Abstract

This article presents indicative estimates of multi–factor productivity (MFP) to 2012 using estimates of quality adjusted labour inputs and capital services. Using a growth accounting framework, output growth can be decomposed into contributions due to changes in labour and capital inputs, and a residual component variously described in the literature as 'disembodied technical change', the 'Solow residual', total factor productivity (TFP) or – as in this article - MFP. This approach complements traditional measures of productivity, which focus only on one factor of production – labour – and take account only of changes in the volume of labour input (that is, hours worked) but not changes in the composition of labour input over time. Capital input to production is measured by capital services which similarly take account of changes in the composition of the productive stock of capital over time. These new growth accounting estimates show a small negative contribution to UK output growth from MFP in 2011 and a larger negative contribution in 2012. There are no significant revisions to growth accounting estimates up to 2010 last published in September 2012. However, readers should bear in mind that estimation of capital services is particularly challenging due to changes in ONS systems for production of low-level estimates of investment by industry and asset category, upon which capital services depend. Reflecting this, all of the estimates in this article are purely indicative and should not be interpreted as official statistics.

Acknowledgements

1. The authors thank John Allen and Joe Murphy of ONS for research support in preparing this article.

About this release

This is the latest in a series of MFP releases, containing indicative estimates of MFP growth for 1994 to 2012 consistent with Blue Book 2013. The previous edition was published in September 2012 and contained estimates to 2010, based on Blue Book 2011. Thus, although ONS has not published an MFP update based on Blue Book 2012, in this article we have shortened the time lag between availability of Blue Book data and publication of growth accounting estimates by some 8 months. Data are presented for the whole economy, the market sector and ten industry groups. MFP measures the change in real (inflation adjusted) economic output that cannot be accounted
for by changes in measured inputs of labour and capital. Importantly, 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 Franklin and Mistry (2013).

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. The weights used in this capital services framework differ from those used in measuring the value of the stock of capital in the 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 Appendix 2.

**Interpreting these statistics**

Using a growth accounting framework, as first 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). This term is sometimes referred to as the ‘Solow residual’ or total factor productivity (TFP).

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 research and development, will be incorporated into the MFP residual.

The formal growth accounting methodology was set out in Appendix 2 of the [previous edition](#) 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. The results by year are presented in the Reference Table (97.5 Kb Excel sheet) component of this release.

Results: Whole economy

As shown in Figure 1, MFP made a small negative contribution to output growth in 2011 and a larger negative contribution in 2012. The main contribution to whole economy output growth in 2011 came from an increase in labour composition (0.7 percentage points). Labour composition also made a positive contribution to output growth in 2012 (as it has in every year other than 2001). But of more interest is the very large contribution from hours worked in 2012, which combined with a deceleration in the rate of output growth implied a sharp reduction in labour productivity measured as output per hour. Capital made a tiny negative contribution to output growth in 2012, reflecting the weakness of investment in recent years.

As noted in Franklin and Mistry (2013), the positive contribution from labour composition in every year since 2008 exacerbates the “productivity puzzle” since it implies that labour input to production has been even stronger than implied by an unweighted measure of hours worked. Alternatively it implies that the average productive potential of each hour worked has improved over this period, reflecting – on average – a shift towards labour market attributes that are associated with higher productivity such as educational attainment and experience.

Capital services are estimated to have made a small negative contribution to growth in 2012. The positive contribution from capital services to growth in the period 2009 to 2011 may seem surprising given the weakness of investment after 2008. However, it should be recalled that capital services flow from productive capital stocks which, for some long-lived assets such as buildings and structures, depend on investments over many prior years. But persistent weakness in investment will eventually feed through into capital services, as was the case in 2012. Moreover, ONS measures of capital services currently allow for no feedback between the cyclical state of the macro-economy and capital scrapping, whereas it certainly seems possible that some productive capital has been prematurely scrapped over the recession, as has been shown to be the case in previous recessions (see for example Harris & Drinkwater, (2000)). And as noted in Appendix 2, the capital services estimates embedded in this release are subject to more than usual uncertainty due to gaps in the source data.
As explained above, 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). The difference between capital input (Figure 1) and capital deepening (Figure 2) is particularly apparent in 2012 when aggregate capital services fell only slightly but the volume of capital services per hour worked fell more sharply, reflecting the increase in hours worked. The reverse pattern is seen in 2009, when a fall in hours was reflected in a larger contribution in capital deepening than overall capital services. Labour composition and MFP are identical in Figures 1 and 2.
Comparing Figure 2 with Figure 1, it is apparent that movements in labour productivity and MFP are both pro-cyclical, reflecting movements in output growth. This is especially the case since 2008. In the case of labour productivity, hours are, of course, strongly correlated with output over time, but on a year-by-year basis, changes in hours tend to be much smaller than changes in output. Moreover, since movements in labour composition and measured capital inputs are only weakly related to output growth, it follows that much of the year-on-year change in output (and labour productivity) tends to be reflected in MFP. The contribution of labour composition in each of the 4 years since 2008 has been larger on average than prior to the economic downturn.

Results: Industry breakdown

Figure 3 presents the decomposition of labour productivity group by industry, expressed as annual averages over the period 1998 to 2012. Categories on the x-axis refer to industry groupings set out in the notes below Figure 3. WE is the whole economy and MS is the market sector. The first point of interest is that the pattern of MFP contributions varies widely across industries, adding around 2.5 percentage points to growth of industry J (information & communication), and subtracting around 2 percentage points from growth of industries ABDE (primary industries and utilities) and RSTU (arts & entertainment and other services). Of the 10 industries that make up the whole economy, the MFP...
contribution is negative in 7 and positive only in 3 over this period. By contrast, capital deepening and labour composition make positive contributions to output per hour in all industries. Capital deepening is estimated to make the largest contributions in industries F (construction) and RSTU, and the smallest contributions in industries OPQ (public services) and ABDE. Labour composition generally varies less by industry, but is less pronounced in industries ABDE, F and H (transport & storage), and more pronounced in industry K (financial services). As in the case of the whole economy time series (Figures 1 and 2), variations in MFP account for much of the variation in labour productivity growth across industries. For the economy as a whole, the MFP contribution is close to zero over the period 1998 to 2012: that is, all of the growth in output per hour over this period can be accounted for by movements in labour composition and capital deepening. This is also the case for the market sector.

Figure 3: Decomposition of annual average labour productivity growth by industry, 1998 to 2012

Source: Office for National Statistics

Notes:
1. ABDE: Agriculture; Forestry & fishing; Mining & quarrying; Utilities
2. C: Manufacturing
3. F: Construction
4. GI: Wholesale & retail trade; Accommodation & food services
5. H: Transportation & storage
6. J: Information & communication
7. K: Financial & insurance activities
8. LMN: Real estate activities; Professional & scientific activities; Administrative & support activities
9. OPQ: Public administration & defence; Education; Health & social work
The varying contributions of MFP across industries may reflect differences in the diffusion of disembodied technological change, and perhaps also differences in the propensity of knowledge-based activities such as expenditure on R&D and on human capital. Such expenditures are not currently included in the asset base in the system of national accounts and are not therefore captured in capital services\(^1\).

Figure 4 presents a cross section of the decomposition of labour productivity growth across the UK economy in 2012. As stated previously, annual estimates of MFP are quite volatile and Figure 4 should mainly be used as a tool to illustrate the divergences in productivity across industries.

**Figure 4: Decomposition of labour productivity growth by Industry, 2012**

Source: Office for National Statistics

**Notes:**
1. See Figure 3 above for x-axis categories
MFP is estimated to have made a negative contribution to growth of output per hour in 2012 in all industries other than RSTU, which was also the only industry to record growth in output per hour, and one of only 3 industries to record an increase in capital deepening. This industry was the principal beneficiary of the Olympic and Paralympic Games, and the 2012 pattern for this industry contrasts sharply with the average pattern in Figure 3\(^2\). As in earlier figures there is a strong positive relationship between labour productivity and the MFP contribution.

Comparing Figures 3 and 4 it can be seen that 2012 was atypical in a number of respects. Output per hour fell in all industries except RSTU and by around 2% for the whole economy, compared with average labour productivity growth of 1.4% over the period 1998-2012. Capital deepening made a negative contribution in most industries in 2012 compared with positive contributions across the board over the period 1998-2012. And MFP also made a negative contribution to whole economy labour productivity in 2012, compared with an average zero contribution over 1998-2012. Only the labour composition component was broadly typical – adding 0.8 percentage points to whole economy labour productivity in 2012 compared with an average contribution of 0.6 percentage points over 1998-2012, and making a positive contribution in all industries. This underlines the need for caution in interpreting MFP estimates for a single year.

Notes

1. R&D expenditures will be capitalised in Blue Book 2014.

2. The value of Olympic and Paralympic ticket sales has been estimated at £580m. This is around 1.3% of 2012 value-added in industry RSTU.

Revisions since last release

Revisions to the MFP results since Appleton and Franklin (2012) arise from methodological changes since the last release and revisions to data sources. Methodological changes are confined to measurement of labour inputs and are described in Franklin and Mistry (2013). There are no significant methodological revisions either to capital services or to MFP in this release\(^1\).

Revisions to data sources primarily reflect changes to the National Accounts data in Blue Book 2012 and Blue Book 2013. In particular, Blue Book 2013 introduced new methods for estimation of gross fixed capital formation (GFCF), including improvements to the estimation of artistic originals and changes to the estimation of own-account software. These changes are described further in Jones (2013), Hardie et al (2013) and the references therein.

The level of current price GFCF for the combined assets that feed into our estimates of capital services has been revised down by about 3% on average over the period 1997 to 2010 between Blue Book 2011 and Blue Book 2013. However, there are much larger revisions to individual asset categories: tangible investment has been revised down by some 15% on average over this period, while intangible investment has almost doubled in current prices, partly reflecting the changes to artistic originals and own-account software noted in the previous paragraph.
The chained volume investment series also show a large switch from tangible to intangible investment. On this basis, overall investment has been revised up on average (by around 4% over the period 1997-2010). But tangible investment is some 7% lower than recorded in Blue Book 2011, while intangible investment is now 82% higher, on average. In terms of annual growth rates, overall investment growth is around 0.9% per year lower in Blue Book 2013 than in Blue Book 2011, investment in tangible assets is 1.4% per year lower and investment in intangible assets is 1.7% per year higher over 1997-2010.

There are also notable differences in revisions to different tangible assets. Investment in buildings has been revised up in chained volume terms while there have been large downward revisions to real investment in vehicles and other plant and equipment. In growth rate terms, growth of investment in buildings and other machinery and equipment has been revised down (by 0.8% and 3.1% per year respectively), while growth of investment in vehicles has been revised up by 0.9% per year on average over 1997-2010.

Blue Book 2013 also contains significant differences to investment deflators, which feed into the estimation of capital services because user costs include an element to reflect real price changes of capital assets. Between 1997 and 2010 the aggregate investment deflator grew by 1.2% per year on average, compared with a fall of 0.4% on average according to Blue Book 2011. Some of this difference reflects the large difference in asset composition between Blue Book vintages. However there are also significant revisions to deflators for individual assets. Price changes for buildings and other machinery and equipment have been revised up by around 2% per year on average, while price changes of vehicles have been revised down by a similar amount. Price changes of intangible assets have been revised down by 1.4% per year on average between Blue Books.

Revisions to GFCF and deflators feed through to revised capital services estimates although in general these are not especially large, especially when averaged over time. For most industries, capital services growth is a little slower than in the last release. The relationship between GFCF (an annual flow) and capital services (which flow from the accumulated stock of productive capital) is non-linear, but the direction of movement is consistent with the lower growth of real investment noted above.

To give an indication of the drivers of revisions to output growth, Figure 5 plots the average contributions at the whole economy level for the most recent and previous estimates. The data cover the period 1998 to 2010, over which comparable data are available. Over this period, average output growth has been revised downwards from 2.2% to 2.1%. The contributions of both labour hours and labour quality have increased slightly (reflecting methodological changes in the labour inputs framework), and the contribution of MFP has fallen from 0.3 percentage points to 0.1 percentage points. It may seem counter-intuitive that the contribution of capital is very slightly higher, when as noted above capital services growth is lower. This reflects a small shift in factor incomes from labour to capital, thus increasing the weight on capital services within the MFP growth accounting framework.
Figure 5: Contributions to whole economy annual average output growth, 1998 to 2010: new and previous estimates

Source: Office for National Statistics

Download chart

XLS XLS format
(303.5 Kb)

Notes

1. The only methodological changes to capital services are, firstly, that we have made a small change to the inflation benchmark (used to compute real price changes of assets). We now use annual changes in the CPI rather than RPI from 1998 onwards, and annual changes in RPIX between 1976 and 1997. This makes almost no difference to estimates of capital services. Secondly, we have slightly expanded the underlying industry breakdown in response to user feedback. In due course we hope to extend the labour composition framework - and hence the MFP framework - similarly, but in the meantime this makes no difference to capital services estimates.
Next steps

This section describes forthcoming development work on the ONS growth accounting measures. ONS welcomes feedback on all aspects of the statistics produced. For information on how you can communicate this to us see the Background Notes section of this release.

Premature scrapping of capital

ONS estimates of capital services do not currently account for the premature scrapping of assets. The impact of capacity scrapping on capital services is difficult to measure but important, particularly during a turning point in the economic cycle. One approach, used in the ONS wealth-based measurement of capital stocks, adjusts for capital scrapping using information on rates of business insolvencies. Further information on this approach can be found in the Quality and Methodology Information paper for Capital Stocks and Capital Consumption. However, measured insolvency rates do not appear to vary greatly over the economic cycle, and this methodology requires a number of assumptions to be made about the relationship between insolvencies and the capital assets of businesses that are becoming insolvent. In addition, ONS has not published wealth-based measures of capital stocks since 2010.

The productivity branch of ONS intends to explore another approach to capital scrapping, as part of an integrated programme to measure stocks of productive capital in a consistent fashion between the National Accounts and other data environments, including the ONS virtual micro-data laboratory. This builds on EU-funded micro-data linking work carried out over 2010-13, including work to update and develop estimates of productive capital at the level of individual enterprises. See Field and Franklin (2013a, 2013b) for more information. Following Harris & Drinkwater (2000), this provides a route to adjusting for capital scrapping using information on firm demographics – essentially by permitting the quantification of productive capital of firms that cease to exist, then making assumptions about the share of this capital that is re-allocated to other firms. This is a priority line of research for 2014.

Quarterly growth accounting estimates

Another objective is to shorten the time lag between publication of the UK national accounts and publication of growth accounting estimates, with the medium term aim of moving towards a quarterly framework for growth accounting. Considerable progress has already been made in developing a quarterly process for quality-adjusted labour inputs. One application of this work is the development of consistent measures of unit labour costs below the whole economy level, see Franklin and Mistry (2012).

Measurement of capital services on a quarterly basis is conceptually feasible but is some way off in practical terms. As noted in Appendix 2, there are issues with the SIC(2007) production system for low-level investment estimates by sector, industry and asset, which are one of the main inputs to the capital services framework. Capital services estimates used in this release have been based largely on previously published SIC(2003) estimates. Nevertheless, measurement of capital services is a requirement of the 2008 System of National Accounts (SNA 2008) and the 2010 European System of National and Regional Accounts (ESA 2010) and ONS has a work programme in place to meet this requirement.
One issue for consideration is the value of more frequent publication of quality-adjusted labour inputs to users, other than as component of a wider growth accounting framework. ONS welcomes comments from users on this issue.

**Background notes**

1. **User engagement**

   ONS is keen to develop a greater understanding of the use made of productivity statistics. If you have any feedback please get in touch via productivity@ons.gsi.gov.uk.

   This release will be discussed at a productivity statistics user group workshop in London on 28 January 2014. For more information email us at productivity@ons.gsi.gov.uk.

2. **Other information on productivity**

   ONS publishes 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.

   ONS publishes 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.

   ONS also publishes a range of public sector productivity measures and related articles. These measures define productivity differently from that employed in the ONS Labour Productivity and MFP estimates. Further information can be found in Phelps (2010) (252.5 Kb Pdf).

   More information on the range of ONS productivity estimates can be found in the ONS Productivity Handbook.

3. **Details of the policy governing the release of new data are available by visiting www.statisticsauthority.gov.uk/assessment/code-of-practice/index.html or from the Media Relations Office email: media.relations@ons.gsi.gov.uk**

**Copyright**

© Crown copyright 2014

You may use or re-use this information (not including logos) free of charge in any format or medium, under the terms of the Open Government Licence. To view this licence, visit www.nationalarchives.gov.uk/doc/open-government-licence/ or write to the Information Policy Team, The National Archives, Kew, London TW9 4DU, or email: psi@nationalarchives.gsi.gov.uk.
This document is also available on our website at www.ons.gov.uk.

References


Appendix 1 - Data sources

The approach undertaken in this article to growth accounting 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.

The use of QALI allows for the contribution of labour inputs 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 the labour, in terms of the skill composition of the workforce. QALI is mainly derived from quarterly Labour Force Survey (LFS) data. LFS captures information on the educational, industrial, age and gender composition of the workforce. Making the assumption that factors are paid their marginal products, the hours worked by each of these compositional categories are weighted by their share in total labour income. For the most recent analysis of QALI, see Franklin and Mistry (2013). The QALI estimates used in this release have been benchmarked to labour income weights consistent with Blue Book 2013 (and specifically the Supply-Use tables component of the Blue Book release) but are substantially identical to those reported in Franklin and Mistry (2013).

Capital services are analogous 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 weight together the growth in the net stock of assets using rental rather than purchase prices. This 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.

The main challenge in assembling estimates of capital services is to impute rental process of capital assets (also referred to as “user costs of capital”), which are not normally observed or collected. Our approach is to impute rental prices endogenously, conditioned on profits, real price changes of assets and depreciation. For more information on this method see chapter 5 of the ONS Productivity Handbook (Camus, 2007) and chapter 8 of the OECD Measuring Capital manual (OECD, 2009). Industry level profits are derived from ONS Supply-Use tables and extrapolated using a methodology consistent with the derivation of labour income weights in the QALI framework and the quarterly estimation of section-level unit labour costs.

However, owing to current production issues with compilation of investment series disaggregated by asset, industry and sector in ONS, this edition of the MFP release has been compiled using indicative capital services estimates consistent with high level investment by broad asset published in Blue Book 2013. For more information see Appendix 2.

Output measures used in this MFP analysis are chained volume indices of GVA at basic prices, consistent with the latest Quarterly National Accounts (QNA) published by ONS in December 2013\(^1\). 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’ and includes returns to both capital and labour. Capital income excludes that part 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 (see www.euklems.net) which additionally apportions output growth to the intermediate inputs of energy, materials and services. Whilst this approach to growth accounting is conceptually preferable, its data requirements are much more onerous. In particular, constant price supply use tables, which are not currently published by the ONS, represent a barrier to adoption of this approach.

Notes

1. The December 2013 QNA contains some revisions since Blue Book 2013 was published in July 2013. But there are no material revisions either to GVA or to GFCF up to 2012.

Appendix 2 - Derivation of indicative capital services estimates and sensitivity analysis

Deriving capital services estimates
The core data requirements for capital services are long time series of real investment, corresponding deflators, parameters to describe the relationship between investment flows and the evolution of the productive stock of capital, and industry estimates of the pre-tax return to capital.

Disaggregated gross fixed capital formation (GFCF) data by asset and industry have been published on the Ad Hoc pages of the ONS website, most recently in October 2013. However, there are a number of known issues with some of these estimates, including implausibly large (positive and negative) estimates for some low-level components, very large year-on-year changes in components and inconsistencies between chained volume series, current price series and implied deflators.

For the purposes of this article the approach varies for different assets. For buildings, vehicles and other machinery and equipment (OME) we have used SIC(2003) data to 2009 consistent with the 2011 capital services release (Appleton & Wallis, 2011), converted to SIC(2007) using a standard ONS conversion matrix. This conversion was carried out in value and volume terms, and the resulting asset and SIC(2007) industry group shares of investment have been benchmarked to the 2013 Blue Book aggregates. Within the capital services framework, OME is split into computers and other OME. This split uses historic current price estimates of computer investment by industry derived from successive vintages of the ONS supply-use tables, converted to volumes using a common deflator. Volume series for other OME can then be backed out.

As noted in the Revisions section above, there are revisions to aggregate GFCF between Blue Book 2011 and Blue Book 2013, as well as large revisions between asset classes. In these circumstances it is clearly not optimal to revert to historic SIC(2003) low-level components. In the light of this and other issues with the capital services estimates, we present some sensitivity analysis below.

For 2010 to 2012 we have used, for buildings and vehicles, industry share movements in current price terms derived from survey data. Our constant price estimates for these assets reflect the current price share movements and are conditioned to movements in the aggregate asset implied deflator from Blue Book 2013. Where survey data are not available we have assumed constant shares of investment in current and constant price terms.

For OME we have used unpublished ONS estimates (which seek to address some of the issues with the October 2013 estimates) expressed as changes in investment shares in current and constant price. As with the historic data, total OME investment has been benchmarked to Blue Book 2013 aggregates. The computer investment component of OME has been derived from unpublished ONS current price estimates and benchmarked to overall current price computer investment derived from the ONS Business Investment dataset, with other OME backed out as the residual.

The capital services framework includes 4 intangible assets: artistic originals, mineral exploration rights, purchased software and own-account software. In general we have used estimates published on the Ad Hoc pages of the ONS website in October 2013 for these series, combined with unpublished deflator series. One exception is that we have used separate deflators for each of purchased and own-account software, whereas the ONS published series use a common deflator for all software. This implies an inconsistency between real intangible investment in the capital services framework and the corresponding Blue Book series. Strictly speaking it also implies an inconsistency in the growth accounting framework itself, since a different path for real tangible investment would of course feed through into real growth. However, the impact on overall growth in this case is vanishingly small.
It should be emphasised that the resulting estimates of capital services are not official estimates and have been produced solely for the purpose of this growth accounting exercise.

Sensitivity analysis

In this section we look at the impact on growth of capital services of varying some of the key assumptions and judgements made in compiling estimates of capital services.

(i) Conversion of historical GFCF estimates to SIC(2007)

Data on capital spending by firms were not collected on a SIC(2007) industry basis prior to 2008. Given that we need long time series of consistent data to compile estimates of capital services, we need some means of converting historic data to the SIC(2007) industry structure. The conventional approach is to use a standard conversion matrix, using detailed industry level estimates of value-added derived from dual industry coded vintages of the Annual Business Survey (ABS) and the Inter-Departmental Business Register. This conversion matrix is used across ONS National Accounts, and is used in compiling the estimates in the main text of this release. But analysis of the micro-level data suggests that, for the limited period for which dual-coded micro-level data are available, the correlation between value-added and capital expenditure is not especially strong.

Our preliminary analysis suggests that using an alternative conversion matrix, based on capital spending over the period 2008-10 as reported in the ABS, would lead to a significantly different allocation of historical investment between SIC(2007) industries. Assuming that aggregate investment by asset was unchanged from Blue Book 2013, the different allocation across industries would be sufficient to lead to a small but significant increase in growth of capital services, as shown in Table A2.1.

Table A2.1 Compound Growth Rates of Capital services using Capex and Turnover Conversion

<table>
<thead>
<tr>
<th></th>
<th>Turnover Conversion</th>
<th>Capex Conversion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume of capital Services</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1970-1979</td>
<td>5.1%</td>
<td>5.4%</td>
</tr>
<tr>
<td>1980-1989</td>
<td>4.0%</td>
<td>4.2%</td>
</tr>
<tr>
<td>1990-1999</td>
<td>4.1%</td>
<td>4.3%</td>
</tr>
<tr>
<td>2000-2009</td>
<td>3.9%</td>
<td>4.1%</td>
</tr>
</tbody>
</table>

The intuition behind this result is that the alternative mapping re-allocates GFCF, on balance, from industries with lower rates of return to industries where the returns on capital are higher.

One important caveat is that, were ONS to adopt a different conversion matrix for GFCF within its core National Accounts systems, there could be implications for the level of aggregate GFCF and
hence for the overall level of economic activity. This could occur where, for example, re-allocations of GFCF across industries necessitated changes in supply-use balancing.

(ii) Investment decay profiles

Our capital services framework assumes that the services into production provided by a unit of asset accumulation (measured by GFCF) decay geometrically over time. These decay functions vary, principally by asset but also to a lesser extent by vintage (that is, the year in which the asset accumulation occurs), in terms of the average life length of assets and the degree of convexity of the decay function.

The evidence base for these parameters is limited. ONS does not routinely capture information on asset lives from business surveys. Some information can be implied from financial accounts of capital consumption (See McLaren et al, 2011), and ONS has conducted 2 small surveys which have collected information on asset lives of a range of intangible assets (for the most recent survey results, see Field and Franklin, 2012).

Evidence on the curvature of the decay function is similarly patchy. Research in this area has mainly looked at used asset prices but there are a number of limitations to this approach. Firstly, the research is confined to a limited range of asset types (such as vehicles and certain types of plant) with viable used markets. Second, the research has generally focused on non-UK used asset markets. Third, researchers have found high levels of variability in prices for ostensibly similar assets in terms of age and quality. Fourthly, used asset prices are only a proxy for the flow of productive services that an asset delivers. For example, Akerlof’s famous ‘market for “lemons’” paper (Akerlof, 1970) showed that used asset prices may be affected by information asymmetries.

ONS is considering commissioning research to improve our estimates of asset lives and the shape of decay functions. In the meantime, our preliminary analysis suggests that varying these parameters within reasonably plausible limits makes only limited differences to growth of capital services.

(iii) Capitalisation of R&D

It is relatively straightforward to expand the capital services framework to include R&D assets. Provisional (pre supply-use balancing) time series of current price final expenditure on R&D assets by industry and sector, and corresponding deflators are available from ongoing work to capitalise R&D for Blue Book 2014, together with parameters to describe the decay function. What is not currently available is the impact of capitalisation on the income account, or indeed the final impact of R&D capitalisation on overall economic activity, which will depend on supply-use balancing.
Table A2.2 Compound growth rates of capital services with and without R&D

<table>
<thead>
<tr>
<th></th>
<th>Without R&amp;D</th>
<th>With R&amp;D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume index of Capital services</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1997-1999</td>
<td>3.9%</td>
<td>5.0%</td>
</tr>
<tr>
<td>2000-2008</td>
<td>3.7%</td>
<td>4.0%</td>
</tr>
<tr>
<td>2009-2012</td>
<td>1.0%</td>
<td>1.1%</td>
</tr>
</tbody>
</table>

Table source: Office for National Statistics

Assuming that the industry distribution of R&D expenditure is broadly reflected in the industry distribution of income, these preliminary estimates would result in capital services growing a little faster with R&D added to the asset base than without R&D (as in the main text of this release), as shown in Table A2.2. It is important to note that this will not necessarily be true in the final incorporation of R&D in Blue Book 2014. Moreover, it does not necessarily follow that MFP will be lower, on average, with R&D capitalisation, even if the full implementation in the National Accounts preserves this provisional finding of faster growth of capital services. This is because capitalisation of R&D may change the growth as well as the level of real output.

(iv) Negative supply shock

As described in the Next Steps section of the main text above, a priority line of research for ONS in 2014 is to try to quantify premature scrapping of capital using firm-level data.

In order to illustrate the sensitivity of the growth accounting framework to exogenous shocks, Figure A2.1 shows the effect of a once-for-all across the board 5% reduction in the productive capital stock in 2009. We have used a figure of 5% because this is the figure used by HM Treasury to estimate the impact of the financial crisis on UK trend output, see HM Treasury (2009). Comparing Figure A2.1 with Figure 1 in the main text, it can be seen that the contribution of capital to growth turns negative in 2009. The contribution of MFP, while still negative in that year, is correspondingly reduced by about 2 percentage points. There are no differences in other years.
Readers should be aware of the limitations of this sensitivity analysis. First, it is extremely unlikely that the impact of the financial crisis would be uniform across all asset classes and across all industries. On the contrary, it is much more likely that the impact will have varied widely across industries according to a range of factors including exposure to the financial sector. Moreover, some asset classes can be more easily transferred between alternative uses (and spatially within and across national frontiers) more easily than other assets. The distribution of the supply shock matters because flows of capital services from the productive capital stock vary considerably across assets and industries as well as over time.