Accounting for the UK Productivity Puzzle: A Decomposition and Predictions*

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Keywords: innovation, productivity growth
JEL reference: O47, E22, E01

First draft: October 2014
This version: November 2015

Abstract

This paper revisits the UK productivity puzzle using a new set of data on outputs and inputs and clarifying the role of output mismeasurement, input growth and industry effects. Our data indicates an implied labour productivity gap of 13 percentage points in 2011 relative to the productivity level on pre-recession trends. We find that: (a) the labour productivity puzzle is a TFP puzzle, since it is not explained by the contributions of labour or capital services (b) the re-allocation of labour between industries deepens rather than explains the productivity puzzle (i.e. there has been actually been a re-allocation of hours away from low-productivity industries and toward high productivity industries (c) capitalisation of R&D does not explain the productivity puzzle (d) assuming increased scrapping rates since the recession, a 25% (50%) increase in depreciation rates post-2009 can potentially explain 15%(31%) of the productivity puzzle (e) industry data shows 35% of the TFP puzzle can be explained by weak TFP growth in the oil and gas and financial services sectors and (f) cyclical effects via factor utilisation could potentially explain 17% of the productivity puzzle. Continued weakness in finance would suggest a future lowering of TFP growth to around 0.8% pa from a baseline of 0.9% pa.

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1. Introduction
This paper revisits the UK productivity puzzle by using a new set of data on outputs and inputs and clarifying the role of output mismeasurement, input growth and industry effects. We shall argue that the productivity puzzle is a TFP puzzle and use this observation to try to make some predictions about the longer range prospects for UK productivity.¹

The UK² productivity puzzle is well known. Before the 2008 financial crisis, value added per hour worked grew in the UK relatively quickly, at 2.64%pa (2000-07). Since the crisis, it has hardly grown at all. This can be expressed in terms of a productivity gap: the level of UK productivity in 2011 was 13 percentage points below what it would have been had value added per hour continued at a 2.64%pa rate. This is the gap we seek to account for using growth accounting techniques,³ as follows.

Firstly, at the time of writing, the ONS are in the process of capitalising R&D into the National Accounts. We update our datasets to incorporate this development. The capitalisation of R&D changes both GDP, since value added changes, and TFP, since inputs change. Existing datasets do not capitalise R&D and so cannot examine the impact of capitalisation on productivity. This is of interest in at least two regards. First, it is widely alleged that the UK has had falling R&D relative to competitors and so it is of interest to see how R&D capitalisation affects TFP growth. Second, in recent years, R&D investment has held up relative to other forms of investment (Goodridge, Haskel et al. 2013) and so it is of interest to see if this explains part of the productivity puzzle (if R&D output is not included in GDP then measured output growth is too low in periods of relatively fast growth in R&D investment, which shows up as low measured productivity growth). We shall argue this does not actually explain any of the puzzle.

Second, it has been argued that labour composition has played a role in the puzzle, with growth in employment since the recession being in low-skilled, less productive, labour (Martin and Rowthorn 2012). We examine the data on labour composition, both the skills within industries and the

¹ Predictions of future productivity have been debated for the US in, for example, Gordon (2012), Mokyr (2013) and Brynjolfsson and McAfee (2014). Gordon (2012) is commonly represented as predicting a slowdown in technological progress but, as noted particularly in Gordon (2014), it is other headwinds, such as demographics, education and public debt, which lead to Gordon’s prediction of weak per capita growth of which technical progress is but one part.
² The puzzle is also an international one. Fernald (2014) notes a slowdown in US productivity since 2003. Hughes and Saleheen (2012) and Weale (2014) show a labour productivity slowdown in many developed countries. Conference Board Productivity Briefs (2014; 2015) study TFP and note a TFP slowdown in almost all advanced economies. The puzzle can also be thought of in terms of the distance between the UK and the frontier. From the 1960s, UK output per hour was converging with that of the US. However, around 2003, this convergence ceased. Both UK and US productivity growth slowed around this point (Fernald 2014).
³ We consider the scale of the productivity puzzle in relation to TFP growth between 2000 and 2007 rather than the more common assumption to include the 1990s. We do this because TFP growth in the 1990s was high by historical standards. Had we used 1990-2007, the implied TFP gap would be 12.9 percentage points as opposed to 12.2.
reallocation of labour between industries. We find that this deepens rather than explains the puzzle: since 2008, upskilling has gained in pace and labour has been allocated towards high-productivity industries.\footnote{\textsuperscript{4}}

Third, a number of authors (e.g. Pessoa and Van Reenen (2013)) have argued that the recent fall in UK productivity has been due to labour-capital substitution (capital shallowing) as real wages have fallen in the recession. Proponents of the view that the UK has lost output permanently are often challenged as to where the output capacity in the economy has gone: falls in capital seem like an obvious hypothesis to be investigated. Pessoa and Van Reenen (2013) calculate new UK capital \textit{stocks} under the assumption of premature scrapping and substitution away from capital and towards labour. Oulton (2013) criticises their calculations and suggests that capital \textit{services} would be a more appropriate concept for productivity analysis (capital services data were not available to him at the time, but see Oulton and Wallis (2014) for more recent data). We set out new capital services data, including R&D capital, and growth accounting results that allow for premature scrapping over the recent crisis: to the best of our knowledge we are the first to do this.

Our new capital services data reject the capital shallowing view. Using conventional depreciation rates, there has been no capital shallowing (that is, capital services per hour has continued to rise). We therefore look at increased depreciation rates. We show that if depreciation has risen by 25% (50%) since 2008 then this can account for 15% (31%) of the TFP gap. We note that even if post-2008 depreciation rates are raised by 25%, growth in capital services per hour still remains positive, but turns negative when depreciation rates are raised by the more extreme 50% assumption. Thus even with these aggressive assumptions and raised depreciation rates to account for potential premature scrapping, the labour productivity puzzle is a TFP puzzle. Note, the extent of capital scrapping during economic downturns is disputed, and in this paper we also present some limited evidence of life-lengthening in the context of transport equipment. Gordon (2000) also disputes premature scrapping and instead argues the case for life-lengthening.\footnote{\textsuperscript{5}} We therefore apply Gordon’s method to allow for variable retirement rates and find that this deepens the puzzle.

Fourth, we also test whether there is mismeasurement of inputs due to changes in factor utilisation. We use two methods. First we use data on commercial property vacancies to estimate the effect of lower utilisation of buildings. We find that this could explain only 1% of the TFP gap. Second we

\footnote{\textsuperscript{4} The allocation of labour between industries depends of course upon the definition of industries: due to data availability, we have nine industries. Thus we cannot rule out allocation of labour within our broad industries as a contributor to the slowdown in productivity growth.} \footnote{\textsuperscript{5} Gordon argues that retirement rates are not constant, rather retirements occur when new investments are made. Thus when investment declines, as during the recent Great Recession, retirements do also. Therefore, rather than raising depreciation rates, one could argue the case for reducing depreciation rates, to account for a reduced retirement or discard rate.}
follow Basu, Fernald et al. (2004) and estimate changes in factor utilisation using changes in average hours. We find this could explain 17% of the gap.

Fifth, since the labour productivity puzzle is a TFP puzzle, what explains TFP growth? Some have argued it is due to the slowdown in particular industries such as a maturing oil and gas sector or an increasingly regulated financial services sector. To examine this we use an industry data set, with consistent measures of labour and capital services. We find that 35% of the TFP productivity puzzle can be explained by the weakness of TFP growth in the oil and gas; and financial services sectors.\(^6\)

Readers wishing to skip to our main findings will find them summarised in Table 1. Row 1 shows labour productivity growth (market sector value added per hour, \(\Delta \ln V/H\)) pre- and post recession, at 2.64%pa and -0.46%pa, the deceleration giving an implied gap of 13 percentage points in 2011 relative to the productivity level on pre-recession trends.\(^8\) The other rows show the components of \(\Delta \ln V/H\): in row 2 and 3 for example, the contribution of labour services per hour and capital services per hour accelerated and decelerated. Our findings are then:

(a) labour services per hour accelerated and so are not an explanatory part of the productivity puzzle, rather they add another 1.2 points to the puzzle (row 2);

(b) capital services per hour decelerated and account for 3.2 out of the labour productivity gap (row 3);

(c) therefore the labour productivity puzzle is a TFP puzzle (row 4);

(d) re-allocation of labour between industries deepens rather than explains the puzzle (i.e. there has been actually been a re-allocation of hours away from low-productivity industries and toward high productivity industries (row 5);

(e) capitalisation of R&D does not explain the puzzle (row 6);

(f) 15% (31%) of the TFP puzzle could be explained by increased scrapping of 25% (50%) (row 7 and 8);

(g) however, if there has been capital life-lengthening, this deepens the puzzle (row 9);

\(^6\) In this paper we estimate and comment on TFP as residual. There is of course the deeper question of what drives TFP. In theory, it is technical progress, but in practice can include increasing returns to scale, omitted inputs, factor utilisation and cyclical effects, measurement error and a host of other factors. To the extent that it is technical progress, Fernald (2014) and Gordon (2012) argue it has slowed due to the end of exceptional but temporary ICT-fuelled gains. Benigno and Fornaro (2015) point to a weakness in aggregate demand and the joint occurrence of liquidity and growth traps.

\(^7\) Taken separately, Agriculture, Mining & Utilities account for 10%, and Financial Services for 25%.

\(^8\) Our dataset ends in 2011 and is consistent with Blue Book 2013. Results in Connors and Franklin (2015), consistent with Blue Book 2014, show that extending the analysis to 2013 would produce similar results, with both market sector labour productivity growth and TFP growth negative in 2012 and 2013. They estimate average market sector TFP at -1.51% pa, 2007-11, and -1.4% pa 2007-13. Crafts (2015) also shows strong negative TFP over 2007-13, there TFP is estimated at -1.36% pa though it is based on whole economy GDP rather than market sector – whole economy TFP has held up better than market sector TFP in the post-recession period (see e.g. Connors and Franklin (2015)).
(h) 35% of the TFP puzzle can be explained by the weakness of TFP growth in the oil and
gas and financial services sectors (row 10);
(i) 17% of the TFP puzzle can be explained by changes in factor utilisation (row 11).

Table 1: The productivity puzzle^ (growth rates pre- and post-crisis and implied gaps relative to pre-
crisis growth)

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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<tbody>
<tr>
<td></td>
<td>Before (00-07)</td>
<td>After (07-11)</td>
<td>Implied gap</td>
<td>% of gap explained</td>
</tr>
<tr>
<td>ΔlnV/H*</td>
<td>2.64%</td>
<td>-0.46%</td>
<td>13.0</td>
<td></td>
</tr>
<tr>
<td>Components</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contribution: Labour Composition</td>
<td>0.35%</td>
<td>0.64%</td>
<td>-1.2</td>
<td></td>
</tr>
<tr>
<td>Contribution: Capital deepening</td>
<td>1.61%</td>
<td>0.84%</td>
<td>3.2</td>
<td></td>
</tr>
<tr>
<td>TFP</td>
<td>0.94%</td>
<td>-2.17%</td>
<td>12.2</td>
<td>0%</td>
</tr>
<tr>
<td>Labour re-allocation</td>
<td>-0.26%</td>
<td>0.23%</td>
<td>-1.9</td>
<td></td>
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<tr>
<td>R&amp;D</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>TFP: without R&amp;D capitalised</td>
<td>0.97%</td>
<td>-2.17%</td>
<td>12.3</td>
<td>-1%</td>
</tr>
<tr>
<td>Capital: premature scrapping</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TFP: raise dep rates by 1.25 after 2009</td>
<td>0.94%</td>
<td>-1.67%</td>
<td>10.3</td>
<td>15%</td>
</tr>
<tr>
<td>TFP: raise dep rates by 1.5 after 2009</td>
<td>0.94%</td>
<td>-1.16%</td>
<td>8.4</td>
<td>31%</td>
</tr>
<tr>
<td>Capital: life-lengthening</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>TFP: variable dep rates (Gordon)</td>
<td>1.04%</td>
<td>-2.85%</td>
<td>15.0</td>
<td>-24%</td>
</tr>
<tr>
<td>Oil &amp; Gas/Financial Services</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TFP: without Ag/Min/Utils &amp; Financial Services**</td>
<td>0.89%</td>
<td>-1.09%</td>
<td>7.9</td>
<td>35%</td>
</tr>
<tr>
<td>Cyclical</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TFP: adjusted for utilisation (Basu, Fernald, Kimball)</td>
<td>1.01%</td>
<td>-1.53%</td>
<td>10.1</td>
<td>17%</td>
</tr>
<tr>
<td>TFP: adjusted for utilisation (Buildings, this paper)</td>
<td>0.99%</td>
<td>-2.08%</td>
<td>12.0</td>
<td>1%</td>
</tr>
</tbody>
</table>

Notes to table: Sources of growth decomposition for UK Market Sector, comparing the period before the
recession (2000-07) to the period after (2007-11). Columns 1 and 2 are per annum log difference rates. The
implied gap, column 3 is the difference between the level predicted by the four year growth rate in the pre-crisis
column (column 1) and the level realised by the four year growth rate in the post-crisis second column. So for
instance, the TFP gap (row 4) is 12.2 percentage points, and when we account for factor utilisation (row 11) the
gap is 10.1 percentage points. Column 4 presents the percentage of the gap explained, calculated as the part of
the gap explained as a proportion of the total TFP gap (12.2) e.g. in row 11, (12.2-10.1)/12.2=17%.
Decomposition carried out at the industry- level, except row 12 which is carried out at the market sector level. In
row 1, * signifies that R&D has been capitalised. ^ All rows except 2, 3 and 5 are TFP growth rates. ** Here
we subtract the weighted TFP contribution of Agriculture, Mining and Utilities (Ag/Min/Utils) and Financial
Services to adjust aggregate market sector TFP.

Source: authors' calculations.

What of the longer term? We start with the 0.94%pa growth rate of TFP 2000-07. This already
includes the drag from the oil and gas sector, which we expect to continue. Suppose that TFP growth
in financial services will be half of what it was pre-crisis due to increased regulation. The pre-crisis
contribution to total TFP from the financial sector (i.e. its share in value added times its TFP growth
rate) was 27% of aggregate TFP and so this assumption would reduce TFP growth by 1/8th i.e. to
0.83% (assuming that all other sectors restore their TFP growth to the pre-crisis rates and the value-
added structure of the economy does not vary too much). This is dependent on our use of 2000-07

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Although note, increased spreads could strengthen measured output and TFP growth in financial services.
average TFP (0.94% pa) as a baseline. If one considered a 1990-2007 estimate of 1.13% pa to reflect the baseline, then future TFP will be slightly higher on this calculation. Alternatively, using a 1970-2007 average of 0.75% pa would produce a more pessimistic outlook for future TFP.\(^\text{10}\)

The rest of this paper is set out as follows. Sections 2 and 3 describe our underlying data, our method and choice of baseline. Section 4 considers the role of R&D. Sections 5 and 6 examine the role of labour, both composition and re-allocation. Section 7 looks more closely at the contribution of capital and sections 8 and 9 respectively consider sectoral and cyclical factors. Section 10 presents a future outlook for TFP growth and the final section concludes.

2. Our data

Our dataset is that from Goodridge, Haskel et al. (2014), without additional intangibles not capitalised in the National Accounts but including R&D, and consistent with 2013 Blue Book. More details are available in that paper, but are briefly summarised here. Our output data are built bottom-up using ONS industry data,\(^\text{11}\) to a market sector definition comprising of SIC07 sections A-K, MN and R-T, thus excluding real estate,\(^\text{12}\) public administration & defence, health and education services.\(^\text{13}\)

Data on capital services are from Oulton and Wallis (2014), also built bottom-up using ONS data on nominal investment and asset prices and historic series to estimate UK capital stock and capital services growth since the 1950s. The tangible capital data distinguishes four asset types, which are: buildings, computer hardware, (non-computer) plant & machinery, and vehicles; and intangible data consists of software (purchased and own-account), mineral exploration, artistic originals and R&D. For National Accounts intangibles we use ONS GFCF and for R&D, we build our own estimates using the Business Enterprise R&D (BERD) release.\(^\text{14}\) The ICT hardware price index is the (exchange rate adjusted) US Bureau of Economic Analysis (BEA) index, and the purchased software

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\(^{10}\) Average TFP for 2000-07 is based on the industry dataset used in this paper. Data for the 1990s are based on an aggregated market sector dataset using previous vintages of ONS data. The estimate for 1970-2007 is taken from the EUKLEMS 2012 release. That dataset is consistent with this paper in the sense that it is for the market sector (defined in the same way), with capital (except R&D, which is not capitalised in EUKLEMS data) measured as capital services rather than capital stocks, and with growth in labour composition accounted for in the decomposition of labour productivity. We ignore potential for catch-up, see section 10.

\(^{11}\) We note that ONS estimates of industry value-added use single deflation in their estimation, as opposed to conceptually superior double deflation. That is, in the ONS method, nominal value-added is deflated using a gross output price index. Double deflation would involve deflating gross output and intermediate inputs separately in the derivation of real value-added.

\(^{12}\) We exclude real estate as dwellings are not productive capital from the perspective of productivity analysis and so we must also exclude the output associated with them (actual and imputed rents).

\(^{13}\) Note therefore that our market sector definition differs from the official ONS market sector definition, which excludes some of the publicly-provided services in R (e.g. galleries and libraries) and includes private delivery of education, health and social care.

\(^{14}\) In doing so we correctly convert capital expenditure (by R&D performers) to user costs (of capital in R&D production), and we also use shares implied by the Input-Output tables to allocate R&D that takes place in the R&D industry to the purchasing industries. Note that our R&D data therefore pre-dates the latest ONS data on R&D investment and so is not 100% consistent with that. Differences are however small.
price index is an unweighted average of the US BEA pre-packaged software price index and the UK own-account software index.\textsuperscript{15} The own-account software index is a wage index based on the salaries of software professionals and includes an adjustment for assumed productivity growth in in-house software creation. To deflate R&D investment in each industry, we use the implied value-added deflator for that industry. We also incorporate a full set of tax adjustment factors (based on Wallis (2012)) for each (tangible and intangible, including R&D) asset to better estimate rental prices, income shares and capital deepening contributions.

Data on labour input are taken from the ONS release on quality-adjusted labour input (QALI) (Franklin and Mistry 2013), based on ONS person-hours by industry with the composition adjustment using wage-bill shares for composition groups based on age, education and gender. Data on labour income, that is compensation of employees plus a proportion of mixed (self-employed) income, are from the ONS. Capital compensation is estimated residually as nominal gross value-added less total labour compensation. All nominal data are aggregated by simple addition. Real variables are aggregated as share-weighted superlative indices benchmarked in levels to 2010 nominal data. We work with nine disaggregated industries, with data for the period 1997 to 2011. For our market sector analysis, we extend our aggregates back using data from Goodridge, Haskel et al. (2012), which are also built using data from the previous Standard Industrial Classification (SIC03), such that the dataset runs from 1980 to 2011.

In what follows, we analyse the gap set out in Table 1 in more detail.

3. Growth-accounting methods and findings

Suppose that for industry $j$ capital and labour (respectively $K_j$ and $L_j$) produce (value-added) output $V_j$. That capital asset might or might not include intangible capital. Thus for each industry, we have the following value-added defined $\Delta \ln TFP_j$:

$$\Delta \ln TFP_j = \Delta \ln V_j - \bar{v}_{K,j} \Delta \ln K_j - \bar{v}_{L,j} \Delta \ln L_j$$

$$v_{K,j} = \frac{P_{K,j} K_j}{P_{V,j} V_j}, v_{L,j} = \frac{P_{L,j} L_j}{P_{V,j} V_j}, \bar{v}_j = 0.5(v_{j,t} + v_{j,t-1}) \tag{1}$$

Where the terms in “$v$” are shares of factor costs in industry nominal value-added, averaged over two periods, $K_j$ and $L_j$ refer to aggregates of capital and labour types for that industry,\textsuperscript{16} and $P_K$ and $P_L$ are rental prices of $K$ and $L$.

\textsuperscript{15} The own-account software index is incorporated into the purchased software index to account for purchases of customised software.

\textsuperscript{16} For details on aggregation of $K$ and $L$, see Appendix 1.
Define changes in aggregate real value added as a weighted sum of changes in industry real value added, where the weights are nominal industry value-added as a share of aggregate value-added:

$$\Delta \ln V \equiv \sum_j \tilde{w}_j \Delta \ln V_j, \quad w_j = \frac{P_{v,j}V_j}{\sum_j (P_{v,j}V_j)}, \tilde{w}_j = 0.5(w_{j,t} + w_{j,t-1})$$

(2)

The relation between aggregate real value added growth, its industry contributions and industry TFP is:

$$\Delta \ln V \equiv \sum_j \tilde{w}_j \Delta \ln V_j = \left( \sum_j \tilde{w}_j \tilde{v}_{K,j} \Delta \ln K_j \right) + \left( \sum_j \tilde{w}_j \tilde{v}_{L,j} \Delta \ln L_j \right) + \sum_j \tilde{w}_j \Delta \ln TFP_j$$

(3)

Which says that the contributions of $K_j$ and $L_j$ to aggregate value added growth depend upon the share of $V_j$ in total $V$ ($w_j$) and the shares of $K_j$ and $L_j$ in $V_j$ ($\tilde{v}_{K,j}$ and $\tilde{v}_{L,j}$) (which multiply out to be the shares of each capital and labour payment in aggregate value added). Thus, if we perform industry level growth accounting, we can see the contributions of $\Delta \ln L_j$ and $\Delta \ln K_j$ to industry value added ($\tilde{v}_{L,j} \Delta \ln L_j$ and $\tilde{v}_{K,j} \Delta \ln K_j$), but their contributions to aggregate value added have then to be multiplied by $w_j$.

Turning finally to labour productivity, the relation between aggregate and industry labour productivity is:

$$\Delta \ln (V/H) \equiv \sum_j \tilde{w}_j \Delta \ln V_j - \Delta \ln H$$

$$= \left( \sum_j \tilde{w}_j \tilde{v}_{K,j} \Delta \ln (K/H)_j \right) + \left( \sum_j \tilde{w}_j \tilde{v}_{L,j} \Delta \ln (L/H)_j \right) + \sum_j \tilde{w}_j \Delta \ln TFP_j + R^H$$

(4)

Where, when aggregating from the industry-level, aggregate labour productivity incorporates the labour reallocation term, $R^H$, which arises because aggregate value added per hour can grow via growth in all industry value added per hour but also with a reallocation of hours towards high-productivity industries.\textsuperscript{17}

\textsuperscript{17} To see this, see Appendix 1.
In Table 2 we present aggregate results for the UK market sector. Due to uncertainties over measurement in the UK public sector, notably health and education, we aggregate to the UK market sector. Table 2 presents average decade results for the 1980s, 1990s and 2000s.

Table 2: UK growth in market sector value added (ΔlnV), labour productivity (ΔlnV/H) and the capitalisation of R&D, 1980-2011

Panel 1: ΔlnV/H

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<tr>
<th></th>
<th>ΔlnV</th>
<th>sΔlnL/H cmp</th>
<th>sΔlnK/H otthtan</th>
<th>sΔlnK/H intan NA</th>
<th>sΔlnK/H rd</th>
<th>ΔlnTFP</th>
<th>R²</th>
<th>Memo: sLAB</th>
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</thead>
<tbody>
<tr>
<td>a) With National Accounts Intangibles: software, mineral exploration and artistic originals</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>1980-90</td>
<td>2.69%</td>
<td>-0.08%</td>
<td>0.22%</td>
<td>0.37%</td>
<td>0.24%</td>
<td>-</td>
<td>1.94%</td>
<td></td>
</tr>
<tr>
<td>1990-00</td>
<td>2.95%</td>
<td>0.22%</td>
<td>0.33%</td>
<td>0.88%</td>
<td>0.25%</td>
<td>-</td>
<td>1.26%</td>
<td></td>
</tr>
<tr>
<td>2000-11</td>
<td>1.49%</td>
<td>0.46%</td>
<td>0.11%</td>
<td>0.96%</td>
<td>0.17%</td>
<td>-</td>
<td>-0.17%</td>
<td>-0.04%</td>
</tr>
<tr>
<td>b) With National Accounts Intangibles plus R&amp;D</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>1980-90</td>
<td>2.70%</td>
<td>-0.08%</td>
<td>0.21%</td>
<td>0.36%</td>
<td>0.24%</td>
<td>0.07%</td>
<td>1.90%</td>
<td></td>
</tr>
<tr>
<td>1990-00</td>
<td>2.94%</td>
<td>0.21%</td>
<td>0.32%</td>
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<tr>
<td>2000-11</td>
<td>1.51%</td>
<td>0.46%</td>
<td>0.11%</td>
<td>0.94%</td>
<td>0.17%</td>
<td>0.11%</td>
<td>-0.19%</td>
<td>-0.08%</td>
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</table>

Panel 2: Δln(V)

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<tr>
<th></th>
<th>ΔlnV</th>
<th>sΔlnL cmp</th>
<th>sΔlnK cmp</th>
<th>sΔlnK otthtan</th>
<th>sΔlnK intan NA</th>
<th>sΔlnK rd</th>
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<th>R²</th>
<th>Memo: ΔlnH</th>
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<tbody>
<tr>
<td>a) With National Accounts Intangibles: software, mineral exploration and artistic originals</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>1980-90</td>
<td>3.11%</td>
<td>0.14%</td>
<td>0.23%</td>
<td>0.55%</td>
<td>0.26%</td>
<td>-</td>
<td>1.94%</td>
<td></td>
<td>-0.42%</td>
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<tr>
<td>1990-00</td>
<td>2.69%</td>
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<td>0.83%</td>
<td>0.25%</td>
<td>-</td>
<td>1.26%</td>
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<td>-0.26%</td>
</tr>
<tr>
<td>2000-11</td>
<td>1.27%</td>
<td>0.23%</td>
<td>0.11%</td>
<td>0.93%</td>
<td>0.17%</td>
<td>-</td>
<td>-0.17%</td>
<td></td>
<td>-0.22%</td>
</tr>
<tr>
<td>b) With National Accounts Intangibles plus R&amp;D</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>1980-90</td>
<td>3.12%</td>
<td>0.13%</td>
<td>0.22%</td>
<td>0.53%</td>
<td>0.25%</td>
<td>0.08%</td>
<td>1.90%</td>
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</tr>
<tr>
<td>1990-00</td>
<td>2.68%</td>
<td>0.02%</td>
<td>0.32%</td>
<td>0.80%</td>
<td>0.25%</td>
<td>0.04%</td>
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<tr>
<td>2000-11</td>
<td>1.29%</td>
<td>0.23%</td>
<td>0.11%</td>
<td>0.92%</td>
<td>0.17%</td>
<td>0.06%</td>
<td>-0.19%</td>
<td></td>
<td>-0.22%</td>
</tr>
</tbody>
</table>

Notes to table. Data are average growth rates per year for intervals shown, calculated as changes in natural logs. Contributions are Tornqvist indices. In panel 1, data are a decomposition of labour productivity in per hour terms. In panel 2, data are a decomposition of growth in value-added. First column is growth in value-added (in per hour terms in panel 1). Column 2 is the contribution of labour services (per hour in panel 1), namely growth in labour services (per hour) times share of labour in market sector gross value-added (MSGVA). Column 3 is growth in computer capital services (per hour) times share in MSGVA. Column 4 is growth in other tangible capital services (buildings, plant, vehicles) (per hour) times share in MSGVA. Column 5 is growth in intangible capital services (per hour) times share in MSGVA, where intangibles are those already capitalised in the national accounts, namely software, mineral exploration and artistic originals. Column 6 is R&D capital services (per hour) times share in MSGVA, with R&D capitalised in the UK accounts in 2014. The price index used for R&D is the implied GVA deflator. Column 7 is TFP, namely column 1 minus the sum of columns 2 to 6. Column 8 presents the labour reallocation term, which only arises in the 2000s where we use our industry dataset (data for the 1980s and 1990s are based on an aggregated market sector dataset built using a previous

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18 All our key results are based on data for the market sector and industry-level over the 2000s. Table 2 has a longer run of data but just for the market sector. To clarify the relation between our industry and market sector data, for 1997-2011 we have consistent industry-year output data on the SIC2007 classification. To match these we construct capital data at industry-asset-year level and labour data at industry-type-year level, so all data 2000-2011, upon which almost all results in this paper depend, are consistently aggregated bottom-up data. Before 1997 we do not have industry-year output data by SIC07, but by SIC03. Thus we do not build industry-level data before 1997, rather a market-sector data set. We backcast the output data from the SIC07 level using SIC03 changes in output and aggregate the capital by asset-year. Thus data for the 1980s and 1990s in Table 2 are not based on a complete bottom-up aggregated set. In the appendix we show that this method gives very similar growth rates in the overlapping years (the 2000s) except for slight differences in non-computer tangible, and R&D intangible capital growth rates, and also value-added growth rates.
version of the SIC). Column 9 presents memo items, in the first panel we show the share of labour payments in MSGVA, and in the second panel we show average changes in market sector hours.

**Source:** authors’ calculations

Before establishing our baseline, we first comment on the results in Table 2. Since in this paper we are concerned with productivity, we focus on the labour productivity decomposition, with R&D capitalised (Panel 1b)). First, we note the speedup in labour productivity growth, from 2.7% pa in the 1980s to 2.94% pa in the 1990s, before slowing down to 1.51% pa in the 2000s. Looking at the factor contributions, we see that in the 1980s, growth in labour composition was negative but has since been positive, with strong growth in labour composition in the 2000s.\(^{19}\) On the contribution of capital deepening in ICT hardware, that peaked in the 1990s and decelerated to just 0.11% pa in the 2000s.\(^{20}\)

In contrast, the contribution of capital deepening from other tangible capital (buildings, plant & machinery (P&M) and vehicles) accelerated in the 1990s and maintained pace in the 2000s. The reason is as follows. Other tangible capital is largely made up of buildings and P&M, with the income share for vehicles being small. As we will show in Table 3, due to their low depreciation rate, in the most recent period (2007-11) growth in capital services from buildings is lower but has remained strong (3.08% pa in 2007-11 compared to 4.45% pa in 2007-11). Growth in P&M capital services is also lower, at 2.44% pa in 2007-11 compared to 3.67% pa in 2000-07.\(^{21}\) However, aggregation of capital services relies on the weighting of each asset with its share in capital compensation. The income share for buildings has increased (from 0.16 in 2000-07 to 0.21 in 2007-11), whilst that for P&M has declined from 0.10 in 2000-07 to 0.07 in 2007-11. Thus the increase in the buildings share, and higher growth in buildings capital services compared to P&M capital services, means that other tangible capital services grow faster in the 2007-11 period than would be expected had the income shares remained constant.

The contribution of national accounts intangibles (software, mineral exploration, artistic originals) has decelerated in the 2000s, to 0.17% pa, reflecting weaker investment in software and a fast depreciation rate (0.33). The contribution of R&D was stronger in the 1980s, and decelerated in the 1990s but did not decelerate in the 2000s, with R&D investment having held up well since the

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\(^{19}\) As shown in Table 1, this is driven by particularly strong growth in labour composition during and since the recession. For more on labour composition, see the Appendix.

\(^{20}\) Due to the low rate of investment and the high depreciation rate (\(\delta=0.4\)) for this asset.

\(^{21}\) Thus growth in capital services from buildings and plant & machinery have both remained positive since the recession. Inspection of the industry data shows that this was true for all industries with the exception of Agriculture, Mining and Utilities. In all other industries, the contribution of other tangible capital, primarily driven by buildings, was positive. Growth in capital services from other tangible capital was strongest in: Wholesale and Retail; Construction and Professional and Administrative Services. However, although growth in capital services was positive, there was a slowdown in the contribution of other tangible capital services in all industries except Construction, where the contribution of other tangible capital deepening actually sped up (see Appendix 5).
recession. Thus the TFP record is one of very strong growth in the 1980s (1.9% pa), weaker but still historically strong growth in the 1990s (1.24% pa), followed by a decline in TFP in the 2000s (-0.19% pa).

On our choice of baseline, the top rows in panels (a) and (b), without and with R&D capitalisation, show $\Delta \ln(V/H)$ was 2.7%pa 1980-90, 2.94%pa 1990-2000, and 1.51%pa 2000-11. In Table 1 we use a 2000-07 average for our baseline and so that already assumes a productivity growth deceleration relative to 1990-2000 (had we chosen the longer period of 1990-2007 with average labour productivity growth of 2.82% pa for our baseline then the labour productivity gap would be 13.8 percentage points).

There are a number of points worth noting regarding our 2000-07 choice of baseline, which is lower than pre-2000 $\Delta \ln(V/H)$. First, both ICT use and ICT production contributed strongly to productivity growth in the late 1990s. As column 3 shows, the 2000s were a period of substantially slower ICT capital deepening. This is a result of both weaker nominal investment in ICT but also slower declines in the measured prices of ICT products. Figure 1 shows that the share of ICT manufacturing value added in total manufacturing has also fallen since 2000 meaning that any productivity boost from ICT production will also have fallen. For these reasons we exclude the “ICT boom” from our baseline. Excluding the peak ICT contribution period from the baseline assumes that the future ICT contribution will not be of the magnitude seen during the late 1990s, which might not be true of course.

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22 The contribution of R&D capital deepening is not directly comparable between the 1990s and the 2000s. Using the market sector dataset, the comparable figure for the 2000s is 0.05% pa. Reasons for this are explained in footnote 18 and the Appendix.

23 Oulton (2012) finds that main boost to growth is from ICT use (due to falls in prices and improved terms of trade) not production i.e. even if the ICT sector has declined, the economy benefits from falling import prices. So there can be benefit from ICT production if TFP in ICT production is higher than in rest of the economy. But even if there is no domestic ICT production, domestic growth is still increased due to falls in relative price of ICT.

24 Depending on the ICT asset definition applied, one element of the future ICT contribution will be the capital services derived from the transformation and analysis of (big) data. Goodridge and Haskel (2015) attempt to measure the contribution of data-based knowledge assets to growth in the UK market sector, including their potential contribution in the upcoming decade.
Some further support for our choice of baseline can be found in Fernald (2014), who argues that US labour productivity and TFP growth had already slowed down by the mid-2000s before the onset of the recession, with the late 1990s and very early 2000s being a period of “exceptional but temporary” growth driven by the production and use of ICT capital.

4. How has capitalisation of R&D affected $\Delta \ln TFP$?

The 2014 ONS National Accounts Blue Book treated R&D as investment for the first time. As shown in Table 1 above, if we do not capitalise R&D the TFP gap is 12.3 percentage points, with R&D capitalised the TFP gap is 12.2 points. Therefore for the purposes of this paper, official capitalisation of R&D will not explain the TFP gap. The Appendix explores the robustness of this finding to a relatively neglected issue, namely the choice of R&D deflator. As Table 2 shows, the contribution of R&D capital deepening in 2000-2011 is around 0.05%pa, an estimate that assumes that R&D prices grow at same rate as the industry value-added deflator, as is conventional. But one might assume that the process of R&D has changed with the introduction of ICT: computers have made simulations quicker and easier and the internet has made research collaboration and information gathering cheaper. In this case, the price of performing R&D might have fallen, possibly dramatically and so the Appendix looks at the case where that price falls in line with pre-packaged software. In the software case, the contribution of R&D capital deepening in the 2000s rises very substantially, to 0.18%pa, but for our purposes the productivity puzzle is not explained. The reason is that $\Delta \ln V/H$ is slightly larger with R&D capitalisation and by about the same amount as the increase in contribution from $\Delta \ln K^{R&D}$ so that $\Delta \ln TFP$ remains the same.

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25 Ker (2014) explains that the UK R&D deflator is derived from a price index of UK R&D costs (mostly labour). Following Eurostat recommendations, this is not adjusted for productivity and so the price index rises, as labour costs do, at a similar rate or even slightly faster than a typical value-added deflator. The US adjust their price index by average US TFP growth, which at around 2%pa means their index is also roughly in line with the implied GDP deflator. The pre-packaged software deflator falls at around 5%pa.
R&D may however help understand the productivity slowdown in the following sense. $\Delta \ln TFP$ was relatively fast in the 1990s (1.24% pa, 1990-2000) but this is a considerable slowdown from the 1980s (1.9%, 1980-1990). As is well-documented, R&D spending has slowed very considerably as well over this long period ($\Delta \ln K_{R&D}$ grew at 4.6% pa in 1980-90, 2.1% pa 1990-2000, 2.2% pa 2000-11). Such a fall in $\Delta \ln K_{R&D}$ might help explain a fall in $\Delta \ln TFP$ if $\Delta \ln K_{R&D}$ is associated with spillovers, for which there is some evidence ((see e.g. surveys by Hall, Mairesse et al. (2009) and Griliches (1973)). If spillovers take a very long time, then the fall in $\Delta \ln K_{R&D}$ between the 1980s to 1990s might lead to some fall in the 2000s. (If the lag operates within the decade, then the fall in $\Delta \ln K_{R&D}$ between the 1980s to 1990s would have contributed to the fall in $\Delta \ln TFP$ between the 1980s to 1990s). This then would be another reason to benchmark the underlying $\Delta \ln TFP$ rate to the 2000s.27

5. Labour composition

As we can see from the tables above, the inclusion of labour quality (composition) deepens the productivity puzzle. As Table 1 shows, its contribution sped up from an average of 0.35% pa in 2000-07, to an historically very large 0.64% pa in 2007-11. Thus it is not the case in the recession that, for example, there was a move to low skilled workers, either in terms of quantity or price, that lowered the composition of labour and so slowed productivity growth. Rather, the opposite occurred.

Why? Labour composition is a wage-bill weighted share of changes in the hours per worker and number of workers of different skills, ages and gender. Thus it can change for a number of different reasons. In the Appendix, using newly-released data from ONS, we document that the faster growth in labour composition since the recession is due to the fall in quantity of low-skilled workers employed, as opposed to changes in income weights (relative wages) or changes in hours per worker.

This finding is supported by Blundell, Crawford et al. (2014), who similarly find that a fall in labour composition cannot explain declines in (wages) productivity. Rather, they find that firms have tended to hold on to their most productive workers, and laid off or cut the hours of their least productive workers, as is typical in recessions, thus improving workforce composition. In particular, they show larger declines in employment rates for younger (less experienced) workers than for older workers,

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26 These estimates are based on an estimate of growth in the aggregate market sector stock of R&D that is not fully consistent with estimates of industry share-weighted growth in $\Delta \ln K_{R&D}$.  
27 Using industry data, Goodridge, Haskel et al. (2014a) estimate an elasticity of $\Delta \ln TFP$ to $\Delta \ln K_{R&D}$ of 0.31 (which includes within-industry spillovers and spillovers derived from knowledge external to the industry, and excludes the private contribution already accounted for in the estimation of TFP). Thus, using that estimate, we may expect TFP growth in the post-1990 period to be lowered by around $(0.31 \times (4.6 - 2.1)) = 0.78$% pa, remarkably close to the actual slowdown of 1.9% - 1.24% = 0.66% pa.
and larger declines for less qualified workers than higher qualified. Thus they find that falls in wages (productivity) are not just due to an increase in lower paid jobs, but due to falls in wages within jobs and across composition groups.

6. Labour reallocation

Having looked at changes in the characteristics of labour within industries (labour composition) we turn to the effect of labour reallocation, that is, the movement of labour from low to high productivity industries that might raise the overall average. As we show above, total output per hour is a value-added-weighted average of output per hour in each industry plus the labour reallocation term ($R_H$). Thus total productivity can rise if (a) industry productivity rises and (b) hours are reallocated to above-average productivity industries.

We can measure this term using industry data, which we describe more fully in the appendix. One observation is that the extent of reallocation depends upon the industries one has, since there can always be reallocation between firms in the same industry. Figure 2 shows the reallocation term in our data.

As Figure 2 shows, with the exception of 2005, the re-allocation term was negative in every year from 2001 to 2008. Then in 2009 it turned, and has remained, positive. Positive values mean that labour has been re-allocated toward high-productivity industries. Therefore, as with labour composition, the data on labour reallocation deepen rather than explain the productivity puzzle.

Figure 2: Labour re-allocation term

![Graph showing labour re-allocation term](image)

Note to figure: Labour re-allocation term ($R_H$). A positive term implies movement of labour toward high-productivity industries.

Source: authors’ calculations.

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28 For 2008-12, they estimate a 5pp decline in the employment rate for workers with less than 5 GCSE’s (A*-C), and a 2pp decline for those with a degree.
7. Labour-capital substitution and premature scrapping

Another suggested explanation for the puzzle, as argued by Pessoa and Van Reenen (2013) is a possible fall in the capital-labour (K/L) ratio. As equation (4) shows, a fall in ΔlnK/H would account for lower ΔlnV/H. As we have seen, at conventional depreciation rates, and measuring capital services, this is not enough to account for the productivity puzzle. Pessoa and Van Reenen (2013) estimate the K/L ratio using estimates of the number of workers employed and the net capital stock in 2008, which is a wealth measure, extended forward using a measure of real investment and an assumed aggregate depreciation rate. As suggested in Oulton (2013), we estimate growth in capital services using investment data disaggregated by asset, asset- and industry-specific depreciation rates, and weighted using asset income shares in total capital compensation. We also use an estimate of total annual person-hours worked for the denominator. Capital services and hours worked are more appropriate measures for productivity analysis. Pessoa and Van Reenen estimate a fall in the K/L ratio of -5% over 2008Q2 to 2012Q4. Our estimate of ΔlnK/H remains positive in 2008-10, before falling back so that it was marginally negative in 2011 (-0.08%). On average, for the years 2007-11, we estimate ΔlnK/H of 2.33% pa.

Is this conclusion robust however to increased depreciation rates? Such rates might be a way of modelling increased disposals of assets after the 2008 recession. The effect of this on capital services is not clear however. Capital stocks will fall since for each industry-asset nj, Knj is built using a perpetual inventory model (PIM) (Knj,t=Inj,t+(1-δnj)Knj,t-1). Capital services weights this by rental prices, Pknj however where Pknj = τk,α(r+δkn,j−πkn,j)Pl,n,j and a rise in δ therefore changes the weight on that asset. The overall effect on ΔlnK is therefore an empirical matter and so we calculate ΔlnK using different capital scrapping assumptions. Table 3 sets out details.

Table 3 suggests the following. Consider first the income shares in the first column for each asset. Note that these are shares of value-added and so sum to the market sector share for capital compensation (0.35 in 2000-07). Almost one-half of this is from buildings, which also accounts for over 40% of the total capital contribution in 2000-07 due to strong growth in buildings capital services throughout the commercial property boom in the 2000s. Non-computer plant & machinery (P&M) also has a slightly smaller share and a smaller contribution as growth in P&M capital services is lower.

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29 At the time of writing for their paper, ONS had suspended publication of capital stock data.
30 Where τk,α is an asset-specific tax-adjustment factor, πkn,j is a capital gains term and Pl,n,j is the investment price.
Looking at the first panel, our baseline estimates with no additional assumption for premature scrapping, we can see that, for each asset, $\Delta \ln K_n$ has decelerated since the recession, with vehicles the only asset for which $\Delta \ln K_n$ has turned negative. Total $\Delta \ln K$ in the later period is therefore lower, by around a half, but remains positive. In terms of the contributions, the total contribution from capital is also approximately halved, but within that we note that the contribution for buildings only decelerated slightly, due to its increased income share in the later period.

The second panel increases all depreciation rates by a factor of 1.25 post-2009. This further reduces $\Delta \ln K_n$ in the later period, with that from computers and National Accounts intangibles turning negative. Total $\Delta \ln K$, and the contribution from capital, remains positive. Note that we increase depreciation rates for the years 2009-11. However, if there has been such scrapping, and if it was concentrated in say 2009, then the depreciation rate for 2010 and 2011 need not be increased. In that case, the potential impact of premature scrapping, for which we have noted that evidence is limited, is even less than reported here.

The third panel makes the aggressive assumption on capital scrapping, increasing all depreciation rates by a factor of 1.5 from 2009. We note that $\Delta \ln K_n$ from buildings remains positive, and that from P&M also remains slightly positive, but that for all other assets is negative. Thus total $\Delta \ln K$ (-0.48% pa) and the contribution of capital (-0.17% pa) are both negative.
Table 3: Capital services under different assumptions around premature scrapping

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<th>Contribution</th>
<th>Income share</th>
<th>Growth in capital services</th>
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<td>sK(cmp)</td>
<td>sK(cmp).ΔlnK(cmp)</td>
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<tr>
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<td>2007-11</td>
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<td>0.09%</td>
<td>0.36</td>
<td>2.33%</td>
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**Note to table:** Data, by asset, for the income share, capital service and capital contribution to value-added. Note, not in per hour terms. First panel are baseline estimates with no additional assumption for premature scrapping. Panel 2 assumes extensive scrapping, with all depreciation rates increased by a factor of 1.25 from 2009. Panel 3 makes an even more aggressive assumption, with all depreciation rates increased by a factor of 1.5 from 2009.
Empirical evidence on scrapping rates is limited, particularly recent evidence. Harris and Drinkwater (2000) estimate that adjusting the manufacturing capital stock for plant closures over the period 1970 to 1993 leaves the capital stock 44% lower in 1993 compared with making no allowance for plant closures. Their estimated annual rate of premature scrapping is consistent with scaling up depreciation rates by a factor of 1.5 over post-2009. But their scrapping rate is estimated for an industry that was in secular decline over their estimation period with manufacturing’s share of the net capital stock falling from 32% to 23%, suggesting that it may be an overestimate. The different structure of today’s economy may also make premature scrapping a far less likely phenomenon.

With these capital services data in mind, we turn to the impact on labour productivity. To look at the impact of capital scrapping, we start with the data we have calculated using standard depreciation assumptions. Those results are shown in the top panel of Table 4. The table is set out as follows. Panel 1 are our baseline estimates with no assumption for capital scrapping. Panel 2 presents results when we increase all depreciation rates by a factor of 1.25 from 2009. As shown in columns 3 to 6, this reduces the contribution of $\Delta \ln K/H$ for all assets, such that those for computers and national accounts intangibles turn negative, and that for other tangibles is reduced by around a third. TFP thus increases by around a quarter to -1.67% pa. Note 1.25 is considered to proxy for the upper bound of potential capital scrapping. Panel 3 takes this further, increasing all depreciation rates by a factor of 1.5 post-2009, an assumption far stronger than available evidence would suggest. Here, the contributions of $\Delta \ln K/H$ are reduced further, and TFP increases to -1.16% pa.

Note that the raising of depreciation rates is consistent with both increased scrapping in a physical sense, but also higher obsolescence. That might be due to, say a fall in demand, rendering some goods, particularly intangibles like software etc. useless.
Table 4: Estimates of potential impact of capital scrapping

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<td>Δln(V/H): With National Accounts Intangibles plus R&amp;D</td>
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<tr>
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<td>ΔlnK/H</td>
<td>ΔlnK/H</td>
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<td>ΔlnK/H</td>
<td>ΔlnK/H</td>
<td>ΔlnTFP</td>
<td>R²</td>
</tr>
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<td>a) Baseline (no scrapping)</td>
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<td>2000-07</td>
<td>2.64%</td>
<td>0.35%</td>
<td>0.16%</td>
<td>1.08%</td>
<td>0.24%</td>
<td>0.12%</td>
<td>0.94%</td>
<td>-0.26%</td>
<td>0.65</td>
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<tr>
<td>2007-11</td>
<td>-0.46%</td>
<td>0.64%</td>
<td>0.01%</td>
<td>0.71%</td>
<td>0.03%</td>
<td>0.09%</td>
<td>-2.17%</td>
<td>0.23%</td>
<td>0.64</td>
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<td>b) Increase depreciation rates by 1.25 from 2009</td>
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<tr>
<td>2007-11</td>
<td>-0.46%</td>
<td>0.64%</td>
<td>-0.03%</td>
<td>0.50%</td>
<td>-0.16%</td>
<td>0.03%</td>
<td>-1.67%</td>
<td>0.23%</td>
<td>0.64</td>
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<tr>
<td>c) Increase depreciation rates by 1.5 from 2009</td>
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<td>-0.03%</td>
<td>-1.16%</td>
<td>0.23%</td>
<td>0.64</td>
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</tbody>
</table>

Notes to table. Data are average growth rates per year for intervals shown, calculated as changes in natural logs. Contributions are Tornqvist indices. In panel 1, data are a decomposition of labour productivity in per hour terms, with no assumption on premature scrapping. In panel 2, depreciation rates are increased by a factor of 1.25 from 2009. In panel 3, depreciation rates are increased by a factor of 1.5 from 2009. First column is growth in value-added per hour. Column 2 is the contribution of labour services per hour, namely growth in labour services per hour times share of labour in market sector gross value added (MSGVA). Column 3 is growth in computer capital services per hour times share in MSGVA. Column 4 is growth in other tangible capital services (buildings, plant, vehicles) per hour times share in MSGVA. Column 5 is growth in intangible capital services per hour times share in MSGVA, where intangibles are those already capitalised in the national accounts, namely software, mineral exploration and artistic originals. Column 6 is R&D capital services per hour times share in MSGVA, with R&D capitalised in the UK accounts in 2014. The price index used for R&D is the implied MSGVA deflator. Column 7 is TFP, namely column 1 minus the sum of columns 2 to 6. Column 8 presents the labour reallocation term and column 9 the share of labour payments in MSGVA.

Do we have any independent evidence for premature scrapping? An indicator that is commonly used as a proxy for premature scrapping is the corporate insolvency rate. Indeed, the ONS adjust their capital stock estimates for firm bankruptcy using data on corporate insolvency. They assume that 50% of a bankrupt firm’s capital stock is lost from the aggregate measure. But this only captures capital stock lost due to firm bankruptcy and not premature scrapping by continuing firms. The corporate insolvency rate has remained very low by historical standards during the crisis.

Disposals are not a direct measure of premature scrapping because a disposal is a sale to another firm or household. However, they are an indicator of firms actively disposing of assets and trying to reduce their capital stock. Disposals have remained very low since 2009 and the fall in business investment during the crisis reflects a sharp fall in acquisitions rather than an increase in disposals. This could be regarded as evidence of limited premature scrapping although it could just be a result of a very limited market for used capital goods.

A failure to account for premature scrapping would lead to ΔlnK/H being estimated as too high. But there are also reasons to believe ΔlnK/H may be estimated as too low. During recessions, when firms are credit constrained or because uncertainty has risen, they may choose not to replace older assets at
the same rate as usual. To examine this, Figure 3 shows new evidence on life lengthening. Our capital stock data shows a sharp fall in the net stock of vehicles over the crisis but Society of Motor Manufacturers and Traders (SMMT) data shows that the number of commercial vehicles on the road has stayed the same. This tells us nothing about the efficiency of those vehicles on the road but it does suggest that firms have been holding on to assets (vehicles at least) for longer. This is consistent with the lack of any increase in secondary capital markets (low disposals).

![Figure 3: Evidence of life-lengthening in capital (vehicles)](chart)

**Source:** SMMT and authors calculations

As noted above in the context of vehicles, one hypothesis is that during the recession, firms chose not to replace assets with new investments, and instead have extended the life-lengths of their existing assets. This is a view espoused by Gordon (2000), who argues that retirements coincide with new investment. Thus when the rate of investment ($I/K$) is growing, as in the boom period prior to the recession, the retirement rate ($R/K$) rises, and conversely, when the rate of investment falls so does the retirement rate. This hypothesis appears consistent with UK data which show both low acquisitions and disposals following the recession. We therefore use Gordon’s method to test what effect life-lengthening may have had on estimated $\Delta \ln K/H$ and $\Delta \ln TFP$, by adjusting industry- and asset-specific depreciation rates as in equation (5).$^{31}$

$$\delta_{n,j}^{\text{ADJ}} = \delta_{n,j} \left( \frac{I_{n,j}}{K_{n,j}} \right) / \left( \frac{I_{n,j}}{K_{n,j}} \right)$$

---

$^{31}$ Note, here we use the rate of net investment (acquisitions less disposals) to adjust the geometric depreciation rate. Thus this is slightly different to the method of Gordon who uses the rate of gross investment (acquisitions) to adjust the retirement rate. In the context of the PIM, geometric rates account for deterioration in the vintage, obsolescence and retirement.
Where $\delta_{n,j}^{ADJ}$ is the new time-varying depreciation rate, and $I_{n,j}/K_{n,j}$ is the mean rate of investment over the length of our dataset.

The effect of this is shown in Table 1. In the 2000-07 period, a higher than average rate of investment tends to raise depreciation rates, and in the 2007-11 period, a lower than average investment rate tends to lower depreciation rates. But again, the impact on estimated contribution is not obvious, as the depreciation rate also feeds into the estimation of annual user costs and the income shares associated with each industry-asset. As a matter of data, applying the Gordon adjustment reduces the contribution of capital deepening in 2000-07 (from 1.61% pa to 1.51% pa) and increases it in 2007-11 (from 0.84% pa to 1.52% pa). Thus $\Delta \ln TFP$ is raised in 2000-07 from 0.94% pa to 1.04% pa and reduced in 2007-11, from -2.17% pa to -2.85% pa. Thus the possibility of capital life-lengthening deepens the productivity puzzle, raising the TFP gap to 15 percentage points.

To summarise, we have now considered measurement (R&D), labour composition, labour reallocation, and capital shallowing as potential explanations of the productivity puzzle. We have found the omission of R&D explains little, labour composition and reallocation deepen the puzzle, and capital shallowing explains at most 15% of the TFP gap, but evidence is limited. We have therefore shown that the productivity puzzle is in fact a TFP puzzle. In the next section we look at industry data, in particular industry TFP, to examine some of the sectoral explanations that have been put forward.

### 8. Sectoral weakness in $\Delta \ln TFP$

We turn now to industry level analysis to try to better understand which sectors account for the weakness of TFP growth during the crisis. We set out the relations between market-sector and industry levels of analysis above.

Figure 4 sets out our industry results. The top histogram is for the aggregated market sector using our industry data and, in the top two bars shows the slowdown in $\Delta \ln V/H = \Delta(\Delta \ln V/H)$ and in $\Delta \ln TFP$ (that is $\Delta(\Delta \ln V/H) = \Delta \ln V/H^{07-11} - \Delta \ln V/H^{00-07}$). On these data, $\Delta(\Delta \ln V/H)= -3.59\%$, most of which was explained by $\Delta(\Delta \ln TFP)= -3.11\%$, which is $(-3.11/-3.59=)87\%$ of the productivity slowdown. This is slightly more than in Table 1, where aggregate $\Delta \ln V/H$ is adjusted using the labour reallocation term as explained above.\(^{32}\) The rest of the bars in the market sector part of Figure 4 confirm that slowdowns in $s^k \Delta \ln K/H$ and $s^l \Delta \ln L/H$ do not explain $\Delta(\Delta \ln V/H)$, in fact, $\Delta(s^k \Delta \ln K/H)$ shows a speedup.

\(^{32}\) That is, aggregate ($\Delta \ln V/H$) here is a value-added weighted sum of industry $\Delta \ln V/H$, before the addition of R\(^H\).

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**Figure 4: Industry productivity slowdowns (top panel = market sector; following panels = nine underlying industries)**

<table>
<thead>
<tr>
<th>Market Sector</th>
<th>Recreational and Personal Services</th>
<th>Professional and Administrative Services</th>
<th>Financial Services</th>
<th>Information and Communication</th>
<th>Transportation and Storage</th>
<th>Wholesale and Retail Trade, Accommodation and Food</th>
<th>Construction</th>
<th>Manufacturing</th>
<th>Agriculture, Mining and Utilities</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Δ(Δln(V/H))</strong></td>
<td><img src="image" alt="Graph showing slowdowns" /></td>
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<td><strong>Δ(ΔlnTFP)</strong></td>
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<tr>
<td><strong>Δ(ΔsK.Δln(K/H))</strong></td>
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<tr>
<td><strong>Δ(ΔsL.Δln(L/H))</strong></td>
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</tbody>
</table>

**Note to table:** Data show slowdowns for each industry, where each bar is Δ(ΔlnX) = ΔlnX⁰⁷⁻¹¹ - ΔlnX⁰⁶⁻⁰⁷. Note these slowdowns do not add up to the overall slowdown since they have to be weighted to do so: these are unweighted data. **Source:** Authors' calculations, see text.

The rest of Figure 4 presents data for each industry (note these are the actual slowdown data; the contributions of the sectors to the whole require these data to be multiplied by value added shares of each sector which we set out below). The red (TFP) and blue (labour productivity) lines are the highest in each case, again stressing that the ΔlnV/H slowdown is accounted for in each industry mostly by a ΔlnTFP slowdown. The exceptions to this are as follows. In Recreational and Personal Services, a small industry with a value-added share of just 5%, the slowdown in capital deepening (green line) is far larger than the small slowdown in ΔlnV/H, and ΔlnTFP sped up. In Construction, ΔlnV/H and all its components actually sped up. In Information and Communication, the slowdown in capital deepening accounts for 46% of the ΔlnV/H slowdown, and in Agriculture, Mining and Utilities, it accounts for 38% of the ΔlnV/H slowdown.

To study the contributions of each industry to the market sector slowdown in each sources-of-growth component we have to weight the data in Figure 4, which is done in Figure 5 for TFP (the appendix...
contains the comparable graphs for $s^K \Delta \ln K/H$ and $s^L \Delta \ln L/H$.\footnote{Industry shares in market sector value-added in the pre-crisis (2000-07) and the following (2007-11) periods are also presented in Table A5.1, Appendix 5.} We see that the largest contributions were as follows: financial services, (-0.79/3.11) = 25%; wholesale/retail, (-0.67/3.11) = 22%; manufacturing, (-0.49/3.11) = 16%; professional & administrative services, (-0.41/3.11) = 13%; and agriculture, mining & utilities, (-0.35/3.11) = 11%. Note that industry TFP contributions from construction and recreational & personal services actually sped up.

**Figure 5: Market sector slowdown in TFP and industry contributions, 2000-07 to 2007-11**

**Note to figure:** Figure shows industry contributions to market sector TFP slowdown. The market sector TFP slowdown is estimated as mean TFP in 2007-11 less mean TFP in 2000-07. Industry contributions to the slowdown are therefore the industry contribution to TFP in 2007-11 less the industry contribution to TFP in 2000-07. Red data points are positive and therefore represent a speed-up in the industry contribution.

To summarise, the industry data do support the suggestions of weakness in the financial and mining sectors. Together, financial services; and agriculture, mining & utilities account for over a third (37%) of the TFP slowdown; but we note also large contributions to the slowdown from wholesale/retail (22%), manufacturing (16%) and professional & administrative services (13%). In our outlook for future growth below, we assume that increased regulation and staffing requirements, and a reduced appetite for risk, will reduce future growth in financial services, but we implicitly assume no ongoing weakness in other industries.\footnote{With the exception of an ongoing slowdown in oil and gas (mining) which is already present in the 2000-07 data.}

9. **Utilisation**

As we have seen, even with strong assumptions on capital scrapping, capital shallowing does not appear to explain the puzzle. What Table 3 emphasises however is the dominance of buildings in the measurement of $\Delta \ln K$ and thus the contribution of capital. As shown in the third panel, even when we increase depreciation rates by a factor of 1.5 post-2009, $\Delta \ln K_c$ from buildings still grew on average at 2.51% pa in the 2007-11 period, and the contribution from buildings capital to growth in value-added is still 0.51% pa. But what if there is an excess supply of buildings capital following the commercial
property boom earlier in the 2000s, such that buildings are less utilised than in earlier periods? And more generally, what if there is low utilisation of labour and other capital as well?

Capital utilisation is taken up in Berndt and Fuss (1986) and Hulten (1986) and considered with labour utilisation as well in Basu, Fernald et al. (2004). To guide the discussion, suppose the production function is of the form \( Y = \left( N \cdot G(E, H) \right)^{\alpha} \left( K(1-V) \right)^{\beta} \) where labour services consist of \( N \) workers for \( H \) hours per worker, working with effort \( E \) per hour, such that labour input is then \( N \times G(E, H) \), where \( G \) transforms the bundle of \( E \) and \( H \) into per worker effort-hours. Capital services are \( K \) but, in the buildings example, vacant buildings means that \( K \) yields a flow of services \( K(1-V) \) where \( V \) is the vacancy rate. Thus \( \Delta \ln TFP = \alpha \Delta \ln E + \beta \Delta V \) where \( \alpha \) is the labour share times a constant from the log linearisation of the function \( G \), \( \beta \) is the buildings share and the expression uses the approximation \( \ln(1-V) \approx V \) for small \( V \).

Turning first to buildings, according to the Berndt-Fuss-Hulten theorem, utilisation is captured in the rental price, via a reduced rate of return (\( r \)) and the asset price (\( P_I \)). However, if there is price stickiness for example, the contribution of buildings may be over-estimated. Therefore it is of interest to look at some data on the utilisation of buildings. Figure 6 presents data on UK commercial property vacancies.

![Figure 6: Commercial property vacancies (as % of total commercial property)](image)

**Notes to figure:** Data on IPD annual void rates.
**Source:** IPD UK Annual Property Index.

The data show vacancy rates increasing from 11% in 2006 to 16% in 2009, and remaining at a similar level before increasing to 17% in 2012. If such a series accounts for the utilisation of buildings then the “true” contribution of buildings is: \((1 - v)s^B \Delta \ln K^B\) where \( v \) is the vacancy rate. In 2012, (1-

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35 The Basu, Fernald et al and the Berndt and Fuss ways of thinking about utilization are conceptually distinct. Berndt and Fuss are about measuring the shadow value of the quasi-fixed factor, but they assume the “input” is properly measured. The Basu, Fernald et al approach assumes that there is unobserved variation in capital’s workweek and labour effort.
Therefore, in 2007-11, TFP may be over-estimated by \((0.17 \times 0.61 =) 0.09\%\) pa due to overestimation of the utilisation of buildings. As shown in Table 1, this could potentially explain just 1% of the TFP puzzle, via an over-estimated contribution for buildings. Therefore even if under-utilisation is not captured in the rental price, this also does not appear to provide a significant explanation of the TFP puzzle.

Regarding unobserved effort, E, Basu, Fernald et al. (2004) suggest measuring it by actual hours per worker per year \((H/N)\). To do this, they suggest running the regression

\[
\Delta \ln TFP_{MEAS} = \alpha + \gamma \Delta \ln (H / N)
\]

which allows us to form a measure of utilisation-adjusted TFP as

\[
\Delta \ln TFP_{ADJ} = \Delta \ln TFP_{MEAS} - \frac{\gamma}{\gamma} \Delta \ln (H / N).
\]

Thus growth in \(H/N\) means that measured TFP is overstated, since some of measured TFP captures the increase in effort. We therefore implemented this using our industry data. We were unable to find sensible results with agriculture/mining/utilities, finance and arts/recreation/other services included: whereas all hours and most TFP fell in 2008, for these industries, their TFP rose. For the remaining sectors, we estimated the following (t-statistics in brackets) using random effects, 6 market industries over 14 years:

\[
\Delta \ln TFP_{MEAS} = 0.005 + 0.75 \Delta \ln (H / N) \quad (1.18) \quad (2.05)
\]

What is the economic significance of this result? Adjusting TFP in the way set out above for the selected industries, and aggregating up to the market sector, we find that utilisation adjusted TFP was 0.07pppa higher than measured TFP in the pre-recession 2000-07 period (adjusted TFP of 1.01% pa compared to measured TFP of 0.94% pa) and 0.64pppa higher in the 2007-11 period (-1.53% pa compared to -2.17% pa). In terms of the TFP gap we set out earlier, the results suggest that factor utilisation explains 17% of the TFP gap.

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36 Consider a firm employing \(N\) workers for \(H\) hours per worker, working with effort \(E\) per hour, where \(E\) is unobservable. Labour input is then \(N \times G(E,H)\), where \(G\) transforms the bundle of \(E\) and \(H\) into per worker effort-hours. A firm wishing to raise \(E\) or \(H\) will face some costs of doing so. Assume they are optimising on all margins. Then the first order condition holds: \(dG/dH(H/G) = dG/dE(E/G)\). Log linearising, one can write the unobservable \(E/N\) in terms of the observable \(H/N\) as \(\ln E/N = \gamma \ln (H/N)\) as is done above.

37 Where \(MEAS=\)“measured”. Note, we also tried detrending \(\Delta \ln (H/N)\) and found it made no discernable difference to the results or the degree of precision, as also noted by Basu, Fernald et al. (2004).

38 Where \(ADJ=\)“adjusted”.

39 In the context of capital, \(E\) can be thought of in terms of the workweek of capital \((W)\).

40 The full regression is reported in a table in Appendix 6.

41 In this paper we study data up to 2011, but what about more recent data? Inspection of ONS data for \(\Delta \ln (H/N)\) in the market sector show that hours per worker declined in 2008 and then declined even more sharply in 2009. In 2010, they returned positive, before again falling negative in 2011. In 2012 and 2013, \(\Delta \ln (H/N)\) was positive, with the data point for 2013 being the highest in the series which begins in 1999. Thus we conclude that the cyclical effect observed during and immediately after the recession is no longer a factor in the more recent data.
10. The outlook for TFP growth

McCafferty (2014) suggests possible productivity declines due to declining fecundity of North Sea Oil as well as minimum staffing requirements in what is a very capital-intensive industry. In finance, he notes the move away from riskier types of activity, the necessity of maintaining a minimum operating scale, and increased staffing required to meet stricter regulation and maintain a greater focus on risk management. In transportation and storage, he argues that continuing tightening of security regulation might harm future productivity.

If we consider the future path of $\Delta \ln TFP$, starting from 0.94%pa in the 2000-07 period, this already includes the drag from the oil and gas sector, which we might expect to continue. Suppose that TFP growth in the financial sector will be lower than it was pre-crisis due to increased regulation. According to our industry data, Figure 5, the contribution to total TFP of the financial sector was 27% of aggregate TFP, 2000-07. If this contribution drops by one-half, then future $\Delta \ln TFP$ slows to 0.83%pa(0.95%pa*(1-0.135)). This could of course be higher in the short run if there was a catch-up effect.

We use 2000-07 as our baseline as that excludes the stronger productivity performance observed in the 1990s usually associated with the deployment of ICT. If one considered a 1990-2007 estimate of 1.13% pa to reflect the baseline, then future TFP will be slightly higher on this calculation, at around 0.98% pa. Alternatively, using a 1970-2007 average of 0.75% pa would produce a more pessimistic outlook for future TFP, at around 0.65% pa. Using even longer run estimates of average TFP of 1.11% pa (1870-2007) from Bergeaud, Cette et al. (2014) results in an estimate of around 0.96% pa.

The 0.83% prediction assumes no catch-up of the productivity gap due to the uncertainty around the extent of any catch-up. Of course, if there is a catch up then there will be a temporary rise in the growth rate. At most, assuming full catch-up, this could add around 1 percentage point per annum to TFP growth and this would leave TFP growth close to its average growth rate in the decade after the 1990s recession. Oulton and Sebastiá-Barriel (2013) find that banking crises reduce short short-term productivity growth such that the long-term level is lower than it would have been had the crisis not

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42 Data kindly provided by Antonin Bergeaud.
43 Estimates for 2000-07 are from the industry dataset in this paper and are extended to 1990-2007 using the market sector dataset, using capital services and accounting for labour composition. Estimate for 1970-2007 are from EUKLEMS 2012 release with similar features, that is, market sector, capital services, with labour composition, but without R&D capitalised. We note as a matter of data that EUKLEMS market sector TFP for 1970-2007, without accounting for labour composition, as often quoted in long-run work, is 1.06% pa. Estimate for 1870-2007 (1.11% pa) is from Bergeaud, Cette et al. (2014) which is for the whole economy, is time-series filtered, using capital stocks and not accounting for labour composition.
occurred. In other words, the level of labour productivity does not fully ‘catch-up’. Although they do not work with TFP, their results suggest a permanent reduction in the level of UK TFP following the crisis. The OECD and UK OBR also take the view that the crisis has permanently reduced the level of productivity but has had no impact on growth implying no post-crisis catch up (Crafts 2015).

In this paper we discuss the productivity slowdown in terms of the TFP gap relative to the previous trend. However, if TFP (technological progress) is a random walk with time-varying drift then technical progress need not necessarily revert to any previous trend. Using long-run data from Bergeaud, Cette et al. (2014), over the post-war period 1947-2007, UK mean ΔlnTFP grew at a rate of 1.43% pa with a standard deviation of 1.37%. Thus the probability of a sustained period of negative ΔlnTFP is very small if variation in ΔlnTFP is considered random.

11. Summary

We have revisited the UK productivity puzzle using a new set of data on outputs and inputs and clarifying the role of output mismeasurement, input growth and industry effects. The productivity puzzle is a TFP puzzle: the productivity slowdown cannot plausibly be explained by slowdowns in labour and capital services, conventionally measured. So the TFP puzzle is a 12.2 percentage point gap with respect to pre-crisis TFP levels. The inclusion of R&D makes very little difference, and labour composition and labour reallocation only serve to deepen the puzzle. We find that 35% of the TFP productivity puzzle can be accounted for by weakness in the oil and gas and financial sectors. A further 15% could be accounted for by premature scrapping, although we note the potential for capital life-lengthening during and since the recession, which would only serve to deepen the puzzle. A further 17% could be accounted for by cyclical variation in factor utilisation. Overall these factors could account for around two-thirds of the TFP gap. Finally, continued weakness in finance would suggest a future lowering of TFP growth from 0.95% to 0.83%.
References

Appendix 1: Relations between industry and aggregate labour productivity

1a. Industry and aggregate labour productivity

Following Jorgenson, Ho et al. (2007) define labour productivity as value-added per hour where unsubscripted variables are aggregates and subscript \( j \) refers to industry

\[
ALP^H = V / H
\]
\[
ALP_j^H = V_j / H_j
\] (A1.1)

Labour hours aggregate as a simple sum of industry hours since they are in natural units

\[
H = \sum_j H_j
\] (A1.2)

Rewriting (A1.1) in terms of growth rates gives the relation between \( \Delta \ln ALP \) and \( \Delta \ln ALP_j \) as

\[
\Delta \ln ALP = \sum_j \bar{w}_j \Delta \ln ALP_j + \left( \sum_j \bar{w}_j \Delta \ln H_j - \Delta \ln H \right)
= \sum_j \bar{w}_j \Delta \ln ALP_j + R_H
\] (A1.3)

1b. Industry and market-sector total factor productivity growth

Consider labour and capital of types \( l \) and \( k \). Define labour and capital services as a share-weighted aggregate, where the shares are averages over adjacent years as follows:

\[
\Delta \ln K = \sum_k \bar{w}_k \Delta \ln K_k, \quad \text{capital type} \ k
\]
\[
\Delta \ln L = \sum_l \bar{w}_l \Delta \ln H_l, \quad \text{labour type} \ l
\]

\[
\bar{w}_k = P_{K,k} K_k / \sum_k \left( P_{K,k} K_k \right), \quad \bar{w}_l = P_{L,l} L_l / \sum_l \left( P_{L,l} L_l \right), \quad K_j = \sum_j K_{j,j} \forall k, \quad L_j = \sum_j L_{j,j} \forall l,
\]

\[
\bar{w}_l = 0.5(w_l + w_{l-1})
\] (A1.4)

Therefore, capital services (\( \Delta \ln K \)) are a share-weighted sum of changes in the industry-stock of each asset (\( \Delta \ln K_k \)), where the weights are that industry-assets share of payments in total capital compensation. Similarly, labour services (\( \Delta \ln L \)) are a share-weighted sum of changes in the hours worked (\( \Delta \ln H_l \)) of each worker type, where the weights are that worker types share of payments in total labour compensation.

We build a real capital stock via the perpetual inventory method whereby for any capital asset \( n,j \), the stock of that asset evolves according to

\[
K_{n,j,t} = I_{n,j,t} + (1 - \delta_{n,j,t}) K_{n,j,t-1}
\] (A1.5)

Where \( I \) is real investment over the relevant period and \( \delta \) the geometric rate of depreciation. Real investment comes from nominal tangible investment deflated by an investment price index. Second, that investment price is converted into a rental price using the Hall-Jorgenson relation, where we assume an economy-wide net rate of return such that the capital rental price times the capital stock
equals the total economy-wide operating surplus (on all of this, see for example, Oulton and Srinivasan (2003).

The definition of industry TFP and its relation to the aggregate is set out in the main text. Note here that, for the economy as a whole, the definition of aggregate $\Delta \ln TFP$ based on value added is the same, that is:

$$
\Delta \ln TFP \equiv \Delta \ln V - \bar{\nu}_K \Delta \ln K - \bar{\nu}_L \Delta \ln L
$$

$$
\Delta \ln TFP \equiv \Delta \ln V / H - \bar{\nu}_K \Delta \ln K / H - \bar{\nu}_L \Delta \ln L / H
$$

(A1.6)

Where the “v” terms here, that are not subscripted by “j”, are shares of K and L payments in economy wide nominal value added, averaged over the current (t) and previous (t-1) period. To construct our market sector data for earlier years where we don’t have the industry data, we aggregate hours directly as hours have a natural unit, whereas the approach in equation (4) when working in per hour terms aggregates with value-added weights, thereby introducing the reallocation term (the second term on the right in equation (A1.3)). Therefore there is no reallocation term for our market sector results for the 1980s and 1990s in Table 2.

As well as the re-allocation term(s), there are also other differences between our industry dataset and that for the market sector. First, there are small differences between estimated aggregate value-added growth in the two datasets. The reason is that in the industry file, R&D is capitalised at the industry-level, thus changing real industry output growth and the implied industry price index. The nominal weights also change as nominal industry value-added changes. In contrast, in the market sector file we aggregate measured real industry growth using measured nominal value-added as weights. The measured data are based on Blue Book 2013 and so R&D is not already capitalised. Then we capitalise R&D after the aggregation. The two methods give slightly different results, hence the differing estimates of $\Delta \ln V$ in Table A1.1 below.

Second, the capital data differs slightly. In the industry-file, the capital data are constructed using industry and asset-specific depreciation rates. In the market sector file, depreciation rates are asset specific but are implicitly the same across industries. All our key results are based on data for the market and industry-level over the 2000s. Table 2 and Table A4.1 have a longer run of data but just for the market sector. To clarify the relation between our industry and market sector data, for 1997-2011 we have consistent industry--year output data on the SIC2007 classification. To match these we construct capital data at industry-asset-year level and labour data at industry-type-year level, so all data 2000-2011, upon which almost all results in this paper depend, are consistently aggregated bottom-up data. Before 1997 we do not have industry-year output data by SIC07, but by SIC03. Thus we do not build industry-level data before 1997, rather a market-sector dataset. We backcast the output data from the SIC07 level using SIC03 changes in output and aggregate the capital by asset-year. Thus data for the 1980s and 1990s in Table 2 are not based on a complete bottom-up aggregated set. In Table A1.1 we show that this method gives very similar growth rates in the overlapping years (the 2000s) except for small differences in non-computer tangible, and R&D intangible capital growth rates, and also value-added growth rates.
Table A1.1: Growth-accounting decomposition, 2000-11, Aggregate market sector vs industry aggregation

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ALPG</td>
<td>Total</td>
<td>Computers</td>
<td>Other</td>
<td>NA Intang</td>
<td>R&amp;D</td>
<td>Composition</td>
<td>Reallocation</td>
<td>DlnV/H</td>
</tr>
<tr>
<td>Market Sector data, with R&amp;D</td>
<td>1.45%</td>
<td>1.14%</td>
<td>0.08%</td>
<td>0.84%</td>
<td>0.17%</td>
<td>0.05%</td>
<td>0.37%</td>
<td>-</td>
<td>0.37%</td>
</tr>
<tr>
<td>Aggregated Industry data, with R&amp;D</td>
<td>1.51%</td>
<td>1.33%</td>
<td>0.11%</td>
<td>0.94%</td>
<td>0.17%</td>
<td>0.11%</td>
<td>0.46%</td>
<td>-0.08%</td>
<td>0.11%</td>
</tr>
</tbody>
</table>

**Notes to table:** All figures are average annual percentages. The contribution of an output or input is the growth rate weighted by the corresponding average share. Panel 1 is a decomposition of labour productivity growth and panel 2 a decomposition of value-added growth. Columns are annual average change in natural logs of: column 1, real value added (per hour), column 2, contribution of total capital (which is the sum of the next four columns), column 3, contribution of IT hardware capital, column 4, contribution of other non-IT tangible capital, column 5, contribution of national accounts intangibles, column 6, the contribution of R&D, column 7 is the contribution of labour services (per person hour), column 8 is the labour reallocation term and column 7, TFP, being column 1 less column 2 and column 7. Row 1 is based on ONS data for the market sector, with R&D capitalised. Row 2 is ONS industry data, with R&D capitalised in each industry, 2000-11, aggregated to the market sector. In row 2, ALPG includes the labour reallocation term, R^H. In each the market sector is defined using our definition of SIC(2007) A-K, MN, R-T. **Source:** authors’ calculations

Appendix 2: The impact of labour composition during and since the recession

As shown in Table 1, 2007-11 saw a strong increase in the contribution of labour composition. It rose from 0.35% pa in 2000-07 to 0.64% pa in 2007-11. The following tries to unpick the reasons behind this rise.

Our series for Quality-adjusted labour input (QALI), based on ONS data, is derived from data for (9*6*3*2=324 worker types i.e. 9 industries, 6 qualification levels, 3 age-groups and 2 genders). Our previous work (supplementary appendices to Haskel, Goodridge et al. (2011)) showed that QALI is primarily driven by the qualification category. We therefore collapse the six qualification levels into 3 groups: high, medium and low skill (HS, MS and LS); and use that single characteristic to approximate labour services. Using this reduced method, growth in labour composition, or labour services per person-hour, can be written as:

\[
\Delta \ln (L/HN) = \frac{w^{HS}HN^{HS}}{\sum wHN} \Delta \ln HN^{HS} + \frac{w^{MS}HN^{MS}}{\sum wHN} - \Delta \ln HN^{MS} + \frac{w^{LS}HN^{LS}}{\sum wHN} - \Delta \ln HN^{LS} - \Delta \ln HN
\]  

(A2.1)

Where L are labour services, H is hours per person, N is persons, thus HN is person-hours, and w is an hourly wage. We have data for each of these terms. Therefore Figure A2.1 compares official ONS estimates of labour composition (red line, based on 324 worker types) with those using equation (A2.1) (green line, based on just 3 worker types).
We now look in detail at the terms in equation (A2.1) to understand what has changed and what drives the growth in labour composition from 2008. The following table presents averages for each term.

<table>
<thead>
<tr>
<th>Period averages for terms in equation (12)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Growth in labour composition</td>
</tr>
<tr>
<td>[Δln(L/H)]&lt;sup&gt;HS&lt;/sup&gt;</td>
</tr>
<tr>
<td>2000-07</td>
</tr>
<tr>
<td>2007-11</td>
</tr>
</tbody>
</table>

Note to table: period averages (before and after recession) for all terms in equation (12)
Source: ONS data

What has changed according to Table A2.1? First, we see that the income share for the high-skilled has increased, at the expense of both the medium-skilled and low-skilled. Second, there is a strong fall in the growth of low-skilled hours, falling from -0.5% pa to -3.76% pa.

Let us first consider the change in the income shares. In principle, this change could be driven by either: (a) changes in relative wages; or (b) changes in employment shares. Table A2.2 compares annual income and employment shares for each of our three worker types over the period in question.

The first thing to note is that the employment share of the high-skilled has increased significantly over the period, and that of the low-skilled has decreased. Second, the income shares have changed similarly, such that the difference between the income and employment shares is very stable over the whole period. Any changes in relative wages have therefore been small.

Therefore, relating this to Table A2.1, increased growth in labour composition is driven by (a) an increased employment share for the high-skilled, and (b) strong falls in hours worked of the low-skilled. Of course, these two things are related, with employment consisting of more hours worked by the former at the expense of the latter.
Table A2.2: Income and employment shares: HS, MS, LS

<table>
<thead>
<tr>
<th>Year</th>
<th>Employment share: High skilled</th>
<th>Income share: High skilled</th>
<th>Difference: High skilled</th>
<th>Employment share: Medium skilled</th>
<th>Income share: Medium skilled</th>
<th>Difference: Medium skilled</th>
<th>Employment share: Low skilled</th>
<th>Income share: Low skilled</th>
<th>Difference: Low skilled</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>0.17</td>
<td>0.26</td>
<td>0.09</td>
<td>0.35</td>
<td>0.36</td>
<td>0.01</td>
<td>0.48</td>
<td>0.38</td>
<td>-0.09</td>
</tr>
<tr>
<td>2002</td>
<td>0.17</td>
<td>0.26</td>
<td>0.09</td>
<td>0.36</td>
<td>0.36</td>
<td>0.00</td>
<td>0.47</td>
<td>0.38</td>
<td>-0.09</td>
</tr>
<tr>
<td>2003</td>
<td>0.18</td>
<td>0.27</td>
<td>0.09</td>
<td>0.35</td>
<td>0.35</td>
<td>0.00</td>
<td>0.47</td>
<td>0.38</td>
<td>-0.09</td>
</tr>
<tr>
<td>2004</td>
<td>0.19</td>
<td>0.27</td>
<td>0.09</td>
<td>0.35</td>
<td>0.35</td>
<td>0.00</td>
<td>0.46</td>
<td>0.37</td>
<td>-0.09</td>
</tr>
<tr>
<td>2005</td>
<td>0.19</td>
<td>0.28</td>
<td>0.09</td>
<td>0.35</td>
<td>0.35</td>
<td>0.00</td>
<td>0.46</td>
<td>0.37</td>
<td>-0.09</td>
</tr>
<tr>
<td>2006</td>
<td>0.20</td>
<td>0.29</td>
<td>0.08</td>
<td>0.34</td>
<td>0.35</td>
<td>0.01</td>
<td>0.46</td>
<td>0.36</td>
<td>-0.09</td>
</tr>
<tr>
<td>2007</td>
<td>0.22</td>
<td>0.30</td>
<td>0.08</td>
<td>0.33</td>
<td>0.34</td>
<td>0.01</td>
<td>0.45</td>
<td>0.36</td>
<td>-0.09</td>
</tr>
<tr>
<td>2008</td>
<td>0.22</td>
<td>0.31</td>
<td>0.09</td>
<td>0.33</td>
<td>0.33</td>
<td>0.00</td>
<td>0.45</td>
<td>0.36</td>
<td>-0.09</td>
</tr>
<tr>
<td>2009</td>
<td>0.23</td>
<td>0.32</td>
<td>0.09</td>
<td>0.33</td>
<td>0.32</td>
<td>-0.01</td>
<td>0.44</td>
<td>0.35</td>
<td>-0.09</td>
</tr>
<tr>
<td>2010</td>
<td>0.24</td>
<td>0.33</td>
<td>0.09</td>
<td>0.34</td>
<td>0.33</td>
<td>-0.01</td>
<td>0.42</td>
<td>0.34</td>
<td>-0.08</td>
</tr>
<tr>
<td>2011</td>
<td>0.26</td>
<td>0.35</td>
<td>0.09</td>
<td>0.34</td>
<td>0.33</td>
<td>-0.01</td>
<td>0.40</td>
<td>0.32</td>
<td>-0.06</td>
</tr>
</tbody>
</table>

**Source:** ONS data

Growth in labour composition is therefore driven by the fall in low-skilled hours worked, first through the fall in $\Delta \ln H_{LS}$, and second through the reduced employment (and hence income) share for the low-skilled, and the higher employment (and hence income) share for the high-skilled. In principle, the fall in low-skilled hours could come from two sources. The first is reduced hours-per-worker, and the second is reduced employment. The ONS have kindly supplied us with data on the former from the QALI source data. The following chart presents estimates of hours per worker for each of our three skill groups.\(^44\)

![Figure A2.2: Average hours per worker by skill group (index, 2008=1)](image)

**Note to figure:** Index of average hours worked per job (2008=1) by skill group. HS=high-skilled, MS=medium skilled, LS=low-skilled. The line Total is an average across all individuals.

**Source:** ONS data

As Figure A2.2 shows, between the years 2008 and 2011, there has been a fall in hours per worker, but this is true for all skilled groups, and the profile for low-skilled workers does not stand out. In fact, the fall among the low-skilled was similar to that of the high-skilled, and less marked than that of the medium-skilled. Post-2011, average hours per worker have increased for all skill groups.

\(^{44}\) We thank Mark Franklin and Joe Murphy for publishing these data. The data are actually hours per job since the QALI methodology is based on jobs rather than workers.
Figure A2.3 presents an index of the number of jobs by skill group and shows that since 2008, growth in the number of jobs has largely been among the high-skilled with some increase also evident for the medium-skilled. In the case of the high-skilled, this is part of a long-term trend, hence the similarity in growth in high skilled hours in both 2000-07 and 2007-11, shown in Table A2.1.

Figure A2.3: Number of jobs by skill group (index, 2008=1)

Note to figure: Index of number of jobs (2008=1) by skill group. HS=high-skilled, MS=medium-skilled, LS=low-skilled. The line Total is an average across all individuals.

Thus we conclude that increased growth in labour composition in the 2007-11 period reflects reduced employment of low-skilled workers.

Appendix 3: The impact of labour re-allocation during and since the recession

It has also been suggested that one of the reasons behind the productivity puzzle is the re-allocation of labour from high- to low-productivity industries. In the context of an argument around labour hoarding, Martin and Rowthorn (2012) argue that increased employment since the recession is derived from increases in low-skilled labour in low-productivity industries. Our study of the data on labour composition (see Appendix 2) shows however that this is not the case.

For the 2000s, the period for which we use our bottom-up industry dataset, Table 2 shows an average reallocation term of -0.08% pa, which as shown above is the difference between the change in value-added weighted industry hours (Σv_jΔln(HN_j)) and changes in aggregate hours (Δln(HN)). Figure A3.1 presents a comparison of these terms. The difference between the two is the labour reallocation term (R^H).

The data show that the reallocation term tended to be negative in the years 2001 to 2008. Thus in the years preceding the recession, labour reallocation made a negative contribution to growth in labour productivity. That is, labour was being re-allocated to lower productivity (in terms of the level of productivity) industries. However, from 2008, the sign is reversed and labour reallocation makes a positive contribution to productivity growth. Thus, since the onset of the recession, labour has been re-allocated to high productivity industries. We note however that the reallocation term is small. The reason is that Δln(HN) is the same in each case, but Δln(HN) is implicitly aggregated using shares of HN, as opposed to shares of value-added. With some exceptions, shares based on hours or value-added are typically similar, hence the reallocation term is small.
Figure A3.1: Aggregate hours worked and a weighted industry total: Labour re-allocation

Note to figure: ΔlnHN are changes in aggregate hours worked in the UK market sector. ΣvjΔlnHNj is a value-added weighted aggregate of industry changes. The difference between them is the labour reallocation (RH) term.

Source: authors’ calculations

Appendix 4: Impact of capitalisation of R&D
Table A4.1 provides some more details. Comparing panel 1 to panel 2 in Table 2, capitalisation of R&D means ΔlnV/H is hardly affected. But R&D generates a new asset thus adding to the share of ΔlnV/H accounted for by capital inputs, and Table 2 shows it accounts for around 0.11%pa, 2000-11.

How robust is this finding? Of course capitalisation of R&D requires some estimate of the price of R&D. In Table 2 we assumed that the price of R&D can be approximated using the GVA deflator for each industry. In the official measurement R&D will be deflated by a share-weighted input price index for R&D, which is well approximated by the implied market sector GVA (MSGVA) deflator. Three observations suggest that using a GVA deflator overstates the price deflator for R&D, and so understates the impact of R&D on the economy. First, many knowledge-intensive prices have been falling relative to wider GVA. Second, the advent of the internet and computers would seem to be a potential large rise in the capability of innovators to innovate, which would again suggest a lowering of the price of knowledge, in contrast to the rise in prices implied by a GVA deflator. Third, this second effect may have been enhanced by the emergence of (big) data and increased use of data analytics, which may also have positive effects on productivity in R&D production. Thus use of a GVA deflator almost certainly understates the importance of knowledge assets.

Therefore in Table A4.1 we experiment with alternative deflators. In panel 1 we use the industry GVA deflator. In panel 2 we use the R&D deflator developed by the US BEA, which is a share-weighted input price index but with an adjustment for assumed productivity growth in R&D production based on US TFP. In panel 3 we use a deflator that implies even stronger productivity growth in R&D production than is implicitly assumed in the BEA R&D price index. One knowledge intensive output with fast-falling prices is pre-packaged software. We therefore use the BEA deflator for pre-packaged software to test just how much that effects the estimated contribution of R&D.

Looking at each panel in Table A4.1, and focusing on the 2000s, the first panel repeats the decomposition of labour productivity using the implied GVA index to deflate R&D. The contribution of R&D is 0.11%pa. The second panel uses the BEA price index for R&D, the impact of which is to slightly reduce ΔlnV/H. On the input side, the contribution of R&D is reduced slightly to 0.09%pa. Thus TFP is raised slightly to -0.18% pa.
### Table A4.1: Alternative deflators for R&D, 1990-2011

<table>
<thead>
<tr>
<th></th>
<th>ΔlnV/H</th>
<th>ΔlnL/H</th>
<th>ΔlnK/H cmp</th>
<th>ΔlnK/H othtan</th>
<th>ΔlnK/H NA intan</th>
<th>ΔlnK/H rd</th>
<th>ΔlnTFP</th>
<th>R²</th>
<th>Memo: sLAB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panel 1: Using GVA deflator for R&amp;D</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1980-90</td>
<td>2.70%</td>
<td>-0.08%</td>
<td>0.21%</td>
<td>0.36%</td>
<td>0.24%</td>
<td>0.07%</td>
<td>1.90%</td>
<td>-</td>
<td>0.64</td>
</tr>
<tr>
<td>1990-00</td>
<td>2.94%</td>
<td>0.21%</td>
<td>0.32%</td>
<td>0.86%</td>
<td>0.25%</td>
<td>0.04%</td>
<td>1.24%</td>
<td>-</td>
<td>0.62</td>
</tr>
<tr>
<td>2000-11</td>
<td>1.51%</td>
<td>0.46%</td>
<td>0.11%</td>
<td>0.94%</td>
<td>0.17%</td>
<td>0.11%</td>
<td>-0.19%</td>
<td>-0.08%</td>
<td>0.64</td>
</tr>
</tbody>
</table>

| Panel 2: Using BEA price index for R&D |        |        |            |                |                |            |         |    |           |
| 1980-90 | 2.73%  | -0.08% | 0.21%      | 0.36%          | 0.24%          | 0.12%      | 1.88%   | -  | 0.64      |
| 1990-00 | 2.93%  | 0.21%  | 0.32%      | 0.86%          | 0.25%          | 0.06%      | 1.22%   | -  | 0.62      |
| 2000-11 | 1.50%  | 0.46%  | 0.11%      | 0.94%          | 0.17%          | 0.09%      | -0.18%  | -0.08%  | 0.64 |

| Panel 3: Using BEA price index for pre-packaged software, for R&D |        |        |            |                |                |            |         |    |           |
| 1980-90 | 2.94%  | -0.08% | 0.21%      | 0.36%          | 0.24%          | 0.38%      | 1.82%   | -  | 0.64      |
| 1990-00 | 3.09%  | 0.21%  | 0.32%      | 0.86%          | 0.25%          | 0.26%      | 1.17%   | -  | 0.62      |
| 2000-11 | 1.59%  | 0.46%  | 0.11%      | 0.94%          | 0.17%          | 0.18%      | -0.19%  | -0.08%  | 0.64 |

**Notes to table.** Data are average growth rates per year for intervals shown, calculated as changes in natural logs. Contributions are Tornqvist indices. First column is growth in value-added per hour. Column 2 is the contribution of labour services per hour, namely growth in labour services per hour times share of labour in market sector gross value-added (MSGVA). Column 3 is growth in computer capital services per hour times share in MSGVA. Column 4 is growth in other tangible capital services (buildings, plant, vehicles) per hour times share in MSGVA. Column 5 is growth in intangible capital services per hour times share in MSGVA, where intangibles are those already capitalised in the national accounts, namely software, mineral exploration and artistic originals. Column 6 is R&D capital services per hour times share in MSGVA, with R&D due to be capitalised in the UK accounts in 2014. The three panels use alternative deflators for R&D. As the US price index for pre-packaged software is only available back to 1985, the series is extended back using the ICT hardware deflator. Column 7 is TFP, namely column 1 minus the sum of columns 2 to 6. Column 8 is the labour reallocation term and column 9 the share of labour payments in MSGVA. Data for the 2000s are from the bottom-up aggregated industry dataset described above, and data for the 1980s and 1990s are for an aggregate market sector dataset built using a previous version of the SIC.

Panel 3 uses the BEA price index for pre-packaged software as a proxy for the price of R&D. The impact on the decomposition is large. First, ΔlnV/H is stronger by 0.09 pppa in the 2000s. The contribution of R&D capital deepening is also very strong, and almost doubles in the 2000s. However, since both outputs and inputs changes, TFP is unaffected. Thus, whilst a more accurate price index for R&D could explain a small part of the labour productivity puzzle, it does not explain the sustained slowdown in TFP.

### Appendix 5. Industry contributions to the overall productivity slowdown: capital and labour services

The text above sets out the contributions of TFP. Below are charts of industry contributions to the market sector slowdown for labour composition and capital deepening. Industry contributions to the market sector are the within-industry contributions multiplied by the industry share in market sector value-added. Industry shares in market sector value-added for the pre- and post-crisis periods are shown below in Table A5.1.
### Table A5.1: Industry value-added shares and contributions to the total Market Sector

<table>
<thead>
<tr>
<th>Industry</th>
<th>2000-07</th>
<th></th>
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<tr>
<td></td>
<td>(s_i^V = \frac{P_iV_i}{\sum P_iV_i})</td>
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</tr>
<tr>
<td><strong>(2): Industry LPG:</strong></td>
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<tr>
<td></td>
<td>(\Delta \ln(V_i/H_i))</td>
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<tr>
<td>Agriculture, Mining and Utilities</td>
<td>0.07</td>
<td>-0.87</td>
<td>-0.62</td>
<td>0.13</td>
<td>0.02</td>
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<td>0.06</td>
<td>0.15</td>
<td>0.00</td>
<td>-0.09</td>
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<tr>
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<tr>
<td>Recreational and Personal Services</td>
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<td>0.00</td>
<td>0.13</td>
<td>0.00</td>
<td>-0.13</td>
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<tr>
<td><strong>Sum: Market sector</strong></td>
<td>1.00</td>
<td>2.90</td>
<td>1.61</td>
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<tr>
<td></td>
<td>(s_i^V = \frac{P_iV_i}{\sum P_iV_i})</td>
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<td><strong>(2): Industry LPG:</strong></td>
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<td>(\Delta \ln(V_i/H_i))</td>
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<tr>
<td>Agriculture, Mining and Utilities</td>
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<td>0.19</td>
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<td>-0.19</td>
<td>0.05</td>
<td>0.04</td>
<td>-0.27</td>
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<tr>
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<td>1.26</td>
<td>0.11</td>
<td>0.02</td>
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<tr>
<td>Financial Services</td>
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<td>0.12</td>
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</tr>
<tr>
<td>Professional and Administrative Services</td>
<td>0.16</td>
<td>0.28</td>
<td>0.05</td>
<td>0.11</td>
<td>0.12</td>
<td>-0.18</td>
</tr>
<tr>
<td>Recreational and Personal Services</td>
<td>0.05</td>
<td>-0.09</td>
<td>0.00</td>
<td>0.06</td>
<td>0.04</td>
<td>-0.10</td>
</tr>
<tr>
<td><strong>Sum: Market sector</strong></td>
<td>1.00</td>
<td>-0.69</td>
<td>0.84</td>
<td>0.64</td>
<td>-2.17</td>
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Note to table: Data are averages for the 2000-07 period (top panel) and 2007-11 period (bottom panel). Column 1 is the industry share of nominal value-added in the UK market sector. Column 2 is industry labour productivity growth (LPG) in per hour terms, Column 3 is the industry contribution to market sector LPG (MSLPG), estimated as column 1 times column 2. Column 4 is the industry contribution to market sector capital deepening, estimated as column 1 times the within-industry contribution. Column 5 is the industry composition to market sector labour composition growth, estimated as column 1 times the within-industry contribution. Column 6 is the industry contribution to market sector \(\Delta \ln \text{TFP}\), estimated as column 1 times industry \(\Delta \ln \text{TFP}\). All growth rates calculated as changes in the natural log.

In Figure A5.1 we present industry contributions to the market sector speedup for labour composition.

**Figure A5.1: Market sector speed-up in the contribution of labour composition \((s_i^L \Delta \ln L/H)\), 2000-07 to 2007-11**

![Market sector speed-up graph](image)

**Note to figure:** Figure shows industry contributions to the speed-up in the contribution of market sector labour composition. The market sector labour composition speed-up is estimated as the mean contribution of labour composition in 2007-11 less the mean contribution in 2000-07. Industry contributions to the speed-up are therefore the industry contribution in 2007-11 less the industry contribution in 2000-07. Green data points are negative and therefore represent a slowdown in the industry contribution (the estimate for Agriculture, Mining and Utilities is marginally negative).
The data show that industry contributions to the speedup in labour composition are dispersed across a number of sectors. In particular, professional & administrative services contributed \((0.07/0.29=)23\%\) of the speedup. Wholesale/retail, transportation & storage, information & communication, financial services and recreational & personal services each contributed \((0.04/0.29)=13.5\%\) of the speedup.

Next, Figure A5.2 looks at the industry contributions to the slowdown in the contribution of capital deepening. It shows that Agriculture, Mining & Utilities accounts for \((-0.22/-0.77=)28\%\) of the total capital deepening contribution slowdown. Information & communication and wholesale/retail also contribute \((-0.13/-0.77=)17\%\) and \((-0.1/-0.76=)14\%\) respectively. The contribution of capital deepening in construction actually speeds up.

**Figure A5.2: Market sector slowdown in the contribution of capital deepening \((s^K\Delta\ln K/H)\), 2000-07 to 2007-11**

Note to figure: Figure shows industry contributions to the slowdown in the contribution of market sector capital deepening. The market sector capital deepening slowdown is estimated as the mean contribution of capital deepening in 2007-11 less the mean contribution in 2000-07. Industry contributions to the slowdown are therefore the industry contribution in 2007-11 less the industry contribution in 2000-07. Red data points are positive and therefore represent a speed-up in the industry contribution.

**Appendix 6. Factor Utilisation (Basu, Fernald et al. 2004)**
The following table reports more fully the regression estimated in section 9. Panel regression estimated using random effects, over 14 years (1998-2011) and for 6 market sector industries (Agriculture, Mining & Utilities; Financial Services; and Recreational and Personal Services are excluded). Due to the availability of industry data, the actual data used for the right-hand side variable is the change in hours per job \((\Delta\ln(H/J))\) rather than hours per worker.

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>(\Delta \ln TFP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\Delta \ln (H/J))</td>
<td>0.751** ((0.367))</td>
</tr>
<tr>
<td>Constant</td>
<td>0.00491 ((0.00418))</td>
</tr>
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</table>

Observations 84
Number of ind 6

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1