July 2018

UK Economic Outlook

Special features on:

- UK housing market outlook
- What will be the net impact of AI and related technologies on jobs in the UK?

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Contents

Highlights and key messages for business and public policy

Key projections

	2018	2019
Real GDP growth	1.3%	1.6%
Consumer spending growth	1.1%	1.3%
Inflation (CPI)	2.5%	2.3%
House prices	2.9%	2.8%

Source: PwC main scenario projections

Recent UK developments and prospects

- In our main scenario, we project UK growth to remain modest at around 1.3% in 2018 and 1.6% in 2019. This is due to continued subdued real consumer spending growth and the drag on business investment from ongoing economic and political uncertainty relating to the outcome of the Brexit negotiations.
- The stronger global economy, and the competitive value of the pound, have boosted UK exports and inbound tourism, offering some support for overall UK GDP growth that should continue through 2018. However, the Eurozone economy has slowed recently and any further escalation of international trade tensions could dampen global growth in 2019 and beyond.
- Service sector growth should remain modest but positive in 2018-19, while manufacturing also retains some positive momentum despite a slowdown in early 2018. But the construction sector has fallen back due to the weakness of commercial property investment and this looks set to continue.
- London has grown significantly faster than other UK regions for most of the past three decades, but recently there have been signs from both the labour and housing markets that London's relative performance has been less strong. We therefore expect London to grow at only slightly above the UK average rate in 2018-19.
- In our main scenario, we assume that the Bank of England raises interest rates by 0.25% later this year, although the precise timing of this will be data-dependent and the pace of any subsequent rate increases will remain limited and gradual.

House price growth to remain moderate across UK and negative in London this year

- In our main scenario, we project a further softening of UK house price growth to around 3% in 2018 and we expect this to continue at a similar average rate in the medium term to 2025. This implies that the average UK house price would rise from £221,000 in 2017 to around £285,000 by 2025. Price growth at this pace would mean that the ratio of house prices to earnings would remain broadly stable, but still at high levels by historical standards.
- We expect that most regions will experience moderate house price growth in 2018 broadly similar to the UK average. The exception is London, where we project that average house prices could drop by nearly 2% in 2018 compared to 2017.

AI and related technologies should create as many jobs as they displace

- AI and related technologies such as robotics, drones and driverless vehicles could displace many jobs formerly done by humans, but will also create many additional jobs as productivity and real incomes rise and new and better products are developed.
- We estimate that these countervailing displacement and income effects on employment are likely to broadly balance each other out over the next 20 years in the UK, with the share of existing jobs displaced by AI (c.20%) likely to be approximately equal to the additional jobs that are created.
- Although the overall effect on UK employment is estimated to be broadly neutral in our central projections, there will inevitably be variations by industry sector. The sectors that we estimate will see the largest net increase in jobs due to AI over the next 20 years include health (+22%), professional, scientific and technical services (+16%) and education (+6%). The sectors estimated to see the largest net long-term decrease in jobs due to AI include manufacturing (-25%), transport and storage (-22%) and public administration (-18%).
- We identify a number of policy areas where action could help to maximise the benefits of AI (e.g. boosting research funding, ensuring competition is adequate to ensure productivity gains are passed on to consumers) and/or mitigate the costs (e.g. a national retraining programme for displaced workers).

1 – Summary

Recent developments

The UK economy held up well in the six months after the EU referendum, but growth slowed from early 2017. This slowdown continued into early 2018, although early signs are that GDP growth was somewhat stronger in the second quarter of this year as the weather improved.

Higher inflation has squeezed real household incomes and this has taken the edge off consumer-led growth, together with a slowdown in the housing market. Brexit-related uncertainty has also dampened business investment growth.

On the positive side, UK exports have been boosted by the upturn in global growth over the past two years. The weaker pound, although bad for UK consumers, has been helpful to exporters and inbound tourism. Jobs growth has remained strong, with the employment rate at record levels. Fiscal policy has also been relaxed somewhat since the Brexit vote, particularly as regards public investment.

Future prospects

As shown in Table 1.1, our main scenario is for UK GDP growth to remain moderate at around 1.3% on average in 2018 and 1.6% in 2019. Our views on growth and inflation are broadly similar to the latest consensus and OBR forecasts (see Table 1.1).

Consumer spending growth is expected to moderate to only around 1% in 2018, but may pick up slightly next year as real wages recover.

The stronger global economy should continue to have some offsetting benefits for net exports this year, although there are downside risks in 2019 and beyond if recent US tariff policy changes were to escalate into a wider international trade war. Brexit-related uncertainty may also continue to hold back business investment in the UK.

Table 1.1: Summary of UK economic growth and inflation prospects

Indicator (% change on previous year)	OBR forecasts (March 2018)		Independent forecasts (June 2018)		PwC Main scenario (July 2018)	
	2018	2019	2018	2019	2018	2019
GDP	1.4	1.5	1.4	1.5	1.3	1.6
Consumer spending	1.0	1.2	1.1	1.3	1.1	1.3
Inflation (CPI)	2.6	2.2	2.5	2.1	2.5	2.2

Source: Office for Budget Responsibility (March 2018), HM Treasury survey if independent forecasters (average value of new forecasts made in June 2018 survey) and latest PwC main scenario.

The slowdown in UK growth should be offset in part by planned increases in public investment and some easing of austerity over the next two years as announced in the November 2017 Budget. Recently announced NHS spending plans could imply some further loosening of fiscal policy in the medium term if this is partly funded by higher borrowing rather than increased taxes. But we will not get details of this until the November 2018 Budget.

There are always uncertainties surrounding our growth projections, as illustrated by the alternative scenarios in Figure 1.1. There are still considerable downside risks relating to possible pitfalls on the road to Brexit and a global trade war, but there are also upside possibilities if these problems can be contained and global growth continues to pick up. In our main scenario, we expect the UK to continue with moderate but steady growth in 2018-19, but businesses need to monitor and make contingency plans for potential alternative scenarios related to Brexit and other factors such as global trade tensions.

Inflation should fall back gradually to around its 2% target rate by the end of 2019, assuming no major shifts in exchange rates or global commodity prices.

Given continued uncertainties around Brexit and the UK economy, we expect the Monetary Policy Committee to remain cautious about the pace of future interest rate rises, but in our main scenario we assume a one quarter point rate rise later this year (either in August or November) and one further increase in 2019.

Housing market trends and prospects

UK house price growth remained relatively resilient in 2017 despite a weakening economic backdrop, but has shown signs of moderating during the first half of 2018, particularly in London.

As discussed in detail in Section 3 of this report, we project a further softening of UK house price growth to around 3% in 2018 and we expect this to continue at a similar average rate in the medium term to 2025. This implies that the average UK house price would rise from £221,000 in 2017 to around £285,000 by 2025. Price growth at this pace would mean that the ratio of house prices to earnings would remain broadly stable, but still at high levels by historical standards.

We expect that most regions will experience house price growth in 2018 broadly similar to that of the UK average (see Table 1.2). The exception is London, where we project that average house prices could drop by nearly 2% in 2018 compared to 2017. In the medium term, however, London house price growth should pick up again, and a large affordability gap will remain between the capital and other UK regions as illustrated by the projections for average regional house prices in 2022 in the final column of Table 1.2.

We have also considered the effect of the recent marked trend towards fixed rate mortgages, which in 2017 accounted for 94% of new mortgages compared to only around 50% in 2010. At the same time, only around 28% of UK households now have a mortgage, as opposed to renting or owning their home outright. Combining these two factors, we estimate that only around 11% of all UK households would now be immediately affected if mortgage interest rates rose, compared to around 24% in 2012. This would be a reason for the MPC not to be overly concerned about small rate rises causing significant short-term economic damage.

Past rises in UK house prices have been driven by a number of factors, but one of these has been a lack of new housing supply. To further investigate this we have carried out new analysis at the local authority level across England, which suggests a clear link between a lack of new housing supply, relative to population growth, and local house price growth since 2011. This has been particularly marked in London, where we estimate that around 110,000 more homes would need to have been built between 2011 and 2016 to keep up with population growth.

Figure 1.1 – Alternative UK GDP growth scenarios

Sources: ONS, PwC scenarios

Table 1.2: Projected regional house price growth and house price values (£000's) in our main scenario

	Average house price growth			Average house price values (£'000s in cash terms)	
Region	**2018**	**2019**	**2020-2022 (average)**	**2017**	**2022**
East of England	4.0%	4.5%	3.4%	283	340
East Midlands	4.4%	3.7%	3.4%	180	216
South West	4.3%	3.7%	3.6%	245	295
West Midlands	4.8%	4.3%	3.6%	185	225
South East	2.3%	3.1%	3.3%	318	369
North West	3.2%	2.7%	3.5%	155	182
London	-1.7%	-0.2%	2.6%	480	509
Wales	3.0%	2.1%	3.4%	150	175
Scotland	4.8%	3.4%	3.6%	143	172
Yorkshire & the Humber	3.5%	2.7%	3.4%	155	182
Northern Ireland	3.4%	3.9%	4.0%	128	154
North East	1.2%	0.7%	3.1%	127	141
UK	**2.9%**	**2.8%**	**3.4%**	**221**	**259**

Source: ONS, PwC analysis

Looking ahead, if the government can achieve its target of building 300,000 new homes a year in England by the mid-2020s, then this should exceed the increase in housing demand from projected population growth and therefore start to make up the backlog from past under-supply. But our local analysis suggests that many of these homes need to be built where demand is highest in London and the South East and the East of England to prevent a further worsening of affordability in those regions. Local targets need to be set and met for housebuilding, linked to supporting infrastructure development, as well as national targets.

What will be the net long-term impact of AI and related technologies on UK jobs?

AI and related technologies such as robots, drones and driverless vehicles could displace many jobs formerly done by humans over the coming decades. But, as we discuss in detail in Section 4 of this report, this will also create many additional jobs as productivity and real incomes rise and new and better products are developed.

We estimate that these countervailing displacement and income effects on employment are likely to broadly balance each other out over the next 20 years in the UK, with the share of existing jobs displaced by AI (c.20%) likely to be approximately equal to the additional jobs that are created. However, there will inevitably be 'winners' and 'losers' by industry sector (see Table 1.3).

The sectors that we estimate will see the largest net increase in jobs due to AI and related technologies in the long run include health (+22%), professional, scientific and technical services (+16%) and education (+6%). The sectors estimated to see the largest net long-term decrease in jobs due to AI include manufacturing (-25%), transport and storage (-22%) and public administration (-18%).

Table 1.3: Estimated job displacement and creation from AI by industry sector (2017-37)

Industry sector	% of existing jobs (in 2017)			Number of jobs (000s)		
	Creation	Displacement	Net effect	Creation	Displacement	Net effect
Health and social work	34%	-12%	22%	1,481	-526	955
Professional, scientific and technical	33%	-18%	16%	1,025	-541	484
Information and communication	27%	-18%	8%	388	-267	121
Education	12%	-5%	6%	345	-158	187
Accommodation and food services	22%	-16%	6%	518	-371	147
Administrative and support services	23%	-24%	-1%	698	-733	-35
Other sectors	13%	-15%	-2%	466	-533	-67
Wholesale and retail trade	26%	-28%	-3%	1,276	-1,403	-127
Construction	12%	-15%	-3%	279	-355	-75
Financial and insurance activities	18%	-25%	-7%	209	-286	-77
Public administration and defence	4%	-23%	-18%	64	-339	-274
Transportation and storage	17%	-38%	-22%	296	-683	-387
Manufacturing	5%	-30%	-25%	133	-814	-681
Total	**20%**	**-20%**	**0%**	**7,176**	**-7,008**	**169**

Source: PwC analysis

Based on differences in industry structure alone, our projections do not imply large variations by region, though our central estimates imply a small net job gain in London offset by small net losses in the North and Midlands. But other factors could lead to larger regional variations than captured by our analysis.

Although our central estimate is that the net effect of AI on jobs will be broadly neutral, there are many uncertain factors that could tip the balance towards more optimistic or pessimistic scenarios.

We identify some policy areas where action could help to maximise the benefits (e.g. boosting research funding for AI, ensuring competition is adequate to ensure productivity gains are passed on to consumers) and/or mitigate the costs in terms of impacts on jobs (e.g. a national retraining programme for older workers as well as renewed efforts by schools and universities to build STEAM skills).

2 – UK economic prospects[1]

Key points

- In our main scenario, we project UK growth to continue at moderate rates of around 1.3% in 2018 and 1.6% in 2019.
- The world economy remains relatively strong, but the UK will lag behind in 2018-19 due to the drag on domestic demand from higher inflation and Brexit-related uncertainty.
- A key factor behind the UK slowdown is subdued consumer spending growth as real incomes have been squeezed by higher inflation, the housing market has cooled and further rises in borrowing become hard to sustain.
- Government investment has picked up recently, but business investment will remain constrained by uncertainties related to Brexit despite the stronger global economy. The latter could also be put at risk in 2019 and beyond if there is further escalation of the recent US-led trade war.
- We expect UK growth to become more balanced across regions in 2018-19, with London no longer growing significantly faster than the UK average and all regions growing at 1% or above.
- Wage growth is projected to pick up gradually during the course of this year and next, with positive real wage growth resuming as consumer price inflation slowly moderates, but staying below pre-crisis levels as productivity growth remains subdued.
- The Bank of England is expected to continue with very gradual interest rates rises over the next few years, but the timing of these will depend on the evolution of both the economic data and the Brexit negotiations.

Introduction

In this section of the report we describe recent developments in the UK economy and review future prospects. The discussion covers:

Section 2.1	Recent developments in the UK economy
Section 2.2	Economic growth prospects: national, sectoral and regional
Section 2.3	Outlook for inflation and real earnings growth
Section 2.4	Monetary and fiscal policy options
Section 2.5	Summary and conclusions.

1 This section was written by John Hawksworth with additional material from Andrew Sentance in Box 2.1.

2.1 – Recent developments in the UK economy

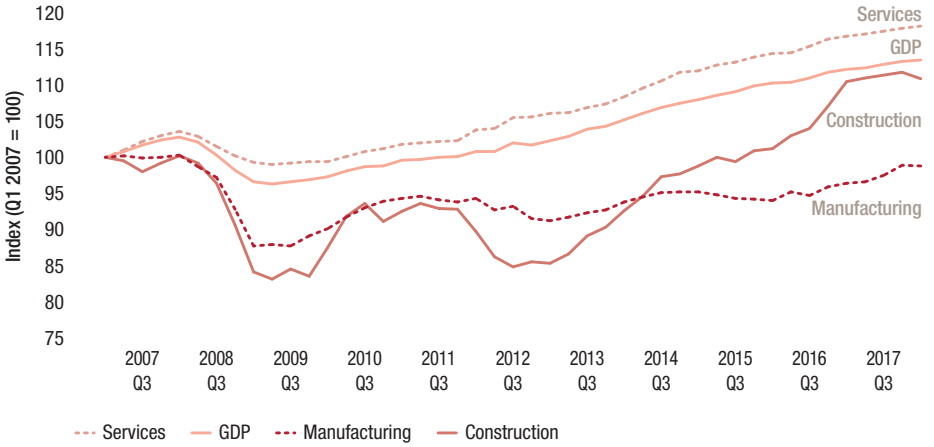
UK economic growth slowed in 2017 as inflation bit into consumer spending power and Brexit-related uncertainty dampened business investment, although this was offset in part by an upturn in the global and Eurozone economies. UK growth then fell further in the first quarter of 2018, although this decline was exaggerated somewhat by the negative effects of the snow in late February and March.

Manufacturing sector output is still slightly below pre-crisis peak levels, but has generally been on a rising trend since 2015 (see Figure 2.1). Most recently, manufacturing output bounced back strongly in the second half of 2017 due to higher demand for UK goods exports because of stronger global and European demand, as well as the competitive value of sterling. But manufacturing growth moderated somewhat in early 2018 as both the domestic economy and key Eurozone markets saw some slowdown.

The construction sector has been volatile over time, but had generally been growing relatively strongly in 2014-16 before declining again since early 2017 (with a significant snow-affected drop in Q1 2018). Commercial construction activity has been particularly weak over the past year, perhaps reflecting the impact of Brexit-related uncertainty.

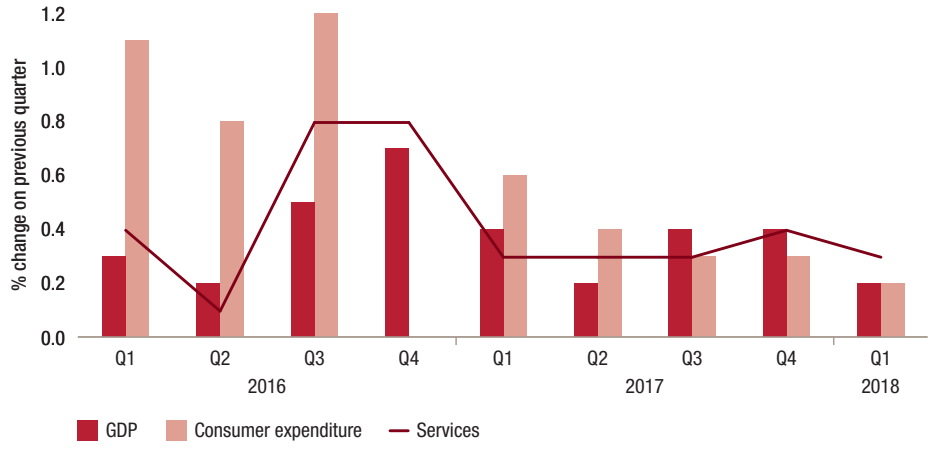
The dominant influence on UK growth comes from the services sector, however, which now accounts for almost 80% of UK GDP (compared to only around 10% for manufacturing and around 6% for construction). Services sector output has shown relatively steady growth ever since the recession bottomed out in mid-2009, although there have been some fluctuations in the pace of services growth more recently as Figure 2.2 shows.

Figure 2.1 – Sectoral output and GDP trends



Source: ONS

Figure 2.2 – Trends in GDP, consumer spending and the services sector



Source: ONS

The fourth quarter of 2017 saw stronger services growth, but this then fell back markedly in the first quarter of 2018.

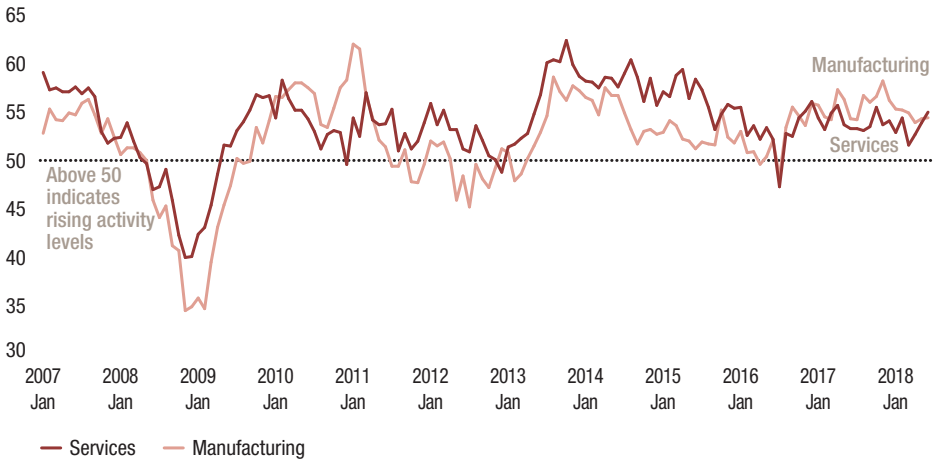
Figure 2.2 also shows the influence of slower consumer spending growth on overall GDP growth in recent quarters. This reflects the dampening effect of higher inflation on real household spending power.

As discussed in more detail in Section 3, the housing market has also slowed, particularly in London. Retail sales growth was particularly weak in the first quarter of 2018, but has recovered in April and May with better weather and business surveys suggest continued stronger growth in June.

While official data are more comprehensive, business surveys can provide a more timely indication of short term economic trends. In particular, it is worth keeping an eye on the Markit/CIPS purchasing managers' indices (PMIs) for services and manufacturing, as shown in Figure 2.3. Despite some volatility, the manufacturing PMI had been relatively strong in the second half of 2017, but has moderated somewhat over the past six months. The services PMI showed positive but relatively modest growth during the first quarter of 2018, but has picked up during the second quarter.

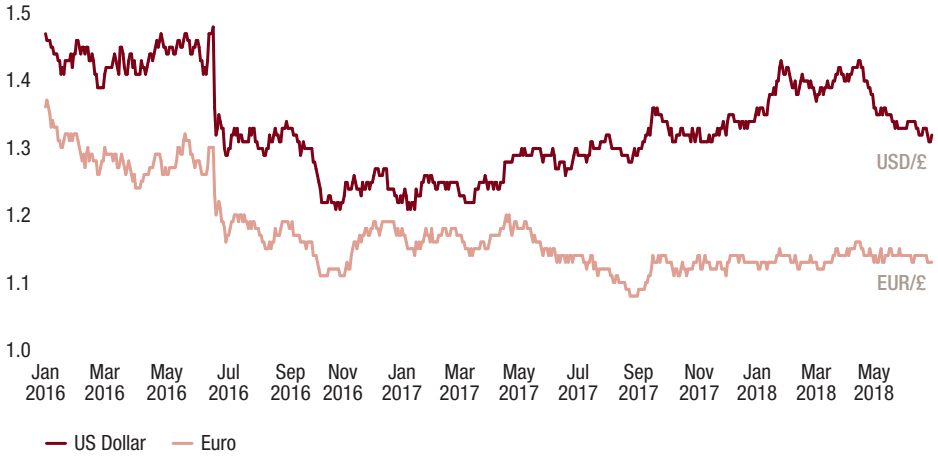
A key factor underpinning recent UK economic trends has been the relative weakness of the pound since the Brexit vote, as shown in Figure 2.4. Sterling regained some ground against the dollar between mid-2017 and April 2018, but has fallen back again since then and remains weak against the euro. A weak currency makes UK exports relatively cheaper for overseas customers, promoting the sale of British goods and services while also improving tourist inflows. But depreciation also raises the prices of imports and this pushed up inflation, so squeezing consumer spending power as discussed above.

Figure 2.3 – Purchasing Managers' Indices of business activity



Source: Markit/CIPS

Figure 2.4 – US dollar and euro exchange rates against the pound



Source: Bank of England

Figure 2.5 – Trends in productivity and employment

Source: ONS

UK creates record numbers of jobs, but productivity growth subdued since the crisis

In the July 2017 edition of UK Economic Outlook, we discussed how the recent combination of low wage growth and low unemployment indicated a flattening of the traditional Phillips Curve (which describes the historical negative relationship between wage inflation and unemployment). One of the key reasons for subdued real wage growth has been relatively weak UK productivity growth since the financial crisis as illustrated in Figure 2.5 for output per worker. The positive side of this has been strong jobs growth, particularly since 2012.

As discussed in an article by Andrew Sentance in the November 2017 edition of this report[2], weaker post-crisis productivity growth rates in financial services and property-related sectors have played a significant part in this slowdown.

In the second half of 2017 there were some signs of productivity bouncing back, but this was more due to weaker jobs growth than particularly strong output growth. During the first quarter of 2018, jobs growth has picked up again, but productivity has fallen back again, leading to weak overall output growth. The ideal combination of strong jobs growth and robust productivity growth, as seen before the crisis, has generally proved elusive over the past decade and this continues to be the case.

Why has productivity been weak since the crisis?

Many possible explanations have been put forward for recent weak productivity growth, including measurement error (in particular, not capturing the full benefit of digital innovations like smart phones). Soon after the recession, some put it down to labour hoarding by firms or credit constraints by banks, but both these explanations are less convincing now after eight years of recovery since mid-2009.

Reduced competition in some sectors might be a possible explanation, but against that some other sectors have seen their markets disrupted by technology-savvy new entrants, which would usually be associated with increased innovation and productivity growth. Another possible explanation is that 'zombie firms' could have been kept alive by low interest rates despite low productivity, impeding the reallocation of capital and labour to higher productivity activities within the economy.

The most convincing explanation from our perspective is that business investment, while picking up since the recession, has not done so to the extent seen in most past recovery cycles. Many businesses have been reluctant to invest in new labour-saving automation technologies that are relatively risky when compared to the alternative of using more low cost labour, including migrant workers from the EU (although this inflow is now dropping back). Uncertainty around Brexit has been a further dampener on business investment over the past 18 months, which has been broadly flat at a time when global economic conditions and very low interest rates might normally have been expected to lead to much stronger UK business investment growth.

Looking 10-20 years ahead, emerging technologies like robotics and artificial intelligence could hold the potential for faster productivity growth[3], with a net impact on employment that we think could be broadly neutral as we discuss in detail in Section 4 of this report. But, at least for the next few years, productivity growth may remain relatively subdued, with any recovery being at the expense of slower growth in jobs and hours worked.

2 https://www.pwc.co.uk/economic-services/ukeo/ukeo-nov17-productivity pdf
3 See, for example, our report on the potential impact of AI on the UK economy here, which suggests gains of up to 10% of GDP by 2030: https://www.pwc.co.uk/services/economics-policy/insights/the-impact-of-artificial-intelligence-on-the-uk-economy.html

2.2 – Economic growth prospects: national, sectoral and regional

Our main scenario is for real GDP growth of around 1.3% in 2018 and 1.6% in 2019, somewhat below the UK's estimated longer term trend growth rate of just over 2%. Further details of this main scenario projection are set out in Table 2.1.

As discussed further in Box 2.1, UK growth in 2017-19 seems likely to be disappointing relative both to historical average UK performance and average growth in other G7 economies in 2017-19. This moderate growth outlook is despite our assumption here that the Brexit negotiations will proceed reasonably smoothly, and therefore that the UK will avoid an extreme 'hard Brexit' where it falls out of the EU in March 2019 without any trade deal or transitional arrangement, so reverting immediately to WTO rules. But clearly this is a key downside risk as discussed further below.

The projected deceleration in growth as compared to 2016 has been driven primarily by slower consumer spending growth due to the squeeze on real household incomes from higher inflation. So far consumers have increased borrowing to keep spending growth going at a reasonable pace but, as discussed in detail in the March 2018 edition of this report, there are limits to how much further this can go. We therefore expect consumer spending growth to slow to only around 1% this year before picking up modestly in 2019 as real wages recover.

Table 2.1 – Main scenario projections for UK growth and inflation

% real annual growth unless otherwise stated	2016	2017	2018	2019
GDP	1.8	1.7	1.3	1.6
Consumer spending	3.2	1.9	1.1	1.3
Government consumption	0.8	-0.1	1.0	0.8
Fixed investment	2.3	3.4	0.4	1.9
Domestic demand	2.4	1.3	0.9	1.3
Net exports (% of GDP)	-0.7	0.6	0.5	0.3
CPI inflation (%: annual average)	0.7	2.7	2.5	2.2

Sources: Latest ONS estimates for 2016-17, PwC main scenario for 2018-19

Total fixed investment growth lost momentum during the course of 2017 and is expected to remain relatively slow in 2018-19 as Brexit-related uncertainty drags on business investment. Overall, UK domestic demand growth is expected to average only just over 1% per annum in 2018-19, down from an average rate of around 2.7% in 2013-16.

Weaker domestic demand growth is expected to be offset to a degree by a positive contribution from net exports, reversing the strongly negative contribution in 2016. This reflects a boost to exports from recent strong global growth, as well as the relatively competitive level of the pound. But there are downside risks here too as discussed further below.

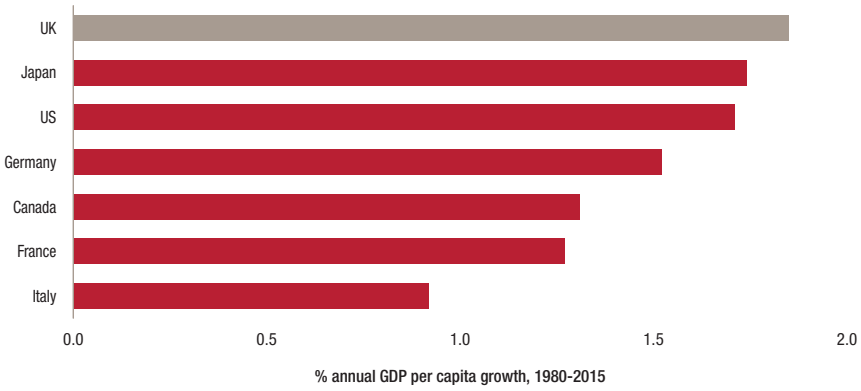
Box 2.1 – Why has recent UK economic growth been so disappointing?[4]

The UK economy has been accustomed to being one of the better performing major economies in the Western world. If we look back to the period since 1980, UK GDP growth from 1980 to 2015 averaged 2.3%. This was the third highest in the G7 - below the US and Canada but these economies benefited from stronger population growth. Among the G7 economies, the UK achieved the strongest growth in GDP per head between 1980 and the mid-2010s[5] – 1.9% per annum on average, compared with 1.7% for the US and Japan and 1.5% for Germany (see Figure 2.1.1).

But the UK is no longer performing so strongly relative to its G7 counterparts. Economic growth over the past year in the UK has been the second lowest in the G7, with only Japan showing weaker economic growth over the past twelve months. As Figure 2.1.2 shows, after outperforming the rest of the G7 from 2012-16, we project UK GDP growth to be significantly slower than the average of other G7 economies over the period 2017-19.

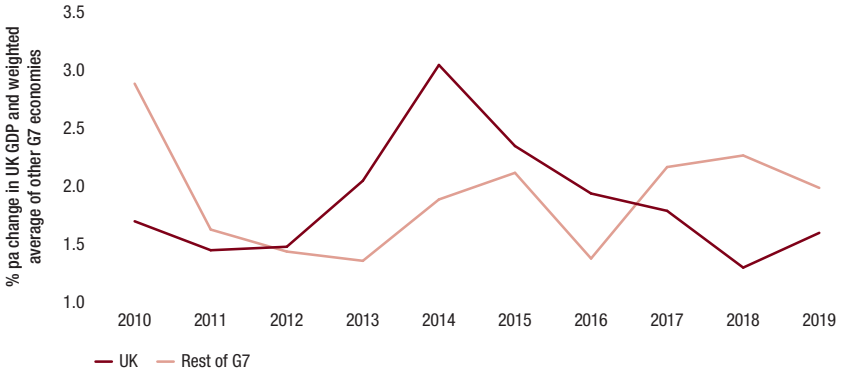
This might be seen as an issue of swings and roundabouts. A ranking of GDP growth covering the decade of the 2010s (using the latest PwC main scenario projections for 2018-19) indicates that our current projection of 1.9% average growth for the UK over the years 2010-19 is somewhat behind Germany, Canada and the US (2.1-2.3%), but well ahead of France and Japan (1.4%) and Italy (0.4%).

Figure 2.1.1 – UK led the G7 on average GDP per head growth in 1980-2015



Source: IMF World Economic Outlook Statistical Database (April 2018 edition)

Figure 2.1.2 – UK growth now lagging behind the average of other G7 economies



Source: IMF World Economic Outlook (2010-17) and latest PwC projections (2018-19)

4 This box was written by Andrew Sentance, senior economic adviser at PwC
5 Although the UK's relative growth performance over this period may be flattered somewhat by the catch-up from its relatively weak performance in the 1970s as well as the deep recession in the base year of 1980.

However, it is unusual for the UK - which has strong trade and investment links with the rest of Europe and the broader global economy – to slow down when our major trading partners are speeding up, as has been the case since 2017. The obvious explanation is the prospect of Brexit, which has squeezed economic growth in the UK in two main ways. First, the fall in the value of the pound has pushed up inflation and depressed consumer spending. This consumer squeeze has been more powerful than any boost to export performance from a more competitive pound.

Second, uncertainty about Brexit has negatively affected business investment. From the end of 2009 until the last quarter of 2015, UK business investment grew at more than 5% per annum in volume terms. The rate of increase since then has been just below 2%, despite buoyant growth across the global economy, which might have been expected to encourage investment in the UK.

Other factors have also played a part in this disappointing growth performance in the UK. Low productivity growth has been a feature across all the major industrialised economies since the financial crisis. But the UK appears to have been particularly badly affected by this productivity slowdown. As we have discussed in previous editions of this report, this partly reflects disappointing performance in a number of high productivity sectors, including financial services. We can see the impact of disappointing productivity growth in the most recent GDP and jobs data. In the past 12 months, GDP has risen by 1.2% while employment has increased by 1.4%. In other words, output per head has actually fallen back over the past 12 months, compared with the normal expectation that productivity should grow by 1-2% a year in advanced economies like the UK.

Will UK growth performance recover after Brexit? Our medium-term projection for GDP growth in the early 2020s is for an average annual growth rate of around 1.8%, half a percentage point below the 1980-2015 average. This is likely to put the UK in the middle of the G7 growth league, alongside France, ahead of Italy and Japan, but behind the US, Canada and Germany. The combination of slow productivity growth and the continuing dampening impact of Brexit are likely to mean that the UK will be only an average growth performer in the early 2020s relative to its peer group of major advanced economies.

Alternative growth scenarios – businesses need to make contingency plans

To reflect the uncertainties associated with any such projections, particularly in light of Brexit, we have also considered two alternative UK growth scenarios, as shown in Figure 2.6.

- Our **'strong growth' scenario** projects that the economy will rebound to around 2.7% growth in 2019. This is a relatively optimistic scenario, which assumes that good early progress is made in UK-EU negotiations and that there are strong favourable trends in the global economy, pushing world growth higher in 2018-19 and boosting UK exports.

- Our **'slow growth scenario'**, by contrast, would see UK growth stall later this year as the global outlook worsens in the face of an escalating US-led trade war and there is little or no progress in negotiations with the EU over the next year, suggesting that the UK may have to fall back on WTO rules with a consequent imposition of tariffs on trade with the EU. The associated uncertainty would be likely to reduce investment, jobs and growth. Even in this downside case, however, we do not expect the UK to fall into a serious recession over this period, barring some major new adverse shock.

Figure 2.6 – Alternative UK GDP growth scenarios

Sources: ONS, PwC scenarios

We do not believe that either of these two alternative scenarios is the most likely outcome, but they are certainly possible. At present, risks to growth appear to be weighted somewhat to the downside given the political and economic uncertainties around Brexit as well as concerns about an escalating global trade war. Businesses would therefore be well advised to make appropriate contingency plans for such less favourable outcomes, but without losing sight of the more positive possibilities for the UK economy should these downside risks not materialise.

More generally, companies should consider making detailed contingency plans for the potential impact of Brexit[6] on all aspects of their businesses, covering the kind of questions listed in Table 2.2.

Table 2.2: Key issues and questions for businesses preparing for Brexit

Issues	Implications	Questions
Trade	The EU is the UK's largest export partner, accounting for around 44% of total UK exports – leaving the EU is likely to make trade with EU more difficult, but the extent of this will depend on the type of deal, if any, agreed with the EU27.	• How much do you rely on EU countries for revenue growth? • Have you reviewed your supply chain to identify the potential impact of tariffs and additional customs procedures on your procurement and logistics? • Have you identified which third party contracts would require renegotiation in different Brexit scenarios (EEA/FTA/WTO)?
Tax	The UK would gain more control over VAT and some other taxes. But Brexit could also open the door to new tax initiatives within the EU that the UK might currently have sought to block.	• Have you thought about the impact of potential changes to the UK and EU tax regimes after Brexit? • Have you upgraded your systems to deal with a significant volume of tax changes?
Regulation	The UK is subject to EU regulation. Brexit could mean less red tape in some areas. But it could also mean that UK businesses need to adapt to a different set of regulations, which could be costly.	• Have you quantified the potential regulatory impact of Brexit to keep your stakeholders up-to-date? • How flexible is your IT infrastructure to deal with potential changes to Data Protection laws? • Is your compliance function ready to deal with any new reporting requirements arising from Brexit?
Sectoral effects	The UK is the leading European financial services hub, which is a sector that could be significantly affected by Brexit. Other sectors which rely on the EU single market could also feel a strong impact.	• Have you briefed potential investors on the impact of Brexit for your sector and organisation? • How up-to-date are your contingency plans in place to deal with Brexit? • Are you aware of the impact of potential volatility in financial markets on your capital raising plans?
Foreign direct investment (FDI)	FDI from the EU makes up around 45% of the total stock of FDI in the UK. Brexit could put some of this investment at risk.	• How much do your rely on FDI for growth? • How does Brexit affect your location decisions? • How are your competitors responding to the risk of Brexit? Are they relocating any key functions?
Labour market	The UK may change its migration policies. Currently EU citizens can live and work in the UK without restrictions. Businesses will need to adjust to any change in this regime.	• How reliant is your value chain on EU labour? • Have you communicated with your UK-based employees who are nationals of other EU countries? What advice should you give them? • Have you considered the additional cost of hiring EU labour after Brexit? • Could changes in access to EU labour increase the case for automation?
Uncertainty	Uncertainty has increased since the referendum and this seems likely to continue through the Brexit negotiation period.	• How well prepared are you to manage future volatility in the exchange rate related to Brexit? • Is your organisation ready for a worst-case scenario where there is a prolonged period of uncertainty and/or a 'hard Brexit'?

Source: PwC

6 For more material on the potential impact of Brexit on your business, please see our EU Referendum hub here: http://www.pwc.co uk/the-eu-referendum.html

Manufacturing growth projected to be relatively strong in 2018 but retail sales slow

The sector dashboard in Table 2.3 shows latest ONS estimates of growth rates for 2017 along with our projected growth rates for 2018 and 2019 for five of the largest sectors within the UK economy. The table also includes a summary of the key trends and issues affecting each sector.

The most marked downward trend in growth is in the distribution, hotels and restaurants sector, which recorded output growth of almost 5% in 2016, but this slowed to just 1.7% in 2017 and we expect only around 1% growth in 2018 as real consumer spending power is squeezed.

Manufacturing should be boosted this year due to stronger exports, but may see growth moderate again in 2019 as earlier competitiveness gains from a weak pound fade and adverse impact of recent US-led tariff rises tend to slow world trade growth. Construction has been weak over the past year and, even if this decline bottoms out, average growth seems likely to be very modest in 2018. But it could revive in 2019 as public investment and housing remain relatively strong.

Business services and finance growth should remain relatively steady at around 2% per annum, although there are downside risks if Brexit negotiations go less smoothly than we assume in our main scenario. UK financial services companies could be particularly badly affected by any loss of access to EU markets, notably through the possible loss of 'passporting' rights for UK-based firms, although there is also positive longer term potential for the sector beyond Brexit[7].

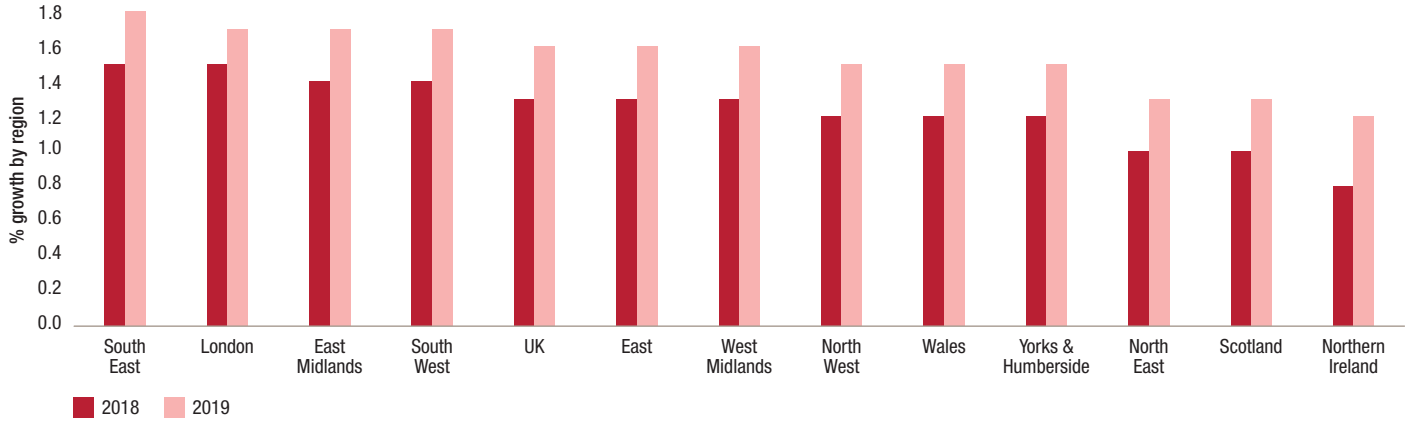
Table 2.3: UK sector dashboard

	Growth			
Sector and GVA share	**2017**	**2018**	**2019**	**Key issues/trends**
Manufacturing (10%)	2.5%	2.0%	1.6%	Manufacturing PMI has moderated somewhat in recent months and output was subdued in April but recovered slightly in May Exporters have gained from a weaker pound and a stronger global economy, though there are concerns about trade wars going forward
Construction (6%)	7.1%	0.4%	1.6%	Construction PMI was relatively weak in recent months, though it picked up a little in June The construction sector was weak during the first four months of 2018, but output bounced back in May The government has boosted infrastructure investment to try to offset weakness in commercial construction due to Brexit
Distribution, hotels & restaurants (13%)	2.2%	0.9%	1.4%	A weaker pound since 2016 has boosted tourism, both from overseas and domestically, leading to increased expenditure in the hospitality sector But its broader effect has been to push up import prices and inflation, slowing down real spending growth (though retail sales picked up in May)
Business services and finance (34%)	2.6%	2.2%	2.0%	The financial sector remains particularly concerned about the possible implications of Brexit, especially if this involves the loss of EU passporting rights The Bank of England has increased the counter-cyclical capital buffer to constrain consumer debt levels, which may impact lending by retail banks Business services have, however, continued to see relatively strong growth in general
Government and other services (22%)	0.2%	0.4%	0.8%	Public services continue to face tight budgets, but austerity has been eased for at least the next two years and NHS spending is planned to increase
Total GDP	**1.7%**	**1.3%**	**1.6%**	

Sources: ONS for 2017 estimates, PwC for 2018 and 2019 main scenario projections and key issues.
These are five of the largest sectors but they do not cover the whole economy - their GVA shares only sum to around 85% rather than 100%

7 For more on the future of UK financial services after Brexit, see our report with TheCityUK here: https://www.pwc.co.uk/industries/financial-services/insights/vision-for-transformed-world-leading-industry.html

Figure 2.7 – PwC main scenario for output growth by region in 2018 and 2019



Source: PwC analysis

Regional prospects: all parts of the UK likely to see moderate growth in 2018-19 with London no longer clearly leading the pack

In contrast to previous years where London has generally had one of the strongest growth rates of any UK region, our latest projections suggest London's growth rate may fall to only just above the UK average in 2018-19 (see Figure 2.7). This is partly due to the greater exposure of some London activities (e.g. the City) to adverse effects from Brexit-related uncertainty, as well as growing constraints on the capital in terms of housing affordability and transport capacity.

Most English regions, as well as Wales, are projected to expand at close to the UK average of around 1.3% in 2018, although the North East, Scotland and Northern Ireland are predicted to lag behind somewhat with growth of only around 1% this year before recovering somewhat next year.

It is important to note that, since regional output data are published on a less timely basis than national data, the margins of error around these regional output projections are even larger than for national growth projections. Therefore, they can only be taken as illustrative of broad directional trends.

2.3 – Outlook for inflation and real earnings growth

Consumer price inflation (CPI[8]) picked up from just 0.7% on average in 2016 to 3% in the year to January 2018 due in large part to the feedthrough from a weaker pound into import prices. The rise in global oil prices from their low point in early 2016 to over $75 a barrel at the time of writing has also played a part here. However, CPI inflation did fall back to 2.4% in the year to May 2018 as the effect of past import price rises fell out of the 12 month inflation calculation.

Over the next 18 months, we expect CPI inflation to decline gradually, eventually returning to close to target by the end of 2019 although there could be some turbulence along the way (see Figure 2.8). Annual average rates of inflation in our main scenario would be around 2.5% this year and around 2.2% in 2019.

8 The ONS switched to CPIH as its main inflation indicator in March 2017, despite some continuing methodological concerns about the reliability of the way that CPIH captures owner occupied housing costs through estimates of equivalent market rents rather than actual outlays on mortgage payments. For the moment, we have stuck to CPI as our key inflation indicator, but we may consider switching to CPIH in the future if this becomes more widely used (in particular if it becomes the MPC's target measure of inflation). In the long run, however, we would not expect significant differences between average inflation on these two measures (based on long-term historical averages).

Alternative inflation scenarios

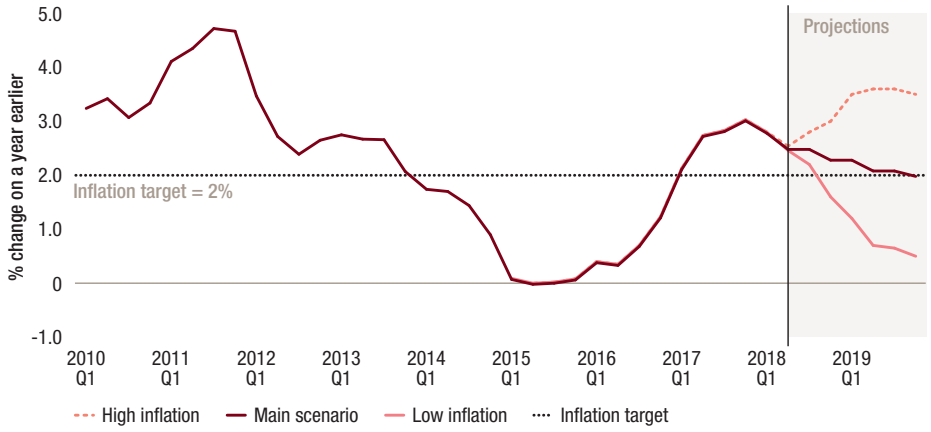
There is always considerable uncertainty over inflation projections as they are particularly sensitive to movements in exchange rates and global commodity prices, both of which are very hard to predict with any confidence. As such, we also present two alternative scenarios for UK inflation in Figure 2.8:

- In our **'high inflation' scenario** we project UK inflation to rise to around 3.5% by early 2019 as a result of renewed falls in the pound and a pick-up in global commodity prices if other economies grow more strongly and/or oil supply is constrained by producers. Wage growth could also pick up faster than expected in this case.

- In our **'low inflation' scenario**, by contrast, the UK and global economies weaken by more than expected in our main scenario leading global commodity prices to fall back sharply over the next year. In this case, UK inflation could fall back to well below the Bank of England's 2% target rate next year.

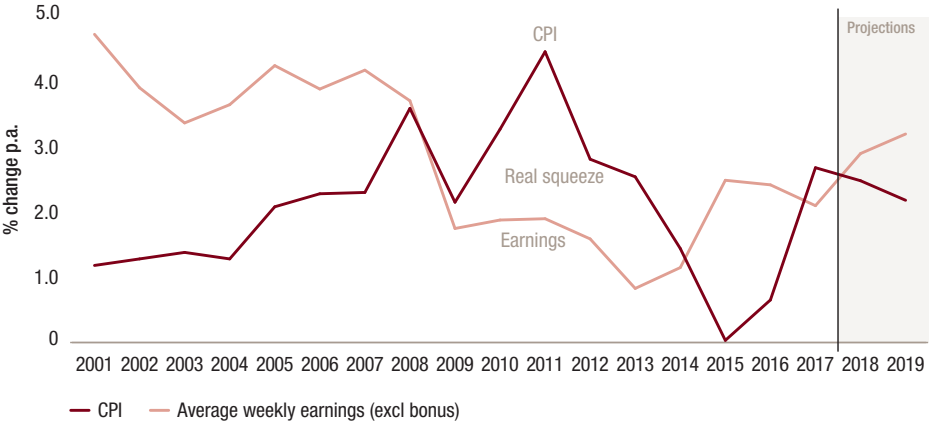
As with our GDP growth scenarios, neither of these two alternative variants is as likely as our main scenario. But given recent volatility and uncertainty, businesses should plan for a broad range of outcomes.

Figure 2.8 – Alternative UK inflation (CPI) scenarios



Sources: ONS, PwC scenarios

Figure 2.9 – CPI inflation vs average earnings growth



Sources: ONS, PwC analysis

Real earnings projected to pick up gradually

As Figure 2.9 shows, real earnings growth was squeezed from 2009-14 but then regained some ground in 2015-16 as low global commodity prices pushed down UK inflation to close to zero. But the real earnings squeeze resumed in 2017 as wage inflation failed to pick up in response to higher consumer price inflation.

Falling inflation means that real earnings growth (excluding bonuses, which tend to be erratic) has now edged back into positive territory and we expect this gradual upward trend to continue in the rest of 2018 and into 2019 (see Figure 2.9). It is difficult for earnings to pick up significantly on a longer term basis, however, unless productivity growth picks up on a sustained basis.

2.4 – Monetary and fiscal policy

The Monetary Policy Committee (MPC) kept interest rates on hold in May and June as it waited for more data on whether the sharp dip in growth in the first quarter of the year was a blip or the start of a more severe downward trend. Since we expect growth to recover in the rest of the year, we do expect a rate rise before the end of this year, possibly as early as August, but the timing of this will depend on how both the economic data and the Brexit negotiations evolve. In the medium term, we assume further small and gradual rate rises, but interest rates will remain very low by historical standards for the foreseeable future. Base rates may end up at around 2-3% as opposed to the 5% pre-crisis norm.

As regards fiscal policy, the Chancellor made no significant tax or spending changes in his Spring Statement, despite public borrowing falling to just under 2% of GDP in the 2017/18 financial year, the lowest since 2001/2. We can expect more substantial changes in the Budget in November, including details of how the government will pay for the more generous NHS spending settlement announced recently, which will require some tax increases. We also expect the Budget to set high level spending totals for the next 4-5 years that will set the envelope for the more comprehensive 2019 Spending Review, which will set medium-term budgets for individual departments. We will review the government's fiscal policy options in more detail nearer the time of the November Budget.

2.5 Summary and conclusions

UK economic growth has slowed over the past 18 months as inflation has squeezed consumers, the housing market has cooled and Brexit-related uncertainty has dampened business investment growth. There has been some offset from a stronger global economy, but not enough to keep UK growth from falling well below its long term trend rate of around 2%.

In our main scenario, we expect this period of modest, sub-trend growth to continue in 2018-19, with GDP growth of around 1.3% in 2018 and 1.6% in 2019 and real consumer spending growth of just over 1% in both years.

The impact of slower growth will be felt across most major industry sectors, although manufacturing exports have received a short-term boost from the depreciation of the pound since 2016 and recent stronger global growth (although any further escalation of US-led trade wars could threaten this relatively rosy global picture in 2019 and beyond). Construction has faced the most marked slowdown over the past year, although this follows a period of considerable strength up to early 2017.

In our main scenario we assume a one quarter point interest rate rise later this year, although the exact timing of this remains uncertain, and another in 2019 as the MPC seeks to bring inflation back down to target. But any such increases will be limited and very gradual, aimed at taking interest rates back to around 2-3% in the longer term.

It is important to note that there are considerable uncertainties around any such projections at present. So organisations should stress test their business and investment plans against alternative economic scenarios and also review the potential wider implications of Brexit for all aspects of their operations.

3 – UK housing market outlook[1]

Key points

- UK house price growth remained relatively resilient in 2017 despite a weakening economic backdrop, but has shown signs of moderating during the first half of 2018, particularly in London.
- In our main scenario, we project a further softening of house price growth to around 3% in 2018 and we expect this to continue at a similar average rate in the medium term to 2025. This implies that the average UK house price would rise from £221,000 in 2017 to around £285,000 by 2025. Price growth at this pace would mean that the ratio of house prices to earnings would remain broadly stable, but still at high levels by historical standards.
- We expect that most regions will experience moderate house price growth in 2018 broadly similar to the UK average, except for London, where we project that house prices could drop by nearly 2% compared to 2017. Elsewhere in the UK, slightly above average price growth is projected in the East of England, the West Midlands and Northern Ireland, while the North East and Wales are expected to lag slightly behind the UK average price growth.
- We also consider the effect of the recent marked trend towards fixed rate mortgages, which in 2017 accounted for 94% of new mortgages compared to only around 50% in 2010. At the same time, only around 28% of UK households now have a mortgage. Combining these factors, we estimate that only 11% of all UK households would now be immediately affected if mortgage interest rates rose, compared to around 24% in 2012.
- Persistently rising house prices can be driven by a number of factors, but one of these has been a lack of new housing supply. To further investigate this we have carried out new analysis at the local authority level, which suggests a clear link between lack of new housing supply, relative to population growth, and local house price growth since 2011. This has been particularly marked in London, where we estimate that around 110,000 additional homes would need to have been built between 2011 and 2016 to keep up with population growth.
- Looking forward, if the government can achieve its target of building 300,000 new homes a year in England, then this should exceed the increase in housing demand from projected population growth and start to make up the backlog from past under-supply. But our local analysis suggests that these homes need to be built where demand is highest in London and the South East and East of England to prevent a further worsening of affordability in those regions. Local targets are therefore needed for housebuilding, as well as national targets.

Introduction

In this section, we explore how the UK housing market has been performing recently (Section 3.1) and also look at the implications of the rising share of fixed rate mortgages (Box 3.1). We then present our projections for national and regional house price inflation to 2025 (Section 3.2). To shine fresh light on the housing supply challenge we also present new analysis of supply and demand trends at the local authority level across England (Section 3.3). Section 3.4 then summarises and concludes. Technical details of our house price modelling methodology are presented in an annex.

1 This article was written by Richard Snook, Tom Fisher and Jamie Durham of the PwC economics practice.

3.1 – Recent housing market developments

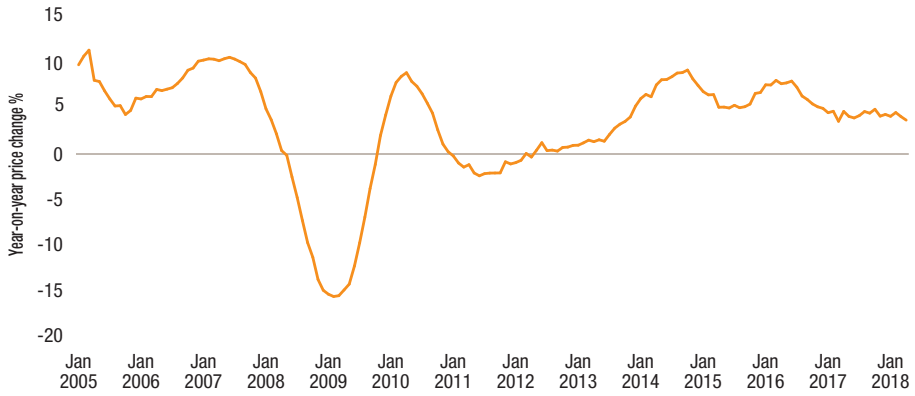
UK house price inflation softened from mid-2016 through to early 2017. The introduction of the Stamp Duty surcharge on second homes in April 2016 – equivalent to an additional 3% tax on the purchase price – and uncertainty following the EU referendum are both likely to have contributed to this trend. During 2017, average UK house price inflation remained fairly steady, hovering between 4.5% and 5%. More recently, however, a further weakening in price growth has occurred, with annual house price inflation dropping to 3.9% in the year to April 2018[2].

There are signals that house price growth will continue to soften in the short term.

The recent weakening in house price growth is in line with broader market data on transactions and mortgage lending. At the UK level, the most recent data shows that total transactions have fallen from around 75,000 in February last year to around 64,000 in February this year. As shown in Table 3.1, sales volume declines were experienced across all UK regions in the year to February. The falls in sales from the year before are most stark in London and the South East.

Looking ahead to the remainder of 2018, we anticipate that this lacklustre housing market activity could begin to weigh further on house price growth.

Figure 3.1 – UK house price inflation since 2005



Source: ONS, Land Registry

Regionally, London house prices have experienced the largest downturn to date.

London house price growth is now the weakest of any region. The capital consistently had the fastest growing house prices over the period from May 2012 to April 2015 but, since then, London house price growth has fallen sharply. For example, annual price growth to March 2016 was around 15% in London, but for March 2018 the equivalent figure was -0.5%. Elsewhere, however, regional house price growth has been more resilient. Our regional house price projections for 2018 onwards are set out in detail in Section 3.2 below.

Table 3.1: Regional housing sales volume change in year to February 2018

Region	Year-on-year change in sales volumes
Wales	-8.6%
Scotland	-9.1%
Northern Ireland	-12.4%
London	-23.9%
South East	-19.7%
South West	-11.9%
North East	-16.2%
North West	-12.0%
West Midlands	-6.9%
East Midlands	-10.1%
East of England	-17.4%
Yorkshire and the Humber	-12.9%
UK	**-14.3%**

Source: ONS, Land Registry

2 April 2018 is the most recent data point available at the time of publication.
3 Complete sales data typically lags two months behind the initial house price estimates. The most recently available sales data is therefore for February 2018 at the time of writing.

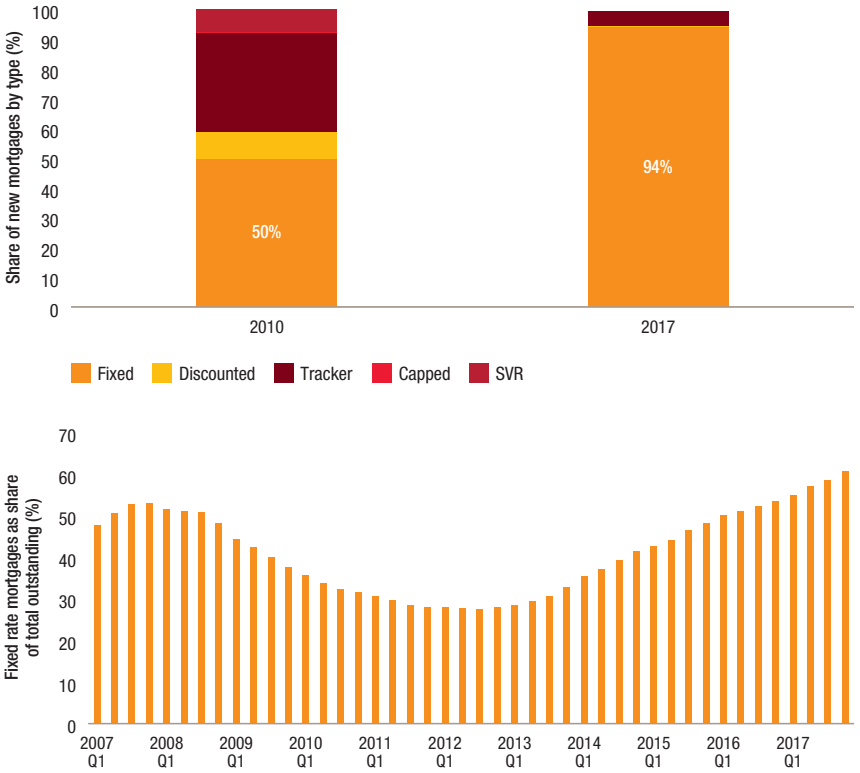
Box 3.1 – The impact of fixed rate mortgages on household budgets

In recent years there has been substantial shifts in the UK mortgage market. First, the cost of borrowing has continued to fall. Homebuyers and those seeking re-mortgage can now access rates of around 1.5% on 2-year fixed mortgages. The cost of borrowing on longer-term mortgages has also continued to decline: for example, the typical interest rate on a 5-year fixed rate mortgage has nearly halved from around 3.75% in mid-2014 to around 2% now[4].

Second, there has been a surge in the popularity of fixed-rate mortgages. As shown below, the share of new mortgages that are fixed-rate has increased from 50% in 2010 to 94% in 2017 (see left hand chart in Figure 3.1.1). This recent upward trend has helped to boost the share of all mortgages that are fixed-rate to over 60% from under 30% in 2012 (see right hand chart in Figure 3.1.1). As we head into 2018, that share of outstanding fixed rate mortgages looks likely to increase even further.

This trend means that fewer households will feel an immediate squeeze on their budgets from any future interest rate rise. For many, the impact may not be felt until some years later[5]. Extrapolating data on home ownership from the English housing survey to the whole of the UK, we estimate that only around 28% of all UK households now have a mortgage (others will own outright or rent).

Figure 3.1.1 – Share of fixed rate mortgages for new mortgages and as a % of the overall stock of mortgages



Source: Council of mortgage lenders

Therefore, assuming only around 40% of these mortgaged households now have a variable rate mortgage based on the data in Figure 3.1.2, we estimate that only around 11% of total households will immediately feel the impact of rate rises on their budgets. The equivalent figure in 2012 was more than twice as high at around 24%.

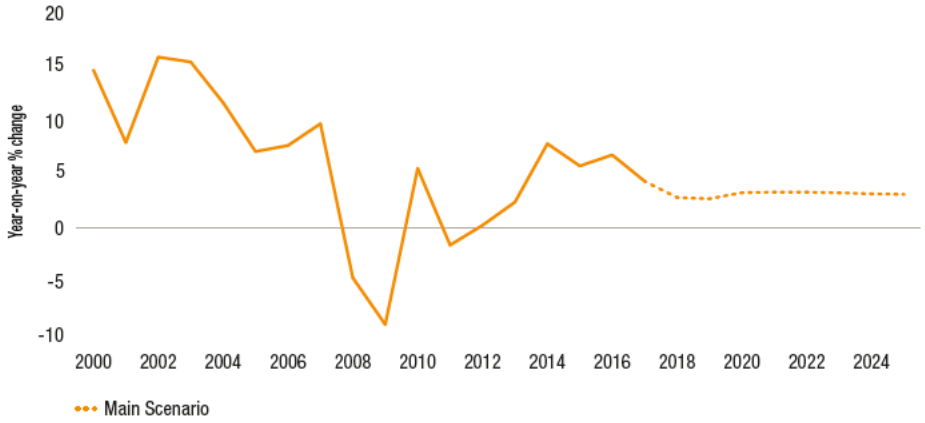
4 Source: Council of mortgage lenders, table IR3, figures for March 2018.
5 The FCA's December 2017 Data Bulletin noted that most popular length of fixed rate mortgage was 2 years, but that 5-year and 10-year fixed rate mortgages were increasing in popularity.

3.2 – UK and regional house price projections

In this section, we present our projections for house price inflation in the UK and regional markets. We use econometric time-series models to make our projections, as described in more detail in the technical annex to this article. These models link house prices to underlying drivers of the housing market and the economy more generally, such as earnings growth, housing supply and credit conditions. We then use these relationships to project how prices may evolve going forward.

In our main scenario we assume that real earnings growth is marginally positive in 2018, and that positive real earnings growth is then sustained out to 2025. In terms of credit conditions, we assume that mortgage lending flattens until 2020 as the UK economy goes through a period of Brexit-related uncertainty. We then assume mortgage lending resumes steady growth from 2021 onwards. Housing stock growth is assumed to remain at a broadly similar level to recent years over the projection period.

Figure 3.2 – UK house price projection in main scenario



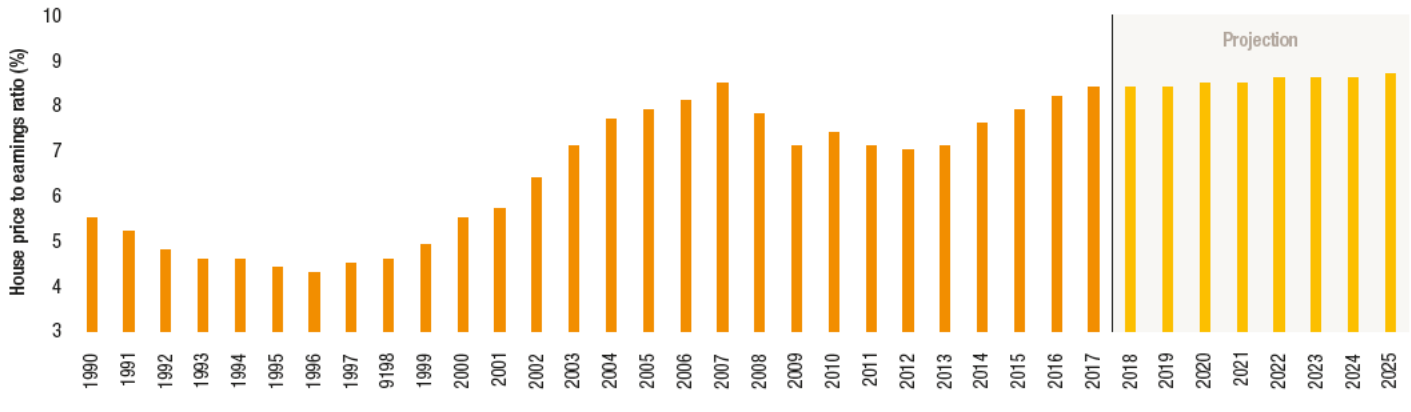
Source: ONS, PwC analysis

UK house prices are projected to grow steadily at around 3% per annum

In our main scenario, we project that house prices in the UK will grow at an average of around 3% this year. This is represents a cooling from recent years where UK house price growth has typically been greater than 5%. Looking beyond 2018 we project average annual UK house price inflation to remain close to the 3% mark in our main scenario as shown in Figure 3.2.

This main scenario projection implies that the average UK house price to earnings ratio would remain high, but relatively stable. This is captured in Figure 3.3 which shows that the average house price to earnings ratio in 2017 was 8.4, and that this is projected to rise only slightly to 8.7 by 2025 in our main scenario[6].

Figure 3.3 – House price-to-earnings ratio, 1990-2025

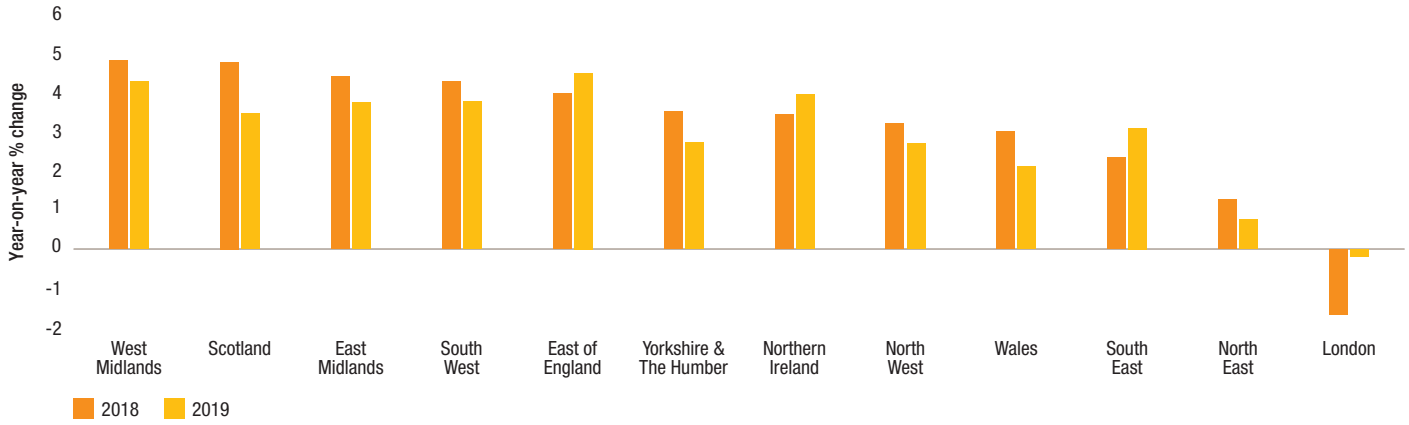


Source: ONS, PwC analysis

Note: Earnings are annualised average weekly earnings for the whole UK economy

6 Earnings here represents the average annualised earnings for an individual in the economy – meaning that average earnings reflects a mix of full-time and part-time work. Earnings would be higher if presented at the household level, rather than the individual level, or if they were just for full-time workers.

Figure 3.4 – Projected house price inflation by UK region in 2018-19



Source: PwC analysis

In our main scenario, the average price of a UK house in 2018 is around £227,000. This represents a £6,000 increase on the average 2017 price. Looking to the longer-term, our main scenario projects the average house will cost approximately £285,000 in 2025. As shown in Table 3.2 even after adjusting house prices for projected general consumer price inflation, there is still an upward trend. Specifically, in real terms at 2017 prices, we project that house prices could be around 9% more expensive by 2025 than in 2017.

Regionally, the average house price differs significantly, ranging from £480,000 in 2017 in London to just £127,000 in the North East of England.

In our main scenario we project that 2018 house price growth will be positive at moderate levels for most regions (see Figure 3.4). We project the strongest house price growth in the West Midlands this year and in the East of England next year, with the weakest house price trends being projected in London and the North East.

Table 3.2: UK house prices - main scenario projections

Year	Main scenario (% growth)	Main scenario (in cash terms)	Main scenario (real terms at 2017 prices)	Price to earnings ratio
2017 (actual)	4.5%	£221,000	£221,000	8.4
2018	2.9%	£227,000	£222,000	8.4
2019	2.8%	£234,000	£223,000	8.4
2020	3.4%	£242,000	£226,000	8.5
2021-2025	3.3% (average growth)	£285,000 (in 2025)	£241,000 (in 2025)	8.7 (in 2025)

Source: PwC analysis based on ONS house price index

In London, where affordability has been most stretched, we project negative average annual house price growth both this year and next. This reflects the downward pressure on property prices from:

- a very high deposit saving hurdle, particularly where Help to Buy (or the "bank of mum and dad") is unavailable;
- increased economic uncertainty related to Brexit acting as a drag on international capital flows into London property; and
- reduced numbers of housing transactions in the capital, which may be partly associated with the increased transaction costs imposed by the introduction of the stamp duty surcharge on second homes in 2016[7].

Our house price growth and average house price level projections by region are set out in more detail in Table 3.3. However, it should be noted that even greater uncertainty exists at the regional house price level compared to the UK level, and in particular, longer term projections should be treated with caution so we do not try to extend our regional analysis here beyond 2022[8].

Table 3.3: Projected regional house price growth and house price values (£000's) in our main scenario

	Average house price growth			Average house price values (£'000s in cash terms)	
Region	**2018**	**2019**	**2020-2022 (average)**	**2017**	**2022**
East of England	4.0%	4.5%	3.4%	283	340
East Midlands	4.4%	3.7%	3.4%	180	216
South West	4.3%	3.7%	3.6%	245	295
West Midlands	4.8%	4.3%	3.6%	185	225
South East	2.3%	3.1%	3.3%	318	369
North West	3.2%	2.7%	3.5%	155	182
London	-1.7%	-0.2%	2.6%	480	509
Wales	3.0%	2.1%	3.4%	150	175
Scotland	4.8%	3.4%	3.6%	143	172
Yorkshire & the Humber	3.5%	2.7%	3.4%	155	182
Northern Ireland	3.4%	3.9%	4.0%	128	154
North East	1.2%	0.7%	3.1%	127	141
UK	**2.9%**	**2.8%**	**3.4%**	**221**	**259**

Source: ONS, PwC analysis

7 Based on the average price of a London house as at April 2017 (£485,000), the Stamp duty surcharge would increase the overall stamp duty to be paid from £14,250 to £28,800, a greater than 100% increase.

8 This is because some unpredictable factors causing regional house price projection errors will be area-specific factors that are not correlated across regions, and so will tend to cancel out when looking at aggregate national house prices. The latter will therefore tend to have lower forecasting errors on average than projections for individual regions (whether for house prices or other economic variables).

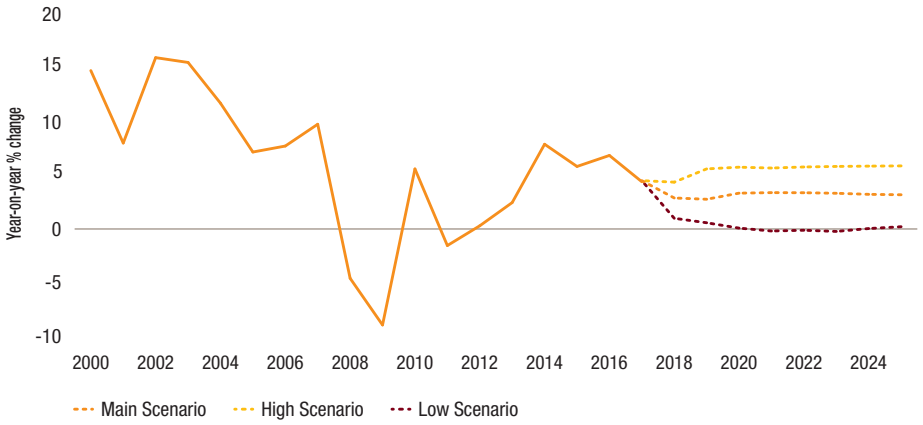
Alternative UK house price scenarios

Projecting house prices involves many uncertainties both about economic drivers like earnings and interest rates and about more intangible factors like buyer or lender confidence. To reflect these uncertainties, we therefore always develop two alternative house price inflation scenarios based on different inputs for the key model drivers (see Figure 3.5).

Our high price scenario assumes real earnings growth reverts relatively quickly to long-run historical trends, which provides a boost to housing demand. This scenario also assumes that credit conditions are more favourable with relatively strong mortgage lending growth to 2025. In this scenario annual house price growth is projected to average 4.4% in 2018, but then reverts to around 6% from 2019 onwards. This would represent a continued stretching of house price to earnings ratios at the UK level. In terms of price implications, the average house price could be over £340,000 by 2025 in this scenario.

Our low price scenario assumes that negative real wage growth reasserts itself and persists into the longer term, dampening housing demand. It also assumes that more challenging economic conditions (linked perhaps to a less smooth Brexit and/or rising global trade restrictions) are associated with a retrenchment in mortgage lending back towards 2014 levels. In this scenario, UK house price growth weakens substantially this year to around 1% and then remains subdued from 2019 onwards, with close to zero average house price growth. In this case, house prices would remain close to 2017 levels, and are estimated to be around £224,000 in 2025.

Figure 3.5 – Alternative UK house price inflation scenarios



Source: ONS, PwC analysis

3.3 – Assessing the local housing supply challenge

The general consensus of housing market analysts, which was also accepted by the government in its housing white paper last year, is that there is a serious shortage of affordable housing in the UK. The fact the UK average house price to earnings ratio has gone back to its pre-crisis peak (see Figure 3.4 above) is one indication of this problem and, in areas like London, Oxford and Cambridge, the affordability challenge is clearly even more severe.

Coupled with higher deposit requirements set by lenders, this poses particular challenges for potential first time buyers. In 2016, we estimated that potential buyers without any parental or other help might have to save for 19 years to buy their first home[9], up from just 3 years in the early 1990s (although mortgage rates were also much higher then, offsetting the benefits of lower initial deposits).

In an attempt to mitigate these affordability issues, the government has launched a number of first time buyer support schemes, including Help to Buy equity loans and ISAs and stamp duty discounts. However, while these schemes make housing more affordable in the short term, they also compound the underlying structural problem by further increasing housing demand. The government's focus more recently has therefore shifted towards longer term solutions to affordability aimed primarily at boosting housing supply.

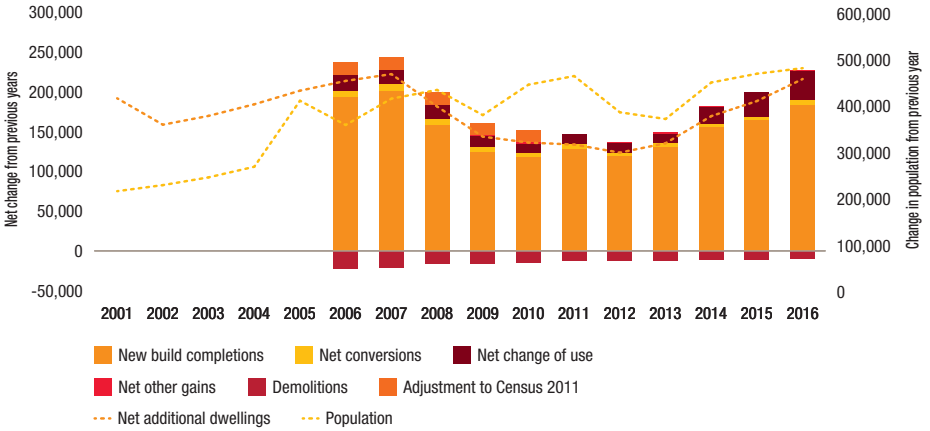
In particular, in his Autumn 2017 Budget, Phillip Hammond announced plans to increase net housebuilding in England to an average of 300,000 homes a year by the mid-2020s[10], up from around 220,000 in 2016. This builds upon a White Paper published by the government in February 2017, "Fixing our broken housing market," which sets out a range of policies that the government should introduce to reform the planning regime and other measures to boost the supply of new homes.

9 Assuming the deposit has to be raised entirely from their own savings without family assistance. See the July 2016 edition of UK Economic Outlook for full details of this analysis.
10 Source: Philip Hammond (2017). Autumn Budget 2017 – Philip Hammond Speech. Source: https://www.gov.uk/government/speeches/autumn-budget-2017-philip-hammonds-speech

Ultimately though housing market conditions vary widely across the country so it is not enough to set national targets; you also need to build the extra homes where demand is highest and the affordability challenges are most severe. We have therefore explored this issue at a local level in England[11] to understand in more detail the extent to which local housing shortage is linked to higher house price growth and where shortages are occurring. We do this by combining housing stock data with population[12] estimates to compare housing supply and demand trends at a local authority level across England.

To set the scene, we first look at the picture for England as whole. Figure 3.6 compares the net change in the dwelling stock in England with the net annual change in population, scaled to match given we are looking at absolute numbers. Table 3.4 then looks at percentage changes in these variables and calculates an 'excess housing demand growth' measure defined as population growth minus net housing stock growth.

Figure 3.6 – Net change in dwellings and population in England (2001-16)[13]



Source: ONS, DCLG, PwC analysis

From Figure 3.6 we can see that, by 2016, growth in the number of dwellings had returned to a similar level as prior to the financial crisis, following several years of subdued housebuilding growth. The number of dwellings made available through a change of use (in which industrial properties may be converted to residential) has also increased year-on-year since 2013, following a relaxation of regulatory restrictions on such conversions.

Nonetheless, the rate of population growth in England was consistently above housing stock growth from 2010-16 as Table 3.4 shows. This is in contrast to the period prior to 2010, where the percentage of net additional dwellings consistently outpaced population growth. At a high level, this supports the hypothesis that excess demand (linked to inadequate supply) has helped to stoke house price growth since the financial crisis, although we also recognise that other factors will have been in play here, including exceptionally low mortgage rates since late 2008.

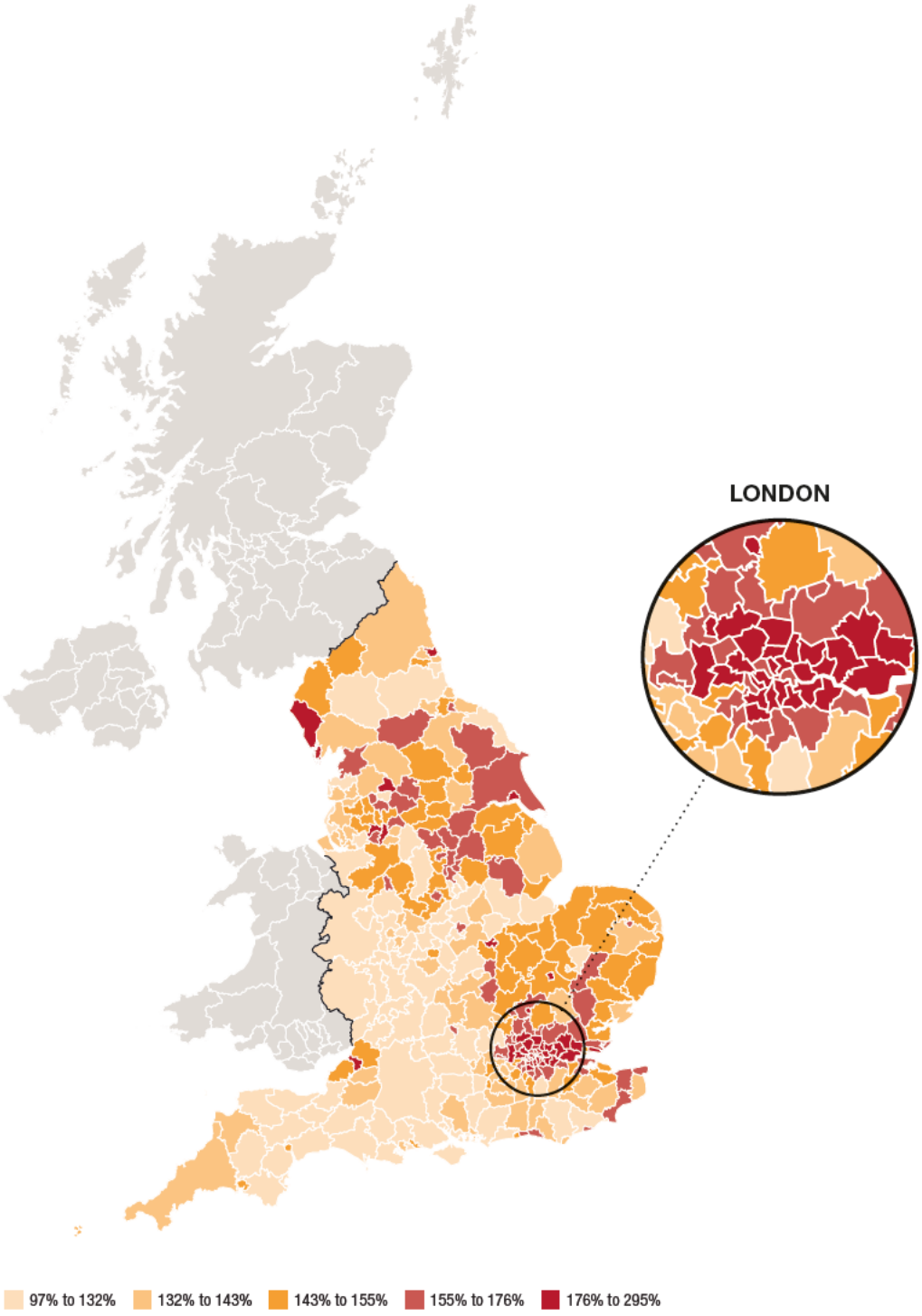
Table 3.4: Population growth, net housing stock change and estimated excess housing demand growth for England

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Population growth	0.5%	0.5%	0.5%	0.8%	0.7%	0.8%	0.8%	0.7%	0.9%	0.9%	0.7%	0.7%	0.8%	0.9%	0.9%
Housing stock growth	0.6%	0.7%	0.5%	1.0%	0.7%	1.2%	1.0%	1.0%	0.5%	0.4%	0.4%	0.3%	0.3%	0.4%	0.4%
Excess demand	-0.1%	-0.2%	0.0%	-0.2%	0.1%	-0.3%	-0.2%	-0.2%	0.4%	0.4%	0.4%	0.4%	0.5%	0.5%	0.5%

Source: ONS, DCLG, PwC analysis

11 We could only carry out the analysis for England as data for all countries within the United Kingdom were not consistently available at local authority level.
12 We also commissioned local authority level data on household numbers from the ONS but found that there was high volatility of these estimates from year to year at local level, perhaps due to small sample sizes. For the final version of this analysis, we therefore chose to focus on local data on population, which was less volatile over time than that for household numbers. We implicitly assume here that average household size is broadly stable over time. Additionally, we tested the conclusions against previous versions of the household dataset at a local authority level published by the DCLG and found a similar relationship between excess demand and price growth, and a similar regional picture.
13 Data for change in dwellings by component is only available from 2006.

Figure 3.7 – Distribution of cumulative house price growth rates in England, 2001-2016



Sources: ONS/Land Registry, PwC Analysis

While population growth has exceeded housing stock growth nationally across England recently, house price growth varies considerably as Figure 3.7 shows (for the longer period from 2001-16).

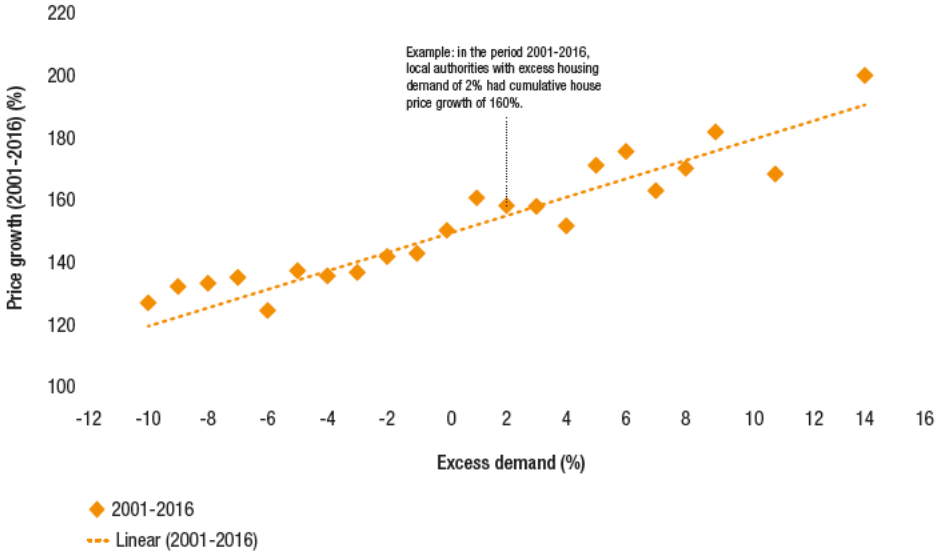
Local authorities with the highest house price growth over the period 2001-2016 are concentrated in London, with cumulative growth of 195% on average in the capital. This contrasts with other parts of the country, though even in the local authority with the lowest cumulative house price growth, Wyre Forest, this was still 97% over this period, about half the London average.

Local house price growth is correlated with excess housing demand growth

So what is causing house price growth to vary between areas? To explore this, we look at the relationship between excess housing demand growth and house price growth at local authority (LA) level. We then group LAs together by rounding excess housing demand growth in each LA to the nearest whole percentage point, and then plot the average house price growth for each group as shown in Figure 3.8. We define excess housing demand growth as the cumulative population growth less the cumulative housing stock growth over the specified period (for example, an excess demand of 2% could mean population has increased by 5% and housing stock by 3%).

The upward sloping trend line in Figure 3.8 shows that local authorities with excess housing demand growth over this period have, as you would expect, also tended to experience greater house price growth. However, there have been significant ups and downs in the economic and housing market cycle over this period. As such, we also break down this analysis into three 5-year periods to understand how the relationship evolved before, during and after the financial crisis (Figure 3.9).

Figure 3.8 – Excess housing demand growth and house price growth, 2001-2016[14]



Source: ONS, DCLG, PwC analysis

Figure 3.9 – Excess housing demand and price growth by 5-year period, 2001-2016

Source: ONS, DCLG, PwC analysis

14 Earnings here represents the average annualised earnings for an individual in the economy – meaning that average earnings reflects a mix of full-time and part-time work. Earnings would be higher if presented at the household level, rather than the individual level, or if they were just for full-time workers.

Figure 3.9 shows that the relationship between excess housing demand and house price growth was negative in the five years to 2006. At first sight, this is surprising but probably just indicates that, over this period, other factors had more influence on house price growth.

Since 2006, however, the relationship has been positive as expected, particularly since 2011. The dispersion of the excess demand variable has also increased over time, particularly in 2011-16 when the positive relationship has been strongest. Of course, there have been a range of demand and supply factors influencing house prices over this period, as summarised in Table 3.5, so we should not focus only on our excess housing demand measure, but this nonetheless does seem to have been a significant part of the story over this period.

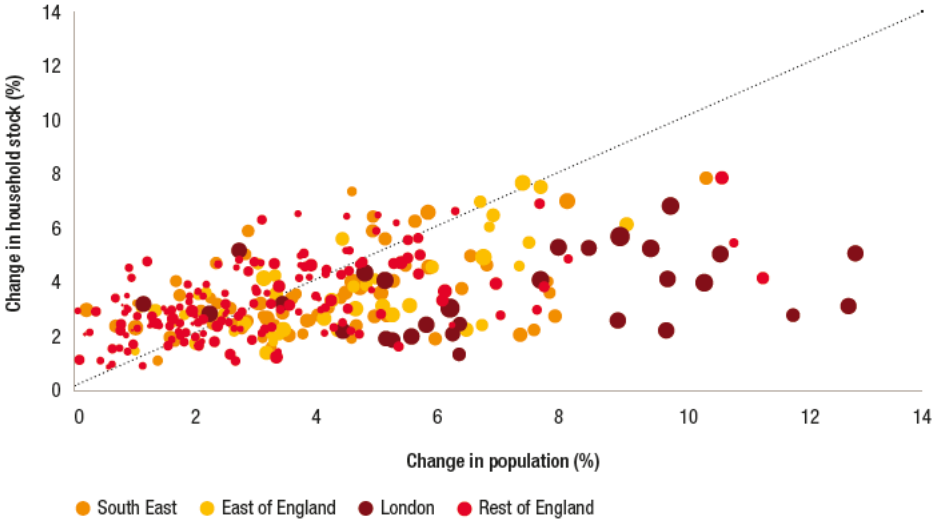
We delve a bit further into the local data in Figure 3.10, which compares housing stock growth and population growth in every local authority in England since 2011. The bubble size is proportional to house price growth over this period. The 45 degree line shows where supply and demand growth are balanced in percentage terms.

Table 3.5: Factors affecting house prices in England, 2011-2016

	Downward pressures on prices	Upward pressures on prices
Demand	• **Macro-prudential policy** has tightened since the financial crisis • Regulation of **buy-to-let** properties has been tightened over recent years, and tax treatment has become less favourable • **Real wage** growth has been weaker • **Stamp duty** has been increased on properties costing more than £937,000	• **Interest rates** have remained consistently low • **Stamp duty** has been abolished for first time buyers on properties up to £300,000, and is lower for everyone on properties up to £937,000 • **Foreign investment** has increased, particularly into London before 2016 • **Help to Buy** schemes introduced
Supply	• A **National Planning Policy Framework** has been introduced, making make the planning system less complex and more accessible • Organisations such as **London Land Commission** has been established, which identify public sector brownfield land for development	• **Housebuilding** slowed following the financial crisis due to weaker economic climate • Fewer people are **moving house**, and choosing to improve them instead

Sources: PwC

Figure 3.10 – Change in population and housing stock in English local authorities, 2011-2016



Source: ONS, DCLG, PwC analysis

Figure 3.10 shows that high growth in population and high excess housing demand were particularly acute in London, illustrated by 85% of London local authorities being to the right of the 45 degree line. Local Authorities in the South East and East of England also experienced relatively high price growth and tended to be to the right of the 45 degree line, but the trend is less pronounced than for London. In England as a whole, half of local authorities had excess demand (i.e. were right of the line) and half did not. This suggests that the supply problems are very much about not building houses in the right place and less so about an overall supply shortage.

Whilst the result that too few homes have been built in London to keep up with population growth is not a surprise, it does enable us to estimate how large the shortfall has been and where it has been most apparent. In Table 3.6 we present figures for the five London local authorities with the greatest excess demand growth and their cumulative housing shortfall from 2011-2106. Overall in London we estimate that an additional 110,000 new homes between 2011 and 2016 would have been needed to match the population growth that was experienced.

Table 3.7 repeats this analysis for the five English local authorities outside London with the highest percentage excess housing demand growth.

In other English local authorities, housing stock growth does not appear to have been a constraint. Demand side factors, such as very low interest rates, rising employment since 2012 and Help to Buy schemes, may be the primary cause of house price increases.

However, it is possible that the housing being built in these areas is not of an appropriate mix (e.g. too many small properties or premium properties), which would make the effective growth in the housing stock smaller. If this is the case, local house building targets may still be beneficial to these areas as well as hot spots like London or Oxford and Manchester.

Table 3.6: Excess housing demand growth and estimated housebuilding shortage for local authorities in London, 2011-2016[15]

Local Authority	Excess demand	Price Growth	Shortfall
Tower Hamlets	12%	60%	12,000
City of Westminster	10%	63%	11,000
Camden	9%	38%	9,000
Islington	8%	56%	8,000
Kingston upon Thames	8%	60%	5,000
London (including all boroughs)	**3%**	**61%**	**110,000**

Source: PwC analysis of ONS and DCLG data (numbers rounded to nearest percent or thousand)

Table 3.7: Excess housing demand growth and estimated housebuilding shortage for selected local authorities in England (excluding London), 2011-2016

Local Authority	Excess demand	Price Growth	Shortfall
Exeter	5%	18%	3,000
Guildford	5%	37%	3,000
Oxford	5%	45%	3,000
Runnymede	5%	42%	2,000
Manchester	5%	23%	10,000

Source: PwC analysis of ONS and DCLG data (numbers rounded to nearest percent or thousand)

15 We exclude City of London from this table as it is an extreme outlier.

Future declines in population growth may help alleviate supply pressures, but housing supply needs to expand to cover past backlogs

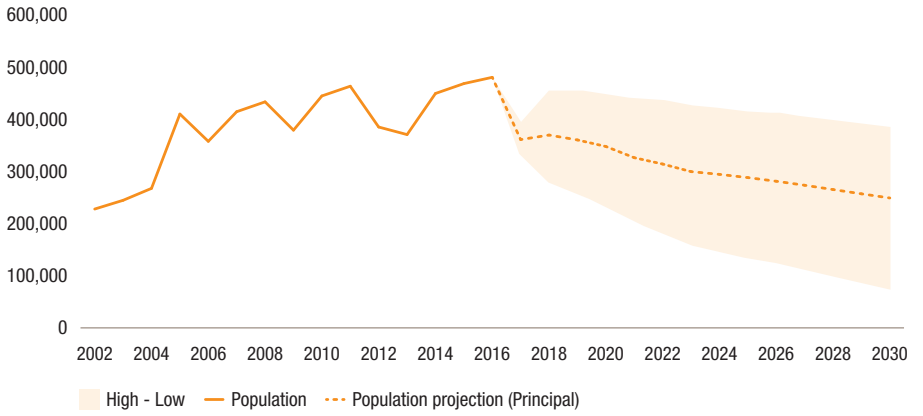
Looking ahead, population growth rates in England are projected by the ONS to fall to below 250,000 a year by 2030 from recent rates of around 400,000 to 500,000 per annum (see Figure 3.11).

We would expect a reduction in the population growth rate to put downward pressure on the number of households and in turn on house prices. DCLG assume that a 1% increase in the population pushes house prices up by 2%, other things being equal, so affordability could improve as a result of declining population growth[16].

If we assume that demand for houses will increase proportionally[17] with the population between 2017 and 2030, then the government's target of building 300,000 new homes per year in England by the mid-2020s would be more than enough to match projected population growth.

However, this ignores the fact that there is a backlog of under-supply to be made up and that, even after that, current affordability levels need to be reduced if the government's long-term objective to get home ownership rates back on an upward trend is to be achieved. We should also note that, by international standards, UK housing stock growth has been relatively slow for many decades, as the analysis in Box 3.2 shows. All of this suggests that it is reasonable to aim for 300,000 new homes per year as a target for England as a whole, but it is important to target these new homes on locations where past under-supply has been most evident, as our local analysis above indicates.

Figure 3.11 – Population projections for England to 2030



Source: ONS, PwC analysis

16 Source: Ministry of Housing, Communities & Local Government (2018). *Analysis of the determinants of house price changes*
17 This assumes a constant average household size, which ONS data suggests has been broadly the case over the past two decades, remaining around 2.4 since 1996.

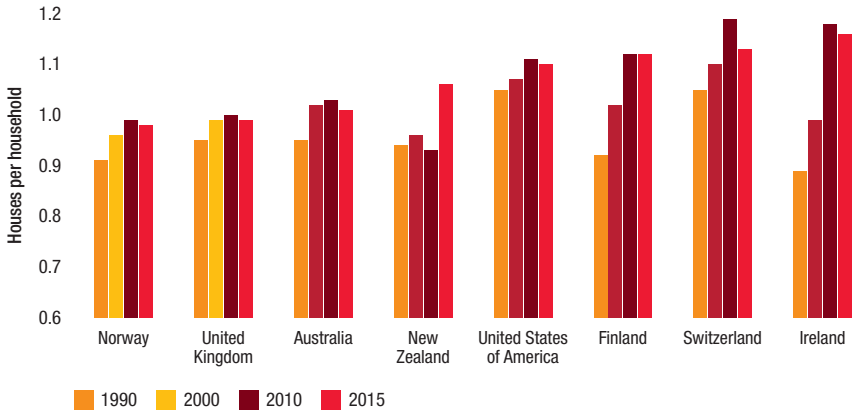
Box 3.2 – UK housing stock growth per household has been slower than other similar countries

We review data for the number of houses per household to understand how the market has changed in the UK and other comparable countries, as shown in Figure 3.2.1.

From Figure 3.2.1, we can see that the UK has experienced the lowest growth in the number of houses per household of similar international economies. While it had one of the highest rates of housing per household in 1990, it had one of the lowest rates in 2015, with around 1 house per household.

It is important to note that this analysis is only illustrative. It does not consider the average size of dwellings: while housing stock may have increased considerably in some countries, this is not to say that living standards (i.e. the quality of their homes) have been maintained. Further, other factors may be influencing the housing stock per household in some countries, such as holiday homes and cultural differences. Nonetheless, it is suggestive of the UK lagging behind in housing supply growth relative to population growth relative to other advanced economies since 1990.

Figure 3.2.1 – International comparison of housing stock per household, 1990-2015[18]



Source: UN, PwC analysis

18 We have assumed a constant household size to derive the number of households, using the latest household size figures from the UN. Over a longer period of time, average household size can change, though generally not by that much for mature advanced economies. ONS data shows, for example, that average household size in the UK has remained at around 2.4 since 1996.

3.4 – Summary and conclusions

UK house price growth remained relatively resilient in 2017 despite a weakening economic backdrop, but has shown signs of moderating during the first half of 2018, particularly in London.

In our main scenario, we project a further softening of UK house price growth to around 3% on average in 2018 and we expect this to continue at a similar average rate in the medium term to 2025. This implies that the average UK house price would rise from £221,000 in 2017 to around £285,000 by 2025. Price growth at this pace would mean that the ratio of house prices to earnings would remain broadly stable, but still at high levels by historical standards.

We expect that most regions will experience house price growth in 2018 broadly similar to that of the UK average except for London, where we project that house prices could drop by nearly 2% compared to 2017. In the medium term, however, London house price growth should pick up again, and a large affordability gap will remain between the capital and other UK regions.

We also considered the effect of the recent marked trend towards fixed rate mortgages, which in 2017 accounted for 94% of new mortgages compared to only around 50% in 2010. At the same time, only around 28% of UK households now have a mortgage, as opposed renting or owning their home outright. Combining these two factors, we estimate that only 11% of all UK households would now be immediately affected if mortgage interest rates rose, compared to around 24% in 2012. This would be a reason for the MPC not to be overly concerned about small rate rises causing significant economic damage.

Persistently rising house prices can be driven by a number of factors, but one of these has been a lack of new housing supply. To further investigate this we have carried out new analysis at local authority level across England, which suggests a clear link between lack of new housing supply, relative to population growth, and local house price growth since 2011. This has been particularly marked in London, where we estimated around 110,000 additional homes would need to have been built between 2011 and 2016 to keep up with population growth.

Looking ahead, if the government can achieve its target of building 300,000 new homes a year in England, then this should exceed the increase in housing demand from projected population growth and should therefore start to make up the backlog from past under-supply. But our local analysis suggests that these homes need to be built where demand is highest in London and the South East and East of England to prevent a further worsening of affordability in those regions. Local targets need to be set and met for housebuilding, linked to supporting infrastructure development, as well as national targets.

Technical annex: Modelling methodologies

UK house price projections

Our analysis focuses on the new ONS and Land Registry house price indices. Data from the ONS vary from those provided by Nationwide and Halifax, though broad trends tend to be similar over time. We focus on the ONS data as they cover a larger sample size, given that Nationwide and Halifax base their indices only on their own mortgage approvals.

The PwC house price model consists of two parts: a long run equilibrium equation and a short run error correction model that indicates how house prices adjust back towards this equilibrium level.

In the long run, we found that real house prices were driven by three key variables: real annual earnings, the ratio of the housing stock to the population ('supply') and a variable which reflects general credit conditions. Monetary values are deflated into real (inflation adjusted) terms using CPI.

In the short run, we found that changes in real house prices were driven by: deviations from the long run equilibrium; changes in real annual earnings; changes in credit conditions; and the previous period's mortgage interest rate (cost of borrowing). The coefficients for these model variables and other summary statistics for both models are shown in the tables below.

The parameters of the model were estimated using the standard ordinary least squares (OLS) econometric technique based on annual data for 1975-2017.

Regional house price projections

The regional house price projections relate to the main scenario only, but it should be borne in mind that uncertainties are even greater at the regional than the national level, so these projections can only be considered illustrative. Our regional projections are based on a regression between house price to earnings ratios and mortgage rates. The results are then adjusted so as to aggregate to the UK average estimates.

Long run model (Cointegrating equation)

R-squared = 0.93

Dependent variable: Real house prices	**No. of observations=43**	
	Coefficient	t-statistics
Earnings	17.3	11.1
Supply	-1611.3	-4.9
Credit	11728.5	1.7
Constant	357893.4	3.5

Short run model

R-squared = 0.63

Dependent variable: Change in Real house prices	**No. of observations=42**	
	Coefficient	t-statistics
L. co-integrating equation residual	-0.10	-1.6
D.Credit	24646.2	4.6
D.Earnings	7.3	3.7
L.Mortgage rate	-604.3	-2.5
Constant	6375.6	2.8

Note: 'D' refers to the first difference of a variable (i.e. change on previous year). 'L' refers to the lagged value of a variable in the previous year.

4 – What will be the net impact of AI and related technologies on jobs in the UK?[1]

Key points

- AI and related technologies such as robotics, drones and driverless vehicles could displace many jobs formerly done by humans, but will also create many additional jobs as productivity and real incomes rise and new and better products are developed.
- We estimate that these countervailing displacement and income effects are likely to broadly balance each other out over the next 20 years in the UK, with the share of existing jobs displaced by AI (c.20%) likely to be approximately equal to the additional jobs that are created.
- Although the overall effect on UK jobs is estimated to be broadly neutral in our central projections, there will inevitably be 'winners' and 'losers' by industry sector.
- The sectors that we estimate will see the largest net increase in jobs in the long run include health (+22%), professional, scientific and technical services (+16%) and education (+6%). The sectors estimated to see the largest net long-term decrease in jobs due to AI include manufacturing (-25%), transport and storage (-22%) and public administration (-18%).
- Based on differences in industry structure alone, our projections do not imply large variations by region, though our central estimates imply a small net job gain in London offset by small net losses in the North and Midlands. But other factors could lead to larger regional variations than captured by our analysis.
- Although our central estimate is that the net effect of AI on jobs will be broadly neutral, there are many uncertain factors that could tip the balance towards more optimistic or pessimistic scenarios. We identify some policy areas where action could help to maximise the benefits (e.g. boosting research funding for AI, ensuring competition is adequate to ensure productivity gains are passed on to consumers) and/or mitigate the costs in terms of impacts on jobs (e.g. a national retraining programme for older workers as well as renewed efforts to build STEAM[2] skills in schools and universities).

Introduction

Societies have worried about technological unemployment ever since the Industrial Revolution of the late 18th century. These concerns have generally not been borne out by historical experience as new technologies have stimulated economic growth, creating new demand for labour to replace jobs displaced in the short term. However, the latest advances in Artificial Intelligence (AI)[3] and related technologies such as robotics have the potential to surpass human capabilities in a broader range of cognitive skills, replacing our 'minds' as well as our 'muscles'. So could this time be different?

In this article we take an objective look at the evidence on this for the UK and weigh up the potential for AI to replace human workers, which we refer to as the 'displacement effect', against the ability for AI to create additional jobs, through a mechanism we refer to as the 'income effect'.

We begin by setting out the background to, and conceptual framework for, the analysis (Section 4.1). Next, we present our estimates of the displacement effect (Section 4.2) and the income effect (Section 4.3). In Section 4.4 we weigh these effects against each other, both for the UK economy as a whole and by industry, and in Section 4.5 we present some illustrative estimates of potential regional job impacts based on differences in industry structure across regions. Section 4.6 then explores the uncertainties around our central estimates by constructing alternative optimistic and pessimistic scenarios.

In Section 4.7 we discuss potential policy implications and Section 4.8 summarises the analysis and concludes. Further details of our methodology are provided in a technical annex.

1 This article was written by John Hawksworth and Yuval Fertig of the PwC economics practice, drawing on earlier data analysis by Tom Markovitch and Richard Berriman.
2 STEAM = science, technology, engineering, art & design, and maths.
3 For brevity we sometimes refer just to 'AI' in this article, but this should be taken to encompass a broader range of technologies including not just AI per se but also robotics, drones, driverless vehicles and other digital innovations aimed at 'smart automation'.

4.1 – Background to and framework for the analysis

We are all familiar with the way in which technology can automate jobs: inventions come along that perform tasks more cheaply, better or more reliably than humans, and so firms replace humans with these labour-saving technologies. We refer to this as the 'displacement effect' and examples are everywhere. Going back in time, most UK workers in the mid-19th century were employed in agriculture and manufacturing, but together these now account for only around 10% of UK employment, which is now dominated by services. Automation has played a key role in boosting productivity both on farms and in factories, so allowing more to be produced by many fewer workers[4].

More recently, we have seen many middle management and back-office jobs automated using computers, with more to come as AI is deployed more widely across the economy. Automated trading has already displaced many jobs in financial markets and driverless vehicles have the potential to do the same in transport in the coming decades, while robots spread from factories to construction sites and warehouses in increasing numbers.

But as well as displacing jobs, new technologies like AI also create them, although the way in which this happens is more complex and less direct. The most significant effects generally come through the impact on (quality-adjusted) prices as labour-saving technologies allow firms to produce the same product at a lower cost[5].

To stay competitive, firms ultimately have to pass on most of these savings to consumers, which has the effect of increasing real income levels. Households can buy more with their money as a result and firms hire additional workers to respond to the extra demand. As well as reducing prices, labour-saving technologies also improve the quality of existing products and enable new products to be brought to market, which also create a need for additional workers. We refer to these types of mechanisms, through which technology ultimately creates jobs, as the 'income effect.

Figure 4.1 illustrates these countervailing forces. It shows how technology can lead to some job losses via the displacement effect, but also how this is counteracted by the income effect in the longer term. The question of whether AI will lead to technological unemployment boils down to whether the displacement effect of AI on jobs will exceed the income effect. We now estimate each in turn.

Figure 4.1 – How AI can both destroy and create jobs through the displacement and income effects

Sources: PwC

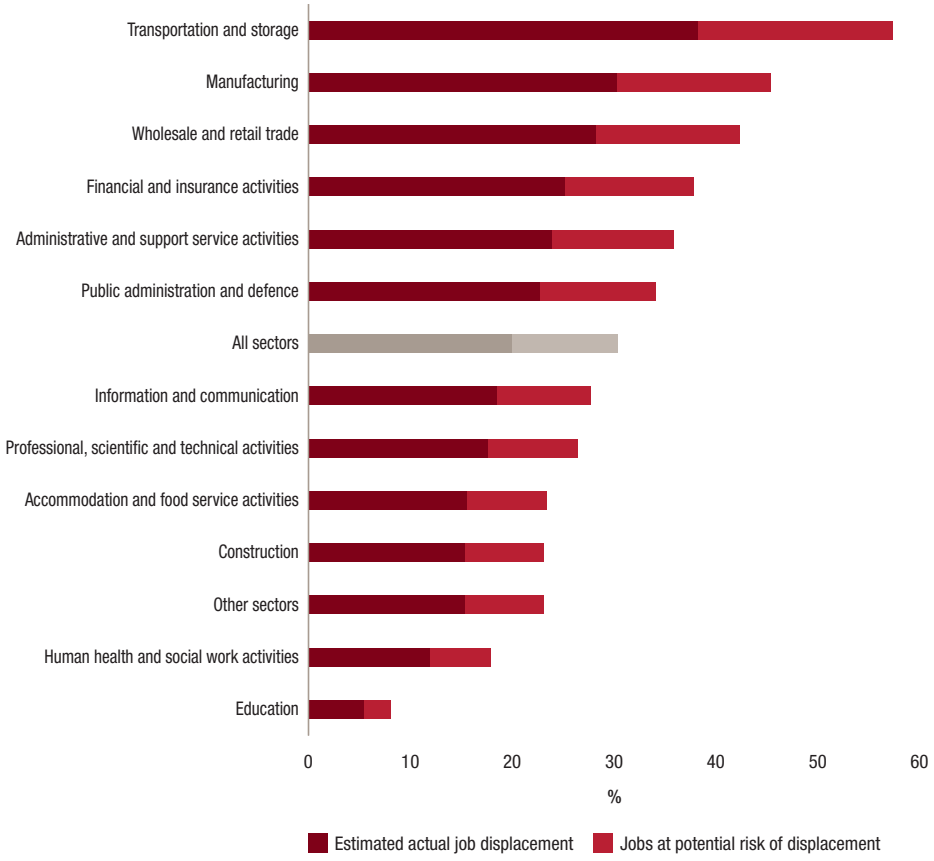
4 In addition, advances in transport and communications technology have allowed more food and manufactured goods to be imported from overseas, so reducing the need for UK-based production.
5 Or a higher quality product at the same (or lower) cost. For simplicity we refer to this as a (quality-adjusted) price reduction.

4.2 – The displacement effect

In their much-cited paper on the susceptibility of jobs to computerisation, Frey and Osborne (2013) considered a list of 702 occupations and used a mixture of expert judgement and machine learning techniques to estimate the probability that each would be automated[6]. Many analysts, including PwC, have since adopted some variant of this bottom-up approach, but estimates of the proportion of jobs at significant long-term risk of automation vary widely. Frey and Osborne's original estimate for the US was 47%, or around 35% for the UK, but more recently Arntz, Gregory and Zierahn (2016) came up with a much lower estimate of around 10% for both countries based on analysing tasks rather than occupations. Our own past estimates using the same OECD PIAAC survey data suggest that the proportion of existing UK jobs at high risk of automation could be up to 30% over the next 20 years, which places us within the range of the estimates mentioned above (see annex for more details of our methodology)[7].

Although we estimate that up to 30% of existing UK jobs could be at high risk of being automated, a job being at "high risk" of being automated does not mean that it will definitely be automated, as there could be a range of economic, legal and regulatory and organisational barriers to the adoption of these new technologies[8].

Figure 4.2 – The proportion of existing UK jobs that could be displaced in each sector over the next 20 years



Sources: PwC analysis using data from the OECD PIAAC survey

6 Frey, C.B. and M.A. Osborne (2013), 'The Future of Employment: How Susceptible are Jobs to Computerisation?', University of Oxford.
7 This is based on a detailed analysis of the task composition of UK jobs using the OECD's PIAAC database.
8 As discussed in more detail in our February 2018 report on job automation here: https://www.pwc.co.uk/services/economics-policy/insights/the-impact-of-automation-on-jobs.html

Based on our earlier probabilistic risk analysis, we think it is reasonable to scale down our estimates by a factor of two thirds to reflect these barriers, so our central estimate of the proportion of existing jobs that will actually be automated over the next 20 years is reduced to 20%. There is uncertainty over the correct scaling factor to use here, however, so we consider a range of alternative scenarios for this estimate in Section 4.6 below.

Automation rates will vary by industry sector as illustrated by our estimates in Figure 4.2. Our analysis implies that the transportation and storage sector could see the highest proportion of existing jobs at risk (nearly 40% even after scaling down as described in the previous paragraph) as driverless vehicles roll out across the economy over the next two decades. Sectors like health and education are projected to see relative low displacement effects, but no sector will be unaffected by automation.

These figures represent the total proportion of existing UK jobs (based on 2017 data) estimated to be automated by 2037, but we would expect some sectors to be hit earlier than others, due to the fact that certain types of AI will develop faster than others (e.g. algorithmic trading is already here while driverless cars will take much longer to roll out)[9]. We presented estimates of the timing of potential job losses in an earlier report, which we would expect to follow a typical 'S-curve' shape with relatively small impacts over the next few years but more substantial effects as we look a decade or more ahead[10].

In this article, however, we are concerned with the long term effects of AI, so we focus on the impact over 20 years, giving time for both the displacement and income effects to take effect fairly fully across the economy. We should recognise, however, that the precise timing of these effects is uncertain, as reflected in the scenario analysis in Section 4.6 below.

4.3 – The income effect

AI creates jobs through its effect on the cost, quality and range of products, which boosts real income levels and creates additional demand for new jobs, as described above. In PwC's 2017 'Sizing the Prize' report we evaluated thousands of potential use cases for AI across all sectors of the economy and combined these in a global econometric model to value the total impact of AI on GDP for the world economy as a whole as well as major individual economies including the US, China and the UK. For the UK, the headline estimate was that GDP could be boosted by around 10% by 2030[11] through application of AI and related technologies (the global average boost to GDP was higher at around 14%, due in particular to very high potential benefits from AI in China).

For this article we have converted this value into jobs numbers by, first, projecting UK output (GVA) growth by industry sector over the next 20 years, and second, estimating the proportion of GVA growth that is attributable to AI, as implied by the estimates in our 'Sizing the prize' report. We assume here that the projected increase in jobs due to the income effect will be the same as the projected increase in GVA since productivity gains are already accounted for through the displacement effect[12]. We explain these steps in more detail in the annex.

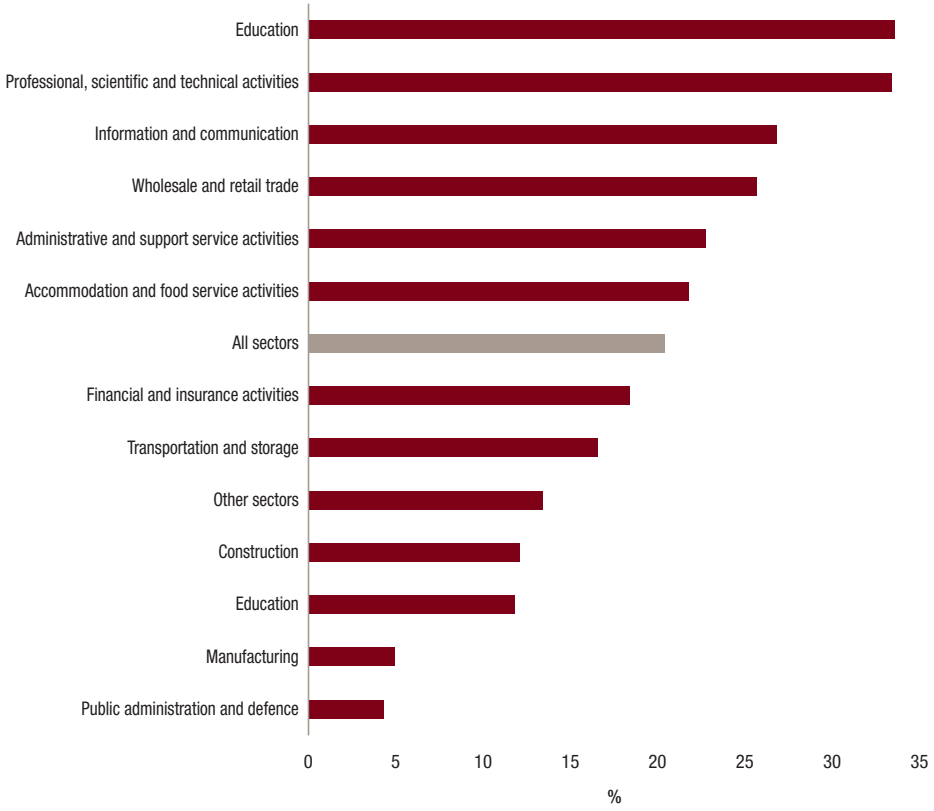
9 For example, our previous analysis finds that the financial sector will see the most job losses for its size by 2030, but will be exceeded by the transport, manufacturing and retail sectors by 2037.
10 PwC, 'Will robots really steal our jobs? (2018): https://www.pwc.co uk/economic-services/assets/international-impact-of-automation-feb-2018.pdf
11 For the present report, we extrapolate this estimate forward from 2030 to 2037.
12 Because we are capturing productivity effects on labour input through the displacement effect, we assume in estimating income effects that the potential percentage increase in jobs from this source is the same as the estimated percentage increase in GVA attributable to AI. This is the same general approach as in the Oxford Economics/Cisco report on 'The AI Paradox' (December 2017) for the US, although they further assume that the income effect on jobs exactly offsets the negative displacement effect, which is a relatively restrictive assumption to make 'a priori'.

The headline result of our analysis is that we expect 46% of long-term UK output growth will come from AI (although this may be higher or lower depending on the sector). Since we are expecting overall UK GDP (and GVA) growth of just under 2% per year on average over the next two decades, this implies that AI contributes around 0.9% growth per annum on average. Over 20 years this serves to increase the number of jobs by around 20% of current levels (after allowing for compounding effects over time). The sectoral breakdown of our income effect estimates is presented in Figure 4.3.

The analysis suggests that there are two notable outliers at both ends of the spectrum: the health sector and the professional, scientific and technical services sector stand to benefit the most from AI in terms of the proportion of additional jobs created, whilst manufacturing and public administration and defence stand to benefit the least.

In general, the sectors benefiting most are those that combine strong underlying demand growth with a relatively high propensity to see benefits from application of AI and related technologies, based on the detailed use case analysis in our 'Sizing the Prize' report.

Figure 4.3 – Estimated additional UK jobs that could be created by AI and related technologies in each sector over the next 20 years, expressed as a percentage of existing jobs in 2017



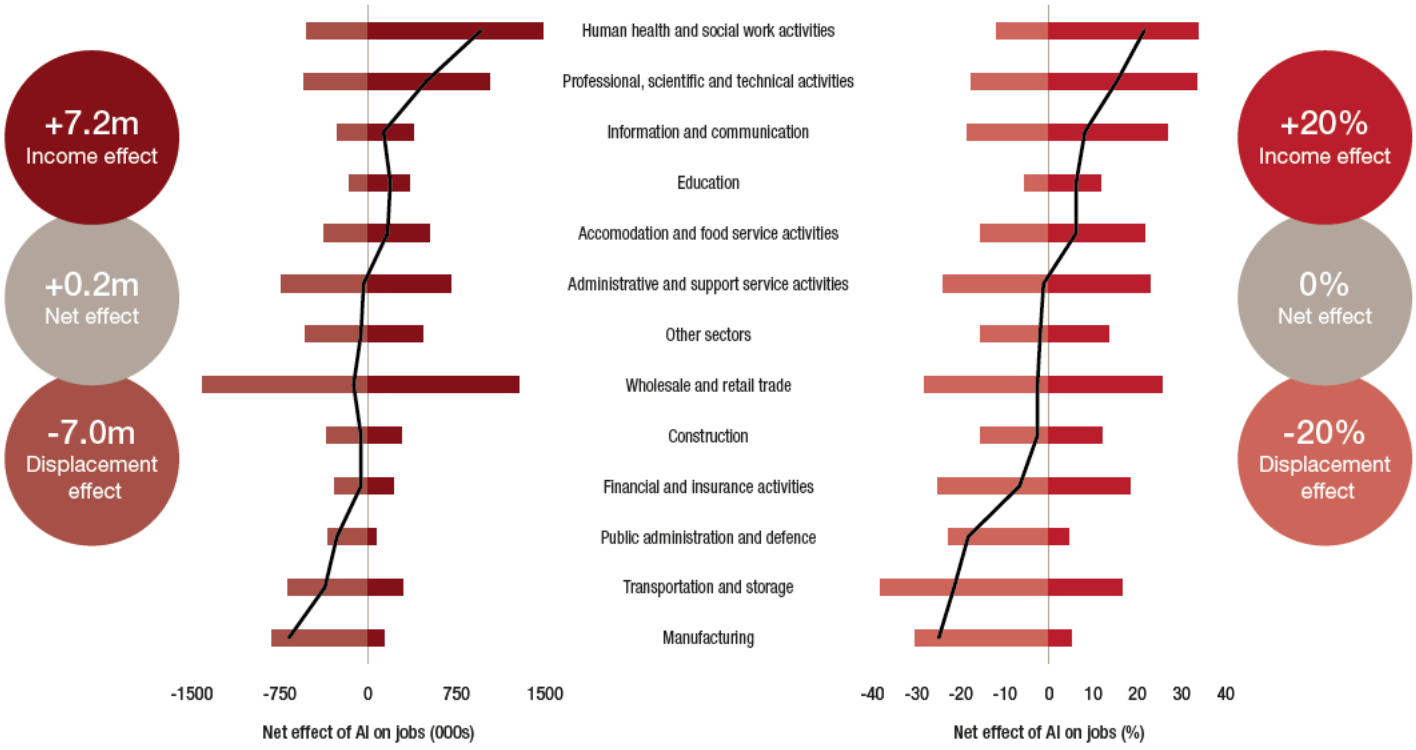
Sources: PwC analysis

4.4 – The net effect of AI on jobs

We can now combine the above estimates of the displacement and income effects to get an estimate of the net UK jobs impact of AI as shown in Figure 4.4 (the net effect is given by the solid line in the charts, with the bars showing the displacement and income effects by sector). We should stress that these are not forecasts of what will happen to total UK employment over the next 20 years: our focus in this article is just on the potential impact of AI on jobs, not on the many other factors that could affect total UK employment over this period.

Our estimates suggest that AI will not lead to technological unemployment as we project that it will displace around 20% of existing UK jobs by 2037, but create a similar number. In absolute terms, around 7 million existing jobs are projected to be displaced, but around 7.2 million are projected to be created, giving a net jobs boost of around 0.2 million. However, as our later scenario analysis shows, this net positive effect of less than 0.1% is too small to be statistically significant relative to the uncertainties surrounding any such long-term employment projections.

Figure 4.4 – Estimated net effect of AI on UK jobs by industry sector



Sources: PwC analysis

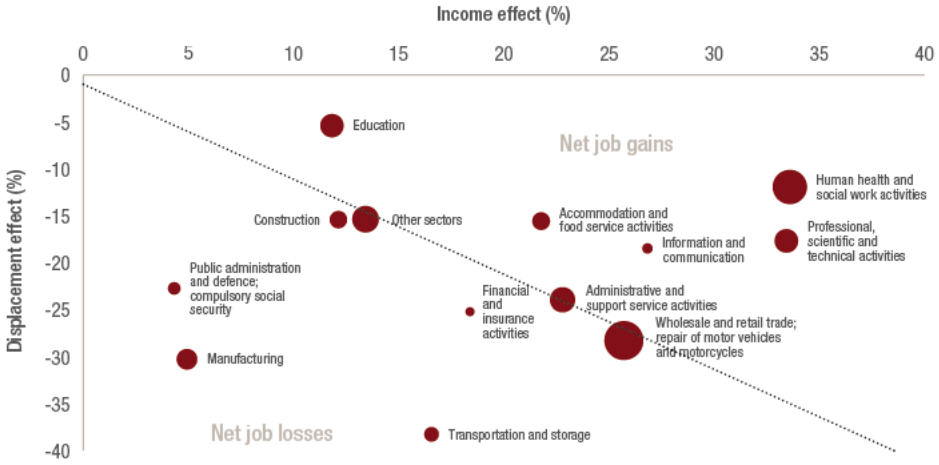
Whilst our central estimate suggests that the overall net effect of AI on UK jobs may be broadly neutral, this is not true for individual sectors. The most positive effect is seen in the health and social work sector, where we expect the number of jobs to increase by nearly 1 million, equivalent to around 20% of existing jobs in this sector. On the other hand, we estimate that the number of jobs in the manufacturing sector could be reduced by around 25% due to AI and related technologies, representing a net loss of nearly 700,000 jobs. Further details of our sectoral results are set out in Table 4.1.

Table 4.1: Estimated job displacement and creation from AI by industry sector (2017-37)

Industry sector	% of existing jobs (in 2017)			Number of jobs (000s)		
	Creation	Displacement	Net effect	Creation	Displacement	Net effect
Health and social work	34%	-12%	22%	1,481	-526	955
Professional, scientific and technical	33%	-18%	16%	1,025	-541	484
Information and communication	27%	-18%	8%	388	-267	121
Education	12%	-5%	6%	345	-158	187
Accommodation and food services	22%	-16%	6%	518	-371	147
Administrative and support services	23%	-24%	-1%	698	-733	-35
Other sectors	13%	-15%	-2%	466	-533	-67
Wholesale and retail trade	26%	-28%	-3%	1,276	-1,403	-127
Construction	12%	-15%	-3%	279	-355	-75
Financial and insurance activities	18%	-25%	-7%	209	-286	-77
Public administration and defence	4%	-23%	-18%	64	-339	-274
Transportation and storage	17%	-38%	-22%	296	-683	-387
Manufacturing	5%	-30%	-25%	133	-814	-681
Total	**20%**	**-20%**	**0%**	**7,176**	**-7,008**	**169**

Source: PwC analysis

Figure 4.5 – Income effect vs displacement effect on jobs in 2037 by sector (size of bubble is proportional to 2017 employment levels)



Sources: PwC analysis

The net job gainers and losers by sector are presented in a different format in Figure 4.5. Sectors towards the bottom left of the chart (e.g. manufacturing) are expected to have the largest percentage net loss in jobs. Sectors towards the top right of the chart (e.g. health) are expected to see the largest net job gains, while those towards the bottom right (e.g. wholesale and retail) show the largest job 'churn' with high levels of both displacement and job creation.

The sectors that are likely to benefit the most from AI are highly 'human' sectors and highly technical sectors.

Human health and social work activities

We estimate that this sector could see the largest net job gains. This is driven by a high income effect, as health is a 'superior good' that will be increasingly in demand as society becomes richer and the UK population ages. Some healthcare jobs will be displaced (e.g. in routine analysis and diagnosis) but many more are likely to be created as real incomes rise and patients still want the 'human touch' from doctors and nurses (albeit that their capabilities will be enhanced by AI and robotics).

Professional, scientific and technical activities

In this sector we estimate that AI could create about twice as many jobs as it displaces in the long run. These jobs are likely to take the form of what MIT researchers have referred to as 'explainers' and 'sustainers' – jobs involved with designing, operating and communicating AI and related technologies[13]. Based on historical evidence, this sector should show relatively fast growth in demand as real incomes rise, so the indirect income effect of AI will be critical in boosting long-term employment in this sector, even if there are automation-related job losses in some areas just involving data analysis in the shorter term. A key insight here is that, as prediction becomes cheaper due to advances in machine learning, so expert human judgement to assess what action to take for a given set of probabilistic predictions will become more valuable[14].

Education

Teaching requires high levels of interpersonal skills that cannot easily be replaced by AI systems or robots, although they can be complemented by them to meet projected rising demand for education over time. As such, we only expect around 5% of educators to be displaced by AI, more than offset by job creation of over 10%. Human teachers will tend to specialise in more 'human' areas (e.g. personal coaching, supervising group work, subjects like art, music, drama and sport), while machines take on the more routine tasks like marking homework and conducting multiple choice tests.

13 MIT, 'The Jobs that Artificial Intelligence Will Create' (2017): https://sloanreview.mit.edu/article/will-ai-create-as-many-jobs-as-it-eliminates/

14 This point is discussed at length by Ajay Agrawal, Joshua Gans and Avi Goldfarb in their excellent recent book 'Prediction Machines: The Simple Economics of Artificial Intelligence' (HBR Press, 2018).

The sectors that are more likely to see net job losses from AI/automation are those involving a high degree of repetitive and routine tasks

Transportation and storage

We estimate that automation could displace almost 40% of existing jobs in this sector by 2037 as driverless vehicles roll out across the economy and warehouses become increasingly automated, but might only create less than half this number of additional jobs through income effects.

Manufacturing

We estimate that there could be around 25% fewer jobs in the manufacturing sector by 2037 as a result of automation, continuing a long-established trend of recent decades. Many of these jobs may be displaced in early waves of AI as routine factory tasks continue to be replaced by algorithms and robots, over and above what has already happened.

Public administration and defence

Clerical tasks in the public sector are also liable to be replaced by algorithms as public finances remain under strain with an ageing population, leading to a continuing focus on efficiency gains through automation of routine tasks. There may be further use of drones, AI systems and related technologies in defence, although there will also be new job creation here for technology experts (e.g. in cybersecurity).

4.5 – Regional differences in AI job impacts

Our analysis reveals that the costs and benefits of AI are unevenly distributed across industry sectors. Since the industry mix of employment varies across different parts of the UK, this has implications for the regional impact of AI/automation on jobs.

Table 4.2 shows the results of applying our analysis at a regional level (assuming that the only difference is due to the varying industrial structure of employment across regions).

According to this analysis, the net effect of AI on jobs may not vary that much across the UK. London has the most positive estimated impact (+2%), which benefits from being home to 28% of the UK's professional, scientific and technical activities, as well as 31% of the UK's information and communication sector. In contrast, regions in the North and Midlands, with higher weightings towards relatively automatable industrial jobs, have marginally negative estimated net impacts, but always by only around 1% or less of existing job numbers.

Table 4.2: Estimated regional jobs impact of AI based only on variations in industry mix

Region	% of existing jobs (in 2017)			Number of jobs (000s)		
	Creation	Displacement	Net effect	Creation	Displacement	Net effect
London	22.0%	-19.7%	2.3%	1,297	1,159	138
South East	20.6%	-19.7%	0.8%	1,019	978	41
Wales	19.7%	-18.9%	0.7%	302	291	11
Scotland	20.2%	-19.6%	0.5%	558	544	15
South West	19.9%	-19.5%	0.4%	582	571	11
North East	20.0%	-19.8%	0.2%	239	237	2
East of England	20.4%	-20.3%	0.1%	648	646	2
North West	20.4%	-20.4%	0.0%	748	749	-1
West Midlands	20.1%	-20.4%	-0.3%	599	607	-8
Northern Ireland	19.4%	-19.8%	-0.4%	172	176	-4
Yorkshire and the Humber	20.0%	-20.4%	-0.4%	532	544	-12
East Midlands	19.5%	-20.7%	-1.1%	478	505	-27
Total	**20%**	**-20%**	**0%**	**7,176**	**-7,008**	**169**

Source: PwC analysis

The relatively small regional differences in Table 4.2 are what we would expect given that we are only looking at the effect of variations in industry structure across regions. In practice, there will also be variations due to other task characteristics of jobs within a particular sector that vary by industry sector (e.g. the typical tasks that account for financial services jobs in London may not be the same as those of financial services jobs in the North East or Northern Ireland). Unfortunately we do not have detailed data on the task composition of jobs at regional level because the OECD PIAAC data we use is only available at national level. But it is certainly possible that allowing for these other factors could lead to wider regional variations in net job impacts from AI than those shown in Table 4.2.

4.6 – Scenario analysis

In the above analysis we made two key assumptions:

1. To estimate the displacement effect, we assumed that, of the 30% of UK jobs estimated to be at potential high risk of being automated, only 2/3 will in fact be automated – i.e. 20% of existing jobs.

2. To estimate the income effect, we used an estimate from our earlier research that AI could contribute around 10% to UK GDP by 2030 and then calculated what this implied about the percentage contribution of AI to overall long-term UK GDP growth (46%).

We now vary these two key assumptions to construct a set of more and less optimistic assumptions:

1. For the displacement effect, we assume that, of the 30% of jobs at potential high risk of automation, the percentage that will in fact be automated ranges from 1/2 and 5/6, giving a range of 15-25% for the proportion of existing jobs (which seems plausible relative to other studies in this field).

2. For the income effect, we assume that AI could contribute between 7.5% and 12.5% of UK GDP by 2030, implying that the proportion of total GDP/GVA growth attributable to AI ranges from around 35% to around 57%[15].

Table 4.3 displays the estimated net effect of AI on UK jobs under each possible combination of these assumptions, giving nine possible scenarios in all. If both the pessimistic assumptions – that 25% of existing jobs are displaced, but only 35% of long-term UK GVA growth is attributable to AI – hold true, then we estimate that AI would displace around 3.6 million (10%) more jobs than it created. Conversely, if both the more optimistic assumptions hold true, we estimate that AI could create around 4 million (11%) more jobs than it displaces.

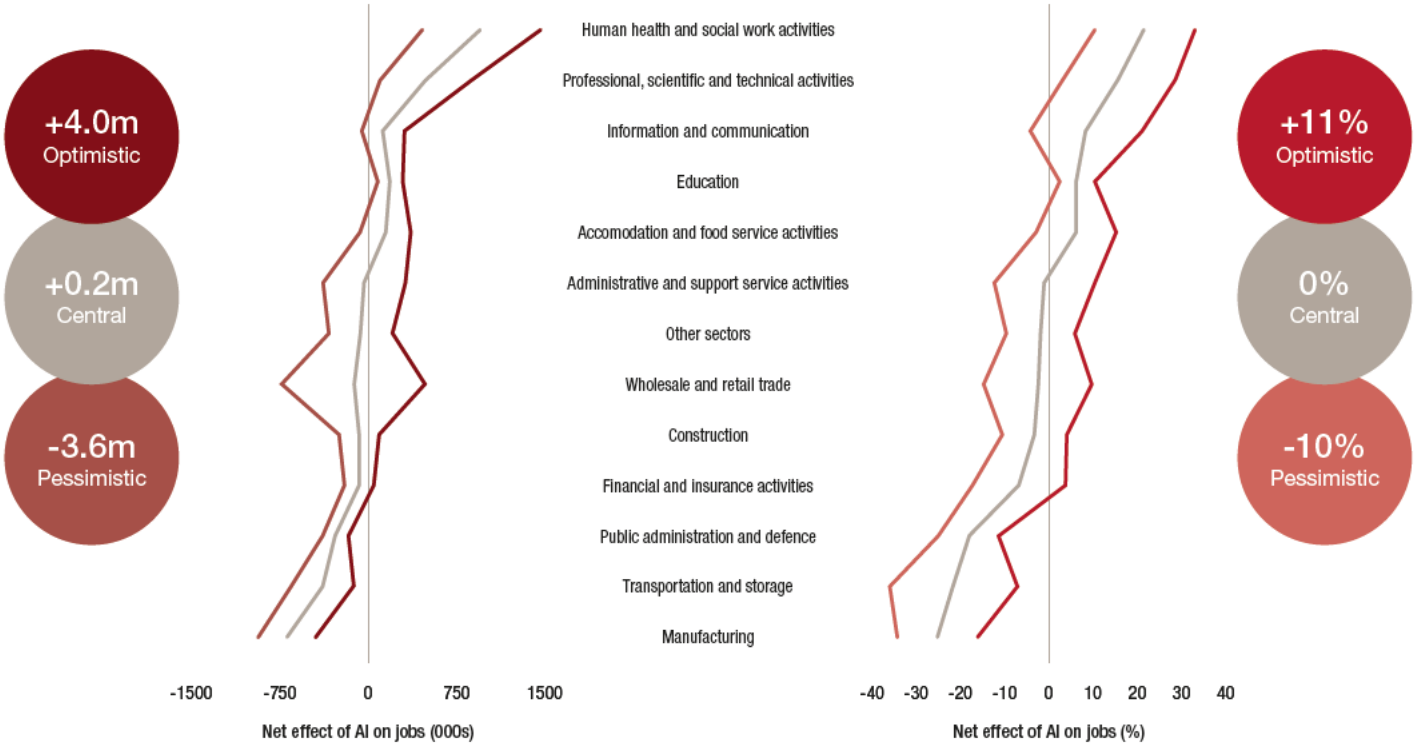
Table 4.3: Net effect of AI on UK jobs under each scenario (millions and as % existing jobs)

		Displacement effect		
		25% of existing jobs automated	20% of existing jobs automated	15% of existing jobs automated
Income effect	AI constitutes 7.5% of GDP by 2030	-3.6m (-10%)	-1.8m (-5%)	-0.1m (0%)
	AI constitutes 10% of GDP by 2030	-1.6m (-5%)	+0.2 (0%)	+1.9m (5%)
	AI constitutes 12.5% of GDP by 2030	+0.5m (1%)	+2.3m (6%)	+4.0m (11%)

Source: PwC analysis

15 As described in the annex we assumed that AI would have a 'high', 'medium' or 'low' impact on each sector, corresponding to 56%, 46% and 36% of growth. We shift these percentages along with the central assumption, e.g. in the pessimistic scenario, where only 35% of total GVA growth is attributable to AI, a 'high', 'medium' and 'low' impact corresponds to 45%, 35% and 25%.

Figure 4.6 – Net effect of AI on jobs by industry sector in the most optimistic and pessimistic scenarios



Sources: PwC analysis

We think the most likely scenarios are those towards the middle of the matrix. This is partly because the central assumptions are those we consider most plausible based on our analysis and partly because we think the uncertainties related to these assumptions may tend to be negatively correlated and so cancel out, at least in part. In particular, if there were to be a high displacement effect this would normally be assumed to be associated with higher productivity growth and so a higher income effect (and vice versa for a low displacement effect).

It is possible to come up with a plausible scenario where both assumptions are at the pessimistic end of the range (e.g. if the cost savings from job displacement accrue mostly to wealthy company executives and owners, who enjoy significant monopoly power and so do not need to pass these savings on to consumers, while not spending much of the extra profits themselves). But this kind of extreme pessimistic (or indeed optimistic) scenario seems relatively less likely.

Nonetheless, the extreme scenarios are far from impossible, bearing in mind also that outcomes beyond our range of assumptions are also possible. We therefore provide further sectoral details on the two most extreme scenarios in Figure 4.6.

The charts show how the range of job impacts depends on both the scale of employment in the sector and how susceptible a given sector is to both the direct and indirect effects of AI. For example, in the wholesale and retail sector, there is a difference of well over 1 million jobs depending on whether we are in the most pessimistic or optimistic scenario, constituting around a third of the total net swing in UK employment between the two scenarios. This is due to the fact that the wholesale and retail sector employs more people than any other sector covered here, accounting for nearly 5 million jobs in 2017, and that we anticipate large-scale disruption in this sector owing to high displacement and income effects (see Figure 4.4). Jobs in the education sector, by contrast, are not as contingent on developments in AI and related sectors, although there will be some such effects. Overall, however, Figure 4.6 suggests that the relative ranking of UK industry sectors on AI net jobs impact would be broadly consistent across the different scenarios.

4.7 – Policy implications

Our scenario analysis shows that the net impact that AI will have on jobs is uncertain, but it is also not pre-determined: it will depend on how individuals, businesses and the government engage with these new technologies. Government, in particular, can play an important role in steering the economy towards a more optimistic scenario by mitigating the costs of the displacement effect while maximising the positive income effects.

Mitigating the displacement effect

- **Government should invest more in 'STEAM' skills that will be most useful to people in this increasingly automated world.** This means focusing more on STEM subjects (science, technology, engineering and mathematics), but also exploring how art and design can feature at the heart of innovation (as is being pioneered by the 'STEAM' movement, where 'A' represents 'Art and design')[16]. Governments should also encourage workers to continually update and adapt their skills so as to stay one step ahead of the machines, for example with the introduction of lifelong learning credits[17]. In addition, job centres could benefit from AI platforms that match jobseekers with jobs.
- **Government should strengthen the safety net for those who find it hard to adjust to technological changes.** While we do not believe that mass technological unemployment is a likely scenario, it is certainly possible that these technologies could favour those who already have strong digital skills and so tend to further increase income and wealth inequality. If this is the case, then governments need to consider how to redistribute some of the significant GDP gains from AI more widely across society. Universal basic income (UBI) has been put forward as a potential way to maintain the incomes of those who lose out from automation, but there are many other options to consider here. For example, the government might make such payments conditional on some contribution to society through work, education, training, volunteering or caring roles so it is not just 'something for nothing'. They could also look again at how best to incentivise (human) work through the tax and benefit system, for example by rebalancing welfare spending back towards working age tax credits rather than state retirement benefits (the reverse of the general UK trend in recent years).

16 See, for example, this paper by the Cultural Learning Alliance and Nesta: https://culturallearningalliance.org.uk/wp-content/uploads/2017/10/CD405-CLA-STEAM-Briefing-Teachers-Notes-08.pdf
17 This point was discussed further in relation to older workers in our 2018 Golden Age Index report here: https://www.pwc.co.uk/goldenage

Maximising the income effect

- **Place-based industrial strategy should target job creation.** Central and local government bodies need to support sectors that can generate new jobs, for example through place-based strategies[18] focused on university research centres, science parks and other enablers of business growth. This place-based approach is, for example, one of the key themes in the UK government's new industrial strategy[19] and its wider devolution agenda. It also involves extending the latest digital infrastructure beyond the major urban centres to facilitate small digital start-ups in other parts of the country.

- **Government should implement its AI strategy in full.** In April 2018, the government published the AI Sector Deal[20]. The report sets out a broad range of policies to support development of the AI sector, linked into the broader industrial strategy. If implemented in full, the AI Sector Deal would go a long way to maximising the income effect of AI on jobs in the UK.

- **Promoting effective competition:** it is critical to maximising the income effect that the productivity gains from AI are passed through in large part to consumers through lower (quality-adjusted) prices. This requires competitive pressure to be maintained both in the technology sector producing the AI and in the sectors using it, so an effective competition policy will be important here that balances the need for a reasonable return to innovation with providing long term benefits to consumers.

18 For more on place-based strategies in the UK context, see also our 2017 Good Growth for Cities report: https://www.pwc.co.uk/industries/government-public-sector/good-growth.html.
19 https://www.gov.uk/government/topical-events/the-uks-industrial-strategy.
20 https://www.gov.uk/government/publications/artificial-intelligence-sector-deal/ai-sector-deal#contents

4.8 – Summary and conclusions

AI and related technologies such as robotics, drones and driverless vehicles could displace many jobs formerly done by humans, but will also create many additional jobs as productivity and real incomes rise and new and better products are developed.

We estimate that these countervailing displacement and income effects are likely to broadly balance each other out over the next 20 years, with the share of existing jobs displaced by AI (c.20%) likely to be approximately equal to the additional jobs that are created.

Although the overall effect on UK jobs is estimated to be broadly neutral in our central projections, there will inevitably be 'winners' and 'losers' by industry sector.

The sectors that we estimate could see the largest net increase in jobs in the long run include health (+22%), professional, scientific and technical services (+16%) and education (+6%). The sectors estimated to see the largest net long-term decrease in jobs due to AI include manufacturing (-25%), transport and storage (-22%) and public administration (-18%).

Based on differences in industry structure alone, our projections do not imply large variations by region, though our central estimates imply a small net job gain in London offset by small net losses in the North and Midlands. But other factors could lead to larger regional employment variations than captured by our model.

Our central estimate is that the net effect of AI on jobs will be broadly neutral, but there are many uncertain factors that could tip the balance towards more optimistic or pessimistic scenarios. We identify some policy areas where action could help to maximise the benefits (e.g. boosting research funding for AI, ensuring effective competition among companies developing and deploying AI so gains are passed on to consumers) and/or mitigate the costs in terms of impacts on jobs (e.g. a national retraining programme for older workers as well as renewed efforts to build STEAM skills in schools and universities).

Technical annex: Methodology

The displacement effect

Our analysis of the displacement effect is adapted from our study 'Will robots really steal our jobs?'[21] In this analysis we scale down the numbers to bridge the gap between the number of jobs could be automated and the number of jobs that will be automated, given the range of economic, legal and regulatory and organisational barriers to automation.

In the previous study we build on research by Frey and Osborne (2013)[22], Arntz, Gregory and Zierahn (2016)[23] and our previous research on this topic in PwC's UK Economic Outlook (March 2017)[24].

In the original study by Frey and Osborne (hereafter 'FO') a sample of occupations taken from O*NET, an online service developed for the US Department of Labor, were hand-labelled by machine learning experts at Oxford University as strictly automatable or not automatable. Using a standardised set of features of an occupation, FO were then able to use a machine learning algorithm to generate a 'probability of computerisation' across US jobs, but crucially they generated only one prediction per occupation.

Using the same outputs from the FO study, Arntz, Gregory and Zierahn (hereafter 'AGZ') conducted their analyses on the OECD Programme for the International Assessment of Adult Competencies ('PIAAC') database, which includes more detailed data on the characteristics of both particular jobs and the individuals doing them than was available to FO. This allows a critical distinction that it is not whole occupations that will be replaced by computers, algorithms and robots, but only particular tasks that are conducted as part of that occupation.

Table A4.1: Projected real GVA growth by UK industry sector over the past and next 20 years (% pa)

	Historical GVA growth	Mean reversion	Projected GVA growth
Manufacturing	0.13%	Low	0.67%
Construction	1.59%	None	1.59%
Wholesale and retail trade	2.05%	None	2.05%
Transportation and storage	3.90%	High	2.13%
Accommodation and food service activities	2.15%	None	2.15%
Information and communication	3.90%	Low	3.31%
Financial and insurance activities	1.84%	None	1.84%
Professional, scientific and technical activities	4.98%	Medium	3.15%
Administrative and support service activities	4.98%	High	2.24%
Public administration and defence	0.01%	Low	0.59%
Education	0.60%	Low	1.00%
Human health and social work activities	3.17%	None	3.17%
Other sectors	1.75%	None	1.75%
All sectors	**1.97%**	**N/A**	**1.93%**

Sources: ONS for historical data, PwC for future growth projections

Furthermore, this allows for the fact that the same occupation may be more or less susceptible to automation in different workplaces.

The PwC automation rate algorithm developed in our earlier study (PwC, March 2017) involved first taking the labels from the FO study and replicating the methodology from the AGZ study using the PIAAC dataset. The methodology was then enhanced using additional data and a refined automation-rate prediction algorithm. This model was initially trained on PIAAC data for the UK, US, Germany and Japan, but then extended to over 200,000 workers across 29 countries.

This much larger sample size gives increased confidence in our estimates of the relative automatability of jobs in different industry sectors and across different types of workers (e.g. by age, gender or education level).

21 'Will robots steal our jobs?' PwC UK Economic Outlook, March 2017, available here: https://www.pwc.co.uk/economic-services/ukeo/pwcukeo-section-4-automation-march-2017-v2.pdf.
22 Frey, C.B. and M.A. Osborne (2013), The Future of Employment: How Susceptible are Jobs to Computerization?, University of Oxford.
23 Arntz, M. T. Gregory and U. Zierahn (2016), 'The risk of automation for jobs in OECD countries: a comparative analysis', OECD Social, Employment and Migration Working Papers No 189.
24 Will robots steal our jobs?' PwC UK Economic Outlook, March 2017, available here: https://www.pwc.co.uk/economicservices/ukeo/pwcukeo-section-4-automation-march-2017-v2.pdf.

The income effect

In our 'Sizing the Prize' report we estimated the total income derived from AI over the period to 2030. For this report we have converted the potential value of AI into jobs numbers by, first, projecting UK output (GVA) growth by industry sector over the next 20 years and, second, by estimating the proportion of GVA growth that is attributable to AI based on our Sizing the Prize report for the UK.

We assume here that the projected increase in jobs will be the same as the projected increase in GVA because we are already capturing the productivity impact of AI in saving on labour inputs through our estimates of the displacement effect, so to include this again here would be double counting. This is the same broad assumption as was made in a previous report by Oxford Economics and Cisco[25], but unlike that report we do not assume that the net jobs impact is exactly zero, as this seems to be too restrictive an assumption to impose a priori.

We have projected sectoral GVA by projecting forward historical average rates and applying a mean reversion adjustment. We apply a mean reversion adjustment of either 0% ('None'), 30% ('Low'), 60% ('Medium'), or 90% ('High') based on our judgement and a constraint that implied overall GDP growth is plausible (c.2% on average over the 20 years to 2037). The resultant GVA projections are shown in Table 4A.1.

In our 'Sizing the Prize' report we estimated that AI could contribute around 10% of UK GDP by 2030. Combined this with our GDP projections, we estimate that AI could account for around 46% of cumulative UK GDP (or GVA) growth over the period to 2030, which we assume also holds over the longer period to 2037.

Table A4.2: Estimated AI contribution to projected GVA and jobs growth due to income effect (% pa over period to 2037)

	Projected GVA growth	AI impact tier	AI contribution to growth
Manufacturing	0.67%	Low	0.24%
Construction	1.59%	Low	0.57%
Wholesale and retail trade	2.05%	High	1.15%
Transportation and storage	2.13%	Low	0.77%
Accommodation and food service activities	2.15%	Medium	0.99%
Information and communication	3.31%	Low	1.20%
Financial and insurance activities	1.84%	Medium	0.85%
Professional, scientific and technical activities	3.15%	Medium	1.45%
Administrative and support service activities	2.24%	Medium	1.03%
Public administration and defence	0.59%	Low	0.21%
Education	1.00%	High	0.56%
Human health and social work activities	3.17%	Medium	1.46%
Other sectors	1.75%	Low	0.63%
All sectors	**1.93%**	**Medium**	**0.89%**

Sources: ONS for historical data, PwC for future growth projections

This impact will vary by sector, so we assume that the growth share due to AI varies from 36% ('low') to 56% ('high') by sector based on previous macroeconomic modelling results. Applying these percentages to the projected growth rates gives us the estimated GVA growth that is attributable to AI, as presented in Table A4.2.

To work out the number of jobs associated with the GVA growth attributable to AI we simply assume that the increase in jobs will be the same as the projected increase in GVA for the reasons discussed above.

For example, if we expect a 1% GVA annual growth rate in the accommodation and food sector over the next 20 years that is attributable to AI, we assume the income effect is to increase jobs by 1% per annum on average in this sector. To find the cumulative income effect we compound these growth rates over the 20 years to 2037.

25 Oxford Economics and Cisco, 'The AI Paradox', December 2017.

Appendix A
Outlook for the global economy

Table A.1 presents our latest main scenario projections for a selection of economies across the world.

World economic growth strengthened through 2017 and this is expected to continue, increasing the global weighted average real growth rate to 3.4% in 2018 before easing slightly to 3.2% in 2019 (using GDP at market exchange rates as weights – global GDP using PPP weights might be just under 4% in both years). This growth is expected to be driven by the large emerging economies with continued strong growth of around 7.4% in India and around 6.5% in China this year. The outlook for emerging markets has also brightened as a result of somewhat improved economic conditions in Russia and Brazil, which are now moving gradually out of recession. Indonesia is also expected to continue to grow strongly at over 5% in 2018-19, with the ASEAN economies as a group also generally performing well.

There has been a clear upswing in Eurozone economic activity over the past two years, increasing projected growth to over 2% this year despite some recent slowdown. Relative to the rest of the G7, strong US growth of just under 3% is projected in 2018 as fiscal stimulus strengthens an already recovering economy. But this could be offset by gradual rises in US interest rates to keep inflation there under control, causing some slowing of growth next year. Any further shift towards greater protectionism by the US could also pose significant downside risks to growth in 2019 and beyond both in the US and in the world more generally.

These projections are updated regularly in our Global Economy Watch publication, which can be found at www.pwc.com/gew

Table A.1: Global economic growth and inflation prospects

	Share of world GDP	Real GDP growth (%)		Inflation (%)	
	2017 at MERs	2018p	2019p	2018p	2019p
US	24.3%	2.9	2.5	2.5	2.2
China	15.0%	6.5	6.3	2.3	2.4
Japan	6.1%	1.0	0.8	0.5	1.1
UK	3.3%	1.3	1.6	2.5	2.2
France	3.2%	2.2	1.9	1.7	1.5
Germany	4.6%	2.4	2.1	2.1	1.7
Greece	0.3%	2.0	2.1	0.8	1.2
Ireland	0.4%	4.6	3.3	0.9	1.3
Italy	2.4%	1.3	1.1	1.1	1.4
Netherlands	1.0%	2.7	2.3	1.6	1.9
Portugal	0.3%	2.1	1.9	1.1	1.7
Spain	1.6%	2.8	2.4	1.7	1.7
Poland	0.7%	3.9	3.4	1.9	2.5
Russia	1.9%	1.8	1.7	4.0	4.2
Turkey	1.1%	3.2	3.8	8.4	8.1
Australia	1.7%	2.9	3.0	2.2	2.5
India	3.3%	7.4	7.6	4.8	5.0
Indonesia	1.3%	5.2	5.3	3.8	3.9
South Korea	1.9%	2.9	3.0	1.6	1.9
Argentina	0.8%	2.1	3.0	23.5	n/a
Brazil	2.6%	2.5	2.7	3.5	4.0
Canada	2.1%	2.0	1.9	2.4	1.9
Mexico	1.4%	2.1	2.2	4.2	3.9
South Africa	0.4%	1.3	1.5	5.3	5.6
Nigeria	0.5%	2.0	3.4	12.1	10.7
Saudi Arabia	0.9%	1.3	1.9	3.7	3.0
World (PPP)		3.9	3.8	3.1	2.9
World (Market Exchange Rates)	100%	3.4	3.2	2.7	2.5
G7	46.0%	2.3	2.0	2.1	1.9
Eurozone	13.9%	2.3	2.0	1.7	1.6

Source: PwC main scenario for 2018 and 2019; IMF for GDP shares in 2017 at market exchange rates (MERs).

Appendix B
UK economic trends: 1979 – 2017

Annual averages	GDP growth	Household expenditure	Manufacturing output growth*	Inflation (CPI**)	3 month interest rate (% annual average)	Current account balance (% of GDP)	PSNB*** (% of GDP)
1979	3.7	4.8			13.7	-0.6	4.2
1980	-2.0	0.1			16.6	0.5	3.9
1981	-0.8	0.3			13.9	1.5	3.0
1982	2.0	1.2			12.2	0.6	2.3
1983	4.2	4.4			10.1	0.2	3.0
1984	2.3	2.5			10.0	-0.5	3.3
1985	4.2	5.1			12.2	-0.3	2.5
1986	3.1	6.0			10.9	-1.0	2.0
1987	5.3	5.0			9.7	-1.6	1.3
1988	5.8	7.3			10.4	-3.5	-0.6
1989	2.6	3.8		5.2	13.9	-4.1	-0.6
1990	0.7	1.0		7.0	14.8	-3.1	0.6
1991	-1.1	-0.5	-4.9	7.5	11.5	-1.3	2.6
1992	0.4	0.9	-0.1	4.3	9.6	-1.5	5.6
1993	2.5	2.9	1.4	2.5	5.9	-1.3	6.7
1994	3.9	3.2	4.7	2.0	5.5	-0.5	5.8
1995	2.5	2.0	1.5	2.6	6.7	-0.7	4.6
1996	2.5	3.8	0.8	2.5	6.0	-0.6	3.3
1997	4.3	4.4	1.7	1.8	6.8	0.0	1.9
1998	3.3	4.0	0.4	1.6	7.3	-0.5	0.3
1999	3.2	4.8	0.5	1.3	5.4	-2.5	-0.7
2000	3.5	4.7	2.2	0.8	6.1	-2.4	-1.5
2001	2.8	3.6	-1.5	1.2	5.0	-2.2	-0.2
2002	2.5	3.8	-2.1	1.3	4.0	-2.3	2.0
2003	3.3	3.6	-0.5	1.4	3.7	-1.9	3.4
2004	2.3	3.1	1.8	1.3	4.6	-2.3	3.3
2005	3.1	3.1	0.0	2.1	4.7	-2.0	3.2
2006	2.5	1.8	2.1	2.3	4.8	-3	2.8
2007	2.5	2.6	0.6	2.3	6.0	-3.6	2.6
2008	-0.3	-0.6	-2.8	3.6	5.5	-4.2	5.4
2009	-4.2	-3.2	-9.4	2.2	1.2	-3.6	10.1
2010	1.7	0.8	4.6	3.3	0.7	-3.4	9.0
2011	1.6	-0.9	2.2	4.5	0.9	-2.0	7.1
2012	1.4	1.7	-1.4	2.8	0.8	-3.8	7.6
2013	2.0	2.0	-1.0	2.6	0.5	-5.1	5.6
2014	2.9	2.1	2.9	1.5	0.5	-4.9	5.3
2015	2.3	2.7	0.0	0.0	0.6	-4.9	4.1
2016	1.8	3.2	0.4	0.7	0.5	-5.2	2.9
2017	1.7	1.9	2.5	2.7	0.3	-3.9	1.8
Average over economic cycles****							
1979 - 1989	2.8	3.7			12.2	-0.8	2.2
1989 - 2000	2.4	2.9		3.3	8.3	-1.5	2.4
2000 - 2014	1.9	1.9	-0.2	2.2	3.3	-3.1	4.4

* Pre-1991 figures for manufacturing output growth are not currently available on a consistent basis ** Pre-1997 data estimate
*** Public Sector Net Borrowing (calendar years excluding public sector banks) **** Peak-to-peak for GDP relative to trend
Sources: ONS, Bank of England

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The Design Group 32949 (07/18)