

Article

# Multi-factor productivity estimates: Experimental estimates to 2014

Decompositions of growth for the market sector and 9 industry groups

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# 1 . Abstract

This article presents multi-factor productivity (MFP) estimates for the UK market sector to 2014. MFP measures the change in real (inflation adjusted) economic output that cannot be accounted for by changes in measured inputs of labour and capital.

These estimates show that in 2014 MFP made the largest contribution to economic growth since 2007, albeit still lower than the average annual contribution prior to the economic downturn. These estimates also suggest that lower capital service per hour worked and weaker than normal improvements in labour quality held back productivity growth in 2014.

## 2 . Introduction

### About this release

This is the latest in a series of multi-factor productivity (MFP) releases, containing estimates of MFP growth for the UK market sector between 1970 to 2014 consistent with [Blue Book 2015](#). The previous edition was published in January 2015 ([Connors and Franklin, 2015a](#)).

MFP estimates use experimental measures of quality adjusted labour inputs ("QALI") and capital services and a growth accounting framework to decompose output growth into the relative contributions of growth of labour and capital inputs and a residual component referred to as multi-factor productivity.<sup>1</sup> This approach complements traditional measures of labour productivity, which focus only on one input – labour – and do not take account of changes in the composition of labour over time. Capital input to production is measured by capital services which similarly take account of changes in the composition of the productive stock over time.

Estimates are presented for the market sector and 9 industry groups. The measurement of labour and capital attempts to adjust for compositional changes as well as pure volume movements. This is most apparent in the case of labour inputs, where the MFP framework distinguishes between changes in hours worked and a "labour composition" component. For more information on measurement of labour inputs, see [Connors and Franklin \(2015b\)](#).

Within an MFP growth accounting framework, movements in capital inputs are captured by capital services. Conceptually this is analogous to the treatment of labour input insofar as weights are given to different forms of capital to reflect their estimated contribution to the production process, although unlike labour there is no equivalent of a pure volume measure of capital and hence no distinction between the quantity and quality of capital. The weights used in this capital services framework differ from those used in measuring the value of the stock of capital in the ONS National Accounts. Intuitively this is because the monetary value of an asset can differ from its contribution to the production process. For more information on the derivation of the capital services estimates used in this release, see [Blunden and Franklin \(2016\)](#).

### Layout of article

The following section describes what's new in this edition. There has been a major methodological change since the previous edition, namely to focus on the market sector rather than the whole economy. This has led to sizeable revisions to estimates of capital services which are covered in depth in Blunden and Franklin (2016) and these in turn impact upon MFP. Next is a short section on interpreting MFP statistics. An important point to note is that output is here measured net of intermediate consumption. At the present time the Office for National Statistics (ONS) is not able to provide the conceptually preferable breakdown of gross output (including intermediate consumption as one of the inputs to production) because our systems do not currently support real measures of gross output and intermediate consumption.

The following results section includes time series decompositions of output growth and labour productivity growth for the market sector. MFP decompositions for individual industries are (a) volatile from year to year and (b) conceptually inferior to decompositions based on real gross output. For these reasons, the article focuses on period average decompositions, to highlight differences across industries.

The article concludes with a section on revisions to MFP since the previous estimates published in Connors and Franklin (2015a) and on next steps, setting out priorities for future development and inviting your feedback.

Further information on data sources and methodology is provided in Appendix 1.

**Notes for introduction:**

1. This is also described elsewhere in the literature as disembodied technical change, the 'Solow residual', or total factor productivity (TFP)

### 3 . What's new?

As noted above, the main change from previous editions is that this release focuses on the market sector<sup>1</sup> rather than, as previously, focusing on the whole economy. The rationale for this change is set out in Blunden and Franklin (2016) and in summary is because the multi-factor productivity (MFP) growth accounting framework is more consistent with the way that we measure the market sector, especially in terms of capital services.

For this release we have compiled industry level gross value added (GVA) estimates using unpublished component level market sector GVA estimates and weights for those industries with non-market elements. Further information on the industries affected is contained in the results by industry section below, but it is worth noting at this point that this results in a reduction from 10 industries in the previous edition to 9 in this release.

The reason for this is that the quality adjusted labour inputs (QALI) estimates in this release have been taken from the most recent QALI release (Connors and Franklin, 2015b), updated only for revisions to aggregate estimates of hours worked and updated income constraints from Blue Book 2015. At the present time, QALI estimates for the market sector are derived by assuming that all non-market labour is located in industries OPQ (public administration and defence, education, health and social work) and RSTU (Arts and entertainment, other services). QALI estimates for all other industries are not affected by parameterisation to the whole economy or to the market sector.

Moreover, QALI estimates for the combined OPQRSTU market sector industry aggregate are derived by treating this industry as the residual for hours worked and for labour income. For example, hours worked in OPQRSTU is derived as aggregate market sector hours worked (taken from the ONS Labour Productivity system) minus hours worked in all other industry groups.

Focusing on the market sector also requires changes to factor income shares which are used as weights in the growth accounting framework. This is done by removing non-market labour income from the combined OPQRSTU industry grouping and by removing capital income accruing to the non-market sector from each industry where such estimates exist in the ONS Supply-Use framework.

**Notes for what's new?**

1. The market sector is defined as the part of the economy where output is sold at economically meaningful prices

## 4 . Interpreting these statistics

Using a growth accounting framework, developed by Solow (1957), growth in output can be decomposed into contributions from growth in labour inputs (in terms of both its quantity and composition) and from growth in capital services. The residual output growth that cannot be accounted for by growth in labour and capital inputs is hence an estimate of multi-factor productivity (MFP). Alternatively, the growth accounting framework can be expressed as a decomposition of labour productivity growth, by dividing all of the elements by the volume of labour input (actual hours worked in this case) into the contributions of weighted labour composition (the difference between the growth of quality adjusted and unadjusted labour inputs), capital deepening (defined as the weighted growth in capital inputs per hour worked) and MFP.

Conceptually the MFP residual can be thought of as capturing technological progress, including the effect of changes in management techniques and business processes or more efficient use of factor inputs. It is important to note that improvements in the quality of capital are examples of “embodied technical change”. In principle, such quality changes are captured in the measurement of capital services and are not included in MFP. MFP is linked, therefore, not to an increase in the quantity or quality of measured factor inputs but rather to how they are employed.

In practice the MFP residual may also capture a number of other effects such as adjustment costs, economies of scale and measurement error in inputs and outputs. For example an improvement in the quality of the labour force not captured by the quality adjusted labour inputs or returns from expenditures that are not currently treated as capital formation within the National Accounts framework, such as workplace-based training, design and branding, will be incorporated into the MFP residual.

The formal growth accounting methodology was set out in Appendix 2 of the 2012 MFP article ([Appleton and Franklin, 2012](#)) and is not repeated here. More information on data sources is set out in Appendix 1 of this release.

Note that due to the volatility of year on year MFP growth, some of the results are presented as averages over the periods. Estimates by industry and year are available back to 1990 in the [dataset](#) component of this release. This dataset also includes estimates back to 1971 for the total market sector and for manufacturing.

## 5 . Results

### Total market sector

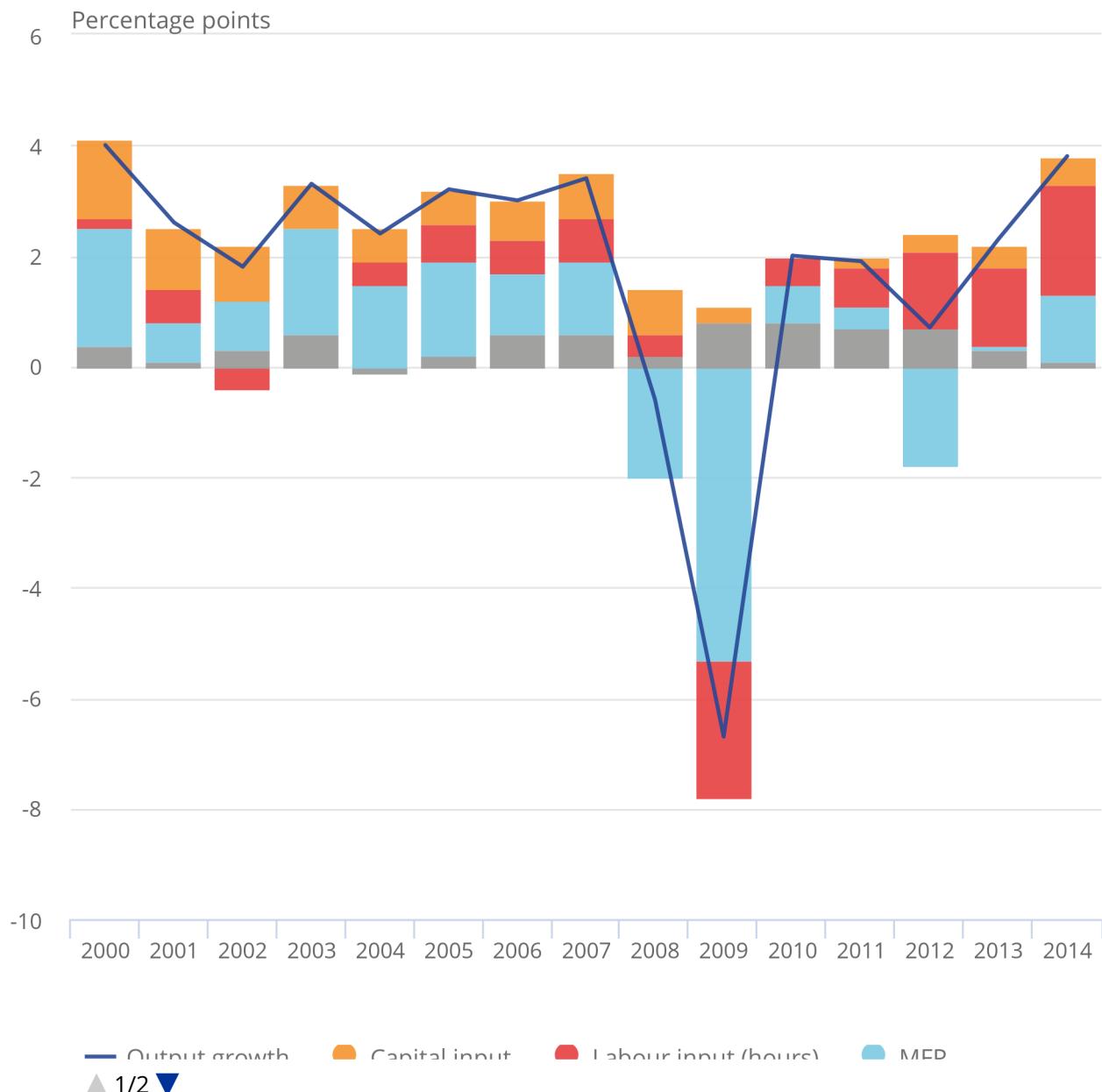
Figure 1 decomposes annual market sector output growth from 2000 to 2014 into contributions from capital and labour input growth (the latter separated into contributions from hours and labour composition) and the residual multi-factor productivity (MFP) contribution. MFP made a positive contribution to output growth in 2014 (1.2 percentage points, out of 3.8 percentage points of output growth), this is the largest MFP contribution since 2007, but still a little lower than the average contribution of MFP to this period prior to the economic downturn (1.4 percentage points). The main cause of increased output growth in 2014 was an increase in hours worked (2.0 percentage points). Capital input contributed 0.5 percentage points to output growth in 2014. This was the strongest contribution since 2008 and reflects an upward trend in the volume of business investment. Labour composition also made a positive contribution to output growth in 2014, albeit only 0.1 percentage points and the weakest since a small negative contribution of this component in 2004.

**Figure 1: Decomposition of annual output growth, 2000 to 2014, UK**

Market sector

Figure 1: Decomposition of annual output growth, 2000 to 2014,  
UK

Market sector



— Output growth □ Capital input ■ Labour input (hours) ▲ MED

▲ 1/2 ▼

Source: Office for National Statistics

Source: Office for National Statistics

The growth accounting framework can be re-arranged to provide a breakdown of movements in labour productivity measured by output per hour, as shown in Figure 2. In this presentation the capital contribution reflects changes in capital services per hour worked (known as capital deepening). Differences between capital input (Figure 1) and capital deepening (Figure 2) are particularly apparent in the period since 2009, where the positive contributions of aggregate capital input in Figure 1 turn into negative contributions in terms of capital deepening, or “capital shallowing”. This is because the growth of aggregate capital services has been slower than the growth of hours worked, resulting in less capital per hour. Labour composition and MFP are identical in Figures 1 and 2.

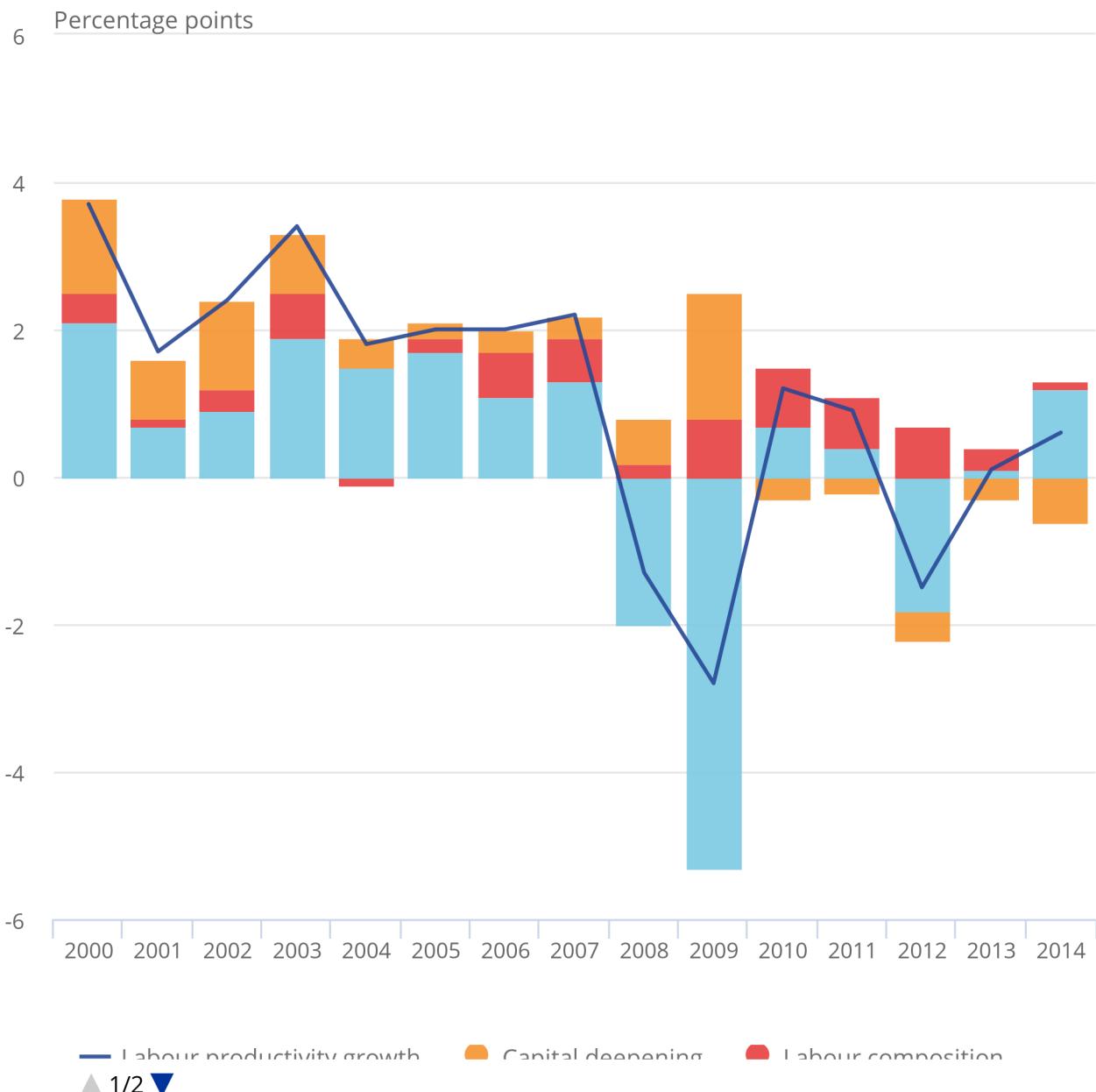
Market sector output per hour rose by an estimated 0.6% in 2014, well below the pre-downturn average of around 2.4% per year. Capital shallowing (-0.6 percentage points) compares with average positive contributions of 0.7 percentage points prior to the economic downturn. The labour composition contribution in 2014 was also lower than the pre-downturn average.

**Figure 2: Decomposition of labour productivity growth, 2000 to 2014, UK**

Market sector

Figure 2: Decomposition of labour productivity growth, 2000 to 2014, UK

Market sector



Source: Office for National Statistics

Source: Office for National Statistics

## Historical perspective

Figure 3 looks at the long run trend in the decomposition of labour productivity for the market sector, carrying the series in Figure 2 back to 1971<sup>1</sup>. There is clear evidence of economic downturns coinciding with periods of negative MFP, in the mid-1970s, the early 1980s and early 1990s as well as 2008 to 2009. The 2008 to 2009 downturn notably had the largest decrease in MFP in comparison with other downturns. Equally there is evidence of rebounds of above-trend MFP following previous downturns, for example in the mid-1970s, early 1980s and mid-1990s. Thus far there has been no such rebound in MFP following the 2008 to 2009 downturn and indeed MFP turned sharply negative in 2012. This prolonged weakness of MFP is one of the defining characteristics of the UK productivity puzzle.

The evidence of a trend decline in capital deepening is striking. Between 1971 and 1997, capital deepening contributed, on average, 1.2 percentage points a year to labour productivity growth. Since 1997, this has fallen to 0.5 percentage points per year on average and since 2009 the average contribution of capital deepening has been minus 0.4 percentage points per year.

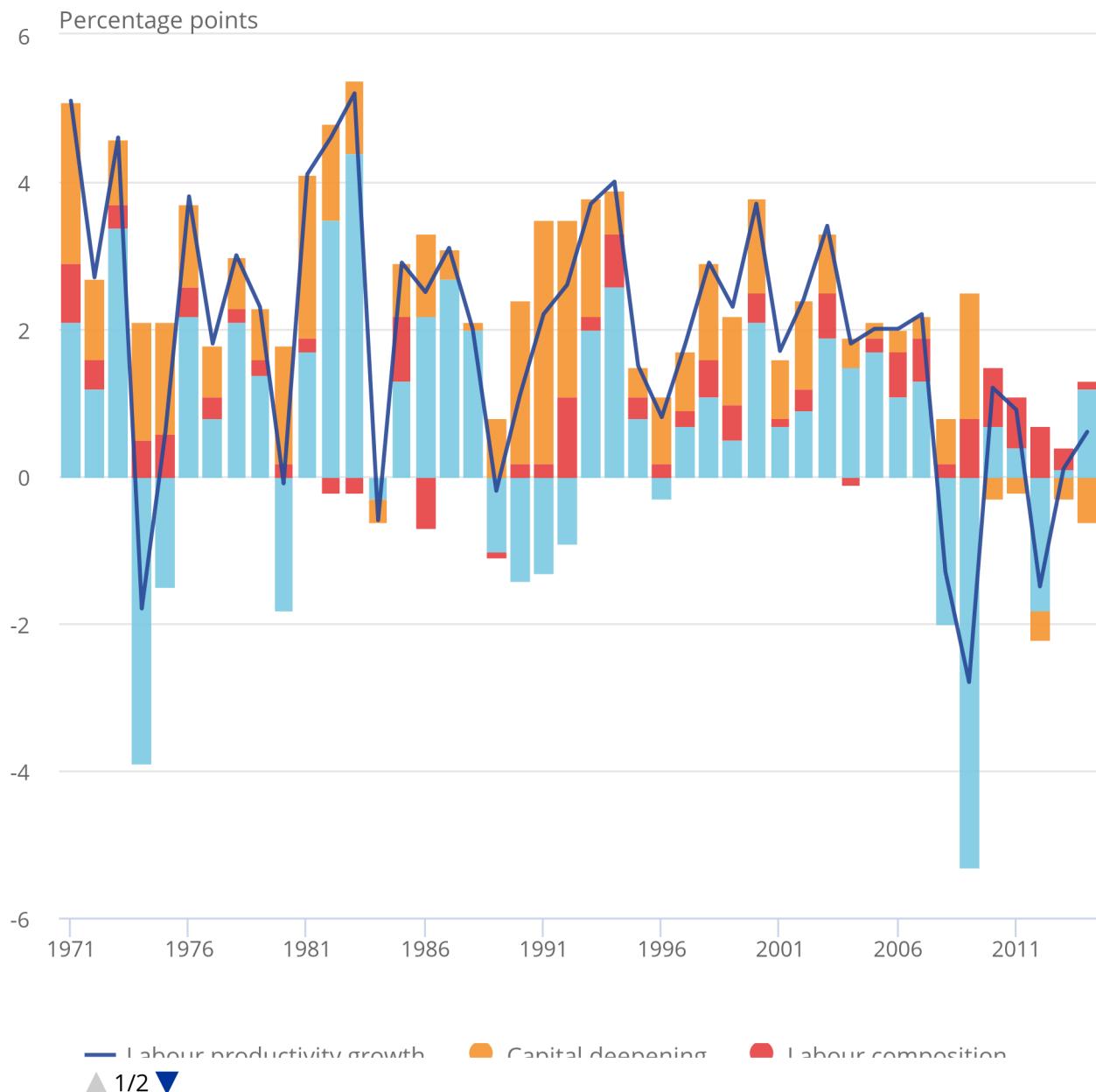
Until recently, movements in labour composition have been in the opposite direction and have acted to partly offset the declining contribution of capital deepening on growth of labour productivity. At the total market sector level, the average contribution of labour composition has increased from around 0.2 percentage points per year prior to 1997 to around 0.5 percentage points per year between 1997 and 2012. However, improvements in labour composition have tailed off sharply in 2013 and 2014.

**Figure 3: Decomposition of labour productivity growth, 1971 to 2014, UK**

Market sector

Figure 3: Decomposition of labour productivity growth, 1971 to 2014, UK

Market sector



Source: Office for National Statistics

Source: Office for National Statistics

On average, MFP growth has been lower since 1997 (0.4 percentage points per year) than prior to 1997 (0.9 percentage points per year). This, together with the downward trend in capital deepening, accounts for the decline in labour productivity average growth rates between these periods.

## Results by industry

This section decomposes labour productivity growth (gross value added (GVA) per hour worked) by industry. Categories on the Y-axis for Figures 4, 5 and 6 refer to the industry groupings set out in Table 1. Total MS is the total market sector.

**Table 1: Industry descriptions**

Industry <sup>1</sup>	Industry Description
ABDE*	Agriculture; Forestry & fishing; Mining & quarrying; Utilities
C	Manufacturing
F	Construction
GI	Wholesale & retail trade; Accommodation & food services
H*	Transportation & Storage
J*	Information & communication
K	Financial & insurance activities
LMN*	Real estate activities; Professional & scientific activities; Administrative & support activities
OPQRSTU*	Public administration & defence; Education; Health & social work; Arts & entertainment; Other services
Total MS	Total Market Sector

Source: Office for National Statistics

Notes:

1. Standard Industrial Classification (2007)
2. \* Denotes industry affected by removal of non-market sector components

The main industry in Table 1 that is affected by the exclusion of non-market activities is OPQRSTU. As noted above, this combined industry grouping is a feature of the ONS quality adjusted labour input (QALI) system and we will look to separate this grouping into at least 2 components (OPQ and RSTU) in future editions. The other industry groups with elements of non-market activity in terms of GVA are LMN (imputed rent and non-market R&D), H (Network Rail), J (broadcasting) and ABDE (waste collection). Industries C, F, GI and K do not contain any non-market elements in terms of GVA.

Figure 4 presents the decomposition of labour productivity growth by industry, expressed as annual averages over the period 1998 to 2014. It can be seen from the chart that average MFP contributions over the last 17 years have varied substantially. Industry J (information and communication) has seen by far the largest positive contribution of MFP (2.8 percentage points per year), whilst the combined OPQRSTU industry group has seen the largest negative contribution (-2.8 percentage points per year), with MFP in ABDE not far behind at -2.6 percentage points per year. MFP made negligible contributions to labour productivity growth in 3 industries: GI, H and K.

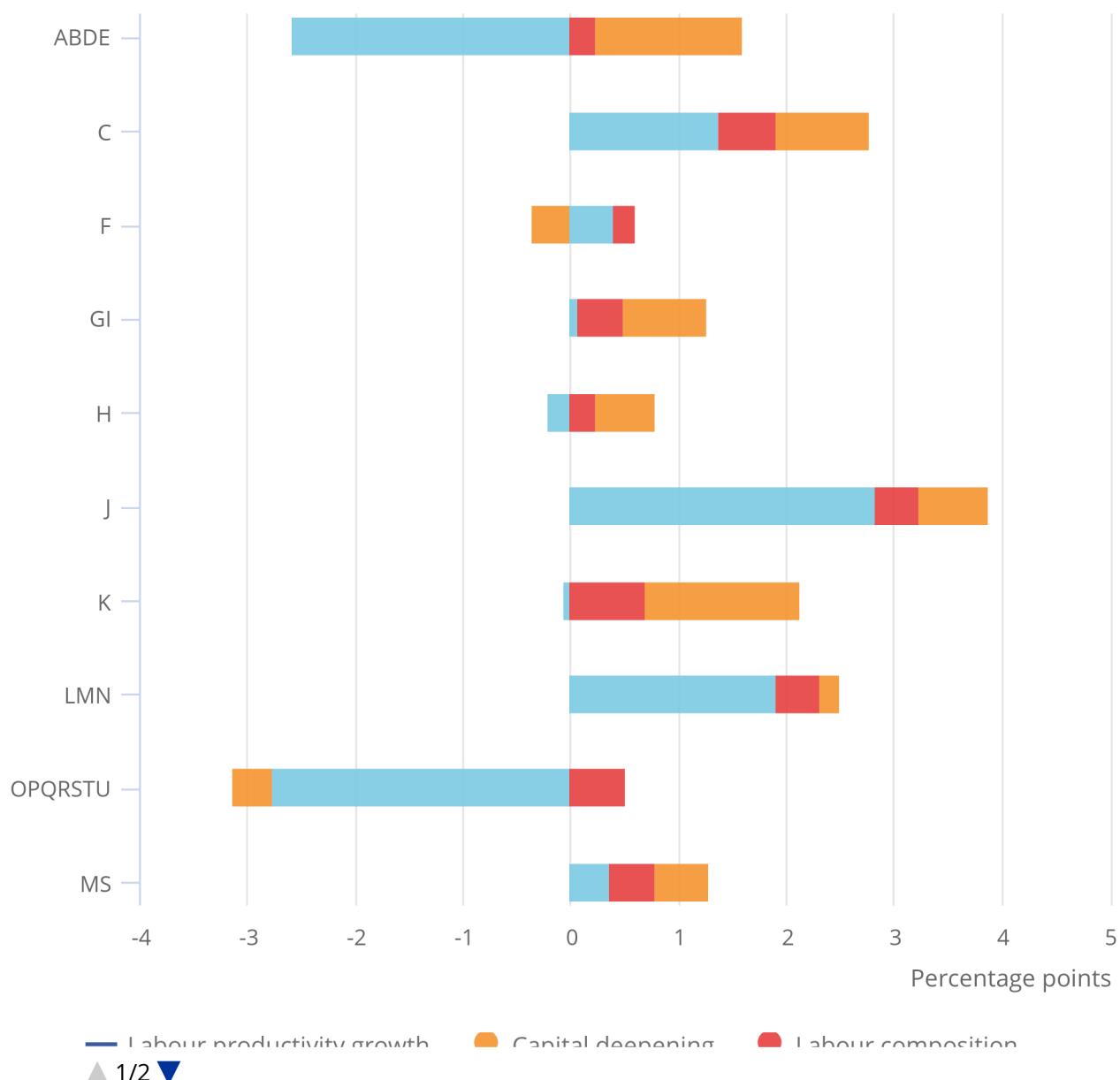
The significant negative contributions of the groupings OPQRSTU and ABDE seem alarming; they do however only represent 9% and 7% of total market sector GVA, with the largest industries in GVA terms being LMN, GI and C at 20%, 18% and 14% respectively.

**Figure 4: Decomposition of annual average labour productivity growth, 1998 to 2014, UK**

By industry

Figure 4: Decomposition of annual average labour productivity growth, 1998 to 2014, UK

By industry



Source: Office for National Statistics

Source: Office for National Statistics

Contributions from capital deepening have also varied across industries although not as much as MFP. Capital deepening is estimated to have made the largest positive contribution in industries K and ABDE, while industries F and OPQRSTU experienced capital shallowing over this period. Labour composition made positive contributions across all industries, with the largest impacts in industries K, C and OPQRSTU.

Focusing on the period since the economic downturn (Figure 5), labour composition is again estimated to have made positive contributions to productivity across the board, while capital deepening has made substantial negative contributions in industries J and OPQRSTU and a strong positive contribution in industry K. However, these elements are dwarfed by MFP contributions which have been large and negative in 6 out of 9 industries. MFP made positive contributions to productivity in industries C, J and LMN, albeit much less than seen in Figure 4.

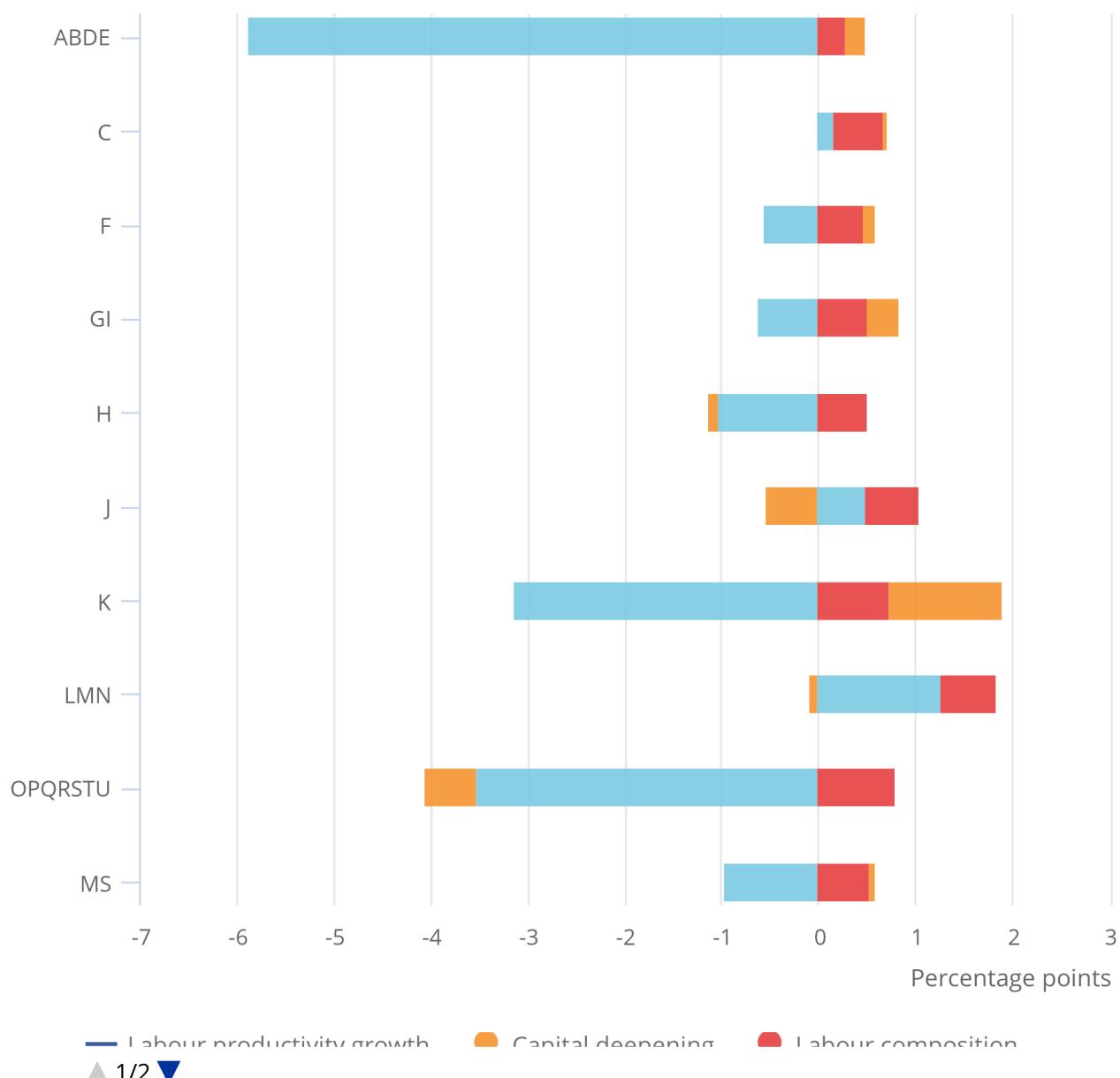
Over this period, overall MFP for the market sector reduced productivity growth by around 1 percentage point per year, more than offsetting the positive contributions from labour composition (0.5 percentage points per year) and capital deepening (0.1 percentage points per year).

**Figure 5: Decomposition of annual average labour productivity growth, 2008 to 2014, UK**

By industry

Figure 5: Decomposition of annual average labour productivity growth, 2008 to 2014, UK

By industry



Source: Office for National Statistics

Variations in MFP account for much of the variation in labour productivity growth across industries. The varying contributions of MFP across industries may reflect differences in the diffusion of disembodied technological change, or perhaps measurement error. Measurement error can vary by industry as, for example, it is generally more difficult to differentiate between volume and price movements in service industries than in production industries. Moreover, as noted above, decomposition of productivity movements below the whole economy level should ideally take account of contributions of (real) intermediate inputs.

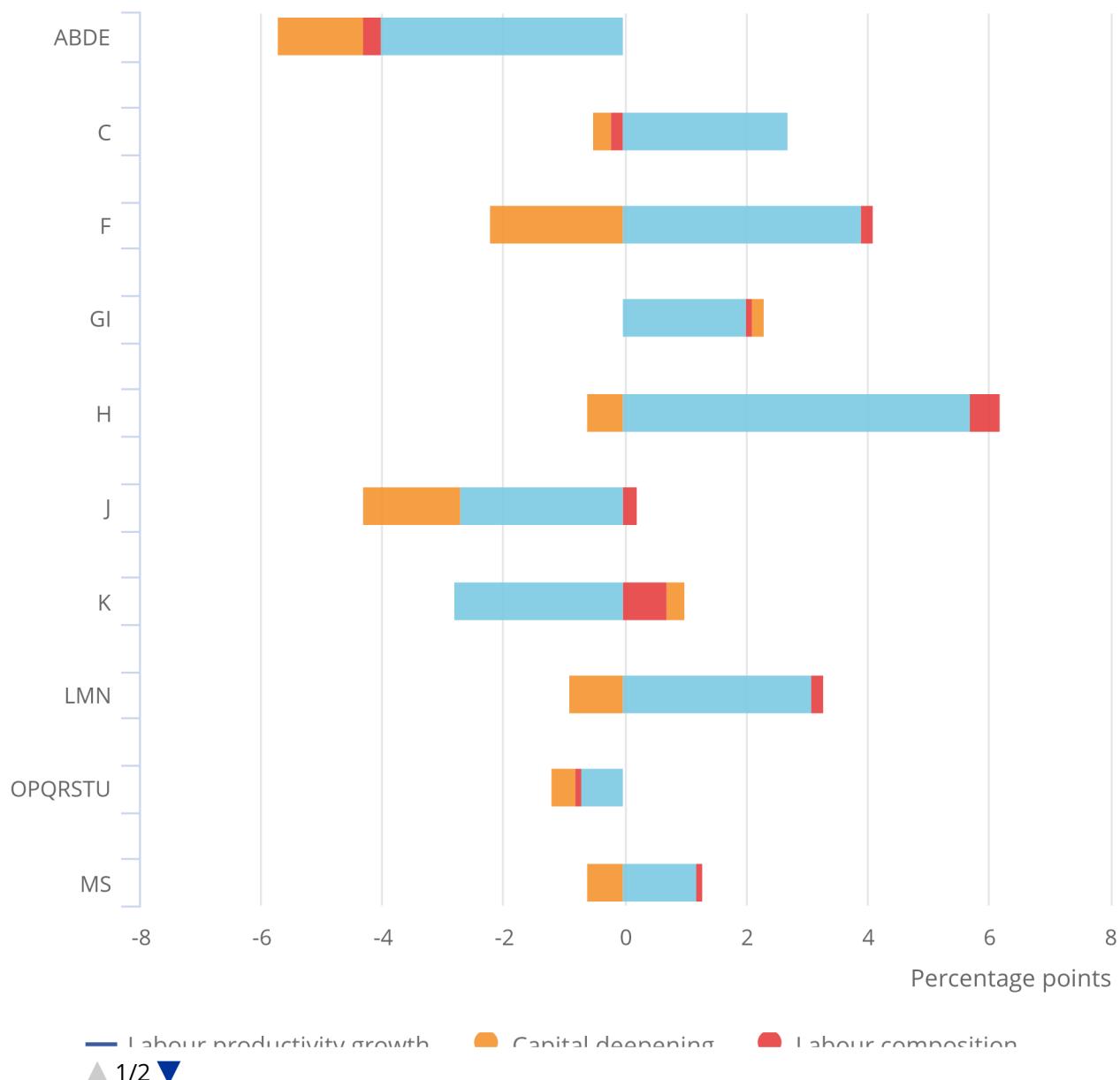
A decomposition of labour productivity in 2014 (Figure 6) shows how much MFP, labour composition and capital deepening can differ across industries in a single year. Yearly estimates of MFP are quite volatile and Figure 5 should mainly be used as a tool to highlight further the divergences in productivity across industries. Differences in MFP account for a large part of the differences in labour productivity across industries.

**Figure 6: Decomposition of labour productivity growth, 2014, UK**

By industry

Figure 6: Decomposition of labour productivity growth, 2014,  
UK

By industry



Source: Office for National Statistics

**Notes for results:**

1. Some historic estimates for market sector GVA and QALI have been compiled using whole economy growth rates. See Appendix 1 for more information

## 6 . Revisions

Revisions to multi-factor productivity (MFP) estimates since Connors and Franklin (2015a) arise from revisions to the component series and can be categorised into 3 broad groups:

- revisions to output growth rates arising from changes to the UK National Accounts introduced in Blue Book 2015 and, for some industries, adjustments to remove the non-market components
- revisions to capital services source data; as detailed in Blunden and Franklin (2016), these are dominated by revisions arising from changes of the ONS Volume Index of Capital Services ("VICS") system to focus on the market sector
- quality adjusted labour input (QALI) revisions arising from re-weighting of LFS micro-data for the 2011 Census, as described in Connors and Franklin (2015b), together with some further changes from adoption of Blue Book 2015 industry level income constraints and latest industry level hours constraints consistent with the ONS Labour Productivity framework

To give an indication of the causes of revisions to output growth, Figure 7 plots the average contributions at the total market sector level for the most recent and previous estimates. The data cover the period 1998 to 2013, over which comparable data are available.

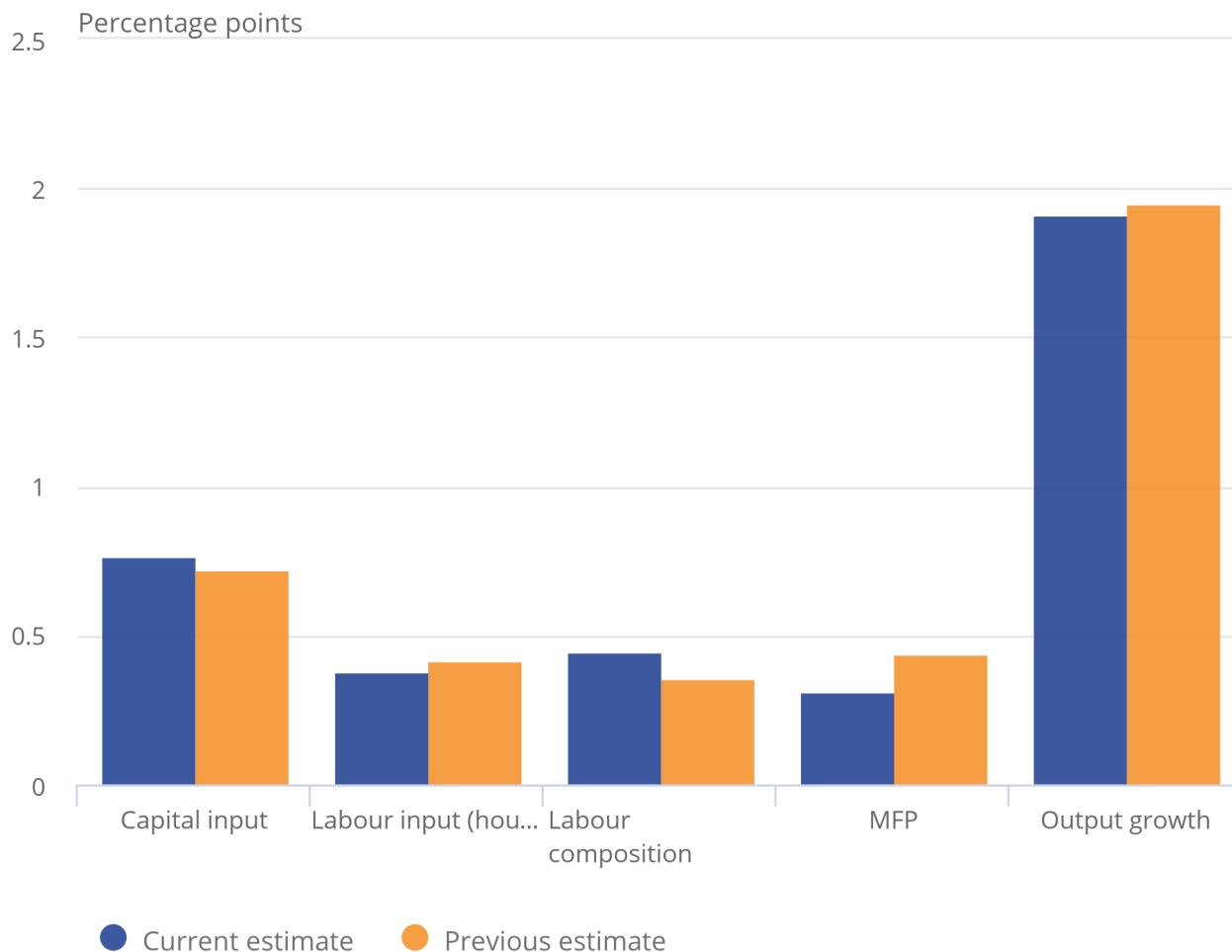
Average output growth and growth of hours worked have both been revised down very slightly over this period, while labour composition has been revised upwards. Considering the fundamental change in methodology, from a top down to a bottom up approach, the revisions to capital are rather modest. Overall revisions have reduced average MFP growth over this period, which may reflect improved accounting across the market sector from the adoption of a bottom up approach in the ONS VICS system. This is described further in Blunden and Franklin (2016).

**Figure 7: Contributions to market sector annual average output growth, 1998 to 2013, UK**

Current and previous estimates

**Figure 7: Contributions to market sector annual average output growth, 1998 to 2013, UK**

Current and previous estimates



Source: Office for National Statistics

Source: Office for National Statistics

## 7 . Next steps

We will publish an Economic Statistics and Analysis Strategy paper later in 2016. This will outline our high level strategic priorities pertaining to multi-factor productivity (MFP) within (i) a broader productivity agenda and (ii) the overall strategy for economic statistics and analysis over the period to 2021. We will update users further in the July UK Productivity bulletin.

At working level, our short-term priorities include a review of our quality adjusted labour input (QALI) framework, including better alignment to the market sector and development of finer industry-level granularity. Depending on your feedback, we may also look to review and extend the historic time series for individual industries. For information on how you can communicate feedback to us see the background notes of this release.

## 8. Background notes

1. We are keen to develop a greater understanding of your use of productivity statistics. If you have any feedback please get in touch via [productivity@ons.gsi.gov.uk](mailto:productivity@ons.gsi.gov.uk).
2. We publish a quarterly [Labour Productivity statistical bulletin](#). This provides more timely and periodic information regarding UK labour productivity, and uses a more disaggregated industry breakdown than this MFP release.

We publish [international comparisons of labour productivity](#) in levels and growth rates for the G7 countries. More international data on productivity are available from the [OECD](#), [Eurostat](#), and the [Conference Board](#).

We also publish a range of [public sector productivity measures](#) and related articles. These measures define productivity differently from that employed in our Labour Productivity and MFP estimates. Further information can be found in [Phelps \(2010\)](#) and [Gill and Kliesmentye \(2015\)](#).

More information on our range of productivity estimates can be found in the [ONS Productivity Handbook](#).

3. Details of the [policy governing the release of new data](#) are available from the [UK Statistics Authority](#) website.

## 9. References

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Phelps M (2010) 'Comparing different estimates of productivity produced by the Office for National Statistics', Economic and Labour Market Review, vol. 4, no. 5, May 2010

Solow R (1957) '[Technical Change and the Aggregate Production Function](#)', Review of Economics and Statistics, vol. 39, no. 3, pp. 312-320

## 10. Appendix 1: MFP sources and methods

The growth accounting approach taken in this article is relatively undemanding in terms of data requirements. It uses gross value added (GVA) as an output measure and quality adjusted labour input (QALI) and capital services as its factor inputs. In addition the income share of each factor of production, labour and capital, is required to determine its contribution to output growth.

## **Quality adjusted labour input (QALI)**

The use of QALI allows labour contribution to be attributed to both an increase in the volume of labour, in terms of actual hours worked and an increase in the quality of labour, in terms of skill composition of the workforce. QALI is mainly derived from quarterly labour force survey (LFS) data, which captures information on the educational, sex and age composition of the workforce.

QALI makes the assumption that workers are paid their marginal product, the hours worked by each of these compositional categories are weighted by their share in total labour outcome. That is, labour input is broken down by industry, age, education and sex and each component is weighted by its income share. The QALI estimates used in this release have been benchmarked to labour income weights consistent with Blue Book 2015 (and specifically the Supply-Use tables of the Blue Book release).

## **Capital services**

Capital services are akin to QALI in capturing compositional changes in capital inputs more fully than alternative measures of capital input, such as changes in net capital stocks. Capital services differ from National Accounts capital stock measures as they weigh together the growth in the net stock of assets using rental prices rather than purchase prices. Rental prices better reflect the cost of owning an asset over a specific time period, which can differ greatly from the costs of ownership over the whole asset life. Further, using rental prices is conceptually more appropriate for use in growth accounting analysis since, under the assumption that factors receive their marginal products, rental prices better reflect the marginal productivity of a given capital asset.

For further information about capital services and the most recent methodological developments, see Blunden and Franklin (2016).

## **Output and income shares**

Output measures used in MFP analysis are chained volume indices of GVA at basic prices, consistent with the Quarterly National Accounts (QNA) published on 31 March 2016. We do not publish industry level market sector GVA estimates. These have been compiled by the ONS Productivity team in conjunction with the GDP(O) team.

Labour and capital income shares are derived in a consistent fashion from the income presentation of the National Accounts and include a decomposition of the income of the self-employed, which is recorded in the National Accounts as mixed income. Mixed income includes returns to both capital and labour. Capital income includes gross operating surplus (GOS), estimates of which for the market sector are available from the ONS Supply-Use framework. We exclude that part of GOS attributable to ownership of dwellings, which are not deemed to be part of the productive capital stock.

An alternative approach to growth accounting is to use a gross output measure and calculate the contributions to growth not only from capital and labour inputs but from intermediate inputs as well. An example of this approach is the [EUKLEMS project](#) which additionally apportions output growth to the intermediate inputs of energy, materials and services. Whilst this approach is conceptually preferable, its data requirements are much more onerous. In particular, constant price supply use tables, which are not currently published by ONS, represent a barrier to adoption of this approach.

## **Historical estimates**

Capital services estimates are available on a consistent basis over the entire period back to 1970. Estimates of QALI prior to 1994 are constructed using data from the EUKLEMS project, which contains industry component series for hours worked and labour composition. The EUKLEMS industry breakdown pre-dates SIC 2007 and series have been mapped across using a conventional industry mapping. A series for the market sector has been approximated based on movements at the whole economy level.

Aggregate market sector GVA (series L48H) is available only back to 1997. We have back-cast this series back to 1991 using an earlier vintage of data, and we have back-cast back to 1970 using growth in whole economy GVA. These approximations should be taken into account when interpreting estimates for the early years in this release.