



BANK OF ENGLAND

# Speech

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## The fall in productivity growth: causes and implications

Speech given by

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## Introduction

Many thanks for the invitation.

Maurice Peston was an inspiration and role model for economists, having combined a distinguished career in academia with an unwavering commitment to public policy. As well as his legacy here at Queen Mary, he also left a big mark at the LSE, both as a student and later as a faculty member. It is a true honour to be here to give the Peston Lecture.

My talk today will be about productivity, and more specifically, about the UK productivity puzzle. Recently we have heard a lot about the productivity puzzle in the media, with policymakers, journalists and academics debating different reasons for the puzzle and many advancing ways to address it. Indeed, many of my colleagues and predecessors on the MPC have already given speeches about the UK productivity puzzle.<sup>1</sup>

To those who have been around for a while, this debate might sound somewhat *déjà vu*, as it is not the first time that the UK economy has shown a “productivity puzzle”. Back in 2003, Basu, Fernald, Oulton and Srinivasan wrote an influential paper trying to explain the missing productivity in the UK economy during the second half of the 1990s. With hindsight, we know now that the productivity puzzle of the 1990s disappeared as measurement improved and as the data were revised.

The current productivity puzzle, however, seems to be lasting longer than the one in the 1990s and it has certainly acquired a greater web-presence, judging by the large surge in the number of Google Scholar citations on the topic.

But although much has been said and written on it before, given the importance of the current productivity puzzle, I will argue it is useful to take a fresh look using the latest vintage of data. I will use it to draw three main conclusions:

- **Just two sectors, finance and manufacturing, can account for most of the fall in UK aggregate productivity growth.**
- **The post-crisis productivity drag from finance should disappear as deleveraging runs its course. Slower manufacturing productivity growth may relate to a reduction in the impact of lower-priced imported inputs from China and other emerging markets.**
- **Persistently weak investment has also been playing an increasingly important role in the weakness of manufacturing and aggregate productivity. But strong global growth should help support a recovery, especially if uncertainty were to be resolved.**

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<sup>1</sup> For example, Dale (2011), Broadbent (2012), McCafferty (2014), Weale (2014) and Haldane (2017).

Before that, my plan is to first discuss concretely what I mean by the productivity puzzle, and to try to put it into context. Next, I will say a few words on why we care about productivity and why it is relevant for monetary policy. I will then explore the questions of where and why productivity got lost. And, although the MPC will not conclude our collective assessment of supply-side conditions until our February forecast, I would like to finish by offering some reflections of my own on what the data can tell us about future productivity growth and the direction of monetary policy.

### 1.1. The Puzzle

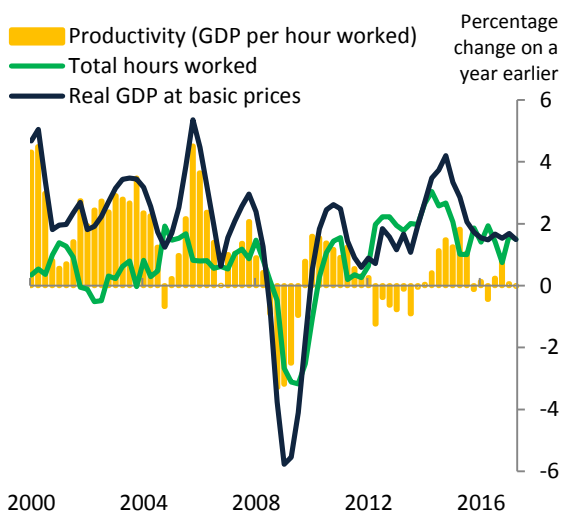
Let us first agree on a definition of the productivity puzzle. Though commentators have referred to different measures of productivity, most have focused on aggregate labour productivity, defined as the total value added of the UK economy divided by the total number of hours worked. In other words, it tells us how much a typical worker in the UK economy produces each hour.

The so-called productivity puzzle is the observation that UK productivity has fallen well below its pre-crisis trend. Productivity fell sharply at the peak of the crisis, 2008 and 2009 – a level shock in the jargon. Since then, productivity has been growing, but at a rate significantly lower than its pre-crisis trend rate (Charts 1 and 2). And though this growth slowdown has been experienced by other advanced economies, it appears to be more accentuated in the UK.

Let me illustrate these points with a few numbers.

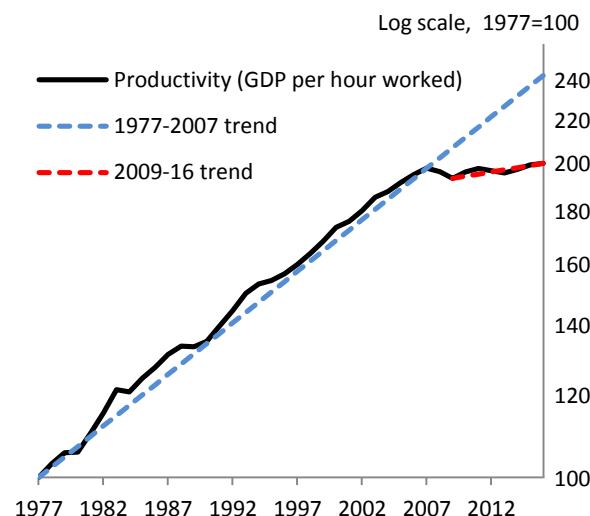
Over the three decades before the global financial crisis, productivity growth averaged 2.3% per year. To get a sense of what this growth means in practical terms, the average UK worker in 2007, working the same number of hours, could produce *twice* as much as she could have just thirty years before.

**Chart 1 – Labour productivity, hours and GDP**



Sources: ONS and Bank calculations.

**Chart 2 – Labour productivity relative to trend**



Sources: ONS and Bank calculations.

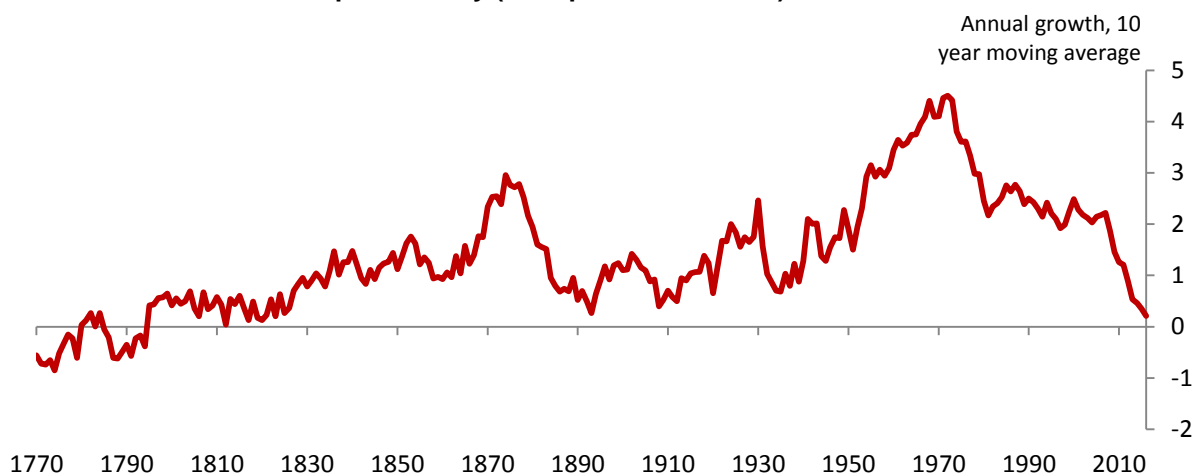
Since then, labour productivity growth has dropped significantly. Productivity *fell* in 2008 and 2009 as the financial crisis hit, and, in the seven years since, it has only grown by an average 0.4% per year. As a result, the typical worker in 2016, while still twice as productive as the 1970s, could only produce 1% more than in 2007.

## 1.2. Productivity: over the years and across the world

Focusing just on the past half-century, the decade since the crisis looks like an aberration. Productivity growth barely deviated from its 2% trend until 2007 (Chart 2). It is little wonder, therefore – looking at these data – that forecasters (the Bank of England included) consistently predicted that productivity growth would recover to a rate close to its 1970s-2000s average.

Over a longer sweep of history, the past decade is far from unusual. Chart 3 shows annual UK labour productivity growth since 1760. Prior to the 1970s, there were often large shifts in the average growth rate of productivity from one decade to the next. Depending on how you interpret the chart, that could be a good-news or a bad-news story.

**Chart 3 – Historical labour productivity (GDP per hour worked)**



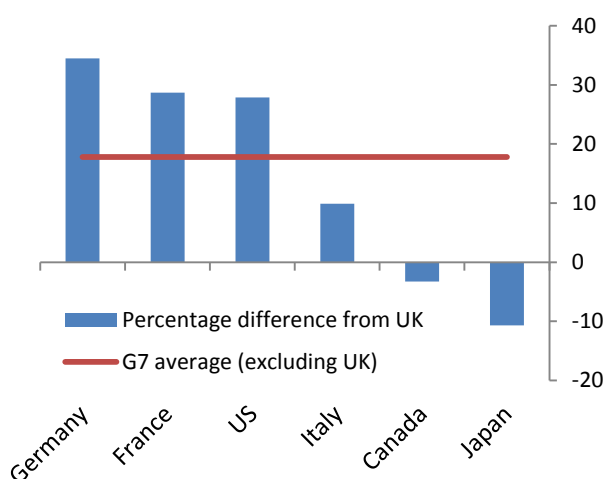
Sources: Thomas and Dimsdale (2017) and Bank calculations.

The 'glass half full' reading might note that we have been through several temporary periods of weak productivity growth before, but have always recovered. But there is also a 'glass half empty' interpretation. Robert Gordon from Northwestern University has argued that the hundred years spanning from 1870 to 1970 were exceptional in the number and scope of life-changing break-through innovations and there is absolutely no reason to expect growth to be as high and broad-based now. The progress since 1970, he argues, has been concentrated in a relatively narrow part of the economy: entertainment, communication and information processing. But in other essential areas like food, clothing and shelter, progress has been much slower.

Gordon's ideas could explain why productivity growth has slowed down globally. But even if they are correct, all is not lost for the UK. That is because of what some have described as the second aspect of the productivity puzzle, namely, that the recent level and growth rates of labour productivity in the UK have been lower than in many of its international peers.<sup>2</sup> So even if productivity in other advanced economies were to stall completely, UK productivity could still grow rapidly for some time, if it were possible to catch-up to other countries' levels.

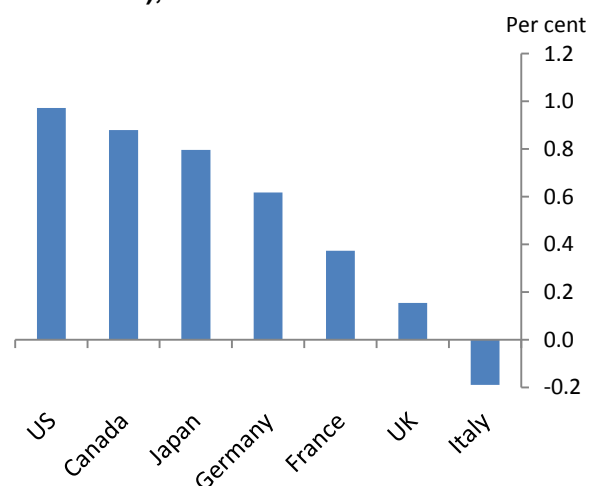
How much catching up is there to do? Cross-country comparisons are tricky, but the ONS estimates that compared to the UK, labour productivity is on average 18% higher in the other six members of the G7, 28% higher in the US and 35% higher in Germany (Chart 4). These are significant differences. If British workers were able to catch-up to the G7 average, what currently takes us five days' work to produce could be done in little over four. If we were able to catch up to Germany, we might all be able to go home from work on Thursday afternoon each week without any fall in GDP.

**Chart 4 – Comparisons of labour productivity (current price GDP per hour worked), 2016**



Sources: ONS.

**Chart 5 – Average annual growth rates of labour productivity (constant price GDP per hour worked), 2007-16**



Sources: ONS.

Rather than narrowing, the productivity gap with our international peers has actually been increasing since 2007 (Chart 5). Despite subdued productivity growth globally – no G7 nation has recorded average annual rates above 1% – the UK has fallen further behind Germany, France and the US, while Canada and Japan have both caught up somewhat. Only Italy has recorded a slower rate of productivity growth.

The plots have illustrated the UK productivity slowdown, both relative to other countries and also relative to the UK's own recent past. Before turning to where we lost ground, let me briefly say why productivity growth – or lack thereof – is so crucially important.

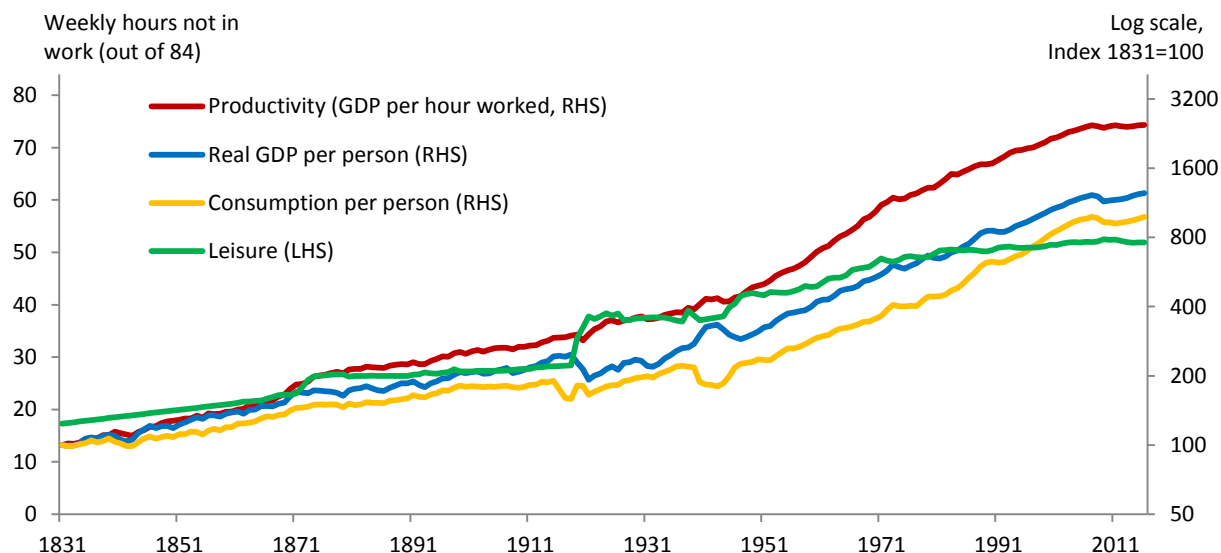
<sup>2</sup> See the transcript of oral evidence given by Sir Charles Bean to the Treasury Committee on the Autumn 2017 Budget on 30 November 2017.

## 2. Why do we care about productivity?

Productivity matters for welfare. Over time and across countries, higher productivity is reliably associated with higher wages, higher consumption levels and improved health indicators. The following charts illustrate these relationships.

Higher productivity is associated, almost mechanically, with higher GDP and consumption per person, (Chart 6). Labour productivity is 25 times higher than in 1831. That has enabled a 12-fold increase in the level of GDP per person and a 9-fold increase in consumption per person. Those increases come despite spending less of our lives working. Leisure time, crudely measured as hours not in work, has increased from less than 20 hours a week in the 1830s to 50 hours a week today.<sup>3</sup>

**Chart 6 – Historical labour productivity and indicators of welfare**

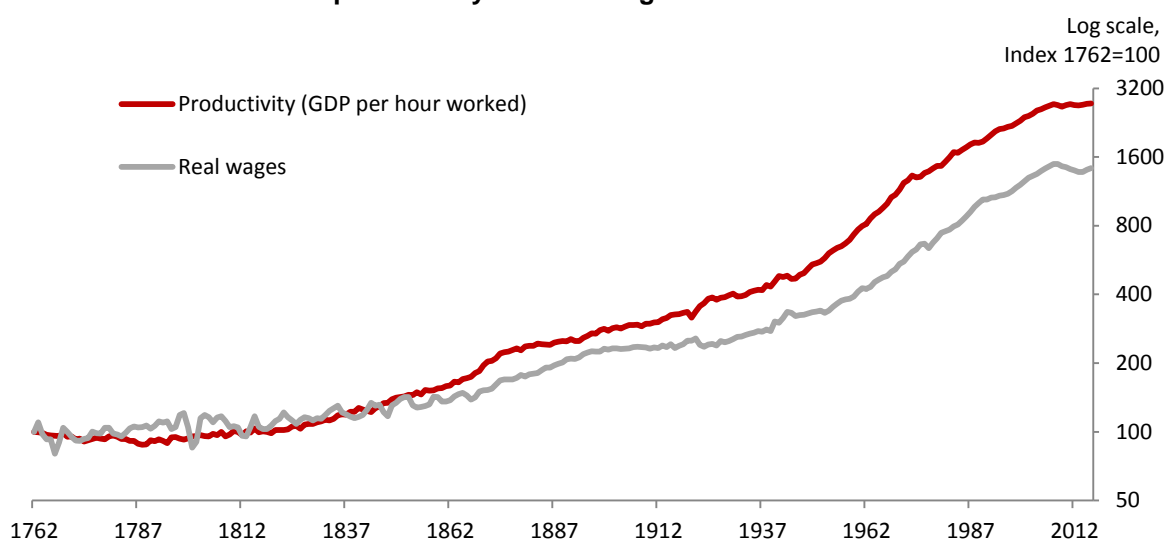


Sources: Thomas and Dimsdale (2017) and Bank calculations.  
Notes: Leisure calculated as 84 minus average weekly hours.

Higher productivity also tends to lead to higher real wages (Chart 7). The average real wage has increased by around 14 times over the past 250 years, as employers have increased salaries for their increasingly productive employees.

<sup>3</sup> Assuming 12 hours per day devoted to sleeping, eating and personal care. The statistic only includes workers, so does not count any benefits from longer periods spend in retirement.

**Chart 7 – Historical labour productivity and real wages**



Sources: Thomas and Dimsdale (2017) and Bank calculations.  
 Notes: Real wages are calculated as earnings and salaries deflated by CPI.

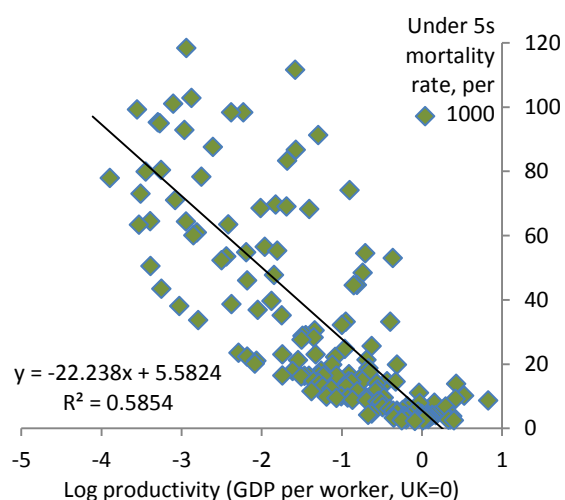
The welfare gains from productivity are not purely financial. While causality is less clear cut, more productive countries have better health outcomes. Being born in a country with 20% higher labour productivity is associated with higher life expectancy of around 1 year (Chart 8), as well as with a lower rate of child mortality, with four fewer deaths per thousand children (Chart 9).

**Chart 8 – Labour productivity and life expectancy across countries, 2014**



Sources: Feenstra, Inklaar and Timmer (2015); World Development Indicators, The World Bank; Bank calculations.  
 Notes: Productivity uses real GDP at current PPPs (2011 \$).

**Chart 9 – Labour productivity and child mortality across countries, 2014**



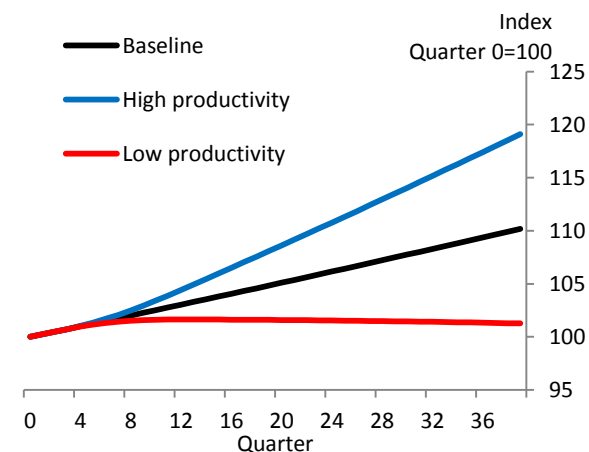
Sources: Feenstra, Inklaar and Timmer (2015); World Development Indicators, The World Bank; Bank calculations.  
 Notes: Productivity uses real GDP at current PPPs (2011 \$).

As economists and as members of the public, my colleagues and I care enormously about productivity and its implications for welfare. However, as an MPC member, the reason I am discussing productivity today is

that it is crucial to setting monetary policy. The MPC’s remit sets out a 2% inflation target over an appropriate time horizon with the rationale that inflation stability can lay the foundations for strong and sustainable growth. Productivity growth is the key determinant of how much demand can grow without creating inflation and hence it is a critical input into our forecast and deliberations.

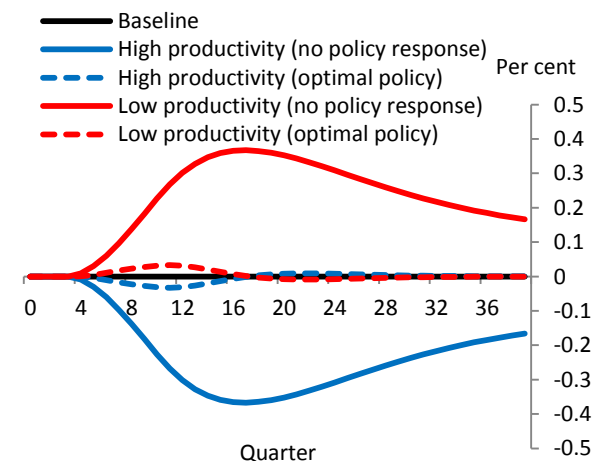
To illustrate how productivity can affect monetary policy, Charts 10a-10d show two alternative productivity scenarios, constructed using a version of COMPASS, the MPC’s main forecasting model.<sup>4</sup> For clarity, I abstract from some of the complications of the current outlook. As a baseline, the black lines show an economy where output and productivity are growing in line with their potential and inflation is at target. Potential productivity grows at a subdued rate of 1% per year, roughly in line with the MPC’s November forecast.<sup>5</sup>

**Chart 10a – Model-based scenarios for the level of potential productivity**



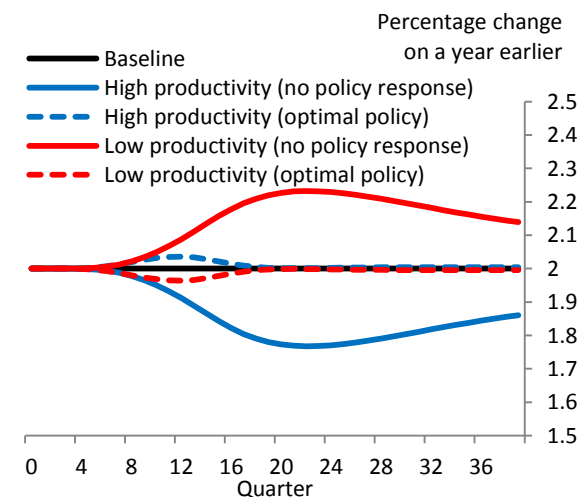
Sources: Bank calculations.

**Chart 10b – Output gap response**



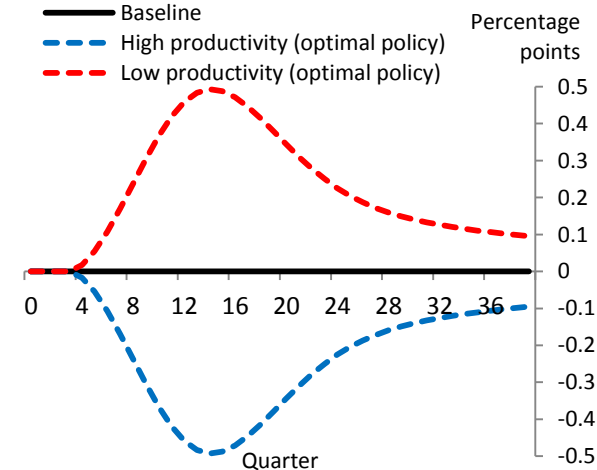
Sources: Bank calculations.

**Chart 10c – Annual inflation response**



Sources: Bank calculations.

**Chart 10d – Optimal Bank Rate change**



Sources: Bank calculations.

<sup>4</sup> Among other things, the model differs from the working-paper version of COMPASS, set out in Burgess *et al* (2013), by including bounded rationality on the part of households.

<sup>5</sup> Overall potential supply growth in the November forecast was a little higher, at around 1½%, since potential labour supply growth was also expected to contribute positively. See Section 5 (page 40) of the November 2017 *Inflation Report*.



The other lines on the charts show the two scenarios. The blue solid lines show a scenario where a 1% growth rate for potential productivity was overly pessimistic (Chart 10a). It picks up instead to 2%, closer to its pre-crisis average. The response of demand to a shock to supply depends crucially on two things: the extent to which people realise that future supply growth will be stronger; and the response of monetary policy. In the scenario, the change in the rate of productivity growth is assumed to be unanticipated. Consequently, if monetary policy doesn't respond to stronger supply growth, then demand rises by less than supply, and a negative output gap of 1/3% opens up (Chart 10b). Price rises slow, and inflation falls below the 2% target for an extended period of time (Chart 10c). The red solid lines show the opposite case. Here, even 1% productivity growth is too optimistic and productivity stagnates. In this case even modest demand growth outpaces supply, so that inflation rises above target.

These suboptimal outcomes suggest a role for monetary policy. Monetary policymakers should seek to influence demand to match these different profiles for productivity and supply. The dashed lines in Chart 10d show how they can best achieve this in the model.<sup>6</sup> Following a positive, unanticipated shock to productivity growth, monetary policy must lower interest rates to stimulate demand in line with stronger supply. As a result, the output gap barely moves, and inflation remains closer to target (Charts 10b and 10c). In the low productivity scenario, monetary policy tightens instead.<sup>7</sup> Appropriate monetary policy clearly depends on how optimistic we are on future productivity growth. It will also depend on how, absent policy, demand responds to any changes in expectations of future supply.

### 3. Why and where did productivity get lost?

Having sketched some of the reasons why productivity is important and observed that productivity growth has fallen since the crisis, the question is why? To attempt an answer, it is helpful to carry out a sectoral analysis, breaking down the productivity slowdown by industry.<sup>8,9</sup>

The sectoral distribution of productivity growth can help us locate *where* it has slowed.<sup>10</sup> A concentrated slowdown in some industries might suggest idiosyncratic causes that call for more targeted solutions. A broad-based slowing could point to possible macroeconomic explanations.

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<sup>6</sup> The optimal policy projections are calculated using the same framework as described in Carney (2017), with relative weights on inflation and the output gap of 1 and 0.25 respectively. They also place a weight of 1 on quarterly changes in the interest rate and on quarterly changes in the change in the interest rate.

<sup>7</sup> In the scenario the shock to productivity growth is modelled as extremely persistent, but it eventually unwinds. If the change to productivity growth were permanent then it would also affect the long-run equilibrium interest rate, which may attenuate or reverse the signs of the policy responses shown here.

<sup>8</sup> In what follows, I show decompositions at the SIC07 section level, based on new decompositions constructed by Bank of England staff. As pointed out by my colleague Ian McCafferty (2014), even at this level, many industries still contain a heterogeneous set of subsectors. But at further levels of disaggregation the data are likely to be less robust. The data used to carry out the growth accounting exercise are also not available at a more granular level.

<sup>9</sup> Similar analyses were carried out by, among others, Goodridge, Haskel and Wallis (2016) and Oulton (2016a), but only using data up to 2011 and 2013 respectively.

<sup>10</sup> There are also limitations to this type of analysis. In particular, GDP is typically thought to be better measured from the expenditure side than the output side (Oulton, 2013). One might therefore be more confident about measurement of the aggregate productivity slowdown than its split by industry, especially since industry-level data does not yet use double deflation.

We can also attempt to decompose sectoral productivity into different factors, to explore *why* productivity growth has slowed. Specifically, for each industry we can measure how much of the fall in productivity growth is due to slower growth in the amount and quality of the capital available to each worker; how much is due to changes in the quality of the labour input or human capital; and how much is due to changes in the efficiency with which quality adjusted capital and labour are used. I do this by industry because there are naturally big differences between the production processes of, for example, a manufacturing firm and one providing business services. The remaining or residual unexplained productivity growth is known as total factor productivity, or TFP. It is often taken as a proxy for technological progress, but in fact can stand in for a range of other factors, including structural change, imperfect competition and measurement error.<sup>11</sup>

Let me be explicit about what I mean by *quality* of inputs. We normally split inputs into two broad categories: capital and labour. But as growth accountants have highlighted, both of these categories encompass a wide range of different subcategories. Capital, for example, includes computers, buildings, vehicles and other assets. The relative importance of each to production varies substantially across industries. I account for this heterogeneity using a disaggregated measure of the services provided by capital.<sup>12</sup> Similarly, the amount that can be produced by each worker per hour depends on their specific *human capital* (their experience, education and other characteristics). I control for this using the ONS's measure of quality-adjusted labour input.

I show the complete results of this industry-level growth accounting exercise in Appendix A1.<sup>13</sup> Each row shows a different industry.<sup>14</sup> The first three columns show the contribution of those industries to productivity growth over three time periods: a pre-crisis spanning from 2000 to 2007; the crisis period from 2007 to 2009 and a post-crisis, going from 2009 to 2015.<sup>15</sup>

The contribution to the slowdown in productivity growth – shown in the fourth column – is measured as the difference between the post- and pre-crisis productivity growth. The rest of the table decomposes the slowing in productivity growth between the two periods. Specifically, the fifth column shows the *where*: which sectors accounted for the slowing? And the remaining columns show the *why*: which changes in the quantity, quality or distribution of inputs explain the slowing? It is to those two questions that I now turn.

### Sector decomposition of the productivity growth slowdown

The slowdown, or difference in the aggregate productivity growth rates between the pre- and post-crisis periods for the UK economy amounted to (a negative) 1.5 percentage points. Remarkably, three-quarters of

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<sup>11</sup> For more detail on the sources of TFP growth, see Caselli (2005) and Oulton (2016b).

<sup>12</sup> The capital services measure has been constructed by Bank of England staff based on the methodology of Oulton and Wallis (2016). See Appendix A2 for more detail.

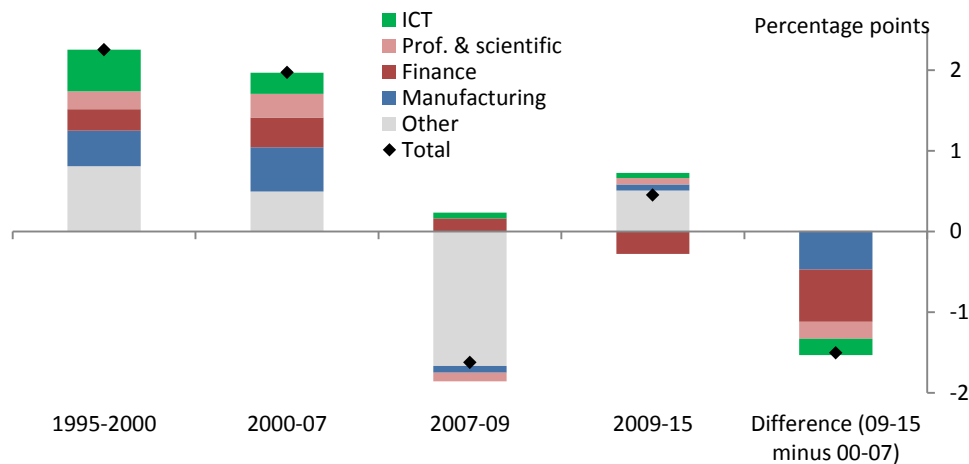
<sup>13</sup> Appendix A2 describes the methodology in more detail.

<sup>14</sup> I exclude the real estate industry from the analysis, since measurement of its output includes imputed rent from owner-occupied housing, which is produced without any additional measured hours worked. Imputed rent therefore artificially inflates the estimates of labour productivity in the real estate sector.

<sup>15</sup> I opt to exclude the 1990s from the comparison to exclude the effects of the ICT productivity boom, following Goodridge Haskel and Wallis (2016). I exclude 2016 since the data are not yet available to carry out the full decomposition.

this productivity growth shortfall is accounted for by just two sectors: manufacturing and finance (Chart 11).<sup>16</sup> Manufacturing contributed an average of 0.5pp per year to the UK's 2% annual productivity growth in the 2000s, with finance contributing another 0.4pp. Since 2009, the manufacturing contribution has shrunk to 0.1pp, while finance has subtracted 0.3pp.

**Chart 11 – Industry contributions to average annual labour productivity growth**



Sources: ONS and Bank calculations.

A further quarter of the slowdown is explained by two more sectors: information and communication technologies (ICT); and professional, scientific and technical services. Together, these four sectors, which make up just one-third of value-added, can entirely account for the slowdown. The remaining 14 sectors contributed 0.5pp to productivity growth, both pre- and post-crisis. In other words, productivity outside those four sectors has been growing at a roughly constant, modest rate.

One part of the story, the figures suggest, is that these four sectors were going through a boom period in the 2000s. Manufacturing and finance alone contributed almost half of the UK's productivity growth in the seven years leading up to the crisis. Without their contributions, UK productivity would have slowed more during the decade *before the financial crisis*.<sup>17</sup> This counterfactual would align our productivity slowdown more closely with that of the US, which is usually dated to the early 2000s.<sup>18</sup> So on one reading, idiosyncratic productivity gains in these two sectors hid an underlying slowdown that was taking place in the 2000s, more in line with global trends.

But this is not likely to be the whole story. There are always some sectors where productivity is growing more rapidly than others: so it would be wrong to assume that any uneven contribution automatically implies that aggregate growth is unsustainable. Moreover, these sectors have also grown unusually slowly

<sup>16</sup> Although the choice of comparison periods obviously affects the precise numbers, the same broad picture emerges for any reasonable cut-offs. For example, grouping the crisis and post-crisis periods together, and comparing productivity growth to its 2007-15 (2007-16) average, manufacturing and finance still account for 52% (54%) of the slowdown. Or comparing a longer pre-crisis period of 1995-2007 to 2009-15, manufacturing and finance account for 63% of the slowdown.

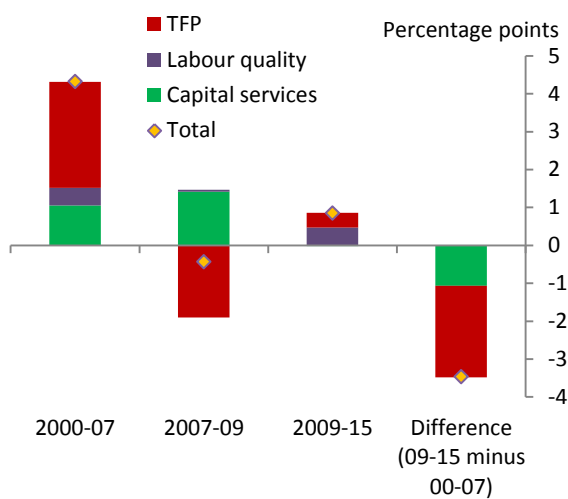
<sup>17</sup> By contrast, productivity gains were distributed a little more equally in the 1995-2000 period.

<sup>18</sup> Cetto, Fernald and Mojon (2016). Although as discussed later, measured manufacturing productivity also grew strongly in the US in the early 2000s, which may have helped the US economy avoid a larger productivity slowdown then.

post-crisis. So any recovery in aggregate productivity growth is likely to require a pickup in their contribution. With that in mind, I now explore the two main sectors driving the slowdown, manufacturing and finance, in more detail.

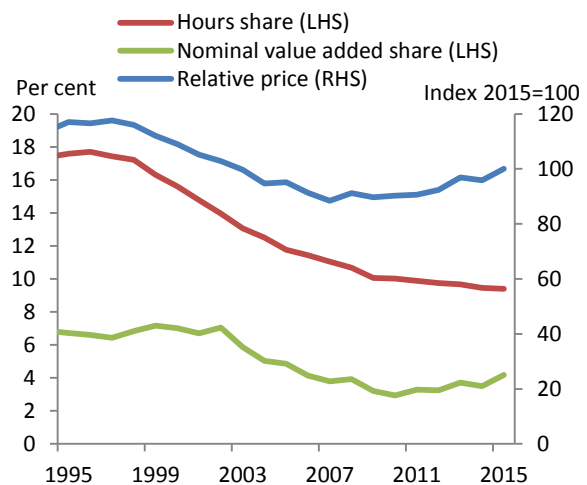
Manufacturing productivity grew at an average of 4.3% per year in the pre-crisis period (2000-2007), a notable increase on its 1990s growth rate (Chart 12). Since 2009, productivity growth has fallen to just 0.8% a year, a slowing of 3.5pp. The slowdown was widespread across most subsectors of the manufacturing industry, suggestive of a common or related set of causes.

**Chart 12 – Contributions to UK manufacturing average annual labour productivity growth**



Sources: ONS and Bank calculations.

**Chart 13 – Manufacturing relative price and sector shares of hours and nominal GVA**



Sources: ONS and Bank calculations.

A slower growth rate of capital deepening can explain around one-third of the manufacturing slowdown. Growth in capital per hour worked accounted for 1.1pp of productivity growth in 2000-07, but none at all in 2009-15. The remaining 2.4pp cannot be explained by measured changes in the quality of labour, so is concentrated in the residual, TFP, which had grown faster than TFP in any other industry before the crisis.

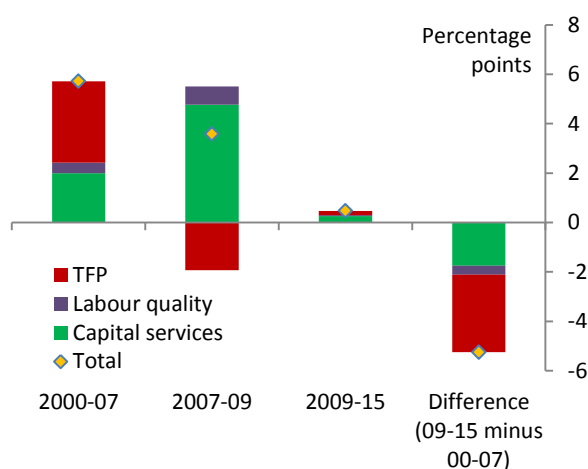
The UK manufacturing industry has undergone large structural changes over the past thirty years, mirrored in many advanced economies. Could this structural transformation be the source of the slowdown? Chart 13 shows that while manufacturing TFP was growing strongly in the 2000s, its relative price and employment share (in hours) were falling quickly. It is possible that productivity-enhancing changes in manufacturing led to higher TFP and hence lower prices. But with fast globalisation, it is also possible that causality ran in the opposite direction: pricing pressures may have led to TFP improvements. As in many countries, UK tradeable goods manufacturers were subject to increased competition from low-cost emerging

market producers in the early 2000s, especially from China, which may have led to investments in capital and processes before the crisis.<sup>19</sup>

A related plausible explanation for fast TFP growth before the crisis is greater offshoring – and what some considered a mismeasurement of manufacturing productivity growth. Houseman and Mandel (2015) point out that rapid globalisation increased offshoring and reduced import prices for manufacturing in ways that are missed by US official deflators. They argue that labour productivity growth in US manufacturing in the early 2000s was materially overstated.

How can offshoring increase measured TFP? Import price indexes miss cost cuts when the sourcing of a product is switched from a local supplier to, say, a lower-cost Chinese supplier. They also miss the cost saving if the switch is, for example, from a European supplier to a Chinese supplier. When the lower cost item is imported from the new supplier, effectively, it is treated as a new item and the item's price fall is not registered by the index. As import prices do not reflect the cost savings from offshoring, then measured import price inflation is higher than it should be and real imports growth is reported as lower than it really is. This, the argument goes, means that real value added and productivity gains are overstated.

**Chart 14 –Contributions to US manufacturing average annual labour productivity growth**



Sources: Jäger (2017) and Bank calculations.

Their arguments also apply to the UK economy, although with some nuances. For aggregate productivity and GDP measured from the expenditure side, similar problems arise as in the US because UK import-price deflators suffer from the same biases. For measuring industry-level manufacturing productivity, UK statistics do not yet use what is known as ‘double deflation’, which could make the offshoring effect even more important.<sup>20</sup> Real industry value added is deflated directly from nominal value added using the sector’s price index, without first deflating imported inputs. Changes in import prices are missed completely, so the effect

<sup>19</sup> Autor, Dorn and Hansen (2013); Bloom, Draca and van Reenen (2016).

<sup>20</sup> Using double deflation to construct the output measure of GDP was one of the recommendations of Bean (2016) review of UK statistics, and the ONS are currently doing development work to allow them to do so.

on manufacturing productivity could be even larger. Interestingly, and perhaps reflecting the fact that many import price falls are missed even using the US methodology, manufacturing productivity in the US and the UK showed similar developments both before and after the crisis, with the rise and fall being more marked in the US economy (Chart 14).

In my view, it is debatable whether this mismeasurement of imported input prices is fundamentally problematic – or indeed a mismeasurement. If an economist is interested in gauging the productivity gains from international trade, there is no reason why she should discount the contribution of lower priced imported inputs: falling costs of imported inputs should in principle also add to the economy's productivity.

Trade economists tend to think of international trade as a production technology in which imports are transformed into exports at a rate equal to their relative prices, or terms of trade. In that sense, an improvement in the terms of trade is comparable to an improvement in productivity.<sup>21</sup> Lower import prices mean that a given amount of exports can be turned into more imports. The country's real income rises, because the economy as a whole can consume more (or work less), purely because of the change in prices. In that framework, productivity improvements coming from domestic TFP or from gains from international trade (in the form of cost savings) are not too dissimilar.

When measuring real GDP, statistical offices aim instead at capturing only the domestically generated productivity gain, which is arguably a more appropriate measure of physical productivity (although, as pointed out, they do not always succeed at the task). This statistical practice attempts to purge from productivity gains any foreign price effects. (I for one, think of lower prices of imported inputs as a real productivity gain and would not count it as mismeasurement.)

At any rate, whether you think as an economist or a statistician, this “offshoring hypothesis” can help explain rapid measured productivity growth in UK manufacturing pre-crisis. Manufacturing sectors have the highest shares of intermediate inputs in production: value-added in the industry is about one-third of gross output, compared to an average of around one-half for the other industries, and manufacturing inputs are highly tradable in international markets.<sup>22</sup>

The subsequent slowdown in manufacturing productivity could be accounted for by the same offshoring argument if input prices fell less rapidly. Recent wage and total cost growth in China and other emerging markets may have slowed down the decline in input prices. The measurement of aggregate productivity may also have improved as statisticians incorporated new imported goods in their baskets. But precisely because there is an intrinsic problem with measurement, the quantitative importance both for aggregate productivity and for UK manufacturing remains an open question.

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<sup>21</sup> See Kehoe and Ruhl (2008), who also discuss how terms of trade changes do affect (correctly measured) real income. For measures of real income, if statisticians have overstated physical productivity, then they will also have understated the gains from trade by an equal amount.

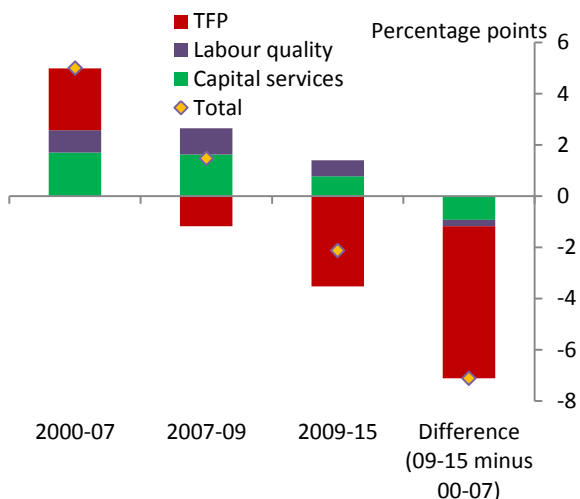
<sup>22</sup> Real product wages in manufacturing did not keep up with productivity increases pre-crisis. This is consistent with the offshoring explanation: if productivity gains were being driven by increased offshoring or low-cost imports, there would be less pressure to pass them on to domestic employees.

While the benefits from offshoring can help explain the rise and subsequent slowdown in TFP, the other question is why capital investment in manufacturing has come to a virtual standstill since 2009. I will come back to this point when I discuss investment in the whole economy, as capital shallowing is also observed in other sectors.<sup>23</sup>

Let me now turn to finance.

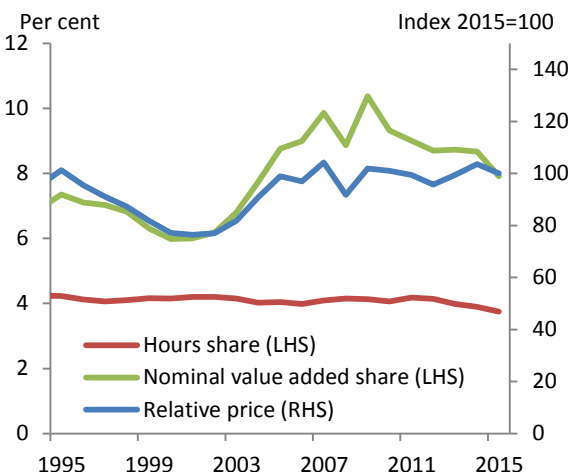
The finance sector is the biggest contributor to the productivity slowdown. It had the fastest-growing labour productivity of any sector in the run-up to the crisis, at 5% per year. Since 2009, productivity has actually shrunk by 2.1% per year.

**Chart 15 – Contributions to UK finance average annual labour productivity growth**



Sources: ONS and Bank calculations.

**Chart 16 – Finance relative price and sector shares of hours and nominal GVA**



Sources: ONS and Bank calculations.

The finance productivity slowdown is overwhelmingly a slowdown in TFP (Chart 15). Capital deepening has held up better than in manufacturing and modest labour quality growth has continued, such that TFP accounts for over 80% of the fall in productivity growth.

Changes in the structural distribution of industry cannot explain much of the fall (Chart 16). Unlike manufacturing, the measured relative price of financial-sector output was increasing during the pre-crisis period. (This is a key difference between these two sectors, which I will come back to later).

<sup>23</sup> Researchers have explored the hypothesis of zombie firms, finding that it was an unlikely explanation for the UK slowdown (Arrowsmith *et al*, 2013; Haldane, 2017). The existence of zombie-firms would lead to investment in unproductive capital and low TFP growth, but not necessarily the collapse of investment. And perhaps more importantly, as economists at the Bank of England have recently pointed out, the biggest contribution to falls in productivity growth are made by firms at the top deciles of the productivity distribution. In other words, this appears to be a story of the most productive firms not keeping pace with their growth, rather a slowdown caused by less productive firms.

There are two possible explanations for the rapid rise and subsequent fall of financial-sector growth and productivity: one real; but another related again to measurement. Both are tightly linked to growth of leverage and under-pricing of systemic risk in the pre-crisis period. And both probably have some role to play in the sector's slowdown.

Financial services is an acute example of some of the challenges inherent in measuring services output more generally. Rapid product innovation; quality change adjustment; and simply defining what constitutes a unit of output all complicate measurement. One particular issue is how to accurately measure the output produced by banks carrying out their day-to-day business of intermediating between borrowers and lenders – a concept known as FISIM (financial intermediation services indirectly measured).<sup>24</sup> Many of the issues relate to its price and hence are less important for real output or productivity. But the growth of real FISIM output is closely related to the growth rate in the stock of loans and deposits on banks' balance sheets. While this is not mismeasurement as such, it is conceptually debatable that the intermediation services provided by banks really increase one-for-one with the size of their balance sheets.<sup>25</sup>

Finance-sector mismeasurement has been suggested many times before as a partial explanation for the UK productivity puzzle. Previous analyses argued that banking-sector mismeasurement could only account for a small amount of the pre-crisis boom.<sup>26</sup> But just as rapid balance sheet growth pre-crisis may have inflated measured finance output and productivity, post-crisis deleveraging may have detracted from it. Some rough calculations can give us a sense of the potential magnitudes. If the contribution of FISIM to real GDP had grown in line with the rest of GDP both pre- and post-crisis, it could explain around 0.2pp per year of the slowdown in GDP, or about one-third of the fall in financial sector TFP growth. If we were to exclude the financial-sector completely from the analysis – an extreme assumption, so definitely an upper bound – aggregate productivity growth would have been 0.2pp weaker per year pre-crisis *and* 0.4pp stronger post-crisis. The overall productivity slowdown would go from an annual average of 1.5pp to just 0.9pp.

It is unlikely that the entire slowdown in financial sector TFP is down to mismeasurement. A complementary explanation is that the key contributors to the crisis itself – risk illusion and increasing financial-sector leverage – may have increased (correctly measured) pre-crisis productivity growth. In doing so, they may also have sowed the seeds of the crisis and subsequent weakness. Increased leverage and higher risk tolerance boosted profits, earnings and output. That may have attracted capital and employees from other sectors of the economy. More broadly, rapid credit growth and low risk premia fed into higher asset prices, with positive spillovers to demand elsewhere in the economy. As the crisis hit, these channels went into reverse, leading to falls in wealth and higher uncertainty. Both lowered spending and output and probably also increased households' labour supply.

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<sup>24</sup> For more detail on this issue, see Haldane, Brennan and Madouros (2010), Burgess (2011) and Akritidis and Francis (2017).

<sup>25</sup> Inklaar and Wang (2007).

<sup>26</sup> For example, Burgess (2011) and Oulton (2013).



Whatever the ultimate trigger of the finance-sector slowdown, its contributions to measured GDP and productivity growth are unlikely to pick up to those we saw in its pre-crisis boom. To achieve that would require a repeat of the type of unsustainable increases in leverage that we saw in the 2000s.

The financial-stability reforms we have seen since the crisis were put in place precisely to prevent the damaging consequences of those episodes.

But nor should we expect finance to continue to drag on aggregate productivity. The sector's post-crisis performance has been as poor as its pre-crisis performance was strong. Credit and deposit growth have been weak as banks and households have sought to deleverage. But those processes have largely run their course. Looking ahead, a neutral projection might assume that the performance of the finance industry begins to move in lockstep with aggregate GDP and productivity in the rest of the economy. Relative to the past few years, that would amount to a helpful boost to productivity growth. If there were positive spillovers to professional services and other complementary industries, there may be even greater grounds for optimism.

Let me re-emphasise an important difference between the productivity performance of manufacturing and finance, the two biggest contributors to the slowdown. This is where the distinction between revenue productivity (defined as nominal value added in the industry deflated by the aggregate GDP deflator) and quantity or physical productivity (nominal value added in the sector deflated by a sector-specific price index) becomes relevant, as prices are an important part of the return to any activity.

While manufacturing was experiencing growth in quantity or physical productivity before the crisis, trends in revenue productivity growth were very different. Because manufacturing prices were falling quickly pre-crisis but flat post-crisis, revenue productivity growth was actually stable over the two periods. In finance, sectoral prices were rising pre-crisis relative to the aggregate GDP deflator.

Indeed, consistent with the fall in manufacturing prices, the sector had been shrinking as a share of the total economy before the crisis. Finance, on the other hand, registered the highest growth rates of revenue productivity growth in the UK and it arguably yielded the highest returns in the pre-crisis period. The sector grew remarkably fast in the UK before the crisis.

As said, together with manufacturing, finance explains three quarters of the productivity slowdown. Professional services and ICT account for the other quarter. The two main subsectors within professional services, accounting for 50 percent of its value added are "Legal and accounting services" and "Management and management consultancy." Naturally, the performance of these services is tightly linked to that of financial services, given the complementarities in activity. These services saw sharp falls in labour productivity during the period. Given the link to finance, their rise and fall likely obey the same causes. Let me just say a few words about ICT.

ICT also experienced a productivity boom pre-crisis, although unlike manufacturing and finance this largely took place in the late 1990s. Productivity growth in the industry then fell steadily from 6.4% per year in 1995-2000, to 3.4% in 2000-07, 1.5% during the crisis, and 0.4% from 2009-15.

In terms of measured inputs into production, around 60% of the slowdown relative to the 2000-07 period can largely be explained with slower capital deepening, with lower TFP growth more than accounting for the rest. ICT capital per hour worked grew at an average rate of 1.4% pre-crisis, but *fell* by 1.1% per year afterwards. This has been amplified by sharp falls in the relative price of ICT goods and services – by around one-fifth since 2000 (and by around one-third since the mid-1990s) – more than any other industry.

Measurement challenges – and specifically adjusting for quality changes is a particular concern in this industry, given the proliferation of free services.<sup>27</sup> There is also an interesting debate on the role of intangibles investment that I will not have time to address, but could probably account for some of the missing growth in productivity in the sector.<sup>28</sup>

#### Factor decomposition of the productivity growth slowdown

So far, I have shown that a small number of industries can account for the fall in productivity growth. I have also suggested that there are a couple of hypotheses – both real and related to measurement – which may help explain the slowdown in measured aggregate productivity. Before turning to the implications, it is useful to see how this maps back into the aggregate data. One reason is that some stories may only be apparent at the aggregate level – reallocations of labour between different sectors can have effects on aggregate productivity, even if sector-level productivity is unchanged. In addition, as I have highlighted so far, there are measurement challenges in the collection of GDP data, which may lead one to place more weight on the whole-economy factor decomposition than its sectoral split.

Table 1 shows an aggregated version of the industry-level decompositions. I will offer a few words on what I take from this, although other interpretations are equally possible.

It is easiest to start with what the decompositions do not show: on these data, we can rule out labour quality and labour allocation explanations for the aggregate productivity slowdown. The quality-adjusted labour data suggest that human capital variations have contributed *more positively* to post-crisis productivity growth, so controlling for these actually slightly increases the size of the puzzle.<sup>29</sup> Pre-crisis, there was a small drag on productivity growth from labour reallocating to less productive sectors. But this has not occurred post-crisis, so this channel has also lessened the slowdown and slightly increases the size of the puzzle.

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<sup>27</sup> More broadly, Bean (2016) discusses a range of emerging challenges introduced by the digital economy in measuring GDP. Coyle (2017) argues that mismeasurement due to digital activities may be making significant contribution to the productivity growth slowdown. She also discusses the role of digital technologies in enabling a shift from market to non-market production.

<sup>28</sup> See Goodridge, Haskel and Wallis (2013).

<sup>29</sup> Although post-crisis, the contribution fell in 2014 and 2015.

**Table 1 – Contributions to average annual labour productivity growth, pp**

Factor	Pre-crisis (2000-07)	Crisis (2007-09)	Post-crisis (2009-15)	Post-crisis difference	(Per cent of total)
TFP	0.6	-3.3	-0.2	<b>-0.8</b>	(54)
Capital services	1.1	1.0	0.1	<b>-1.0</b>	(66)
Labour quality	0.4	0.6	0.5	<b>0.1</b>	(-7)
Labour reallocation	-0.2	0.0	0.0	<b>0.2</b>	(-13)
Other	0.1	0.1	0.1	<b>0.0</b>	(0)
<b>Total</b>	<b>2.0</b>	<b>-1.6</b>	<b>0.4</b>	<b>-1.5</b>	

Sources: ONS and Bank calculations.

As with manufacturing and finance in isolation, the results from aggregating together our 18 industry-level decompositions pinpoint to TFP and lower capital deepening as the sources of the aggregate productivity slowdown. The TFP slowdown is concentrated in finance, manufacturing, and to a lesser extent ICT and professional services – entirely consistent with the sectoral story in TFP I discussed earlier. But in aggregate, capital deepening is at least as important as TFP, accounting for over half of the overall productivity slowdown.<sup>30</sup>

The contribution from lower capital intensity is broad-based across industries, which is suggestive of an economy-wide story. Only three sectors recorded a stronger contribution from capital deepening in the post-crisis period, compared to fifteen where it was lower.<sup>31</sup> This contrasts with the contribution from TFP, which *increased* in the post-crisis period in almost as many industries (eight) as it reduced (ten). Thus, the weakness in labour productivity is partly the consequence of an industry-wide fall in business investment during the crisis, as well as its subdued growth since. Given the productivity gains on offer, why has business investment been so weak? It is likely that the behaviour of the labour market, with unemployment at a 30-year low, is part of the explanation.

Various factors may have led firms to substitute from capital towards greater labour in their production processes, dragging on labour productivity growth (Pessoa and Van Reenen, 2014). This substitution channel was sometimes downplayed in early years of the crisis, as the data showed that capital shallowing was not an important driver of weak productivity at the time.<sup>32</sup> But as an investment recovery has failed to arrive, it has become increasingly important.

<sup>30</sup> Grouping the crisis and post-crisis periods together and comparing 2000-07 to 2007-15, lower capital deepening accounts for 39% of the puzzle (TFP accounts for 78%). Timing is the main reason for the greater role of capital and smaller role of TFP compared to Goodridge, Haskel and Wallis (2016), who compare 2000-07 to 2007-11.

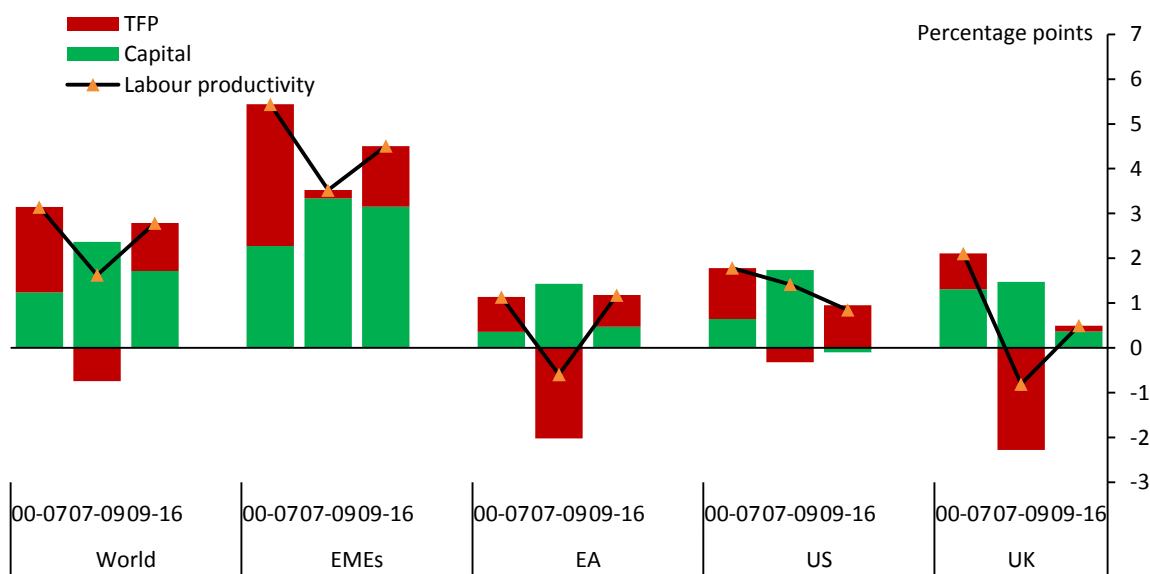
<sup>31</sup> Two of those three industries (agriculture and utilities) are very small as a share of nominal value added. The other is public administration and defence.

<sup>32</sup> Broadbent (2012), Goodridge, Haskel and Wallis (2016), Oulton (2016a).

Pessoa and van Reenen stressed the role of the UK’s flexible labour market in facilitating a fall in real wages, as well as an increase in the cost of capital following the crisis.<sup>33</sup> But this is probably not the whole story. Higher levels of uncertainty post-crisis may also have led firms to opt for labour over capital – employment decisions that can now be more easily reversed – rather than invest in new capital. Higher uncertainty and lower income expectations may also have increased households’ desired labour supply for precautionary motives, contributing to lower real wages.<sup>34</sup> Arguably, uncertainty hit harder in the UK as finance represented a much bigger share of the economy.

International comparisons show that these trends in capital accumulation are one cause of the UK’s *relative* productivity slowdown (Chart 18). Globally, there has been an increase in capital deepening, though this is partly an emerging markets story. Greater capital also explains a significant part of the stronger post-crisis productivity performance in the euro area, however. By contrast, in the US, the post-crisis slowdown in investment has weighed on productivity growth similarly to the UK. Flexible labour markets are one structural feature shared by both economies (but less so in the euro area).

**Chart 18 – Contributions to PPP-weighted average annual labour productivity growth**



Sources: Eurostat, Feenstra, Inklaar and Timmer (2015), IMF *WEO*, US Bureau of Economic Analysis and Bank calculations. Notes: Decompositions use capital services data for the UK, but capital stocks for other countries.

In the more recent data, however, investment has recovered in advanced economies, including the US, but not in the UK. One of the reasons why the UK might be lagging behind is the added uncertainty over the future trading relationship with the European Union. In the short term, this is likely to continue to weigh on business investment and capital accumulation.

<sup>33</sup> Oulton (2017) argues that in the UK context of high migration, this channel is stronger.

<sup>34</sup> Blundell, Crawford and Jin (2014) and Carney (2014) make similar arguments about the role of labour supply.

Looking further ahead, there are more grounds for optimism. As some of the uncertainty is resolved, I expect the drag on investment to wane. Moreover, the cost of capital has fallen in recent years as the health of the banking sector has improved. And if the current tightness in the labour market also translates into a real-wage pickup, as we forecast in November, then the capital-labour substitution process may start to reverse.

### Taking stock

- I have shown that a small number of sectors can account for the slowing in productivity growth since 2009. Those were the sectors driving aggregate productivity growth before the crisis and the ones where growth fell with the crisis.
- For the rest of the economy, low productivity growth after the crisis is fairly similar to their low growth before the crisis. So, in some sense, the true puzzle is why was productivity in the rest of the economy growing so slowly before the crisis.
- I have also shown that there is an important difference in the revenue productivity performance between manufacturing and finance, the two biggest contributors to the slow down. Revenue productivity in finance grew remarkably fast in the UK before the crisis, while in manufacturing revenue productivity growth was modest. In other words, the “returns” to financial sector activities were much higher than in manufacturing - and indeed much higher than in any other sector in the economy.
- It is possible that the growth of financial activities somehow crowded out the growth in the rest of the economy in a competition for talent and resources.<sup>35</sup> In recent years, significant effort has gone into reducing the incidence of bubbles and imbalances in the economy and in the banking sector in particular. The economy is, in this regard, on a stronger position now. While the sector will probably not come back to the high levels of measured productivity growth pre-crisis, as the process of deleveraging runs its course, the negative contribution to aggregate productivity growth in the post crisis period will also, in all likelihood, come to an end.
- What are the prospects for aggregate productivity going forward? The UK productivity level is below that of other advanced economies. The silver lining is that there is scope to catch up with the frontier. How? By adopting technologies and processes that enhance productivity and are already tested and in place in

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<sup>35</sup> This relates to a hypothesis put forward by Murphy, Shleifer and Vishny in 1991. They argued that when rent-seeking rewards talent more than entrepreneurship or innovation, aggregate productivity suffers. They conjectured back then, and I quote literally, that “[t]he flow of some of the most talented people in the United States into law and financial services might be one of the sources of our low productivity growth”. If indeed most of our talent is applied to finance and law, rather than, say, engineering, health or potentially new areas of knowledge in which there is more scope for sustainable growth, aggregate productivity will inevitably suffer. But this should not make us rush to extreme inferences. It does not mean that finance is not good for growth. On the contrary, finance is critical to channel resources from less productive to more productive activities. Finance is also much needed to put talent to good use. And for centuries the UK has shown a comparative advantage in financial services vis a vis other countries. Finance has been an important export and source of national income. But it is also true that there were excesses before the crisis; the amount of systemic risk that built in the economy was unhealthy; and the returns seemed disproportionate once the sector’s valued added and returns over the longer period are taken into account. What the rapid rise and fall in the financial sector has highlighted is the need of a different approach to assessing systemic risk and to containing risky activities that are not conducive to sustainable growth.

other countries. I am optimistic about the long term. Firms in the UK have all the fundamental factors in their favour to be at the technological frontier: an advantageous institutional and legal framework, a favourable geographic location, top-rate research and innovation centres and the human capital to harness resources to foster growth.

- The big question is the timing for that catch up. The global economy and Europe in particular are undergoing a big investment boom, yet the UK is not part of it. Why is the UK the odd one out? The likely culprit, as I mentioned earlier, is the uncertainty regarding future EU trading relations, which many have argued, and I agree, is keeping the levels of domestic and foreign investment in the country relatively low in relation to what one would expect at this stage of the global cycle. We will have to live with some of that uncertainty for some time. And, understandably, firms will postpone some of the investments and structural changes needed to increase productivity.
- Measured UK productivity growth was strikingly weak at the start of 2017, even by recent standards. But the quarterly growth rate since recovered somewhat in Q3, picking up to 0.9%. And if the recent slowing in employment growth persists, then we may see some further cyclical recovery in productivity. In the medium-term, I am optimistic that productivity growth will recover to rates above its weak, post-crisis average. It is perhaps a sign of how poor our productivity performance has been, however, that even as an optimist, I think growth rates close to those we saw pre-crisis are unlikely.

Let me now turn to my views on policy.

#### **4. Monetary policy implications**

Since I joined the MPC, we have faced an outlook of above-target inflation accompanied by modest domestic output growth and of a tight labour market coupled with weak wage growth. Inflation has been above target, but this can be traced back to the sharp fall in sterling following the referendum, which I have expected to dissipate as pass-through nears completion.

When I joined, measures of domestically generated inflation, by contrast, had been at or below target-consistent levels. In line with this, my reading was that activity was still somewhat below potential, though there were signs in the labour market that the gap had been narrowing.

With a small but negative output gap, weak wage growth and only temporarily high inflation, I judged the policy stance prevailing when I joined was appropriate, but that an increase in Bank Rate might be needed if the output gap continued to narrow. As a result, I voted for no change in Bank Rate and the stock of asset purchases in August and September.

As labour market slack reduced – evidenced by surveys reporting increasing recruitment difficulties, robust employment growth and record-low unemployment – by November I felt that removing a small amount of stimulus was justified.

In December, with unit labour cost growth still subdued and inflation likely to be around its peak, my view was that there was ample time for us to continue to monitor the transmission of the November policy change before voting for another change in interest rates.

Going forward, if the economy evolves as in our November forecast, with steadily increasing domestic inflationary pressures, I expect perhaps a couple more increases in Bank Rate will be required over the next three years. But a different outcome for productivity growth would affect that policy rate path. Although I concurred with our November *IR* projections for potential growth, the analysis I have discussed today leads me to think that in the medium-term, the risks to productivity may be skewed to the upside. Whether a more or less positive scenario for productivity materialises, as always, the question from an MPC perspective will be how quickly demand responds. A key part of my job will be to gauge the size of any emergent gaps between demand and output potential.

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## Appendix A1 – Growth accounting decomposition by industry

Sector	Pre-crisis (2000-07) average, pp	Crisis (2007-09) average, pp	Post-crisis (2009-15) average, pp	Change in contribution, pp	(% of total)	of which, change in capital deepening contribution, pp	of which, change in labour quality contribution, pp	of which, change in TFP contribution, pp	of which labour reallocation/other, pp	Share of Sector in nominal GVA, 2007, %	Actual change in <u>quantity</u> productivity growth, pp	Actual change in <u>revenue</u> productivity growth, pp
A: Agriculture, forestry and fishing	0.0	-0.1	0.1	0.0	(-2)	0.0	0.0	0.0	0.0	1	3.2	6.2
B: Mining and quarrying	-0.1	-0.2	-0.1	0.0	(1)	-0.2	0.0	0.0	0.2	3	-6.2	-13.5
<b>C: Manufacturing</b>	<b>0.5</b>	<b>-0.1</b>	<b>0.1</b>	<b>-0.5</b>	<b>(31)</b>	<b>-0.1</b>	<b>0.0</b>	<b>-0.3</b>	<b>0.0</b>	<b>12</b>	<b>-3.5</b>	<b>1.3</b>
D: Electricity, gas, steam and air conditioning	0.0	0.0	0.0	-0.1	(4)	0.0	0.0	-0.1	0.0	1	-4.9	-0.8
E: Water supply, sewerage and waste	0.0	0.0	0.0	0.0	(1)	0.0	0.0	0.0	0.0	1	-2.1	-6.1
F: Construction	0.0	-0.3	0.2	0.1	(-10)	-0.1	0.0	0.2	0.0	8	1.8	0.6
G: Wholesale and retail trade; repair of vehicles	0.4	-0.4	0.3	-0.2	(12)	-0.1	0.0	-0.1	0.0	13	-1.1	-1.0
H: Transportation and storage	0.1	-0.3	0.1	0.0	(3)	0.0	0.0	0.0	0.0	5	-0.7	2.6
I: Accommodation and food service	0.0	0.0	0.0	0.0	(3)	0.0	0.0	0.0	0.0	3	-1.3	2.1
<b>J: Information and communication (ICT)</b>	<b>0.3</b>	<b>0.1</b>	<b>0.1</b>	<b>-0.2</b>	<b>(13)</b>	<b>-0.1</b>	<b>0.0</b>	<b>-0.1</b>	<b>0.0</b>	<b>7</b>	<b>-3.0</b>	<b>-1.0</b>
<b>K: Financial and insurance</b>	<b>0.4</b>	<b>0.2</b>	<b>-0.3</b>	<b>-0.6</b>	<b>(43)</b>	<b>-0.1</b>	<b>0.0</b>	<b>-0.5</b>	<b>-0.1</b>	<b>9</b>	<b>-7.1</b>	<b>-11.7</b>
L: Real estate (excluded)												
<b>M: Professional, scientific and technical</b>	<b>0.3</b>	<b>-0.1</b>	<b>0.1</b>	<b>-0.2</b>	<b>(14)</b>	<b>-0.1</b>	<b>0.0</b>	<b>-0.1</b>	<b>0.0</b>	<b>8</b>	<b>-2.7</b>	<b>-1.2</b>
N: Administrative and support service	0.0	-0.1	0.2	0.1	(-8)	-0.1	0.0	0.2	0.0	5	2.4	0.0
O: Public administration and defence	0.0	0.1	0.0	0.0	(0)	0.0	0.0	0.0	0.0	6	0.3	0.6
P: Education	-0.1	-0.2	-0.1	0.0	(-2)	0.0	0.0	0.0	0.0	7	0.7	-3.3
Q: Human health and social work	0.1	-0.1	0.0	0.0	(1)	0.0	0.0	0.0	0.0	8	-0.4	-3.1
R: Arts, entertainment and recreation	0.0	0.0	0.0	0.0	(1)	-0.1	0.0	0.0	0.0	2	-1.0	-0.1
S: Other service activities	0.0	0.0	0.0	0.0	(-3)	0.0	0.0	0.1	0.0	2	1.7	0.1
<b>Total</b>	<b>2.0</b>	<b>-1.6</b>	<b>0.4</b>	<b>-1.5</b>	<b>(100)</b>	<b>-1.0</b>	<b>0.1</b>	<b>-0.8</b>	<b>0.2</b>	<b>100</b>		
Manufacturing, finance, prof. and ICT only	1.5	0.0	-0.1	-1.5	(103)	-0.4	0.0	-1.1	-0.1	36		
Other sectors	0.5	-1.7	0.5	0.0	(-3)	-0.6	0.1	0.2	0.3	64		

## Appendix A2 – Methodology

The decompositions of aggregate productivity growth are based on a new method developed by Bank of England staff. The decomposition method is very closely related to the approach in Diewert (2015), which we further augment by introducing the usual growth accounting terms following the framework originally proposed by Jorgenson, Gollop and Fraumeni (1987) and used recently for the UK by Goodridge, Haskel and Wallis (2016). The latter two references use an industry-level growth accounting framework that is based on aggregation using Törnqvist indices. The staff method, on the other hand, allows for the ONS's aggregation method using annually-chained Laspeyres indices. It also allows for the attribution of labour reallocation effects to particular industries.

We start with the definition of aggregate productivity as the weighted sum of productivity over sectors:

$$Q_t = \sum_i \omega_{it-1} h_{it} Q_{it}$$

where  $i$  and  $t$  index sectors and years,  $Q$  is labour productivity (value-added over hours),  $\omega_i$  is a sector's 'relative price' (sector over aggregate value-added implicit deflator) and  $h_i = \frac{L_i}{\sum_i L_i}$  is the sector's labour share. Including both relative price and labour share weights ensures the aggregation matches the ONS method.

Growth in aggregate productivity is therefore

$$\frac{\Delta Q_t}{Q_{t-1}} = \frac{\Delta(\sum_i \omega_{it-1} h_{it} Q_{it})}{Q_{t-1}}$$

and the right hand side can be expanded into the four effects coming directly from each sector – changes in relative prices, 'between' type effects of changes in labour share, 'within' effects of changes in sector productivity and a residual second derivative term.

$$\frac{\Delta Q_t}{Q_{t-1}} = \sum_i \Delta \omega_{it-1} h_{it-1} \frac{Q_{it-1}}{Q_{t-1}} + \sum_i \omega_{it-2} \Delta h_{it} \frac{Q_{it-1}}{Q_{t-1}} + \sum_i \omega_{it-1} h_{it} \frac{\Delta Q_{it}}{Q_{t-1}} + \sum_i \Delta \omega_{it-1} \Delta h_{it} \frac{Q_{it-1}}{Q_{t-1}}$$

We make adjustments to these terms before arriving at our final decomposition:

- We exclude **relative price** effects: these always sum to zero.

$$\sum_i \Delta \omega_{it-1} h_{it-1} \frac{Q_{it-1}}{Q_{t-1}} = 0$$

- We adjust the **between effect** to account for indirect effects of labour reallocations by subtracting the unweighted change in labour share from each sector (equal to zero in sum). This apportions between effects across sectors to take account of how 'normal' they are: a sector's labour reallocation only drags on productivity if the product of its implicit deflator and its productivity is above (below) that of the aggregate economy and it loses (gains) labour-share.

$$\sum_i \omega_{it-2} \Delta h_{it} \frac{Q_{it-1}}{Q_{t-1}} = \sum_i \left( \omega_{it-2} \frac{Q_{it-1}}{Q_{t-1}} - 1 \right) \Delta h_{it}$$

- We expand the **within effect** to account for production function (or growth accounting) terms. First we adjust it so that industry level growth rates feature in the term and by approximating industry growth with its log-difference.

$$\sum_i \omega_{it-1} h_{it} \frac{\Delta Q_{it}}{Q_{t-1}} = \sum_i \omega_{it-1} h_{it} \frac{Q_{it-1}}{Q_{t-1}} \frac{\Delta Q_{it}}{Q_{it-1}} \approx \sum_i \omega_{it-1} h_{it} \frac{Q_{it-1}}{Q_{t-1}} \Delta \ln Q_{it}$$

Second, we substitute log-productivity at the industry level with the log of a production function in TFP growth, capital depth and labour quality change terms

$$\sum_i \omega_{it-1} h_{it} \frac{Q_{it-1}}{Q_{t-1}} \Delta \ln Q_{it} = \sum_i \omega_{it-1} h_{it} \frac{Q_{it-1}}{Q_{t-1}} \left[ \Delta \ln TFP_{it} + \alpha_K \Delta \ln \left( \frac{K_{it}}{H_{it}} \right) + \alpha_L \Delta \ln \left( \frac{L_{it}}{H_{it}} \right) \right]$$

Where factor shares ( $\alpha_K$  and  $\alpha_L$ ), labour quality ( $\frac{L}{H}$ ) and capital services ( $K$ ) data are all published or constructed from ONS data (see Goodridge, Haskel and Wallis, 2016 for detail) and TFP is found as a residual.

- The **second derivative** tends to be very small.
- The final decomposition also includes a small **log-approximation error term**.

Taken together, the full decomposition we employ can account for changes in aggregate productivity in terms of contributions from each sector that account for both direct and indirect influences.

#### Capital services data

The decompositions use capital services data from 2000 to 2015, constructed by the Bank of England following the methodology in Oulton and Wallis (2016). They differ from the capital stock, which is the value of all fixed and intangible assets (e.g., machinery, buildings and software) used for production (i.e., excluding dwellings). It measures the stock of wealth. Capital services are intended to measure the flow of services from the existing capital stocks into production.

Intuitively, capital stocks provide services to production just as workers provide hours of service. For this reason, they are more appropriate to include in production functions, as it is the services provided by capital that do the work of producing.

Stemming from this distinction, the two measures are aggregated in very different ways. Although the aggregation of both capital stocks and services is based on the growth rates of net stocks of individual assets, these are weighted differently: by total value of assets in the former, and by total rental income in the latter.

As a result, the largest assets by value have the greatest influence on the aggregate capital stock. By contrast, the largest assets by rental income have the greatest influence on aggregate capital services.