02*	*1.33*	*–1.34*	*–0.15*	*1.05*	*0.72*	*0.37*	*..*
2000	*–1.64*	*1.56*	*–0.52*	*0.84*	*0.26*	*1.16*	*0.79*	*..*
2001	*1.76*	*0.44*	*0.09*	*1.06*	*0.48*	*–0.41*	*–0.13*	*0.69*
2002	*0.84*	*0.30*	*–0.11*	*–0.67*	*0.45*	*0.30*	*–0.10*	*0.20*
2003	*–0.02*	*1.01*	*–1.04*	*0.15*	*1.36*	*0.80*	*0.48*	*0.24*
2004	*2.21*	*0.77*	*0.23*	*–0.68*	*2.18*	*0.40*	*0.33*	*0.79*
2005	*–4.86*	*1.46*	*–0.54*	*0.16*	*–0.91*	*1.38*	*0.30*	*–0.58*
2006	*1.22*	*1.39*	*–0.61*	*1.83*	*0.64*	*0.85*	*1.13*	*0.80*
2007	*–2.44*	*0.70*	*–0.38*	*0.67*	*1.35*	*0.39*	*0.56*	*0.44*
Average	*–0.43*	*0.96*	*–0.45*	*0.34*	*0.77*	*0.72*	*0.46*	*0.37*

Source: Office for National Statistics

the period studied, largely due to the reallocation of financial intermediation services indirectly measured from intermediate consumption to final output and across industries, but also due to the use of a new dataset for the financial services industry, which resulted in a downward revision to growth in that sector. *Blue Book 2008* incorporated substantial revisions to CoE and GOS data, which affected not only the weights applied to labour and capital in the MFP calculation, but also the capital services and QALI estimates themselves. In addition, the constant price investment series on which capital services estimates are based were revised in the last edition of the *Blue Book*.

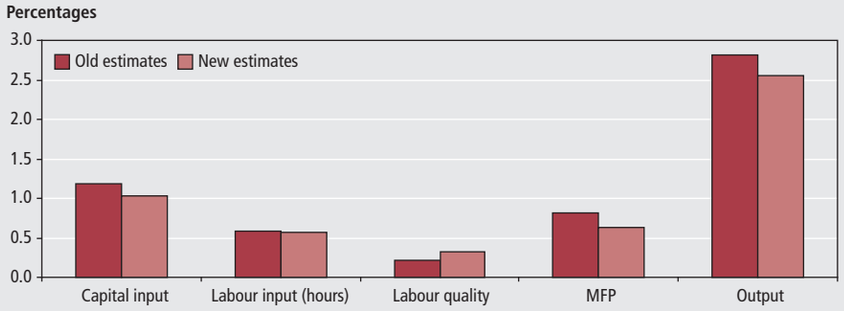
Figure 5 provides an indication of what has been driving revisions to output growth in aggregate, by showing new estimates of contributions from capital, labour and MFP to whole economy output growth against estimates based on previously published data. The period covered in Figure 5 (1998 to 2006) reflects the years for which comparable series are available. Compared with past data, average output growth has been lower than previously estimated, caused by downward revisions to MFP and the contribution from capital, which is in accordance with the downward revision to whole economy capital services in Wallis and Turvey (2009). Interestingly, the contribution of labour composition has been revised upwards, suggesting the importance of skilled labour in driving output growth had previously been understated.

Conclusion

This article has presented growth accounting results for 1998 to 2007, based on experimental quality-adjusted measures of labour and capital input, for the whole economy, broad industry groups and, over a shorter time period, for the market sector. Between 1998 and 2007, the contribution of MFP to whole economy output growth was approximately one-quarter, with the greatest contribution coming from strong growth in capital services, largely as a result of large investments in ICT. The results presented here incorporate revisions from many sources, which have resulted in reduced contributions from capital services and MFP, and an increased contribution from labour composition, compared with the data produced for last year's publication.

The short time period studied, particularly for the market sector, constrains the depth of growth accounting analysis possible, especially given the volatility of MFP growth in the short run. Consequently, estimates will improve as the series is lengthened, though it is not currently possible to extend the series further back due to breaks in the qualification variable on which QALI is partially based.

Figure 5
Contributions to whole economy output growth: new and previous estimates, 1998 to 2006



Source: Office for National Statistics

Notes

1 Further detail on EU KLEMS methodology, and research data produced on a KLEMS growth accounting basis, can be found at www.euklems.com

2 Further information can be found at www.statistics.gov.uk/ukcemga

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