Oxfordshire: a trailblazer for the UK economy

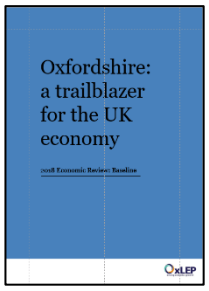
2018 Economic Review: Baseline

DECEMBER 2018

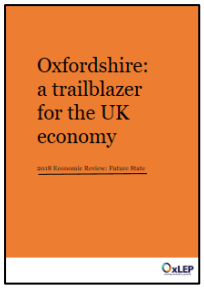
OxLEP
driving economic growth

A GUIDE TO THE SUITE OF OXFORDSHIRE INDUSTRIAL STRATEGY DOCUMENTS

We have produced three reports which, taken together, set an understanding of the current Oxfordshire economy, its future growth potential and how we can work together to deliver the opportunities we have identified. Further information about what you can expect from each report is set out below.



The **Baseline Economic Review** is an objective assessment of Oxfordshire's economic performance to date. It explores how Oxfordshire has performed relative to the UK as a whole, as well as the relative performance of each district authority and different types of businesses and sectors within the county. This report provides detailed economic and spatial analysis that has helped us to shape and prioritise future plans for inclusive growth, productivity improvements and place-based developments, which are set out in the Oxfordshire Industrial Strategy.



The **Future State Assessment** sets out what Oxfordshire has the potential to achieve. It introduces the context for why we are aspiring to be a top three global innovation ecosystem and what this means for Oxfordshire, as well as detail on the key industries in which Oxfordshire can be globally competitive. It details an ambitious economic growth agenda for Oxfordshire, along with the counterfactual 'do nothing' scenario that discusses the risks we face if we do not initiate a step change in growth. Finally this report sets out a spatial vision for Oxfordshire, to ensure that growth in Oxfordshire is achievable and sustainable.

The Oxfordshire Industrial Strategy is the overall plan to deliver inclusive growth across Oxfordshire, drive productivity and innovation, and generate additional growth for the UK. Our vision is to be a top three global innovation ecosystem by 2040: the Oxfordshire Industrial Strategy includes a number of priority interventions to achieve this. It builds on the Strategic Economic Plan whilst setting priorities for the longer term. Its audience will be HM Government, who has commissioned Oxfordshire Local Enterprise Partnership to develop the Oxfordshire Industrial Strategy. It is also designed to help investors, businesses and local communities understand more about our ambitions and how we seek to drive transformative growth in Oxfordshire from now to 2040.

The Investment Prospectus will underpin the Oxfordshire Industrial Strategy. It will take forward the policy interventions central to the Oxfordshire Industrial Strategy, setting out in more detail how we will work with partners across Oxfordshire, the UK and internationally to deliver them. It will also act as an investment prospectus for Oxfordshire, for both public and private investors to understand how they can invest in Oxfordshire to enable us to achieve our growth potential.

Contents

1. INTRODUCTION TO THE ECONOMIC REVIEW: BASELINE

1.1 SCOPE OF THIS REVIEW

This review has been led by Oxfordshire Local Enterprise Partnership (OxLEP). It is focused on developing the economic evidence base needed to underpin an ambitious Local Industrial Strategy. OxLEP is undertaking this as Oxfordshire has been invited by the Department for Business, Energy and Industrial Strategy to be part of the 'trailblazer' programme for developing a Local Industrial Strategy (LIS).

The work to date has brought together a thorough review of available data and evidence, along with significant stakeholder engagement. We have engaged with over 150 individuals representing over 100 key Oxfordshire stakeholders – see Appendix B for more details and key findings from the engagement programme. It has been deliberately framed to build upon the work already undertaken to develop the 2016 Strategic Economic Plan refresh and the 2017 Science and Innovation Audit.

This report brings together all of the work undertaken to establish an economic baseline to underpin the Oxfordshire Local Industrial Strategy. This review has ultimately sought to understand what has accelerated Oxfordshire's growth and success in recent years, telling the story of how Oxfordshire has come to be one of the most successful economic regions in the UK. It also identifies the factors that are constraining growth. Understanding this will help us to shape our strategy for future economic growth. It is an essential report that will feed into the development of the Oxfordshire Industrial Strategy, which will be submitted to Her Majesty's Government (HMG) for formal sign off by March 2019.

Specifically this review sets out:

- **Introduction**: setting out the policy context for this report and the Local Industrial Strategy, and providing an introduction to Oxfordshire: the administrative geography, population, place, economy, key assets and industries.
- **The macroeconomic context:** exploring a number of key trends, analysed through the lens of several indicators including growth, employment, productivity, trade, investment and wages.
- **The microeconomic context:** an industry-level analysis to understand what is driving the macro trends in Oxfordshire;
- **The spatial context:** setting out an overview of Oxfordshire's spatial characteristics, the economic geography and natural assets which have helped to shape growth and development in recent years.

1.2 POLICY CONTEXT

This section will introduce the national and local policy context for this report and for the Oxfordshire Industrial Strategy.

The world is changing rapidly and in ways we cannot fully predict over the next twenty years. A range of economic megatrends, new technologies and global disruptions are transforming our future, providing challenges but also new opportunities. The UK must seek to address the

productivity puzzle it is facing, with its productivity falling increasingly behind that of its competitors.

A number of existing and new policy initiatives are therefore being framed around preparing each part of the UK to seize and secure opportunities for future growth and prosperity and improved productivity.

A consistent theme underpinning each of these initiatives is a belief in locally driven, place-based transformation. Local Enterprise Partnerships (LEPs) are being asked to take a leadership role in working with public sector partners, the private sector and universities. They are being asked to step forwards and shape plans – including Growth and devolution deals and Local Industrial Strategies – which will help to prepare and enable each place and community to thrive in the years ahead.

While a certain degree of focus is placed on growth, there is a broad consensus that this should not be growth at any cost. Policy makers recognise that increasing productivity in one area of the country must not mean displacing growth from elsewhere. Prioritising inclusive and sustainable growth is also leading policy makers to look at addressing a range of complementary objectives through place-based planning initiatives including: a reduction in economic and social inequality; the sustained creation of jobs and training (particularly apprenticeships) that improve social mobility; selective land release and intensification of land use the delivery of affordable housing.

On the next page, we summarise two of the main policy programmes that the Oxfordshire Industrial Strategy will respond to: the UK National Industrial Strategy and the Oxfordshire Housing and Growth Deal. The Oxfordshire Industrial Strategy will not be a standalone strategy – it will build on significant work already undertaken in Oxfordshire and align to existing and emerging strategies and commitment. We set these out on the following pages.

The National Industrial Strategy

In November 2017, HMG launched the UK Industrial Strategy, setting out how we can build a Britain fit for the future. It is a landmark policy announcement for UK economic growth. It seeks to promote prosperity, creating conditions where successful businesses can emerge, grow and invest in the future of our nation. It initiates a new, region-led approach to growth. As part of this, Government is asking every locality across the UK to develop their own Local Industrial Strategies for long-term economic growth. This is why we are now developing the Oxfordshire Industrial Strategy.

The development of the Oxfordshire Industrial Strategy is being led by the Oxfordshire Local Enterprise Partnership (OxLEP). This was established in 2011 with a mandate to work across the County on projects which drive local economic development. Local Enterprise Partnerships (LEPs) were set up as business-led partnerships between districts and businesses with the aim of playing a central role in determining local economic priorities and undertaking activities to drive economic growth and the creation of jobs. OxLEP is responsible for delivering a range of funds and programmes including the Local Growth Funds, the City Deal, European Structural and Investment Fund, Growing Places Fund, the Regional Growth Fund and the development of a Local Industrial Strategy. OxLEP have secured over £2.2 billion of investment for Oxfordshire from a mixture of private and public funds.

Grand Challenges

Sitting on the cusp of a new industrial revolution, the UK Industrial Strategy seeks to seize the opportunities of technological change, propelling Britain to global leadership of the industries of the future. It highlights four Grand Challenges, areas where Britain can lead the global technological revolution. They are an invitation to business, academia and civil society to work together to innovate in areas of strategic importance for the UK.

Growing the Artificial Intelligence and Data driven economy

Shifting towards clean growth

Shaping the future of mobility

Meeting the needs of an ageing society

Pillars of productivity

The UK Industrial Strategy aims to improve Britain's productivity, which has long lagged behind that of our competitors.

To address this challenge, the strategy is centered on five foundations of productivity: ideas, people, infrastructure, business environment and places.

- **Ideas:** To be the world's most innovative economy
- **People:** To generate good jobs and greater earning power for all
- **Infrastructure:** A major upgrade to the UK's infrastructure
- **Business environment:** To be the best place to start and grow a business
- **Places:** To have prosperous communities across the UK

The Oxfordshire Housing and Growth Deal

The Oxfordshire partners have committed to working together in a strong and collaborative way to pursue and deliver projects and investment which align with the County's long-term interests.

To this effect, partners agreed to form a strong governance model built around the Oxfordshire Growth Board. The Growth Board is a joint committee of the five districts, together with key strategic partners - including Oxfordshire's two universities and the LEP. This Growth Board is designed to facilitate and enable joint working on economic development, strategic planning and growth, including housing.

In November 2017, the statutory partners in the Oxfordshire Growth Board signed a deal with HMG which paves the way for an additional £215 million of investment over the next five years to build infrastructure, support the delivery of affordable and new homes and boost economic productivity across Oxfordshire. This represents a major achievement for Oxfordshire and demonstrates the power of the Growth Board to secure backing for transformative large-scale projects.

Under the terms of the deal the Government will provide Oxfordshire's five districts with £60 million of funding for affordable housing, £150 million of funding (£30 million for five years) for infrastructure improvements that will benefit existing communities and unlock new development sites. Oxfordshire councils are already committing in excess of £340 million to infrastructure and housing investment over the period.

As part of the deal, we have committed to:

- Delivering 100,000 homes by 2031
- Developing a Joint Statutory Spatial Plan by 2021, covering all five district councils in Oxfordshire. To support this, partners now have short term planning flexibilities linked to the revised (2018) National Planning Policy Framework.
- Producing the Oxfordshire Industrial Strategy, as a condition of the productivity strand of the Growth Deal

Existing and emerging local strategies and plans

The Oxfordshire Industrial Strategy is not a standalone document. It will align to and build on a number of existing and emerging strategies in Oxfordshire. These include (but are not limited to):

- Emerging Joint Statutory Spatial
- Emerging Oxfordshire Energy Strategy
- 2016 Strategic Economic Plan and sister strategies e.g. for skills and innovation
- 2017 Science and Innovation Audit
- Oxfordshire Infrastructure Strategy (and NIC First Mile/Last Mile 2050 plan)
- Oxfordshire's Local Transport Plan 4 and Oxfordshire Rail Study
- The adopted Local Plans for housing and development for each District
- Oxford – Cambridge Growth Corridor Economic Vision

The Oxfordshire Industrial Strategy

Oxfordshire will be one of the first regions in the UK to develop a Local Industrial Strategy. It is a critical moment in the history of Oxfordshire – an opportunity to initiate a step change in the way we think about, plan for and pursue economic growth for the region. This growth will be innovation-led and will be a step-change for Oxfordshire. It will be inclusive, place-sensitive and sustainable, enhancing our communities, natural environment and quality of life. It will underpin delivery of our county-wide economic agenda between now and 2040, and is one of the most forward-thinking and ambitious strategies that local businesses, political leaders and central Government partners have worked together to develop.

The Oxfordshire Industrial Strategy will set out how Oxfordshire can build on its existing strengths and assets to compete globally and deliver growth for the region and for the County and the UK. It will be shaped as a long-term framework against which private and public sector investment decisions can be made. This baseline review is part of the evidence base for the Oxfordshire Industrial Strategy. It will be used to help local leaders and businesses identify future priority initiatives which can help to unlock a step change in growth.

2 INTRODUCTION TO OXFORDSHIRE

2.1 INTRODUCTION

Oxfordshire is home to around 685,000 people, and covers an areas of over 2,600 sq. km. The region is governed by the Oxfordshire County Council, which is responsible for many statutory functions, and is further divided into five district councils: Cherwell, the City of Oxford, South Oxfordshire, the Vale of White Horse, and West Oxfordshire.

Oxfordshire is one of the strongest economies in the UK, and is one of three net contributors to the exchequer, generating an economic output of around £23 billion of Gross Value Added each year, from about 400,000 jobs and 30,000 businesses.

Oxfordshire has a number of national assets, including globally-renowned education institutions, national research centres, and leading science and technology clusters. It has a highly skilled workforce, near-full employment, and a wide range of successful, growing and world-leading businesses in both established and emerging strategic sectors for the UK.

Over the following pages we set out a short introduction to Oxfordshire as a place, which sets out the context for the following chapter that provides a deeper dive into Oxfordshire's economy.

Figure 2-1 Districts within Oxfordshire

2.2 PLACE

Oxford is the county's functional centre. It is a city steeped in history, first settled in Anglo-Saxon times and now globally-renowned for its universities. The urban area of Oxford has a population of around 160,000, and is contained within a large Green Belt that prevents significant expansion around the city.

Outside of Oxford, the major settlements are stand-alone towns with distinctive and vibrant characters: Bicester and Banbury in Cherwell; Witney and Carterton in West Oxfordshire; Didcot, Thame, Wallingford and Henley-on-Thames in South Oxfordshire; and Abingdon-on-Thames, Wantage and Faringdon in Vale of White Horse.

Parts of Oxfordshire are rural, with areas of rich natural capital. Oxfordshire overlaps with three Areas of Outstanding Natural Beauty: the Cotswolds, North Wessex Downs and Chilterns. It home to stately homes that are major international destinations such as the UNESCO World Heritage Site of Blenheim Palace, historic colleges, medieval streets, the market towns and villages. Oxfordshire's built heritage and natural environment are an integral part of the county's character and are critical to making the region a great place to live as well as work.

The county also has a distinctive cultural landscape, home to outstanding cultural institutions, organisations and venues including nationally significant galleries and museums, theatres, libraries and arts and cultural centres.

For these reasons, Oxfordshire is well known as a great place to live and work. It is distinctive in providing access to all these assets with a mix of urban and rural living. Oxfordshire and the City of Oxford score highly on rankings of places to live, and Oxford has recently been ranked the best city in the UK in PwC's 2018 Good Growth for Cities report, which measures the performance of cities against a range of economic and wellbeing indicators.[1]

Figure 2-2 The Cotswolds

2.3 STRATEGIC LOCATION

Oxfordshire sits in a strategic location in the UK. It is close and well-connected to London and within an hour of Heathrow, a global hub airport. It is an integral part of the UK's Golden Triangle

[1] PwC and Demons, 'Good Growth for Cities 2018: A report on urban economic wellbeing from PwC and Demos', 2018.

(London, Cambridge and Oxford) for research and innovation, which has contributed to the success of the place and the growth of key industries including Life Sciences.

Oxfordshire is also well positioned to play a leading role in the development of the Oxford - Cambridge Arc. The National Infrastructure Commission has identified opportunities to create new communities and deliver one million new homes and jobs across the corridor by 2050. Plans for an East-West rail link and the Oxford-Cambridge Expressway are underway, which will lay the vital infrastructure needed to support future growth. It is estimated that developing the corridor could lead to a £163 billion increase in economic output per annum.

The county also has connections to the Birmingham-London-Bristol triangle, and supply-chain connections across the UK. For example in technology development and manufacturing there are clear links to the northeast and southwest of England along with South Wales.

2.4 KEYSTONE ASSETS

Oxfordshire is a globally-renowned centre for research and innovation, home to a number of national assets and world-leading industry clusters.

The University of Oxford has been ranked the best in the world for the third year running by the Times Higher Education World University Rankings, and has the UK's largest volume of world-leading research.[2] **Oxford Brookes University** is also highly regarded for both its research and teaching – leading to it being among the world's top universities in 15 individual subject areas in the 2018 QS rankings.

Oxfordshire is also home to a unique grouping of internationally-recognised science and research facilities, in Science Vale in the south of Oxfordshire, including the Culham Science Campus, and at Harwell. These are host to national strategic facilities, such as the UK Atomic Energy Authority; Culham Centre for Fusion Energy; the Science and Technology Facilities Council; the Diamond Light Source, the national synchrotron facility; the Medical Research Council's facilities and the UK Space Gateway, including the Satellite Applications Catapult Centre and the European Space Agency.

Oxfordshire has a dynamic business environment, home to fast-growing new businesses, including well-established companies such as Williams F1, Sophos, and Oxford Instruments, and a number of global brands, including BMW, Siemens, Unipart and Oxford University Press, and Bicester Village. This business environment is supported by the county's increasing supply of science and business parks and incubator spaces.

Oxfordshire also has two major new funds established in 2015, including Oxford Sciences Innovation (OSI). This is the largest university spin-out fund in Europe, with £600 million to invest in science and technology-based spinouts from Oxfordshire's research facilities. The University of Oxford's ambition is to spin out a £1 billion firm each year from 2020, adding to Oxfordshire's existing success. So far Oxfordshire has created five companies that have been valued at over US $1 billion – Immunocore, Adaptimmune, Oxford Nanopore Technologies, Circassia and Sophos.[3]

Public and private investment into the innovation ecosystem has continued in recent years through the City Deal Programme and Local Growth Fund, which resulted in four new innovation centres: the BioEscalator at the Old Road Campus, the Begbroke Accelerator, Remote

[2] The Times, 'Times Higher Education World University Rankings', 2019, 2018, 2017.
[3] Oxfordshire Transformative Technologies Alliance, 'Science and Innovation Audit', November 2017.

Applications in Challenging Environments at Culham and the Harwell Innovation Hub. In addition to this the region has recently received further investment to strengthen Oxfordshire's capability in world-leading research and innovation in key sectors through:

- £100 million for the Rosalind Franklin research institute to improve health through physical science innovation;
- £65 million for the Faraday Institution, charged with tackling the global energy and batter storage challenge;
- £99 million for a National Satellite Testing Facility at RAL in Harwell;
- £86 million for a National Fusion Technology Platform at Culham; and
- £68.3 million for Satellite Applications Catapult in Harwell.

Figure 2-3 Diamond Light Source

3 MACROECONOMIC CONTEXT

3.1 INTRODUCTION

Understanding Oxfordshire's recent macroeconomic performance will help us to understand the county's characteristics and identify its strengths and weaknesses. Our analysis explores a range of macroeconomic indicators, including Gross Value Added (GVA), employment, median wages and productivity to compare the county's performance against its peers in England and the UK. By applying some of the same indicators to the five districts, it is possible to spot where the region is performing well and where opportunities for a stronger economic performance exist. These findings inform the microeconomic analysis that follows and includes the following six sections:

- [3.3] Economic size and growth
- [3.4] Employment and skills
- [3.5] Wages
- [3.6] Labour market and demographics
- [3.7] Housing
- [3.8] Productivity

3.2 KEY FINDINGS

- **Economic output:** Economic output from Oxfordshire is high and growth is accelerating. On a per-head basis, the output of its workers is in the top quintile of English regions.
- **Productivity:** Workers are not particularly productive. Output is high, but so are the number of hours worked. On this basis, Oxfordshire's productivity is below the average for the South East of England.
- **Employment:** Oxfordshire fares very well on employment measures. Employment, as measured by the participation rate, is well above the national average. There is also relatively little variation between districts. The workforce is also highly skilled, making its workers desirable.
- **Skills:** High skill levels are rewarded with wages that are well above the national average, and median wage growth has been particularly strong since 2015. Wages for the bottom decile are among the highest in the country.
- **Wages:** There are significant differences between resident and workplace wages. Some districts, such as South Oxfordshire, are home to high-earning workers that commute elsewhere, while others, like Vale of White Horse, host firms offering high-wage positions but cannot find local workers to fulfil them.
- **Labour market:** Growth in the working-age population is slow relative to the rest of the UK, and likely to peter out entirely in the near future. With fewer workers, those that remain will have to become more productive in order to maintain current levels of output.
- **House prices:** The median house price in Oxfordshire is now almost 50% higher than the median price in England. This means that Oxfordshire remains one of the least-affordable places in the country to buy property based on the house price to earnings ratio.

3.3 ECONOMIC SIZE AND GROWTH

In assessing the size of the Oxfordshire economy in recent years, the most appropriate basic measure is GVA. This calculates the income generated by workers and companies in the creation of goods and services. GVA statistics used in this report are in current prices, which means they include the effect of inflation.[4] GVA does not take into account the full impact of infant industries that have yet to demonstrate their potential through large profits.

Data from the Office for National Statistics showed that Oxfordshire's GVA in 2016 was the 10th largest among the 173 UK regions. For context, this means the Oxfordshire economy is approximately similar size to the combined London boroughs of Kensington and Chelsea and Hammersmith and Fulham and to that of the city of Leeds.[5] However, it is necessary to consider GVA on a per-head level to better understand the economy's position within the context of the UK. GVA per-head data shows that average income generation in Oxfordshire in 2016 stood at £33,337. This is above the average for the UK (£26,621), England (£27,108) and the South East (£28,683).[6] Among the ONS's 173 UK regions, Oxfordshire's GVA per head was ranked 18th and was broadly comparable to those of two London boroughs: Lambeth, and Lewisham and Southwark. Combined, these two sets of data show that Oxfordshire is a large and populous economy within the UK, with output well above the nationwide average.[7]

Growth in Oxfordshire's GVA in the past decade has been particularly impressive, averaging 3.9% a year since 2007.[8] In contrast, the UK as a whole, grew at a rate of 2.9%, while the South East expanded by 3.1%.[5] Of particular note was the resilience of the Oxfordshire economy to the global financial crisis. In 2009, GVA in the UK declined by 2.1% year on year, but in that period in Oxfordshire it continued to expand, albeit at the slower-than-usual rate of 0.2%. Similarly, the Oxfordshire economy was able to grow faster than the UK as a whole during recent years. The UK expanded by 3.8% a year between 2013 and 2015, but Oxfordshire grew at a significantly faster rate of 5.1%. Consequently, Oxfordshire's GVA has diverged positively from that of the UK and the South East in the past ten years.

---

[4] ONS 'GVA by local authority', 2017, retrieved from: https://www.ons.gov.uk/economy/grossvalueaddedgva/datasets/regionalgvaibylocalauthorityintheu
[5] Ibid
[6] Ibid
[7] Ibid
[8] ONS 'GVA by local authority', 2017, retrieved from: https://www.ons.gov.uk/economy/grossvalueaddedgva/datasets/regionalgvaibylocalauthorityintheu

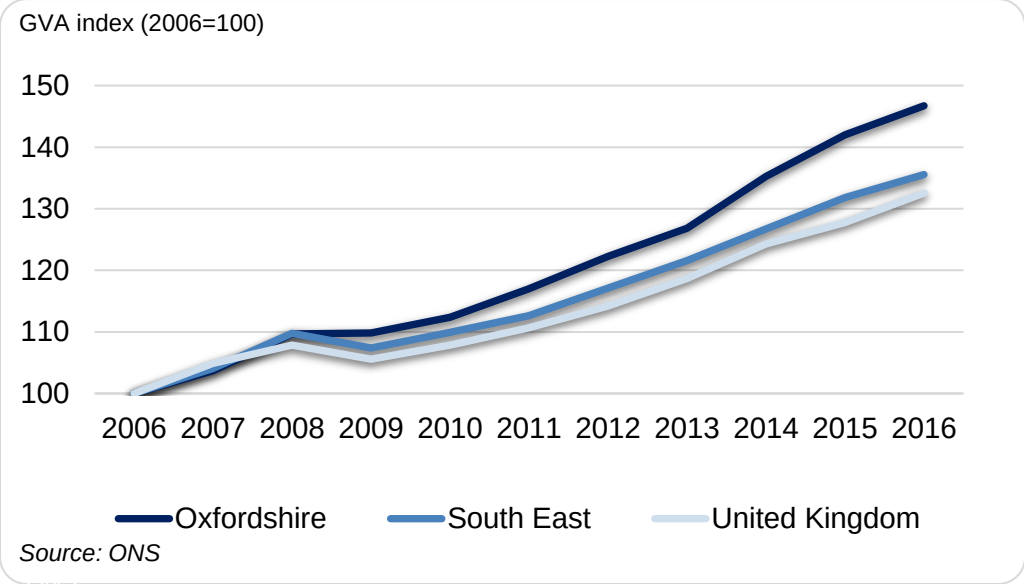


Figure 3-1 Oxfordshire nominal GVA growth, 2006-16

The sectoral composition of Oxfordshire's GVA reveals some strengths and weaknesses. In 2016, the largest proportion was contributed by public administration, education and health (21%).[9] There were other important contributions made by distribution, transport and food (17%), real estate (15%) and professional services (10%). Comparing Oxfordshire to areas with economies of similar size – Leeds, Kensington and Chelsea, and Hammersmith and Fulham in London – Oxfordshire is not overly dependent on its largest sectors. In Leeds, the five biggest sectors accounted for 70% of total GVA, relative to 76% in Oxfordshire and 86% in Kensington, Chelsea, Hammersmith and Fulham. In the current environment of increasingly restrictive public-sector spending, the region's economy will have to look to increase the contribution from private-sector firms if it is to aspire to the fastest possible rate of growth in its GVA.

The foundations for a bigger contribution from the private sector already exist. Data from the ONS's Business reports show that Cherwell and Oxford have significantly more small and medium-sized enterprises (SMEs) that are expanding their headcounts than the national average.[10] Segments such as digital health, space, quantum computing and autonomous vehicles could provide new opportunities in the coming years.

[9] ONS, 'Regional GVA (balanced)', 2017, retrieved from: https://www.ons.gov.uk/economy/grossvalueaddedgva/bulletins/regionalgrossvalueaddedbalanceduk/1998to2016/relateddata

[10] ONS, UK business activity by size and location', 2017, retrieved from: https://www.ons.gov.uk/businessindustryandtrade/business/activitysizeandlocation/bulletins/ukbusinessactivitysizeandlocation/2017/relateddata

Breaking GVA down to the local authority level reveals more about the composition and nature of the Oxfordshire economy. GVA per-head across the five districts within Oxfordshire varies considerably, from £41,042 in Oxford in 2016 down to £26,814 in West Oxfordshire. In the past ten years, the Vale of White Horse and South Oxfordshire, both of which have a lower GVA than the Oxfordshire average, have managed to close the gap on Oxford and Cherwell. This faster pace of growth has been particularly evident since 2012. By contrast, West Oxfordshire has fallen further behind the region as a whole.

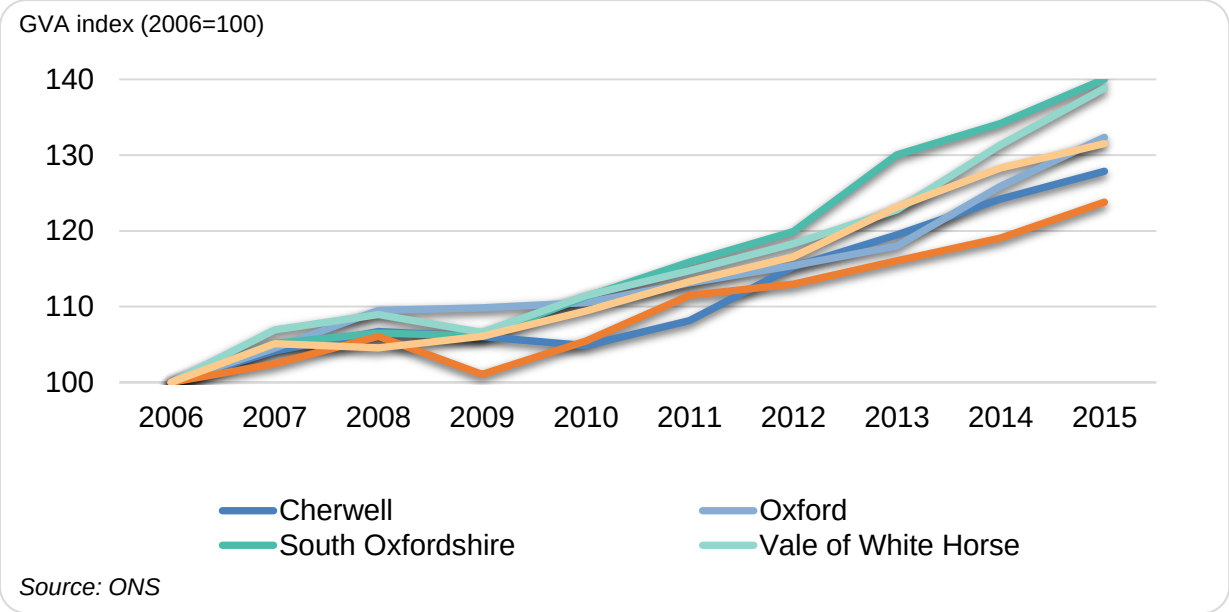


Figure 3-2 Oxfordshire and its local authorities, GVA growth, 2006-15

Social mobility, inequality and deprivation

Although there are substantial variations in GVA per-head, Oxfordshire is a largely affluent county although there are pockets of inequality. According to the government's most recent Indices of Mass Deprivation, five local authority areas in Oxfordshire were ranked in the least deprived half of the index. Of the 326 local authorities surveyed (with a ranking of 1 meaning most deprived), City of Oxford was ranked 166th, Cherwell 251th, South Oxfordshire 309th, Vale of White Horse 311th and West Oxfordshire 315th.

The City of Oxford was among the most deprived quartile of local authority areas on indices for barriers to housing and services and living environment (and just outside the quartile for crime). Barriers to housing services includes factors, such as housing affordability, homelessness and household overcrowding, while living environment considers air quality, traffic accidents and the quality of housing.

This emerging picture of Oxfordshire as a generally wealthy area but with weaknesses regarding housing quality and affordability is given greater clarity by the 2018 Centre for Cities' City Outlook report. Oxford scores exceptionally well on a range of indicators that would make it an attractive place to live and work. It ranked in the top ten cities nationwide for number of patent applications per resident; highest employment rate; lowest rate of jobseeker's allowance claimants; greatest proportion of highly skilled workers (and lowest proportion of low-skilled workers) and highest weekly wage. However, it was also ranked in the top ten for the fastest rise in house prices in 2016/17 and had the worst house-price affordability ratio in the country. It also had the lowest proportion of private-sector jobs.

In the ONS's social mobility index, the five districts generally struggled to score well, with none scoring in the top half. Vale of White Horse and Oxford fared poorly, ranking 256th and 257th out of 324 local authorities. These local authorities scored well on categories relating to wages and education levels of the workforce, but struggled on the performance of early years education.

Lastly, it is crucial to acknowledge that economic disparities, such as pockets of deprivation, are evident within districts as well as between them. Furthermore, marginality must be a key consideration for Oxfordshire as it grows. This is where certain individuals and groups may feel that they are on the peripherals of the social, political and economic systems in place. This emphasises the point that Oxfordshire will need to ensure that all residents feel that they are given equal access to opportunities in the county.

3.4 EMPLOYMENT AND SKILLS

The Oxfordshire economy has seen high levels of employment in recent years relative to the rest of the country.[11]

In the year to March 2018 the employment rate in Oxfordshire as a whole stood at 81.8% for the working-age population of 16 to 64 year olds. This compares favourably with rates of 74.8% in the UK and 78.5% in the South East. Unemployment is also lower than average, at 2.6%, relative to 4.3% in the UK and 3.4% in the South East. Finally, economic inactivity (defined as those neither working nor looking for work), stood at an average of 15.3% in this period, relative to 21.4% in England and 18.7% in the South East. These indicators define Oxfordshire as a region with a strong labour market.

Furthermore, the labour market appears strong across all of the five districts in the year to March 2018. West Oxfordshire had the highest participation rate; at 83.7%, it was one of the highest rates in the country. The differential to the local authority with the lowest rate — South Oxfordshire was relatively narrow, at 6.3 percentage points. Similarly, there was little difference between local authorities with the highest unemployment rate (Oxford, 3.1%) and the lowest (West Oxfordshire, 2.4%). In terms of the simple measure of the proportion of people working, Oxfordshire is performing extremely well. High levels of employment are very important in maintaining and accelerating the growth of the local economy: the fall in local unemployment is likely to have been one of the most significant factors in the improvement in the rate of economic growth in the county since 2013.

Oxfordshire has one of the most skilled workforces in the country.

The region also has a highly skilled workforce, a trait that is required for optimal economic output and the development of urban areas. All districts in Oxfordshire comfortably exceeded the national average for the proportion of the population with the highest level of qualifications — NVQ4 — in 2017.[12] Of the districts outside London, only Woking had a higher proportion of NVQ4 qualified workers than Oxford. The City of Oxford also had one of the lowest levels of workers with no qualifications, at 3.2%, compared with a UK average of 8%. This reflects a highly

---

[11] ONS, 'Regional labour market' local indicators for counties, local and unitary authorities', 2017, retrieved from: https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/employmentandemployeetypes/datasets/locallabourmarketindicatorsforcountieslocalandunitaryauthoritiesli01

[12] Nomis, 'Annual population survey', 2017', retrieved from: https://www.nomisweb.co.uk/query/construct/summary.asp?reset=yes&mode=construct&dataset=17&version=0&anal=5&initsel=

qualified employment pool capable of earning higher-paid jobs that would be beneficial for the local economy, particularly if the highest skilled workers could be retained to work locally.

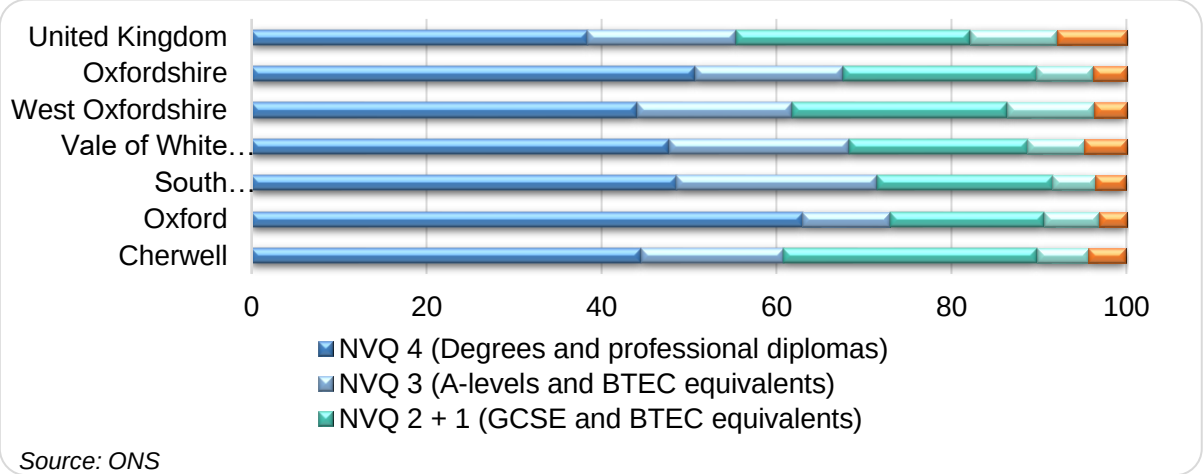


Figure 3-3 Level of qualifications, 2017

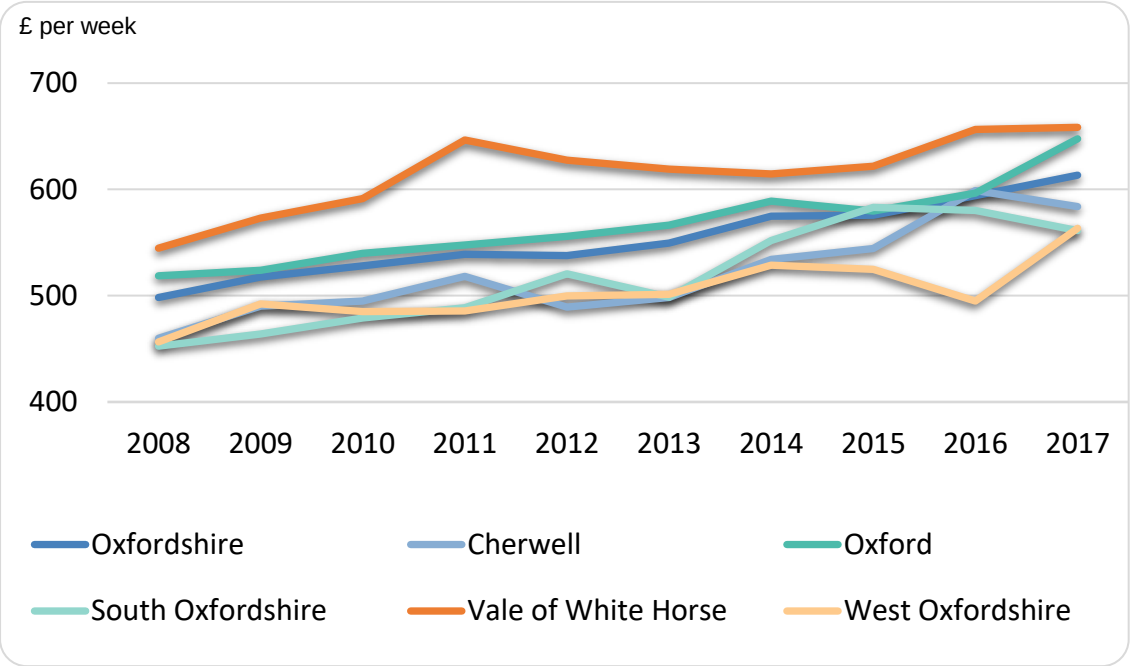
3.5 WAGES

Wage data builds on our existing evidence about the strong state of the Oxfordshire labour market, especially relative to the rest of the UK. Wages are measured in terms of the average median full-time weekly earnings, measured both by place of residency and location of the workplace. According to both measures, Oxfordshire scores impressively. Average weekly resident earnings stood at £632, compared with £550 in the UK, £556 in England and £576 in the South East.[13] Average workplace earnings in Oxfordshire were slightly lower, at £613. This suggests that the wages of those who live in Oxfordshire but work elsewhere are slightly higher than those who work elsewhere but commute in to work in Oxfordshire.

Growth in full-time median wages in Oxfordshire largely tracked those in Great Britain and the South East in the years of and after the global financial crisis. However, wage growth has accelerated since 2014, continuing particularly strongly in 2016 and 2017. This development is consistent with the acceleration witnessed in GVA growth since that year, hinting at a broader-based improvement in the performance of the county economy. Data at the local authority level also demonstrates greater clarity on that performance.

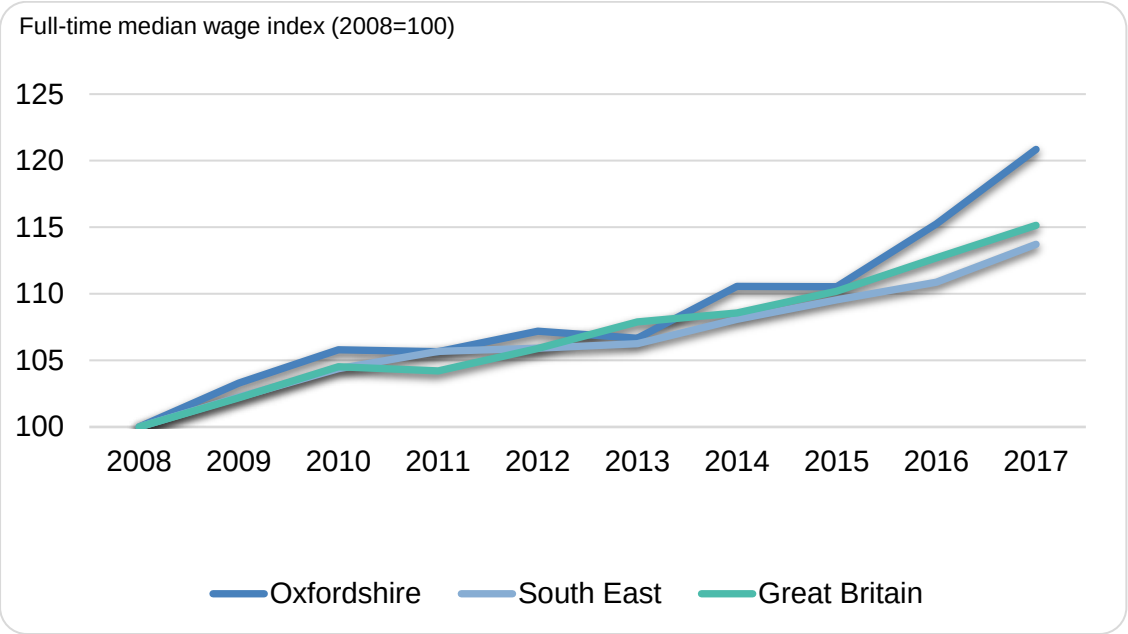
The improvement in Oxfordshire at a whole since 2014 has been driven by four of the five districts. Only South Oxfordshire failed to have a higher median wage in 2017 than it did in 2014. Wages rose quickest in West Oxfordshire and Oxford, while there was some improvement in Cherwell and Vale of White Horse.

[13] Nomis, Labour Market Profile- Oxfordshire', 2017, retrieved from: https://www.nomisweb.co.uk/reports/lmp/la/1941962886/report.aspx?#tabearn



Source: ONS

Figure 3-4 Oxfordshire median wage, 2008-17



Source: ONS

Figure 3-5 Median weekly pay for full-time workers, 2008-17

Real wages

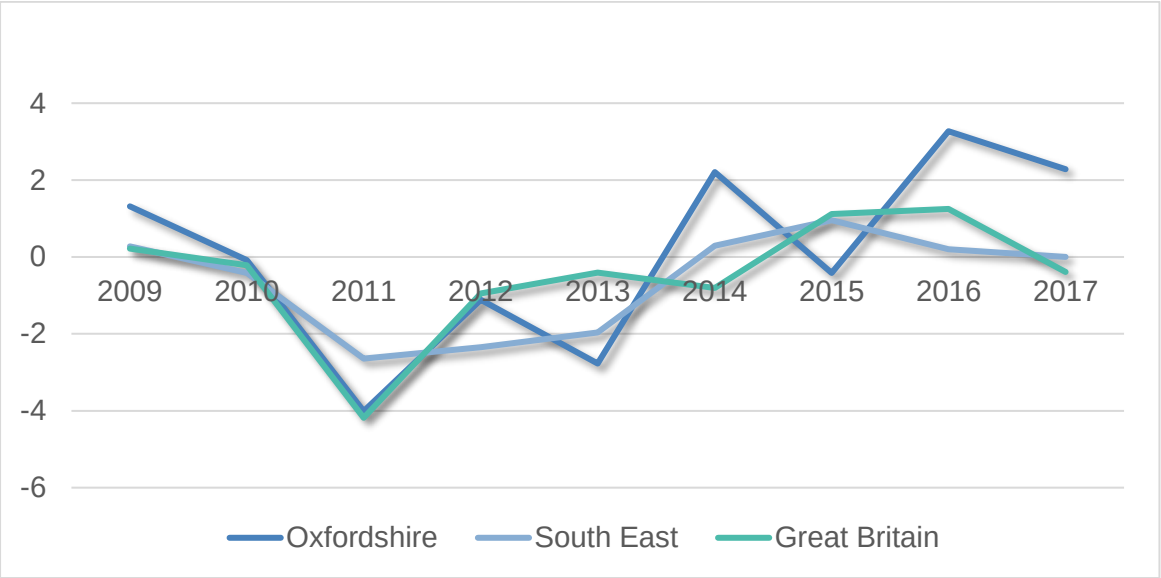
Wage data is useful as an indicator of the availability of labour (wages are likely to rise faster if there is a shortage of workers) and the broader strength of the economy (an economy growing well is likely to be creating new jobs and demanding more labour). However, nominal wage growth does not say anything about the standard of living for these workers. Wages could be rising by 4% a year, giving the impression of workers becoming richer fairly quickly, but if

consumer price inflation is rising at 5%, then in real terms workers would be becoming poorer and unable to maintain their existing lifestyles.

In Figure 3.6 we have subtracted the annual rate of consumer price inflation from nominal wage growth for Great Britain, the South East and Oxfordshire to give an indication of real wages. All three lines fell below zero between 2010 and 2013, indicating that real wage growth was negative. Given the broader state of the UK economy as it came to terms with the global financial crisis, this is not surprising.

However, wage growth returned to positive territory in 2014 and remained there in 2015 and 2016. Then, in 2017 a weaker pound helped to push up inflation, and, for Great Britain as a whole, resulted in another year of shrinking real wages.

Relative to Great Britain and South East, Oxfordshire has performed better, as a consequence of stronger wage growth enabling real wages to remain positive. (This picture would be much more nuanced if regional inflation data were available). Although inflation is typically discussed in terms of the whole country, the change in the cost of living is different across the regions. This is particularly true in Oxfordshire, which has high levels of house price inflation. Nevertheless, as a rough guide, workers in Oxfordshire are likely to have enjoyed slightly stronger wage growth over the past decade than the regional or national average.



Source: ONS

Figure 3-6 Real wage growth, 2009-17

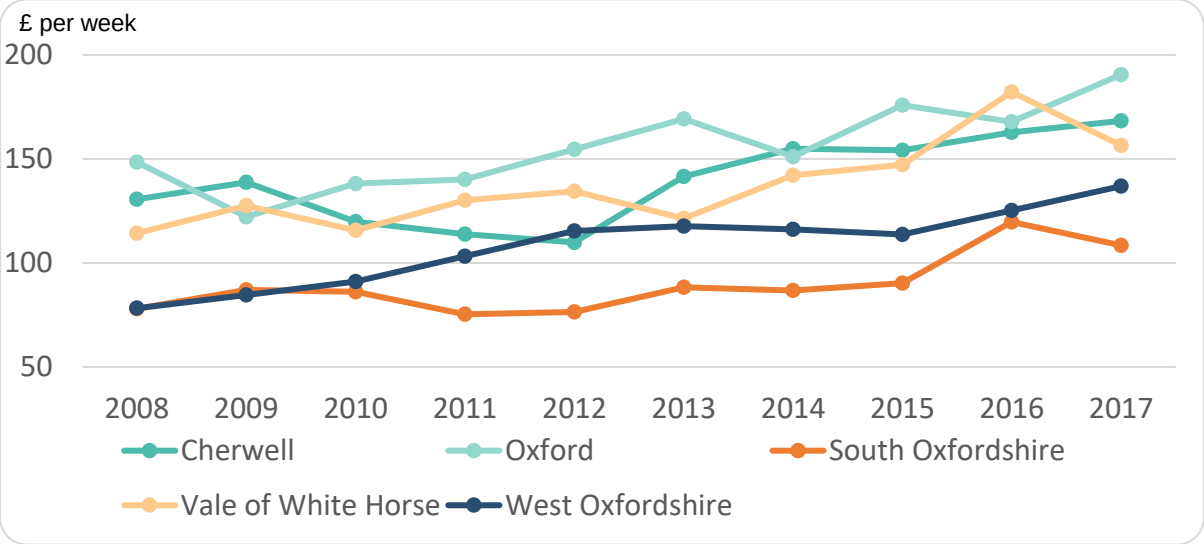
Wages for the lowest 10%

Oxfordshire fares particularly well on nationwide indicators measuring wages for the poorest 10%. In 2008, the county was ranked 15th out of 42 across England, with a median weekly wage of £115. (The index was led by Inner London and Cambridgeshire.) However, by 2017, the median wage for the poorest 10% had risen to £156 and Oxfordshire was second only to Inner London. This means that Oxfordshire's average wage was notably above the average for the UK, of £144 and the South East, of £144.

Throughout the past decade there has been significant variation in median wage levels for the poorest 10% in the five local authority areas. In 2008 they ranged from £78 in South Oxfordshire and West Oxfordshire, to £149 in Oxford. Over the past decade there has been little evidence of

convergence: employers in South and West Oxfordshire continue to pay wages that are much lower than those in Cherwell and Oxford. But nominal wages have been on an upward trajectory, and one that has been steeper than that seen in England as a whole.

This data shows that wages at the lower end of the income spectrum have risen faster in Oxfordshire compared to other parts of the UK – undoubtedly a positive trend. Yet the disparity between the five districts remains. To consider the broader question of whether living standards have improved in this period, it is necessary to explore information on how the cost of living has changed over the same time.



Source: ONS

Figure 3-7 Median weekly pay, lowest 10%, 2008-17

Workplace and resident wages

Another way to consider local wages is to focus on the split between resident wages and workplace wages. Resident wages were highest in South Oxfordshire—the local authority where GVA growth has been strongest in recent years—at £689 a week. The lowest wages were recorded in Cherwell at £595. To put the variation in context, of the 378 local authorities in the UK with resident wage data available, South Oxfordshire was ranked 24th, sandwiched between Barnet and North Hertfordshire (both of which saw significantly higher resident wages than workplace wages, implying that a high proportion of residents in these areas work elsewhere, likely in London), and Cherwell placed 100th. This suggests that jobs held by residents in Oxfordshire are relatively well paid.[14]

[14]. ONS, 'Annual survey of hours and earnings: 2017', retrieved from: https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/earningsandworkinghours/bulletins/annualsurveyofhoursandearnings/2017provisionaland2016revisedresults

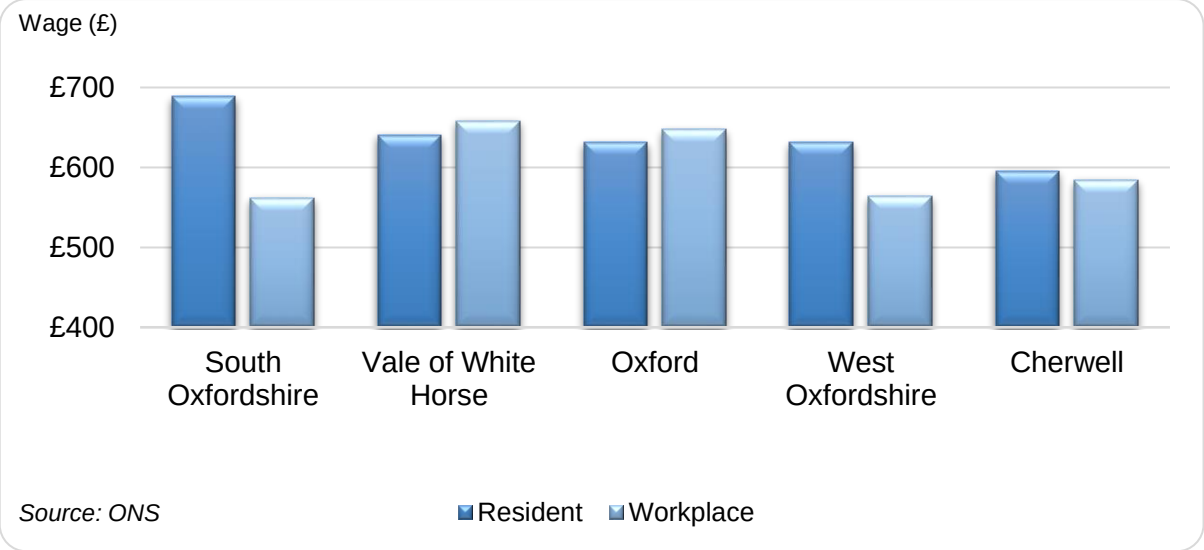


Figure 3-8 Oxfordshire local authorities' resident and workplace wage, 2017

There are some important differences when considering workplace wages. When Oxfordshire is aggregated, there is little to choose between resident and workplace wages. But for the individual districts, the differences are much larger. In Vale of White Horse and Oxford, workplace wages are higher than resident wages, if only by 2-3% or so. This implies a net inflow of commuters seeking higher paid work.[15]

In the other regions, especially West Oxfordshire and South Oxfordshire, workplace wages are much lower than resident wages. In the latter case, the difference between the two measures is close to 25%. This differential is accounted for by residents commuting out of the region to higher-paying jobs. When considering the Oxfordshire districts in a national context, Vale of White Horse is ranked 13th and Oxford 23rd for workplace wages and South Oxford 101st.

Wage data suggests that although Oxfordshire is generally a high-wage region in the UK context, there is a disparity between earnings of workers and residents. This in turn implies a mismatch between the types of jobs created and the skills base of the local labour force. In particular, Vale of White Horse and Oxford contain groups of high-wage companies and organisations, but they are unable to find local workers with the skill profiles to fulfil all of the roles. Consequently, these positions go to employees from outside of the authority areas. Conversely, South Oxfordshire (and to a lesser extent West Oxfordshire) is home to a lot of high-earning residents, but many of these commute outside of the region.

ONS Census data from 2011 suggests that almost 60% of residents in South Oxfordshire and 45% in West Oxfordshire commute outside of the authority for work.[16] This compares with less than 30% in Oxford. The top destinations for commuting in South Oxfordshire outside of

[15].ONS, 'Annual survey of hours and earnings',2017, retrieved from: https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/earningsandworkinghours/bulletins/annualsurveyofhoursandearnings/2017provisionaland2016revisedresults.
[16] Nomis, 'Location of usual residence and place of work by method of travel to work', 2014, retrieved from: https://www.nomisweb.co.uk/census/2011/wu03uk

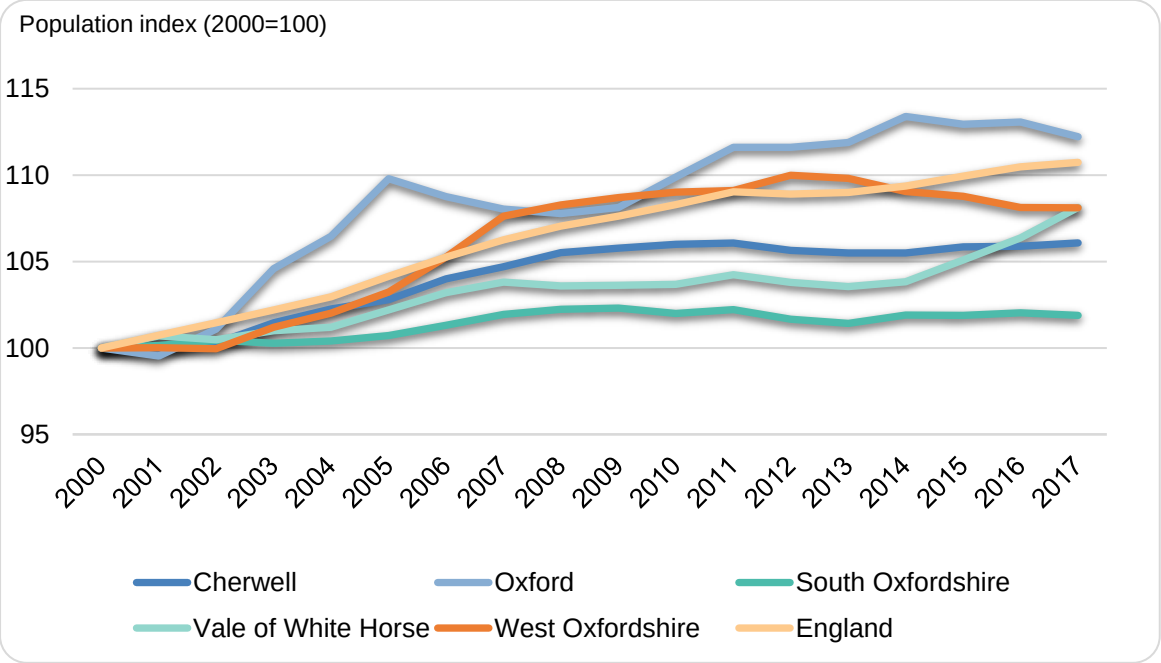
Oxfordshire and the South East were London and Reading and in West Oxfordshire, London and South-West England.[17]

3.6 LABOUR MARKET AND DEMOGRAPHICS

The size of the labour market is a crucial, if complex, factor in increasing the rate of economic output. More workers means the potential for higher output, especially if they are highly skilled , (which is characteristic of a large section of Oxfordshire's labour force), but also puts further upward pressure on transport infrastructure, public services and housing costs.

Data since 2000 shows that the labour market in Oxfordshire is expanding, but with the exception of Oxford, it is doing so at a slightly slower pace than in England as a whole.[18] Indeed, Oxford saw a surge in the working age population between 2001 and 2005 — during which time it grew by more than 10%—but this growth has not been repeated since. Figure 3.9 shows the population has declined in West Oxfordshire over the past five years and there has been no growth in South Oxfordshire in the same period. However, these trends have been more than offset by a rise in the population in Vale of White Horse, which has grown by more than 4% in the past four years. Again, this is consistent with the authority's improved economic performance in recent years.

Taken together, this data shows that the Oxfordshire labour force is continuing to grow, creating higher demand for housing and public services.



Source: ONS

Figure 3-9 Historical working-age population growth, 2000-17

[17] Nomis, 'Location of usual residence and place of work by method of travel to work', 2014, retrieved from: https://www.nomisweb.co.uk/census/2011/wu03uk
[18] Nomis, 'Population estimates by local authority', 2017, https://www.nomisweb.co.uk/datasets/pestsyoala

Oxfordshire's workforce will have to be more productive to support current levels of output.

Looking ahead, ONS forecasts suggest that the Oxfordshire population is likely to grow slowly over the next 20 years, from an estimated 678,000 people in 2016 to 720,800 by 2036.[19] However, the working-age population — defined as those between 15 and 64 — is expected to shrink. Indeed, the only one of the five districts where the labour force is expected to grow is Vale of White Horse. Elsewhere, the working-age population is likely to contract between 0.2% and 0.6% a year.

The missing piece of the puzzle is the pensioner population, which is expected to grow by between 1.5% and 2.5% a year in each of the five districts. A smaller working population demands that existing workers become more productive just to maintain the current level of output.

Oxfordshire's demographic profile is challenging relative to that of England as a whole. England is expected to see a compound annual growth rate of 0.1% in the working-age population over the next 20 years, compared with a fall of 0.3% in Oxfordshire. Similarly, England's pensioner population is likely to rise by 1.9% a year, while Oxfordshire's is expected to rise marginally faster, at 2%.

Lastly, the population of 0-14 year olds, who, of course, will provide the workers of the future, is also set to rise by 0.1% a year in England, but fall in Oxfordshire, by 0.3%. These projections suggest that Oxfordshire will need to consider ways of boosting net migration or encourage its private-sector firms to invest in measures which will enhance productivity if it wishes to maximise its economic growth.

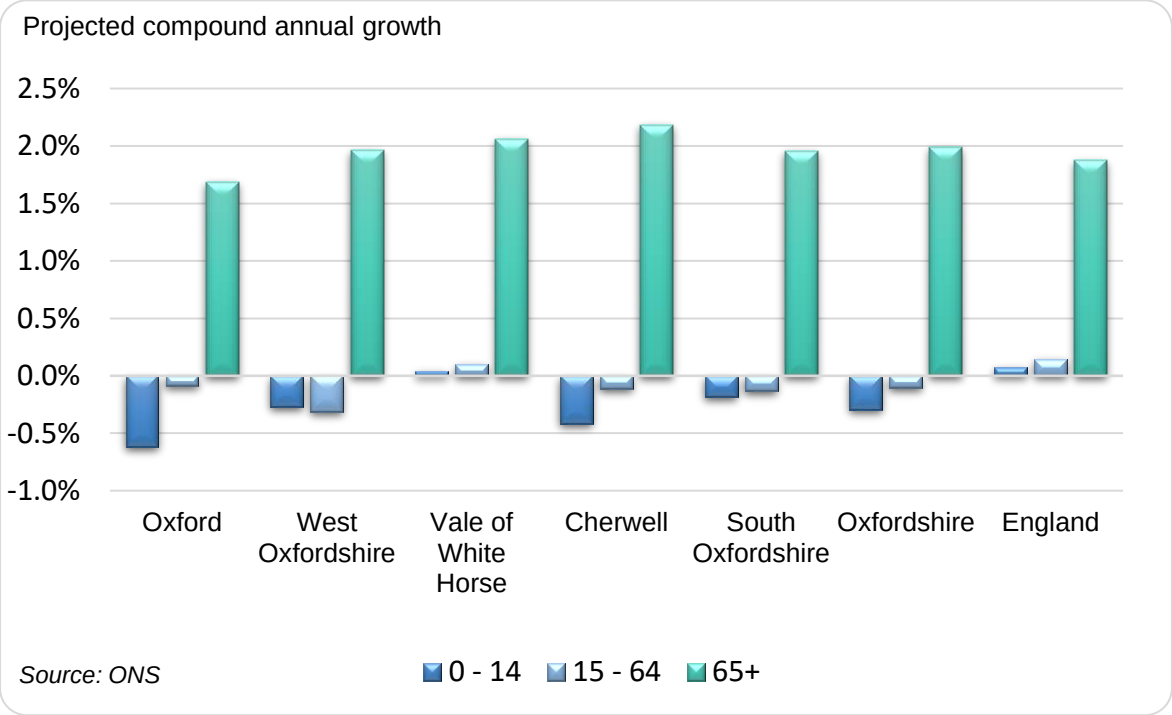


Figure 3-10 Projected growth of population by age group, 2016-36

[19] ONS, 'Subnational population projections for England: 2016-based ', 2017, retrieved from: https://www.ons.gov.uk/releases/subnationalpopulationprojectionsforengland2016basedprojections

3.7 HOUSING

Median house prices in Oxfordshire are 50% higher than the English average.

Median house prices across England have risen quickly in nominal terms since the turn of the millennium, from an average of £75,000 in the year ending March 2000 to more than £234,000 by end-2017.[20] This period can be thought of in three phases. The first, lasting from 2000 until early 2007, saw rapid growth fuelled by a strong national economy, high levels of real wage growth and housing demand stoked by a growing population. Between early 2008 and late 2010 prices were flat, as the market absorbed the effects of the global financial crisis. Household savings rates went up as consumer confidence fell and there was less appetite for taking on new debt. In the period since then, prices have gradually begun to rise again, with the rate quickening slightly since 2014.

Median prices in Oxfordshire were above the English average in 2000 and although local prices have followed the same trend, the divergence has continued. After a dip during the global financial crisis (when the median price fell by 10% from previous peak to trough), prices were essentially flat from the end of 2010 until the beginning of 2014, at which point they began to grow again, and at a faster rate than the English average. Consequently, the median house price in Oxfordshire ended 2017 almost 50% higher than the median price in England.

At the local authority level, the direction of prices in four of the five authorities have largely moved in lock-step since 2000, although there remain some important differences between them. Oxford recorded the highest median price, at £400,000, and Cherwell the lowest, at £301,000. All four districts saw more concentrated growth in prices from early 2014; again this is consistent with the generally improvement in the county economy witnessed from that year. The fifth district, which has followed the same trend but at a slower pace, is West Oxfordshire. Given the persistence of the trend, the reasons for it are likely to be structural: the major urban centres of London, Swindon and Reading are less accessible from West Oxfordshire than the other four districts.

House prices are, on their own, not particularly indicative of the attractiveness or health of a regional economy. Of more value is housing affordability, most commonly measured by comparing the ratio of the median house price to median earnings. Oxfordshire has been shown to be a region with both above-average wages and above-average house prices. However, it is house prices that have showed the greater divergence from the national average and which make Oxfordshire score poorly on measures of housing affordability relative to local wages.

On the next page, Figure 3.13 shows that three of the five districts – South Oxfordshire, Oxford and West Oxfordshire have a higher price to earnings ratio than the average for the South East. Of these, affordability in South Oxfordshire has worsened significantly since mid-2014. This is owing to two factors: the failure of the median wage in South Oxfordshire to grow in recent years and the surge in house prices in that authority over the same period. The median house price rose from £293,000 in 2014 to £377,500. Consequently, the price to earnings ratio in the region approached 13 in 2017, compared with an average for the South East of a little over 10.

[20] ONS, 'House price statistics for small areas in England and Wales', 2018, retrieved from : https://www.ons.gov.uk/peoplepopulationandcommunity/housing/bulletins/housepricestatisticsforsmallareas/previousReleases

Poor housing affordability can prove a deterrent to young professionals hoping to live and work in Oxfordshire. Given the county's unhelpful demographic profile, retention of young workers should be considered a priority. Without these workers, the region's ability to fill positions in high-technology and innovative business sectors would be hampered, weakening Oxfordshire's competitiveness.

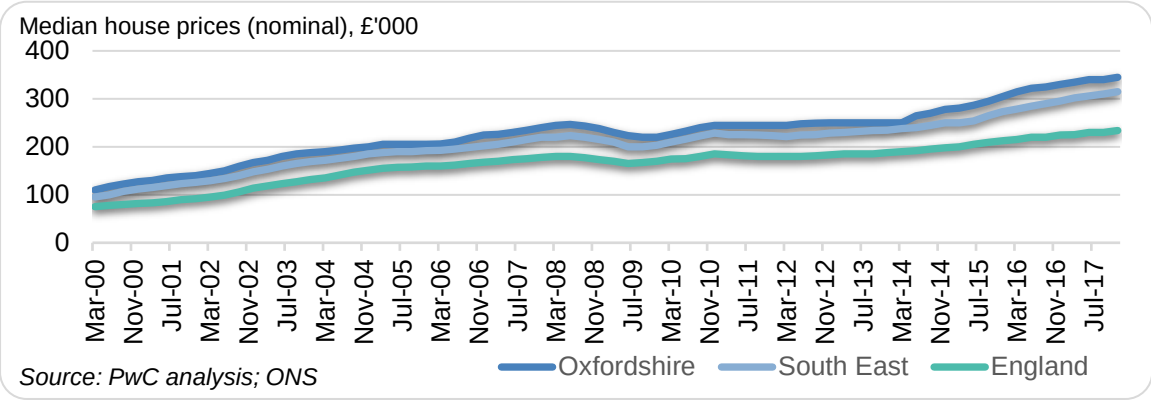


Figure 3-11 Housing prices, 2000-17

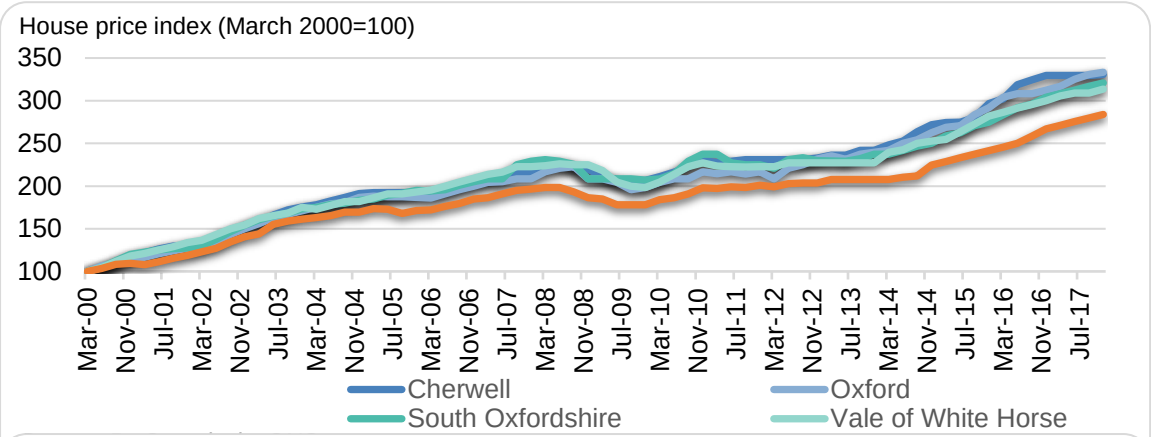


Figure 3-13 House price growth, 2000-17

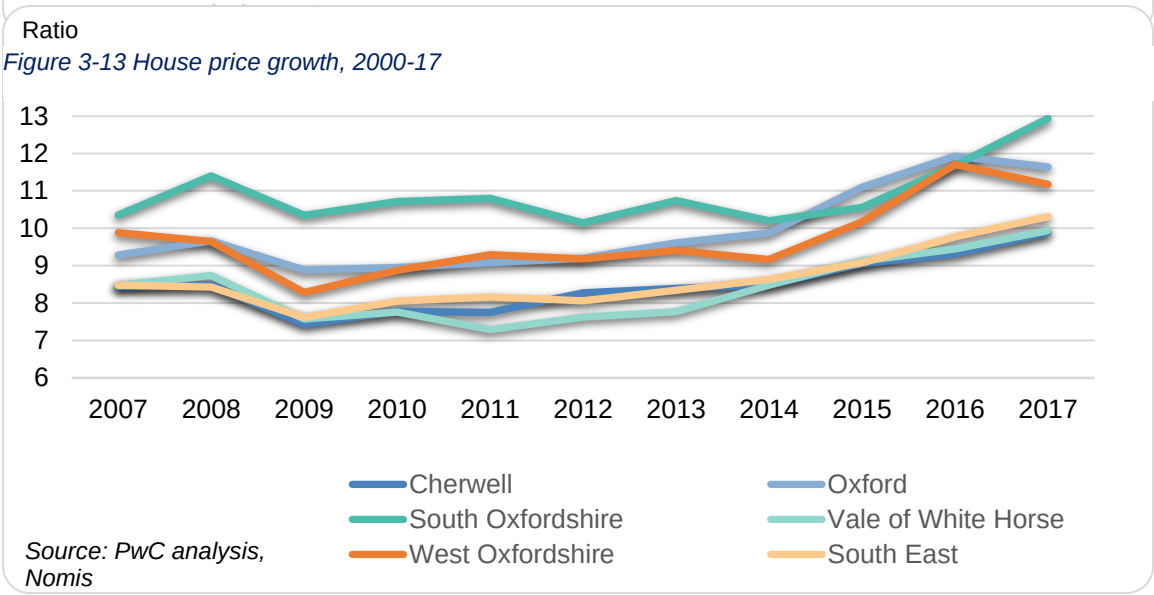


Figure 3-12 Median house price to earnings ratio, 2007-17

3.8 PRODUCTIVITY

In this section, productivity is derived by dividing the data on gross value added of each economic region provided by the ONS by an estimate of the total number of hours worked per year generated by NOMIS.[21]

Oxfordshire fairs moderately well in our analysis of productivity. However, there is undoubtedly room for the rate of productivity growth to rise. Oxfordshire's GVA per hour worked is above the average for England, but in recent years has fallen below that in the South East. Moving to districts, productivity is highest in South Oxfordshire and West Oxfordshire. This makes logical sense for South Oxfordshire, as the authority has had the fastest growth in GVA in recent years. West Oxfordshire's rate of GVA growth has been slower, but its productivity was boosted by a relatively low number of hours worked per employee compared with the other authorities. The fact that Oxford recorded the lowest productivity level is something of a surprise that merits further examination. Although the authority has comfortably the highest GVA per-head within the county, it also has a lot of jobs and a high mean average number of hours worked. These two factors dragged down its productivity results.

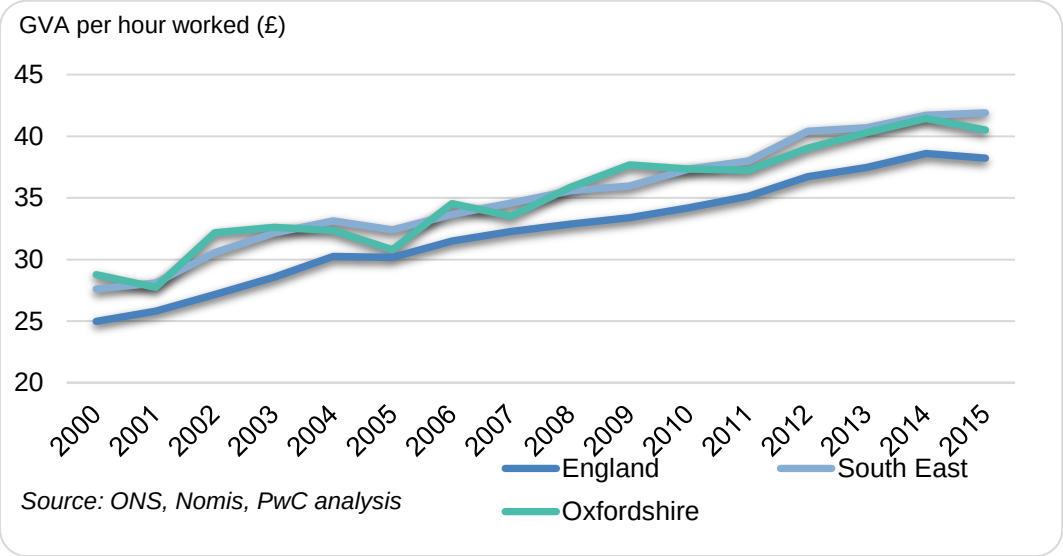


Figure 3-14 Productivity – Oxfordshire, 2000-15

[21] ONS, 'Regional GVA (balanced)', 2017, retrieved from: https://www.ons.gov.uk/economy/grossvalueaddedgva/bulletins/regionalgrossvalueaddedbalanceduk/1998to2016/relateddata https
Nomis, 'Hours worked by local authority', 2013, https://www.nomisweb.co.uk/census/2011/qs604ew

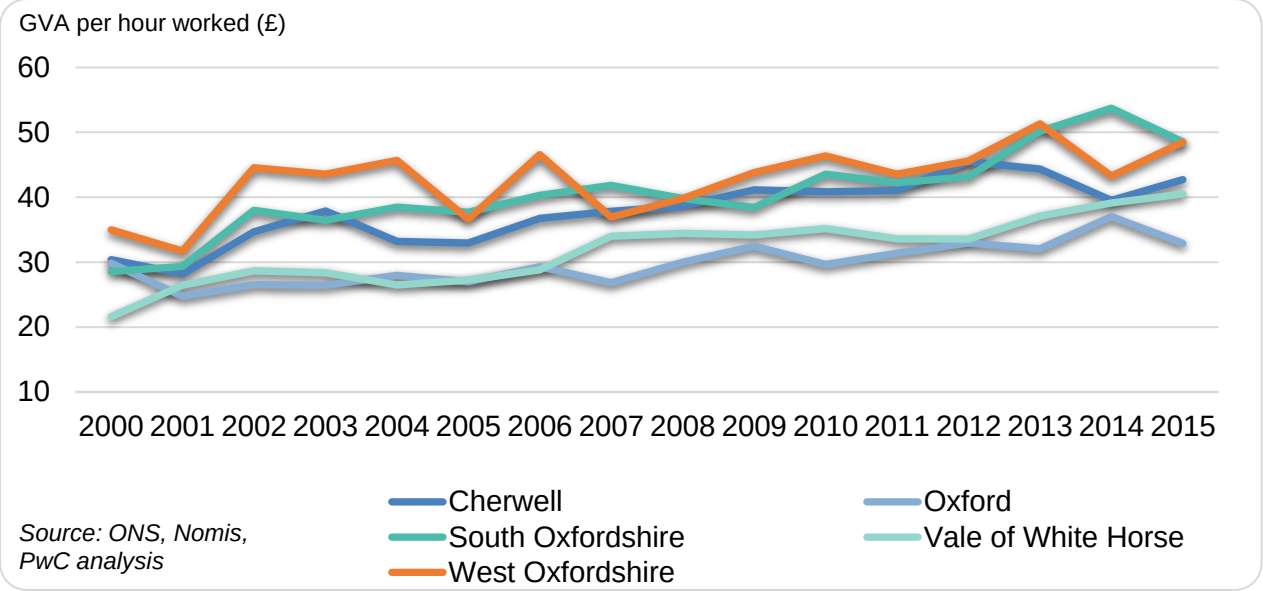


Figure 3-15 Productivity – Oxfordshire districts, 2000-15

When comparing the districts on a nationwide basis, South and West Oxfordshire perform well, ranking 47th and 48th out of 379 local authorities providing data in a list dominated by authorities from London and the South East. Cherwell came in at 88th and Vale of White Horse 109th. Oxford was the only one of the five authorities to fall in the bottom half of the index, where it came 217th. These productivity results display the importance of the Oxfordshire Industrial Strategy putting in place mechanisms (such as the adoption of new transformative technologies) as a basis for improving the regions productivity. A stronger focus on talent acquisition and retention will also support productivity growth in Oxfordshire.

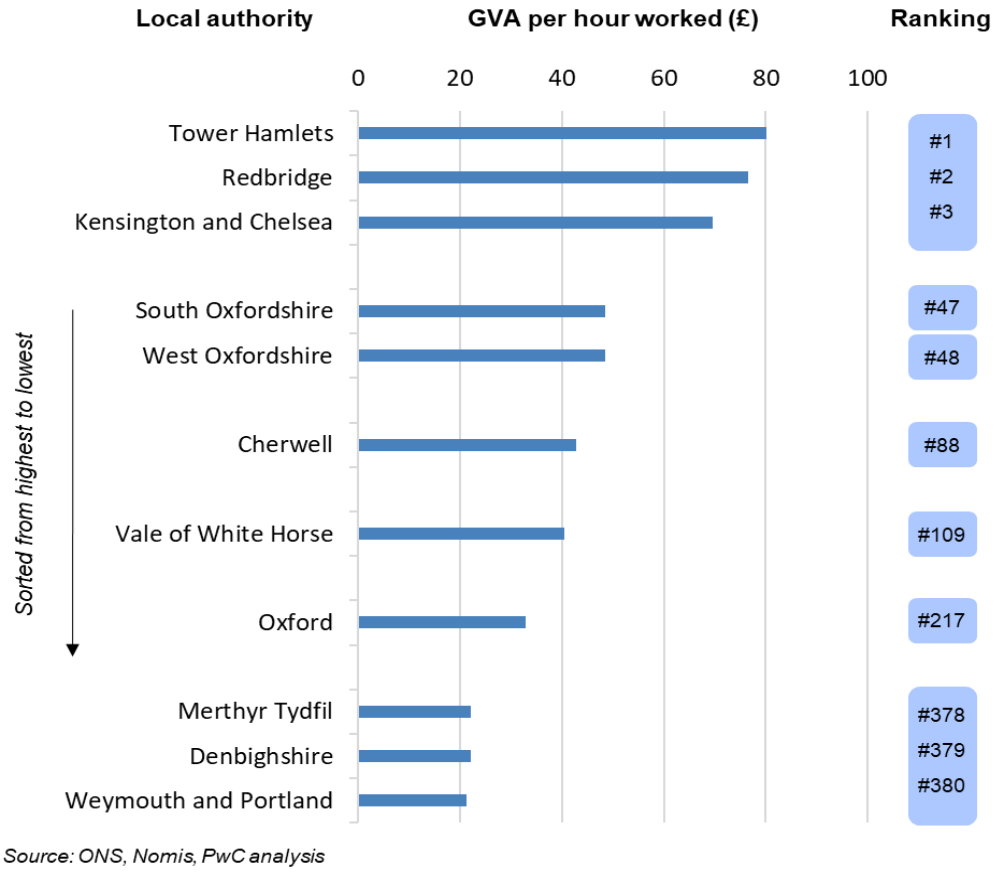


Figure 3-16 Productivity – UK local authorities ranking

Public Finances

Government have stated that Oxfordshire is one of only three net contributors to the exchequer.[22] It is important to understand what this means. Comparing the average amount of taxes raised with the public monies spent, relative to other parts of Great Britain, reveals an intriguing imbalance/contrast for Oxfordshire. Looking at the 'economy' taxes generated per worker in 2013/14 – such as income and corporation tax - Oxfordshire ranks 5th highest within a group of 37 geographies defined by Centre for Cities, which contains combined authorities and LEPs. In contrast with its relatively high contributions to the exchequer, Oxfordshire saw the second *lowest* Government spend per head, with the Thames Valley Berkshire LEP being the only political geography with a lower expenditure per person. The primary drivers of this are lower benefits spend (e.g. due to lower unemployment) and a lower proportion of retired population and consequent spend from older people (e.g. pensions).

Oxfordshire has been able to make a positive contribution to the exchequer, explained by an impressive performance against key macroeconomic indicators as set out in this chapter. Our analysis suggests the Oxfordshire proposition is delivering for a number of key stakeholders including HMG, locally based businesses, employees and students. Equally, there are also challenges ahead – to improve the affordability of living locally, to ensure all districts in Oxfordshire are benefitting equally and to ensure all groups in society have an opportunity to benefit.

[22] UK Government, Oxfordshire Housing and Growth Deal Outline Deal (2018)

4 MICROECONOMIC CONTEXT

4.1 INTRODUCTION

The previous chapter considered Oxfordshire's recent macroeconomic performance to understand where opportunities exist for faster growth. This chapter will consider these opportunities at the micro level. This involves analysing the factors that influence business performance and what interventions should be taken to further support local businesses. This is particularly important for Oxfordshire, as it is seek to develop a Local Industrial Strategy which underpins sustainable growth to deliver benefits for local businesses and residents.

This microanalysis of Oxfordshire is broken down into three stages.

- [4.3] A discussion of how Oxfordshire's vibrant sectoral mix can help it to take advantage of the fourth industrial revolution. This is built on a segmentation of Oxfordshire's business community into two distinct groups: cornerstone businesses and breakthrough businesses, and a set of insights that would support each type of business. Definitions of both groups and their typical characteristics are outlined on the following page.
- [4.4] Sectoral-level analysis for both business groups, looking at trends in enterprise numbers, job concentrations and GVA contribution. These insights are then matched with Stochastic Frontier Analysis (SFA) results which explore the drivers of productivity in greater detail.
- [4.5] An outline of what Oxfordshire can do on a micro level to help achieve its vision of becoming a "…vibrant, sustainable, inclusive, world leading economy, driven by innovation, enterprise and research excellence." The report highlights areas for improvement, covering skills, funding and drivers of efficiency. This will help Oxfordshire allocate its resources and align all stakeholders to deliver its full economic potential.

4.2 KEY FINDINGS

- Oxfordshire is well placed to exploit the opportunities provided by the fourth industrial revolution. This is because of a strong presence in disruptive technology sectors, which have expanded rapidly in recent years.
- The Stochastic Frontier Analysis (SFA) reveals that firms' efficiency varies across geographies and sectors. Business services are particularly more efficient in agglomerated areas. Large parts of Oxford and South Oxfordshire are productive while West Oxfordshire needs to improve. Given the importance of agglomeration for business services, it is crucial that there is better targeted transport infrastructure.
- Oxfordshire should consider four themes when trying to help breakthrough businesses: leadership, business strategy, financial support and skills. The SFA highlights the importance of dynamic and competitive markets, which can be created by lowering barriers to entry and encouraging entrepreneurship. Encouraging global participation through exports and schemes to boost business R&D investment, should be key priorities.
- Oxfordshire performs well on funding and R&D spending, which are associated with greater efficiency. However, Oxfordshire needs to improve graduate retention numbers and promote more tailored labour skills through apprenticeships, given the very tight labour market conditions.

4.3 OXFORDSHIRE'S SECTORAL MIX

This section sets out the segmentation of Oxfordshire's business community into two distinct groups, with definitions of each group as well as factors that influence the growth of each group. It also contains a discussion of how this vibrant sectoral mix can help Oxfordshire take advantage of the fourth industrial revolution.

To illustrate the dynamic nature of companies in Oxfordshire, bringing together mature sectors that employ large numbers of staff, and high-growth technology companies that are rapidly expanding, we group firms under two main categories: cornerstone and breakthrough. While this a high level distinction, and some firms might identify with both categories, it serves to understand the Oxfordshire economy and highlight the different needs of this diverse community. Below we set out how both breakthrough and cornerstone businesses are essential to economic growth.

Cornerstone businesses

These businesses are the backbone of the economy and provide the platform for economic growth. Their performance is closely linked to the performance of the economy as a whole. They tend to me in mature public and private sectors, including education, health, professional services, logistics, retail, leisure and tourism. They represent the majority of the business community, and they support breakthrough businesses by providing essential services and supply chains. They are not usually risk-taking businesses, and although generally see steady growth they do not usually generate rapid growth. They are critical to the future success of the economy by providing the essential platform for economic growth.

Breakthrough businesses

These businesses are riskier, operate in markets where innovation is critical for survival and have the potential to become world leaders in their industry. They tend to rely on innovation and transformative technologies. These technologies, and the innovation spurred by the convergence of technologies across industries, have the potential to drive economic growth at scale and will increasingly drive the productivity of all sectors. They stimulate growth throughout the economy, and can transform cornerstone business models through sharing innovation and technology that can improve productivity. They offer an opportunity for faster economic growth and have the potential to become unicorn companies with market values of over one billion.

Cornerstone businesses in established sectors have historically driven growth.

Cornerstone businesses in established sectors such as public administration, education and health have contributed most to Oxfordshire's GVA growth over the last decade – having historically driven growth, they provide an essential platform for future growth. They provide essential services and supply chains within the Oxfordshire economy and beyond, and provide the majority of jobs for Oxfordshire's residents. This means they are critical for ensuring growth is inclusive, as their success influences the wages and standard of living the majority of Oxfordshire's communities.

New technologies of the twenty first century are now providing new opportunities for rapid future growth.

The external environment is rapidly changing, with technological disruption shaping our futures, industries and the ways in which we live and work. The fourth industrial revolution is the most important technological and social change that the world will witness this century, building on the

personal computing and digital revolution of the late twentieth century and the industrial revolution of the nineteenth century.

The fourth industrial revolution brings new technologies and ‘cyber-physical systems’ that enable technology to become embedded in societies in new ways. They include technologies such as artificial intelligence, robotics, nanotechnology, blockchain, quantum computing, the internet of things, 3D printing, autonomous vehicles and biotechnology. These new technologies and systems create significant opportunities for growth and wealth creation, as well as improvements to the way we life and our quality of life.

The 2017 Oxfordshire Science and Innovation Audit (SIA) has focused on four of these transformative technologies in which Oxfordshire has the highest potential to be world-leading and tap into rapidly growing global markets.[23]

They are four large-scale, disruptive, inevitable and digital technologies for which the UK has great need and world-class strength, particularly in Oxfordshire. These include Digital Health, Space-led Data Applications, Autonomous Vehicles and Technologies underpinning Quantum Computing. These four areas are where the industry is nascent and has the greatest potential for growth. They are specific areas of technology and application development which, combined, have the potential to drive innovation across many sectors. These are industries and technologies which have rapidly growing global markets.

The 2017 Science and Innovation Audit has set out that by 2030 these four transformative technologies could contribute:

- **800,000 jobs to the UK economy, 8% of which would be in Oxfordshire**
- **£181 billion to the UK economy**
- **£1,300 billion to the global economy**

The four technologies in the SIA audit are not the only four in which Oxfordshire has capability and potential – but the four in which we will focus on for the benefit of this analysis. New transformative technologies will also emerge over the next twenty years as Oxfordshire continues to provide the space and environment needed to pioneer the advancement of research and development in this space.

[23] OxLEP, ‘Science and Innovation Audit’, 2017

Space-led data applications
The UK is targeting 10% market share of the global space market by 2030 – this would mean £40bn a year for the UK. Space-led data applications includes earth observation, satellite positioning and communications. Oxfordshire has over 75 organisations, including the Satellite Applications Catapult, world-class research, and international pull. Making it Europes largest space cluster

Technologies underpinning quantum computing
Quantum technologies will profoundly change the world by 2030. The UK has a strong but fragile global position in the race to develop quantum computing technologies, with strengths in areas such as cryogenics. Oxfordshire leads a consortium of 34 organisations to build the Q20:20 Quantum Computer Demonstrator by 2020 and to stimulate quantum industries.

Autonomous vehicles
Oxfordshire is best placed to be a living laboratory for real-world testing of CAV rollout. Oxford Robotics Institute kick-started the UK's autonomous cars programme in 2010. Oxbotica now leads the UK consortium to develop and launch a fleet of driverless vehicles on roads. R&D continues in conjunction with RACE (Remote Applications in Challenging Environments) at Culham.

Digital health
Oxfordshire has over 160 digital health companies – this is a potential major growth cluster for developing and demonstrating technology-based healthcare solutions. Developers with an end-to-end patient pathway and test-bed system can speed up innovation, demonstration and rollout, and better evidence health benefits and cost systems. Oxfordshire can lead the way for the UK in bringing beneficial technologies to market more rapidly.

Oxfordshire is well placed to embrace and capitalise on these transformative technologies that are shaping the twenty first century, through its breakthrough businesses.

Oxfordshire is well placed to embrace these transformative technologies that are shaping the twenty first century. As outlined above, Oxfordshire has a strong skills and knowledge base as well as this distinctive sectoral mix combining both cornerstones and the breakthrough businesses that rely on science and technology innovation.

The SIA also sets out which types of businesses are considered to be using these technologies (see Figure 4.1). However, it is important to recognise that these four technologies have the capability to form a hot-bed for the emergence of new sectors in the coming years.

For Oxfordshire to leverage its skills in relation to these technologies it is important that the county focuses on breakthrough businesses, so defined as their development will determine the county's ability to make the most of the fourth industrial revolution. These businesses are riskier, operate in markets where innovation is critical to survive and have the potential to become world leaders in their industry.

Key sectors	SIC Code	SIC Code description
Autonomous vehicles	26511, 29100, 29310, 29320, 71121, 71122, 72190	Manufacturing of electronic instruments, motor vehicles and equipment related to this, engineering for industrial processes and engineering related technical consulting activities
Digital health	21100, 21200, 62012, 72110, 86220, 86900	Pharmaceutical product manufacture, software development, R&D on biotechnology, specialist medical practice activities and others related to human health.
Space-led data applications	30300, 51220, 61300, 74901	Space transport, environmental consulting, manufacture of air and space craft and machinery related to this, satellite telecommunication activities.
Technologies underpinning quantum computing	24410, 26110, 26120, 26200, 26800, 72190	Precious metal production, electronic component and computer equipment production, loaded electronic boards, manufacture of magnetic and optical media.

Source: ONS, Nomis, PwC analysis

Figure 4-1 Industry Classifications for the four underpinning technologies

In the following pages, we have highlighted factors that influence the success of each business group, looking specifically at which are the most relevant for each group. However, it is equally important to note that businesses, regardless of whether they are cornerstone or breakthrough businesses, have common factors that impact their performance. For example, all businesses require the right skills in the local labour pool, a clear business strategy and high quality digital connectivity in order to achieve their full potential. This evidences the need for a strong foundation of resources for local businesses as well as more tailored support for the unique challenges that each business group must overcome for growth.

What growth factors are most relevant to breakthrough businesses?

The vast majority of Oxfordshire's business base are defined as SMEs (approx. 99%). While some of these businesses will be classified in the cornerstone group, many will also fall into the breakthrough category, therefore research into the business group is useful to develop insights from, informing future policy interventions. In 2016, the Enterprise Research Centre (ERC) carried out a 'Growth Drivers Evidence Review' for SMEs. This research identified five factors that determine growth and productivity in SMEs. [24]

- **Leadership and managerial capacity:** The role of leadership is an indispensable component of business success. Firms that are relatively young often struggle to acquire

[24] Enterprise Research Centre: Growth Drivers Evidence Review (2016) https://www.enterpriseresearch.ac.uk/research-hub/growth-drivers-evidence-review/

effective leaders. Strong leadership provides clear direction, motivation, and experience and insight when key decisions are required.

- **Business strategy:** A clear business strategy is essential to align stakeholders on a single path. Creating a business strategy outlines the vision as well as confirms an understanding of Oxfordshire's capabilities and gaps for improvement before pursuing a clear path to market.
- **Digital connectivity:** World-class digital connectivity is essential if Oxfordshire's breakthrough businesses are to reach new customers and markets online. Full fibre broadband technology is seen as the future of high-speed and high-quality connectivity. The £200m local full fibre networks challenge fund provides an opportunity for Oxfordshire to accelerate the roll out of full fibre networks across the region.
- **Financial support:** Funding is an integral component for firms who are in either the start-up phase or the scaling phase. This is particularly important given the increasing levels of competition, placing pressure on profits and a firm's ability to innovate in order to survive. The SFA results conclude that greater market competition is correlated with a higher level of business efficiency. In this regard, Oxfordshire is in a strong position, having the largest university-focused venturing fund (UVF) in the world, Oxford Sciences Innovation (OSI). OSI has raised over £600m in capital with investments ranging from £100,000 to £10m.
- **Skills and employability:** Hiring and retaining talent is fundamental to a firm's success. It is not only crucial for firms to hire employees with the right qualifications but also with attitudes that fit the firm's culture. A survey conducted by the UK Commission for Employment and Skills in 2015 found that 69% of businesses in Oxfordshire state that employee skills gaps are inhibiting their business performance. It is clear that breakthrough businesses require more tailored career paths at an earlier age, given their demand for niche skills and knowledge.[25]
- **Business space:** A lack of affordable and available business space is constraining productivity and business growth in Oxfordshire.[26] The constraints on land available for development in Oxfordshire, particularly around Oxford City, lead to high prices for business space. New developments and expansions of science and business parks provides an opportunity to provide more affordable 'A' grade and flexible-use office space to enable businesses to grow to scale. This challenge will be explored further in the spatial chapter.

What growth factors are most relevant to cornerstone businesses?

Cornerstone businesses are much more established and integrated within the Oxfordshire economy. The factors that affect their performance are also more closely linked to the economic performance of the UK as a whole. For example, budget reductions taken by central government will affect public sector output at both national and local level. Performance of cornerstone businesses are likely to be influenced by:

---

[25] UKCES Employers Skills Survey (2012), https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/303374/ukces-employer-skills-survey-11.pdf
[26] Savills, Spotlight: is the future bright for Oxford? (2017)

- **Consumer confidence:** Consumer confidence is a useful indicator that measures willingness of consumers to spend their income. The retail and accommodation sectors are relatively more sensitive to this factor than others.
- **Employment levels and job creation:** Similar to breakthrough businesses, all types of businesses must attract and retain their talented staff. Furthermore, during high growth periods, firms within an economy will hire at a faster rate to keep pace with demand, and vice versa in periods of subdued growth. This highlights the importance for Oxfordshire's businesses to consider succession planning, ensuring there is limited impact on business performance during periods of staffing changes.
- **Interest rates and business rates:** Interest rates impact on business expenses for firms with debts. This also determines the cost of borrowing for small businesses who rely on loans from banks and other financial institutions for investment. Lastly, changes in interest rates also make it more or less expensive for consumers to take out loans to buy big-ticket items such as cars and homes. The amount businesses pay in rates has a direct impact on the attractiveness of commercial real estate as an investment, and so affects the amount of economic development that takes place across Oxfordshire and the UK.
- **Inflation:** Inflation represents the rate at which prices in the economy are increasing. This impacts the costs of production for firms, which can also be met with a rise in prices charged by the firm for its products and services. Rising inflation reduces the purchasing power of consumers, unless wage levels increase at an equal or greater rate.

It is important to note that Oxfordshire must bring the best out of both types of business groups. The evidence clearly suggests that businesses in Oxfordshire are diverse which means the region must enact specific interventions to support each type of businesses in different ways.

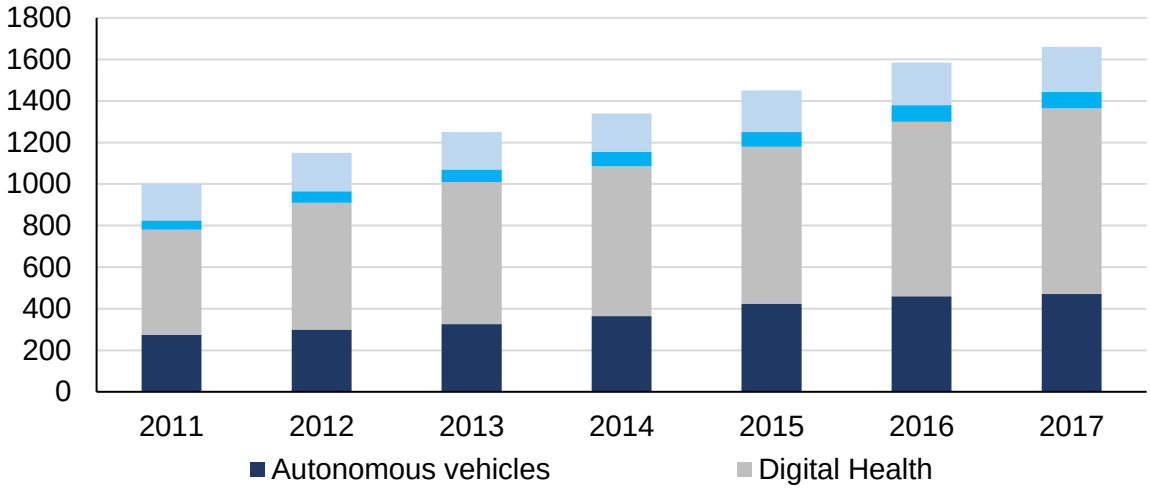
4.4 SECTORAL LEVEL ANALYSIS

This section considers each business group in turn, focusing on enterprise growth, relative job concentrations in Oxfordshire versus Great Britain and the GVA contribution by sector. The section then concludes with the results from our stochastic frontier analysis, which was undertaken to better understand the economic efficiency of businesses in the county relative to the rest of the UK.

BREAKTHROUGH BUSINESS SPOTLIGHT

Oxfordshire currently has over 31,000 businesses located across the county, nearly all of which (99%) are defined as SMEs. Furthermore, according to the latest business count data from the ONS, 88% of all Oxfordshire businesses employ less than nine employees. This is not dissimilar to the UK level, but still indicates that the Oxfordshire business base is vibrant and in a strong position to foster innovation.

In 2017, there were over 1,600 businesses operating in the Digital Health, Space-led Data Applications, Autonomous Vehicles and Technologies underpinning Quantum Computing areas. The number of businesses in this pool has grown by just under 9% a year since 2011. The digital health and autonomous vehicles sectors have experienced the greatest increase in absolute business numbers over the period, adding 390 and 195 new firms respectively.



Source: ONS, Nomis, PwC analysis
Figure 4-2 Enterprise growth of breakthrough sectors across Oxfordshire, 2011-17

Oxfordshire's breakthrough businesses have a broad set of sectoral specialisms.

According to the latest Business Register and Employment Survey data in 2016, approximately 7% of jobs in Oxfordshire were located in the four science and technology sectors as identified in the SIA. This compared with 4% in Great Britain as a whole. Location Quotient (LQ) analysis, which compares an industry's share of Oxfordshire's total employment, divided by the same industry's share of Great Britain's total employment — reveals that three of the four breakthrough sectors have LQs greater than 1, implying that Oxfordshire is more specialised in these areas than Great Britain as a whole.

The Quantum computing sector is significantly more specialised in Oxfordshire compared with Great Britain. This reflects the robust growth in the number of enterprises operating in the sector since 2010, rising by 4.8% year on year on average. The LQ result for the space sector is somewhat misleading, skewed by the sectoral definitions taken from the SIA. Great Britain as a whole is particularly strong in the manufacture of air and spacecraft and related machinery. These are employee incentivised operations. Oxfordshire has a notable specialisation in satellite telecommunication activities which relies on innovation rather than labour intensive activities. Furthermore, the number of businesses in the space sector has grown rapidly at around 18% a year over the period 2010 to 2017.

Both universities in Oxfordshire make a contribution to the key sectors in the economy.

In 2016, 4.8% of Oxford University graduates began working in the field of Science Research and Development and Engineering, with similar figures for Oxford Brookes graduates. Moreover, the University of Oxford generates the largest number of spin-out companies out of all UK

universities – there are currently 149 active start-ups and spin-outs from the university.[27] In 2014/15 a total of 136 spin-out companies generated approximately £147m of GVA, supporting 2,421 jobs in the Oxfordshire economy. The majority of these companies are in the field of Biotech, Engineering and Electronics. For example, in 2017 engineering spin-out, OxMET technologies, began to create products for aerospace, automotive and biomedical markets.

Sector	No. of jobs	Share of total jobs	LQ
Technologies underpinning Quantum Computing	6,170	1.6%	3.34
Autonomous Vehicles	8,250	2.2%	2.02
Digital Health	10,785	2.9%	1.39
Space-led Data Applications	675	0.2%	0.48

Source: ONS, Nomis, PwC analysis

Figure 4-3 Location quotients for breakthrough sectors, 2016

These breakthrough sectors are expanding rapidly in GVA terms.

The data used to analyse the performance of breakthrough sectors in Oxfordshire has been taken from the Annual Business Survey (ABS). The ABS covers the UK non-financial business economy, which accounts for approximately two thirds of total GVA. More specifically we have used the approximate GVA at basic prices to measure the value generated by these very granular sectors of the Oxfordshire economy. Please note that due to this level of sectoral granularity, the insights drawn are indicative trends, providing a sense of how these breakthrough sectors are performing in GVA terms versus job creation in the previous section. Lastly, it is difficult to determine these sector's absolute GVA contribution to the Oxfordshire economy due to the aggregation and disclosure of some sectors, however it is very clear that growth across these sectors has been rapid over the last decade.

As a whole, breakthrough sectors in Oxfordshire are growing between 5% and 10% faster annually than their UK counterpart. This indicates that Oxfordshire's businesses are both findings news ways to generate additional income streams as well as new ways to reduce their business expenditure, resulting in much higher profits.

Figure 4.4 highlights some of Oxfordshire's fastest growing breakthrough sectors between 2006 and 2016 versus their UK counterpart. For example, sic code 71121 demonstrates Oxfordshire's comparative advantage in how its businesses are applying physical laws and principles of engineering in the design of machines, materials, instruments and processes to improve industrial production output. This is very promising as these results highlight the county's capability to transfer research and innovation excellence into the manufacturing process effectively, ensuring that as much economic activity is retained within the county economy versus relocating elsewhere.

[27] Oxford University Economic Impact Assessment, Biggar Economics, April 2017

Sector	Oxfordshire (%)	UK (%)
71121 : Engineering design activities for industrial process and production	30.1%	10.1%
74100 : Specialised design activities	21.6%	10.1%
72190 : Other research and experimental development on natural sciences and engineering	19.3%	5.2%
30300 : Manufacture of air and spacecraft and related machinery	18.9%	3.5%

Source: ONS, Nomis, PwC analysis

Figure 4-4 Annual average GVA growth in breakthrough sectors, Oxfordshire vs. UK, 2006-16

CASE STUDIES: SPIN OUTS IN OXFORDSHIRE

- **Latent Logic**: founded in 2018 and is involved in the key sector of autonomous vehicles. It develops machine learning software which enables autonomous systems to learn to perform tasks and solve complex problems from human demonstrations.
- **OxMET Technologies**: founded in 2017 and uses proprietary software in order to generate new alloys for aerospace, automotive and biomedical purposes. The products it generates can improve the efficiency of planes and cars, improve biomedical implants and can be tailored for 3D printing.
- **Oxford Quantum Circuits**: founded in 2017, is a company that aims to build a quantum computer based upon a superconducting circuit using the latest technology. In terms of funding, it is still an early stage venture.
- **Oxford VR**: founded in 2016, is a company involved with the Digital medicine sector. It develops a virtual reality software to treat people with severe paranoia and bring the best psychological techniques using this technology

CORNERSTONE BUSINESSES SPOTLIGHT

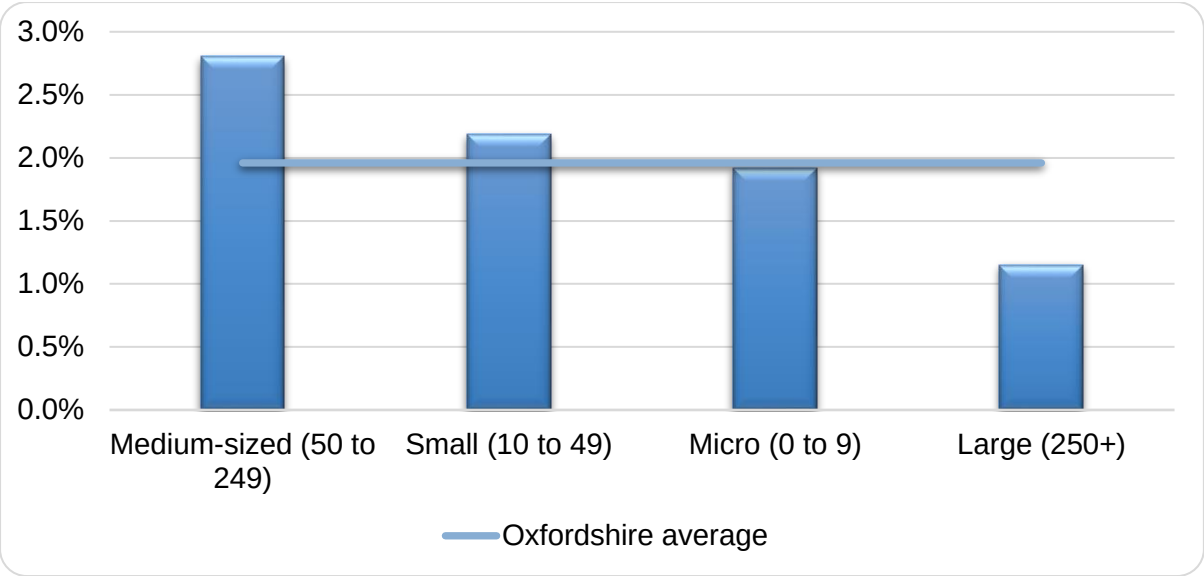
In the decade to 2016, the public sector, distribution, transport, accommodation, food and real estate activities contributed over 50% to Oxfordshire's GVA growth. IT and construction experienced the most rapid expansion annually over the same period, at 5.8% and 5% respectively. The IT sector, in particular, tends to have a larger share of higher value-adding jobs, which also tend to be highly paid, meaning a greater contribution to productivity and growth to the economy.

Sector	GVA contribution (%)	YoY growth (%)
Public administration; education; health	20.1%	3.6%
Distribution; transport; accommodation and food	18.0%	4.1%
Real estate activities	14.8%	3.9%
Professional and administrative services	13.9%	4.1%
Information and communication	11.5%	5.8%
Construction	7.7%	5.0%
Manufacturing	5.4%	2.0%
Recreation and other	4.6%	4.6%
Agriculture, mining, energy, water and waste	2.7%	3.8%
Finance and insurance	1.4%	2.3%

Source: ONS, Nomis, PwC analysis

Figure 4-5 GVA growth by broad sector, 2006-16

Figure 4.6 shows that the pool of enterprises who employ between 50 and 249 employees has seen the strongest growth in the period between 2010 and 2017, at 2.8% a year. This is in contrast to the pool of businesses employing more than 250 employees, growing at a slower rate of 1.2% annually. Faster growth in smaller-scale businesses indicates healthy entrepreneurial spirit across Oxfordshire.



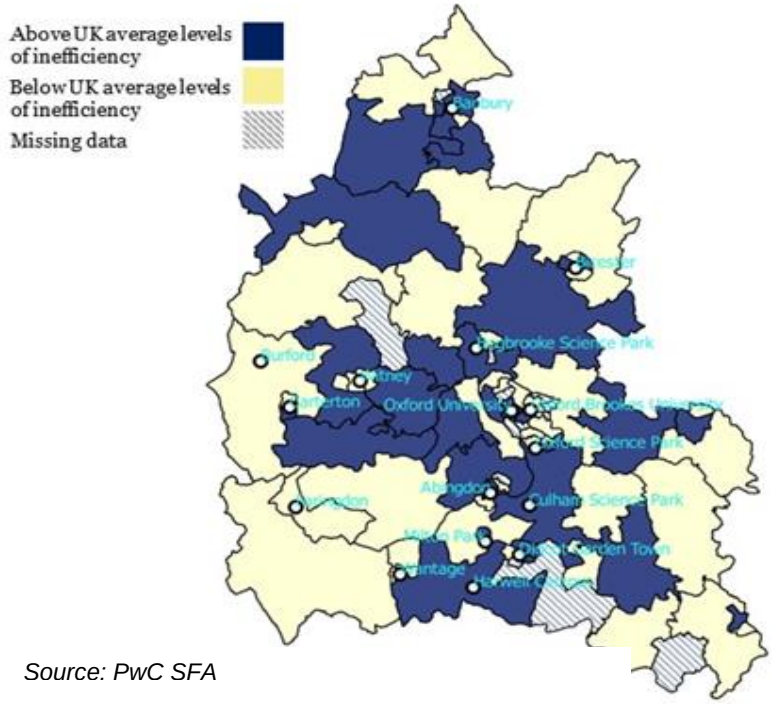
Source: ONS, Nomis, PwC analysis
Figure 4-6 Compound growth in enterprises by employment size-band, 2010–17

Stochastic Frontier Analysis (SFA) shows the economic efficiency of businesses in the county relative to the rest of the UK. The SFA uses UK-wide firm-level data to understand the difference between the maximum level of real business turnover that can be produced given a firm's factor inputs (capital, labour and intermediate materials) and the actual turnover of the businesses. It then segments what proportion of this gap is due to random, or stochastic, effects on business activity and pure business inefficiency.

Figure 4.7 below shows the geographical distribution of average inefficiencies across middle-layer super output areas (MSOAs) in Oxfordshire.[28] It shows that relatively more efficient areas tend to be in and around large towns and the City of Oxford as well as in a number of rural areas, where efficient agricultural businesses are located.

However, it is important to note that the SFA has a number of limitations, particularly when considering the innovative nature of businesses in the region. Firstly, the data-set used does not include public-sector organisations or educational institutions such as universities, which are of particular significance for Oxfordshire. This can lead to some surprising results. For instance, when looking at average estimates for the MSOA within which Culham Science Park resides, it appears to be surprisingly inefficient. This is because there are very few companies within close proximity and as a public institution, the UK Atomic Energy Authority is excluded. Also, some other areas connected to the four breakthrough sectors may appear to be inefficient. But this analysis does not capture emerging firms with future potential. Many firms in breakthrough sectors would start with slow growth only to become highly efficient over a period of time.

[28] For this analysis we used data from Financial Analysis Made Easy (FAME) and extracted data on nearly 200,000 firms across the UK for the period 2008-2017. The MSOAs with no data in the map arise as a result of these MSOAs having companies only present for certain years during our period of analysis or with less sophisticated and less detailed data than that required for our modelling.



Source: PwC SFA

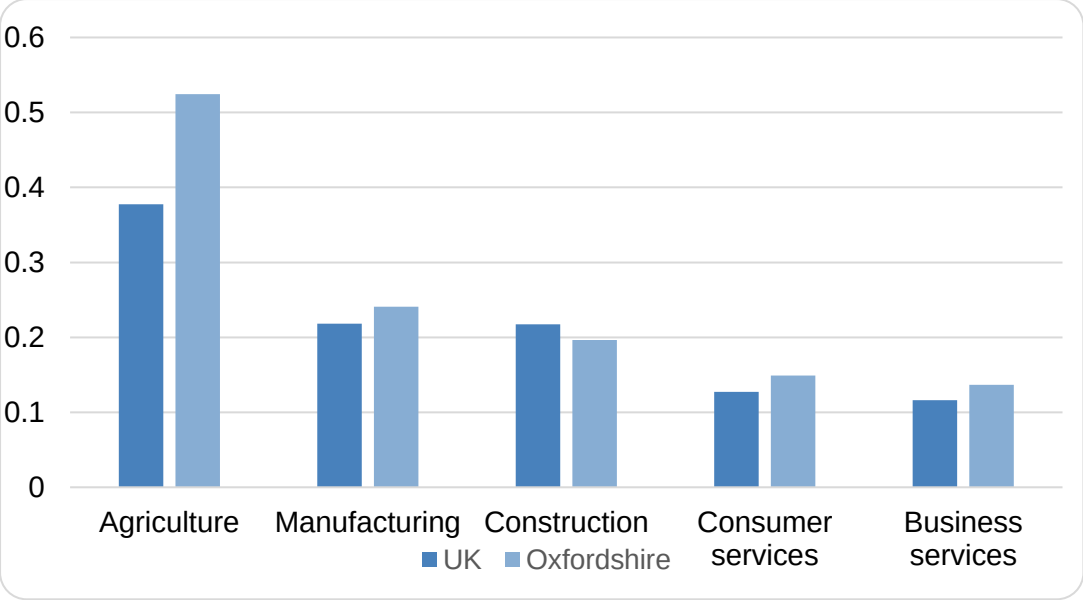
Figure 4-7 Inefficiency across Oxfordshire by MSOA, 2008-17

Businesses in Oxfordshire are outperforming their UK counterparts as a whole, but the region has room to improve.

Figure 4.8 compares average inefficiency scores between Oxfordshire and UK firms within the main sectors.[29] Oxfordshire as a whole is more efficient than the UK in all industries apart from construction, with the difference particularly pronounced for agriculture. Further analysis also shows that Oxfordshire firms are quite polarised in their efficiencies. There are larger numbers of both highly inefficient but also very efficient firms when compared with the UK as a whole. The larger frequency of efficient firms is positive for Oxfordshire, but it will be critical for future policy to support the highly inefficient firms and to bridge this productivity gap.

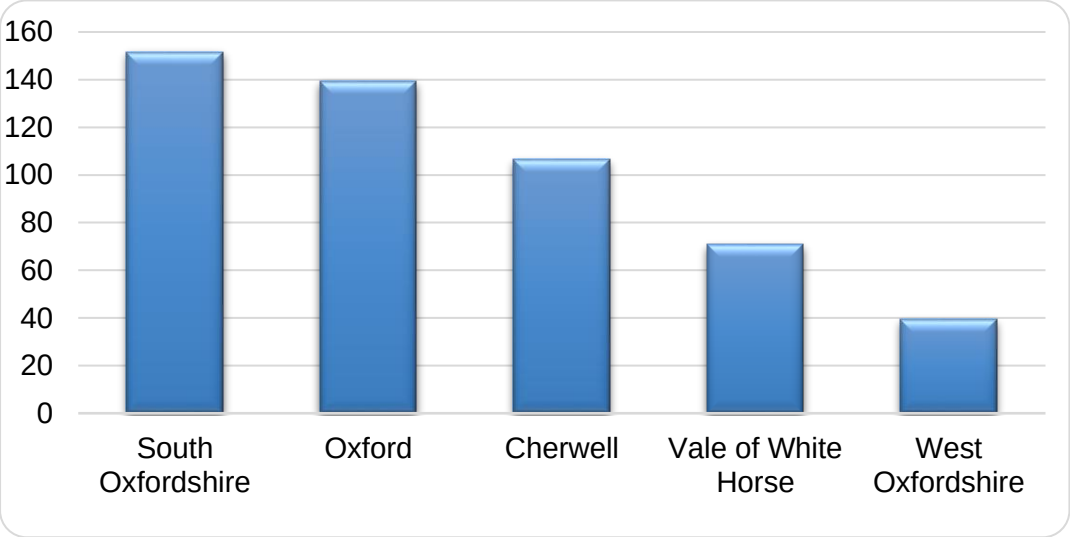
Business services firms are efficient in the City of Oxford where the companies are able to benefit from access to a highly-skilled labour pool, notably from students and graduates coming from the Universities. Examples of highly efficient firms include a number of specialised consultancies and those based on Oxford Science Park. Agglomeration also seems to play a role, with areas in the South-East of South Oxfordshire showing high levels of business services productivity that could be as a result of close links to Reading and London. The growth of the four breakthrough sectors is reliant on efficient supply chains as well as a highly skilled labour pool.

[29] The average inefficiencies are estimated separately for each sector. They are sectoral model which contrasts to the main UK model



Source: ONS, Nomis, PwC analysis
Figure 4-8 Sectoral comparison of efficiency scores, Oxfordshire vs UK counterpart

The macroeconomic analysis in the previous chapter showed that West Oxfordshire lags behind the other districts in terms of employment growth. Figure 4.9 shows that it also struggles with net entry, with only around 40 new enterprises in net terms. One possible reason for this trend is a lack of competitiveness in the district. This possibility is further supported by the fact that there are inefficiencies with respect to business services in large parts of West Oxfordshire that are close to the city of Oxford. To achieve inclusive growth, driving productivity in the key sectors in West Oxfordshire should be a priority. Oxfordshire must ensure new and innovative businesses are able to thrive in each of the districts.



Source: ONS, Nomis, PwC analysis
Figure 4-9 Compound net entry of enterprises across districts, 2010-16

4.5 WHAT CAN OXFORDSHIRE DO ON A MICRO-LEVEL TO ENABLE GROWTH?

The Strategic Economic Plan (SEP), published in 2016, set out four key characteristics that the county aspires to be recognised for by 2030:

- A vibrant place where both businesses and people thrive
- Sustainable growth from an environmental, social and economic perspective
- Oxfordshire will be inclusive for all residents
- Recognised globally for its innovation ecosystem meaning it will be world-leading

Oxfordshire has acknowledged that these objectives are only achievable if the county harnesses its people and their knowledge, ensures strong connectivity and focuses on innovation-led growth in business. All of these things are essential ingredients in driving productivity across the region, which is a key determinant of improving the standard of living. In this section, we have drilled down into firm level efficiency and highlighted some of the key drivers and characteristics of highly productive firms which should be used to inform policy interventions.

Oxfordshire's unique sectoral mix means that it is in a position to transform supply chains and deliver secondary gains both inside and outside of the Oxfordshire economy. This means a greater contribution to the UK as a whole, supporting inclusive growth.

Sustainable growth and the need to improve labour productivity requires the development of the knowledge base. As the SIA report highlights, 'skills are potentially the scarcest resource in achieving the growth opportunities for the region and for these technologies.' Oxfordshire is well placed in this regard when compared to the rest of the UK. The county is famous for its highly skilled graduates coming from two world-class universities. However, it is crucial that a higher proportion of these graduates are retained locally in order to drive future innovation in the region.

The BEIS report highlights that in 2012/13, Oxfordshire was one of the Great Thames Valley LEP areas with relatively low graduate retention.[30] In 2012/13, just over one-third of graduates left Oxfordshire within six months after graduating, with more than half of this group relocating to London. In order to support development of the region, Oxfordshire should take as an example regions such as Greater Manchester and London which have retention rates of over 80%. In order to address this, the cost of living challenges (particularly the cost of housing) should be addressed.

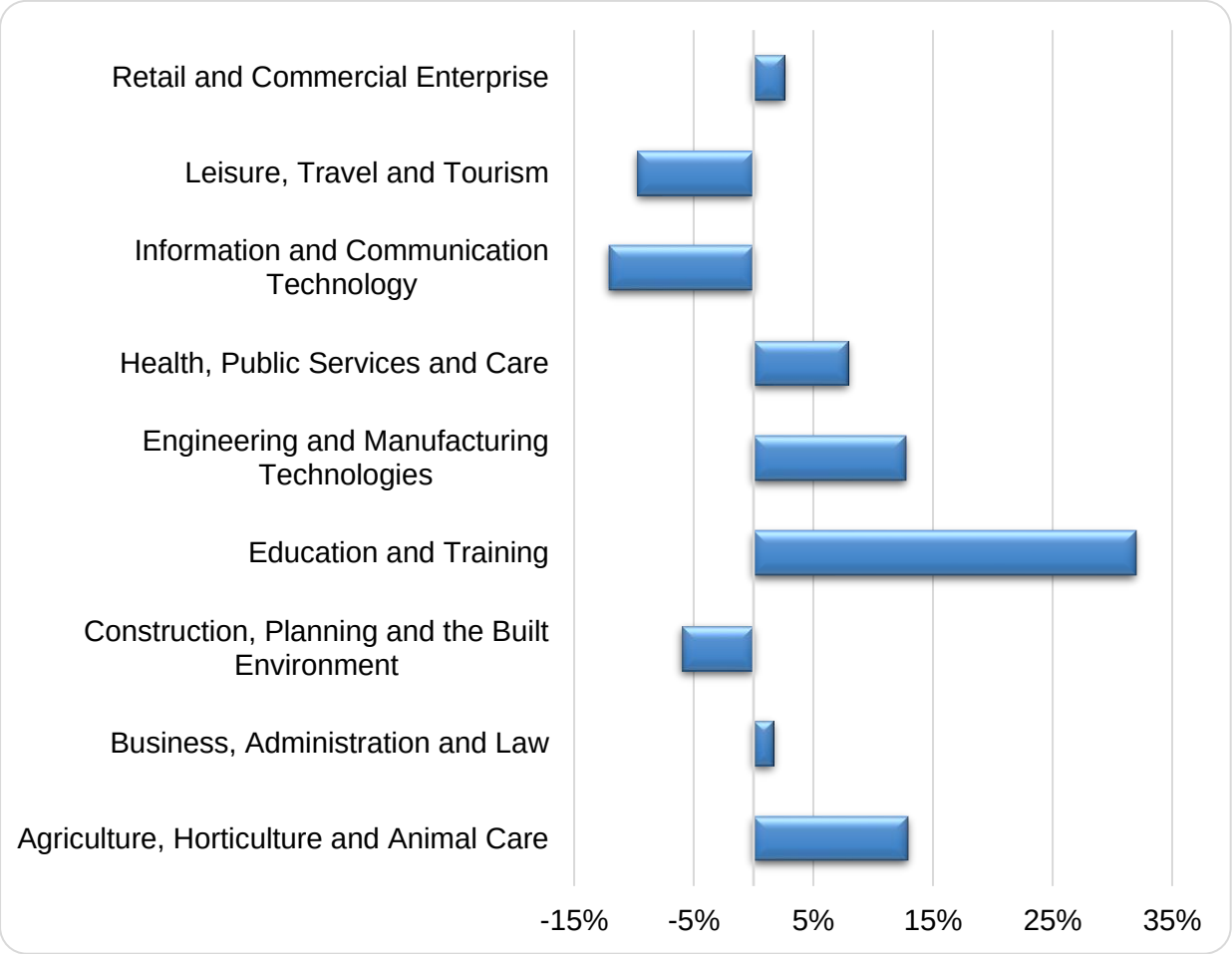
Moreover, there is a clear need from employers for a diversified, skilled workforce with competencies not necessarily taught at universities, such as self-management and soft skills. As highlighted by the 'Barriers to Business' survey, there are gaps between what graduates have and what employers are looking for. [31] Work placements should be encouraged and more tailored support in schools is necessary in order to increase awareness among the future of the workforce about the potential opportunities.

Oxfordshire must put in place plans to encourage vocational skills and training in order to prepare for the demands of the future. Statistics show that 75% of start-ups in Oxfordshire grow into SMEs and MMEs. In order to support a sustainable and ambitious pace of growth in these businesses, apprenticeships must be prioritised. A Confederation of Business Industries (CBI) survey showed that among Oxfordshire respondents, more than half agreed on the need for more STEM-related apprenticeships. Skills Funding Agency data shown in Figure 4.10 shows

---

[30] BEIS: Mapping Local Comparative Advantages in Innovation (2015)
[31] OxLEP: Oxfordshire LEP Skills Strategy (2018)

that compound average annual growth in apprenticeships in 2010-15 was 3%, far below the England average of 12.5%.[32] Key sectors in Oxfordshire such as engineering and manufacturing technologies, health and education and training, exceeded this average, offering a positive outlook. Apprenticeships should continue to be expanded in engineering to support the development of skilled technicians. It should be noted that some sectors, such as science and mathematics, were excluded from the analysis owing to data unavailability. Advanced level vocational courses in this field should also be a priority, alongside engineering and digital technology.



Source: ONS, Nomis, PwC analysis

Figure 4-10 Compound growth in apprenticeship starts by sector, 2010 - 2015

In order to achieve Oxfordshire's objectives, it is also essential to focus on the productivity of the firms that will employ the future labour force. The SFA provides some useful insights into how Oxfordshire firms are performing compared to their UK counterparts as well as identifying the most significant drivers of efficiency at the firm level.

Having estimated firm-specific levels of inefficiency in the SFA, we have used these to derive an efficiency score for each business sector (bounded between 0 and 1). We have then undertaken analysis to understand the extent to which policy relevant factors explain the variation in efficiency scores across businesses in the UK over time. The estimated relationships are high-level and indicative where we can interpret the relationship in terms of the correlations and

[32] excluded Arts, Media, Publishing AND science sectors due to lack of data availability

direction but not causally. Figure 4.11 shows some of the key factors which we found to be related to business efficiency:

The results highlight the importance of encouraging young, start-up firms that are likely to be associated with higher efficiencies as well as facilitating competition, which encourages productivity. The results also showed that increasing the proportion of turnover which is sold abroad is positively related to productivity. Participating in a global market drives innovation and efficiency through competition on a larger scale, but also through gains in new knowledge and expertise. Firms in Oxfordshire already have better export competitiveness compared with the UK average, but should look to build on this advantage. Companies should receive business support and be encouraged to expand their operations, exporting products and services abroad while retaining the company base in Oxfordshire.

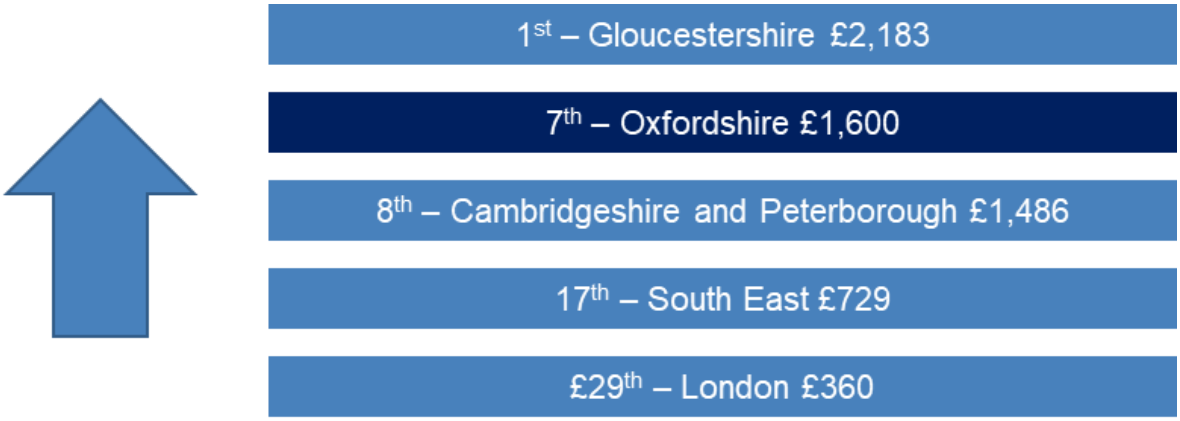
The estimates of inefficiency drivers relate to the UK as a whole. We find that business services are more efficient compared to the 'Other' category. This is different to the relative inefficiency averages for each industry in table D.1, which are calculated for Oxfordshire.

'Driver' of productivity	Effect on productivity
Age	Older firms tend to be less efficient. The associated efficiency score is 0.6% lower for each additional year a business is running.
Export competiveness	Increasing turnover sold abroad by 1% increases efficiency by 0.4%
Agglomeration	1% increase in the level of agglomeration within an LSOA where the firm resides is associated with 0.05% increase in technical efficiency.
Business R&D intensity	R&D expenditure is associated with improved business efficiency. 1% increase in the spend per NUTS2 region increases efficiency by 0.04%.
Market competition	An increase in market competition per local authority district by 1% from its current levels is associated with an increased firm efficiency by 0.04%
Sector dummies	With respect to the category 'Other', business services is more efficient meanwhile manufacturing and consumer services are less.

Source: ONS, Nomis, PwC analysis

Figure 4-11 Drivers of firm efficiency results from the SFA

Businesses in Oxfordshire are showing a willingness to invest



Source: ONS, Nomis, PwC analysis

Figure 4-11 Business expenditure on research and development per FTE, 2014

Business R&D intensity is also positively related to efficiency. As Oxfordshire firms in our data have a higher proportion of employees in business services than the UK average, there would be an opportunity for large productivity gains if these firms were encouraged to invest in additional R&D.

The BEIS report on mapping comparative advantages in innovation found that in 2013, Oxfordshire ranked in the top third of LEPs for BERD spend by FTE. In addition, when comparing the percentage share of BERD to the percentage share of FTE employment, the shares of investment in Oxfordshire are above what the workforce size might suggest. This contrasts to London which is considered a 'big spender' but has below than expected performance given the employment share. These findings are further supported by Eurostat data, which showed that Oxfordshire ranked 7th out of all LEP's in the UK in terms of Business R&D investment, with spending being nearly twice the UK average, also performing better than South East and London. Gloucestershire topped the rankings, owed to its relative concentration of advanced manufacturing activity which typically induces higher levels of business investment.

The UK government has set a target to increase investment on research and development from 1.7% to 2.4% of GDP by 2027. As part of this, Oxfordshire can support the industrial strategy if given greater support through public funding on research and development.

Previous analysis undertaken by PwC (2015), using the same agglomeration data employed in the SFA, has also shown that business services firms in particular benefit from increases in agglomeration. In particular, this analysis shows that for every 1% increase in agglomeration (equivalent to a 1% decrease in UK journey times brought about by transport interventions), business services firms within a given LSOA would be expected to experience a 0.08% increase in productivity on average. This stands in contrast to the equivalent elasticities for manufacturing (0.01%), construction (0.02%) and consumer services (0.05%), this shows that developing connectivity interventions improve the agglomeration of business services firms is likely to lead to high productivity gains, relative to other sectors.

Conclusion

It is clear that at both a macroeconomic and microecomic level, Oxfordshire performs strongly. However, there are still areas which remain untapped to unlock faster growth. Oxfordshire should give renewed focus to supporting its healthy SME base across the four underpinning technologies and also nurture other emerging industries which will help to shape the future including specialised sectors such as motorsport and cryogenics. In addition, Oxfordshire will need to improve the variety of skills in the labour force (specifically vocational and entrepreneurial) as well as giving specific support to the West Oxfordshire district so that it can catch-up with Oxfordshire's performance as a whole. All of these things will help drive higher productivity levels, bringing the standard of living for Oxfordshire's residents up with it.

5 SPATIAL CONTEXT

5.1 INTRODUCTION

Oxfordshire's Industrial Strategy seeks to deliver increased productivity and growth in the region, and deliver on Oxfordshire's ambition to become a top three global innovation ecosystem. As part of this, it is essential to consider the spatial characteristics of the region and the challenges and opportunities that these present. This is important for understanding how growth in Oxfordshire can be sustainable across the region, make the best use of land, and protect the natural environment.

In this chapter, we seek to understand these spatial characteristic, and have split the chapter into the following sections:

- [5.3] Distribution of urban density
- [5.4] Commercial activity
- [5.5] Science and business parks
- [5.6] Spatial constraints

5.2 KEY FINDINGS

- Oxfordshire is an ideal location for developing and commercializing industry-leading science and technology. While the availability of employment land is being increased through Local Plan processes, the region must develop a polycentric network of sites, where businesses take advantage of the agglomeration effect from shared learning and knowledge across these sites.
- Connectivity will be key for unlocking the growth potential within Oxfordshire. It benefits from being an hour from London, close to Heathrow airport, and part of the emerging Oxford - Cambridge Arc recognised as a trailblazer by the National Industrial Strategy and the investment in the East-West Rail link. Transport infrastructure improvements within and beyond Oxfordshire's boundaries should continue to be made, with a particular focus on alleviating pressures on the road infrastructure and encouraging a shift towards more sustainable patterns of travel.
- In order for Oxfordshire to achieve its potential it must deliver more affordable housing, support new forms of housing delivery and expand its commercial districts so that people and businesses can co-habit the same spaces. Living labs are a way to achieve this whilst allowing businesses to test their innovations.

5.3 DISTRIBUTION OF URBAN DENSITY

Settlement pattern

Oxfordshire contains rural areas, market towns, villages and Oxford City itself. Major routes connecting across the region include the M40, A40 and A34 as well as excellent public transport connections to London and Heathrow. Oxford is the largest urban area and is a compact city, which has one of the highest concentrations of knowledge intensive businesses in the UK.

Outside of Oxford city centre, the key settlements and distinctive historic market towns, include:

- Bicester and Banbury together with a new settlement at Upper Heyford in Cherwell;

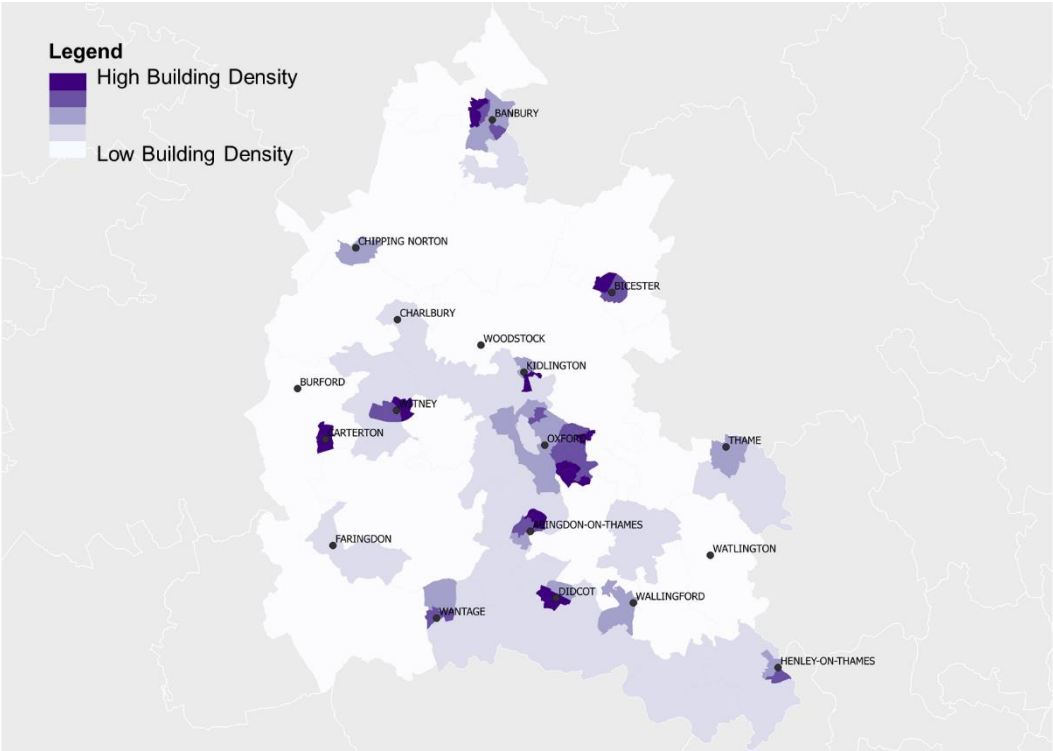
- Witney and Carterton in West Oxfordshire;
- Thame, Wallingford, Henley-on-Thames and Didcot in South Oxfordshire;
- Abingdon-on-Thames, Farringdon and Wantage in Vale of White Horse.

Figure 5.1 shows the building density by each Local Authority area calculated by dividing the number of buildings by the land area. Areas with a high building density and hence a darker blue colouring show areas which have a higher number of buildings per area. Lighter coloured areas show a low building density which is indicative of more rural farmland areas.

This diagram shows a snapshot at present time. However, Oxfordshire is already implementing the expansion of urban settlements, primarily through the form of Garden Towns. Namely, these include:

- Bicester Garden Town
- Oxfordshire Cotswold Garden Village
- Didcot Garden Town

These new garden towns and villages will make a major contribution towards providing much-needed homes and jobs in a high quality living environment.



Source: Ordinance Survey, Building Density (2018)

Figure 5-1 Building density within Oxfordshire

5.4 COMMERCIAL ACTIVITY

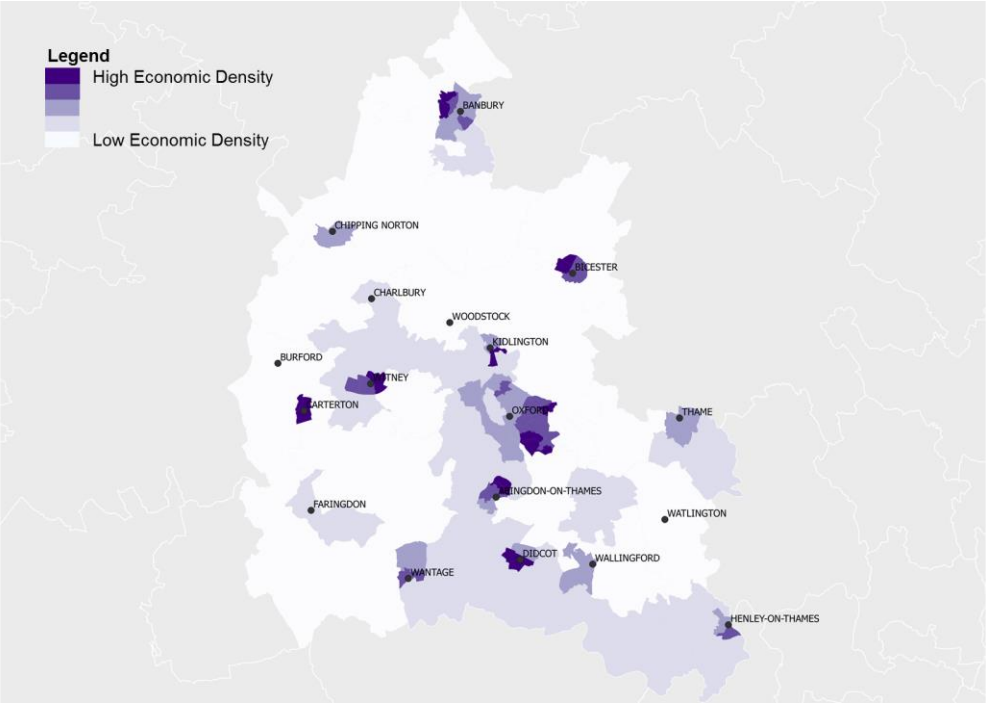
Oxfordshire currently has over 31,000 businesses located across the region. The spread of these businesses is concentrated around the central spine and the east of the region.

This is clearly represented on Figure 5.2 which shows the economic density of the region. For a given Local Authority area, this is a weighted average of aggregated firm revenues in each other Local Authority areas weighted by their road travel time from the given Local Authority area. Dark

purple areas indicate areas of high economic density, primarily centred around Banbury, Bicester, Oxford city centre and East Oxfordshire. Lighter colours show areas of lower economic density where access to economic activity is less accessible by road travel.

The commercial activity within Oxfordshire can be spatially categorised according to cornerstone and high potential businesses:

- **Cornerstone businesses** – given that these types of businesses are more established and integrated into the economy, they are spread more widely and evenly across the region. However, there is a higher concentration of these businesses around Oxford and the central corridor given good access to transport, proximity to national assets and links with Universities. Employment land is being expanded for support of this business activity through Local Plan processes.
- **Breakthrough businesses** – these businesses are often SMEs and rely on innovation for their survival. Currently, the innovation spaces within Oxfordshire are concentrated around Oxford and to the south of the region in Abingdon, Didcot and Harwell. They thrive from close access to Universities and strong transport links to the Oxford and the wider UK and global economies. Local Plans are ensuring that science parks are being expanded to meet the need to intensify this type of business and the clusters they form part of. The following page describes some of these key sites.



Source: Ordinance Survey, Building Density (2018)
Figure 5-2 Economic Density

5.5 SCIENCE AND BUSINESS PARKS

Oxfordshire is home to several science, innovation, technology and business parks that form a spine of knowledge intensive economic activity, running from north of Oxford City to the southern part of the County. Notable science and business parks include:

- **Begbroke Science Park** - is owned and managed by Oxford University and is located five miles to the north of Oxford city centre. There are around 30 companies and some 20 research groups based at the Begbroke Science Park. Advanced materials is a core focus area with key testing facilities, including the Impact Engineering Laboratory, Advanced Research Computing and the Advanced Materials Testing Laboratory. In addition, The Centre for Innovation and Enterprise is located there, which offers serviced incubation units as well as access Oxford University's science and technology departments.
- **Culham Science Centre** - is owned and managed by the United Kingdom Atomic Energy Authority and is a focus for plasma physics and fusion research in South Oxfordshire. Key facilities include the Materials Research Facility (MRF) and RACE (Remote Applications in Challenging Environments) facility. Culham Science Centre also accommodates companies ranging from start-up/virtual serviced offices via the Culham Innovation Centre, through to laboratories/offices for mid to large organisations.
- **Harwell Science and Innovation Campus** - is owned by the UKAEA, the Science and Technology Facilities Council and Public Health England. It is managed by the Harwell Science and Innovation Campus joint venture partnership. Harwell Campus has a core focus on space activity, including Diamond Light Source (UK's national synchrotron science facility), the ISIS Pulsed Neutron Source, the UK Space Gateway and The Satellite Application Catapult.
- **Milton Park** - is a mixed-use business and technology park to the north-west of Didcot that is operated by MEPC plc. There are some 250 organisations on Milton Park, including Adaptimmune, Dow Agrosciences, Evotech, Immunocore, Nexeon, RM Education (digital platforms), Schlumberger (Oilfield services) and Yasa Motors.
- **The Oxford Science Park** - is located four miles outside of Oxford and is owned by Magdalen College. The Magdalen Centre located within the Park provides incubator space for start-ups, whilst the remainder of the Park provides space for larger firms.

5.6 SPATIAL CONSTRAINTS

Understanding the existing and future spatial constraints within Oxfordshire will be critical to enabling future growth across the region.

The spatial constraints in Oxfordshire fall under three main categories:

1. Connectivity
2. Physical environment
3. Land and resource

1. CONNECTIVITY

Existing transport links and the connectivity between locations are critical for economic and industrial growth across the region. At present the central spine of Oxfordshire has good

connections by road and rail promoting economic growth. However, improvements are needed across the region for Oxfordshire to realise its full economic growth potential.

Rail constraints

Oxford sits at the heart of the rail corridor that links the Great Western Mainline (GWML) at Didcot with the London Marylebone to Birmingham line at Aynho Junction, south of Banbury. This corridor is vital for inter-regional passenger and freight services between a range of destinations including the South Coast, the Home Counties, the South West and to the north including the East Midlands, the West Midlands and the North West.

Demand for rail travel in Oxfordshire has grown rapidly with a 70% increase in journeys to and from Oxfordshire stations in the 10 years up to 2017 against a UK average increase of 53%. Oxford Station sees by far the most demand of Oxfordshire stations, with 6.6 million journeys made in 2016-17, almost one third of the county total, and an increase of 46% over ten years. Hanborough Station has seen significant growth in the last ten years, as has Radley.

To unlock growth in areas such as Didcot and Banbury it will be critical to develop the rail network to these areas.

A highly significant factor in understanding future rail demand patterns in Oxfordshire will be the introduction of further East West Rail services. The introduction of East West Rail Phase 1 services between Oxford and London Marylebone in 2016 has already significantly changed demand patterns in Oxfordshire, with stations towards Bicester seeing substantial growth following the Oxford Corridor Capacity Improvement programme Phase 0.

Connections from Didcot to Reading and access to the Crossrail/Elizabeth line open from 2019 will also significantly influence future rail demand patterns in Oxfordshire.

Road constraints

The car is the dominant mode of transport within Oxfordshire.

The key routes connecting across the region include the M40, A40 and A34. At present the road network within Oxfordshire can become congested, particularly along the A34 with impacts on commuters and businesses. Both the A34 and M40 are major freight routes, from Southampton (the second largest port by volume in UK), Dover (largest port by volume) the Thames and Chanel Ports and Heathrow (largest port by value). Motorway junctions are playing an increasing role for freight distribution into and through the region.

To unlock economic growth it will be critical to address this problem. One such way is through the use of Automated Vehicles. Oxfordshire is leading the way with its Connected and autonomous vehicles (CAV) network. It has nurtured CAV thought leaders who now have a global reputation that far outweighs their number or funding. This may help to relieve the current congestion problems that Oxfordshire experiences.

Commuting flows

Oxfordshire is an ideal location for developing and commercialising industry-leading science and technology, as it benefits from the following strategic physical links:

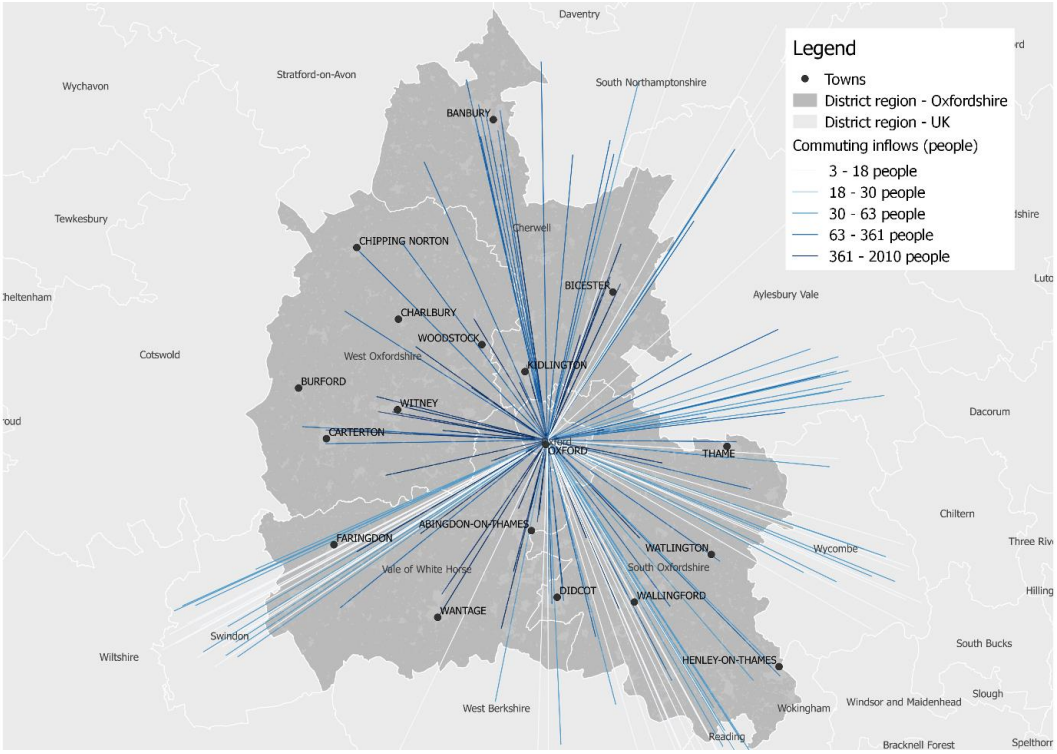
- Oxfordshire is within an hour of London by train, linked by two strategic rail connections, with the opening of the Crossrail/Elizabeth Line from Reading in 2019 set to improve journey times further.
- Close proximity Heathrow airport, with its third runway due to open in 2026, which provides access to global markets

- Location on the emerging Oxford – Milton Keynes – Cambridge Arc recognised as a trailblazer by the National Industrial Strategy
- Integral part of the UK's Golden Triangle, defined between Cambridge, London and Oxford.

Figure 5.3 shows the top ten places of usual residence (by MSOA) for those *working within Oxford City District*. Oxford City has been chosen as the place of work giving the high proportion of the population that work within that District. Based on the 2011 ONS census, there are a total of 45,775 people who commute in to Oxford City from other districts in the UK or abroad.

Figure 5.3 shows that there are large flows of people commuting from the Vale of White Horse, Cherwell and West Oxfordshire – all districts within Oxfordshire County. There is a smaller proportion of people commuting from wider districts such as Aylesbury Vale, Swindon and Wycombe.

This shows that it will be important to consider connectivity within Oxfordshire and from surrounding districts and the wider UK in order to realise its full economic potential.



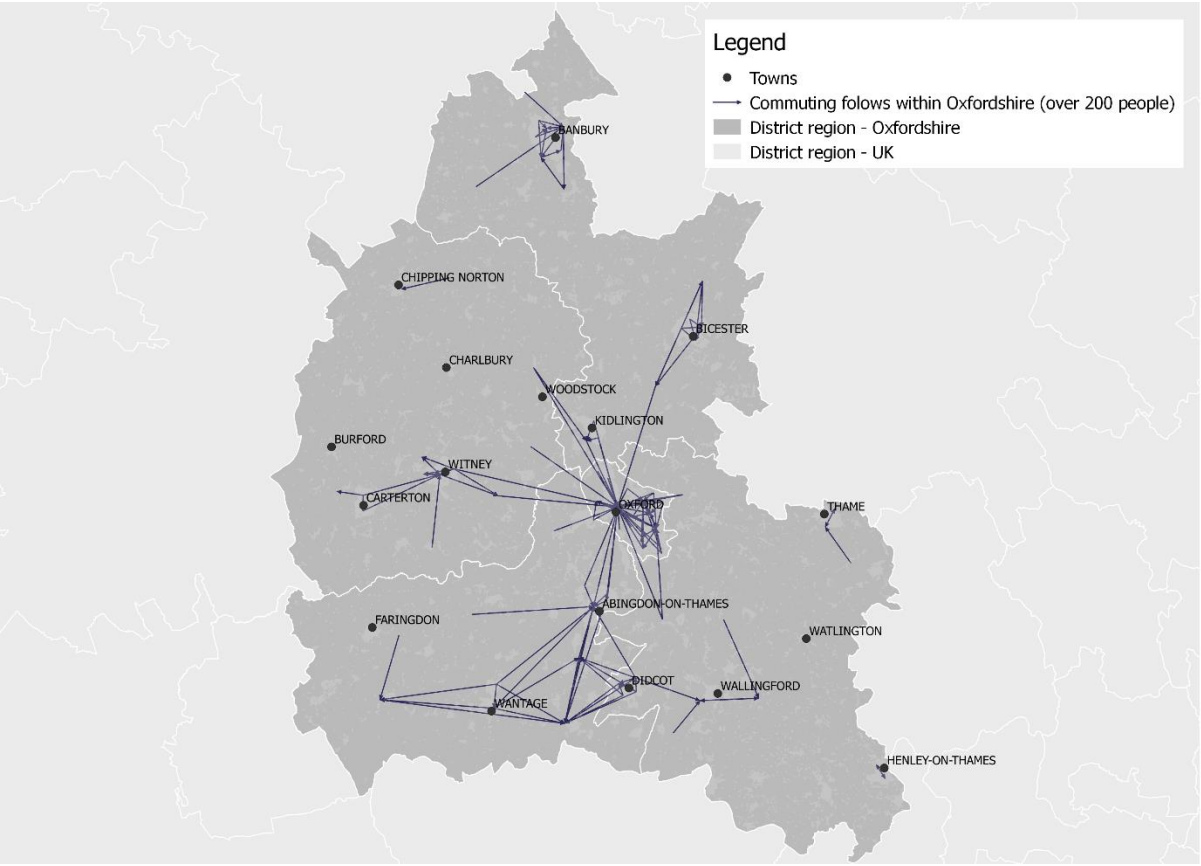
Source: ONS, Census, 2011
Figure 5-3 Location of usual residence for the top 10 locations and place of work (Oxford City)

Commuting flows within Oxfordshire

Figure 5.4 shows the flow from usual residence (by MSOA) to usual place of work within Oxfordshire. Based on the 2011 ONS census, 221,160 people commute within Oxfordshire from their home to place of work.

Figure 5.4 shows that there are large flows of people commuting between the central spine of Didcot, Abingdon-on-Thames, Oxford City Centre and Bicester. There is also a strong corridor within West Oxfordshire from Carterton and Witney to Oxford City Centre. There is a cluster of isolated commuting in Cherwell centered around Banbury.

This shows that at present commuting flows within Oxfordshire are centered around existing transport links which are concentrated around the central spine of Oxfordshire. If Oxfordshire is to expand economic growth to wider regions outside of these boundaries, it would be critical to build increased connectivity between homes and workplaces.



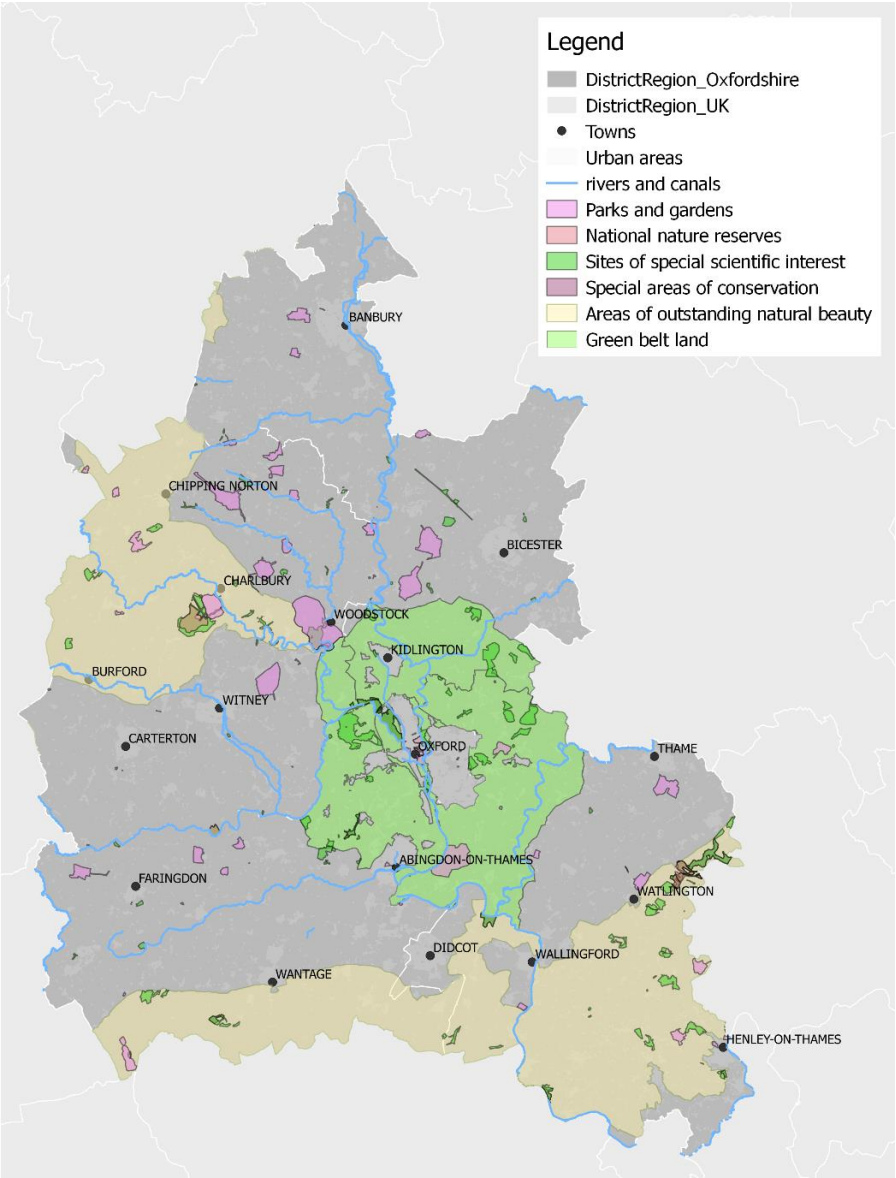
Source: ONS, Census, 2011
Figure 5-4 Location of usual residence and place of work for MSOAs within Oxfordshire

2. PHYSICAL ENVIRONMENT

Within the county, there are extensive areas of high environmental quality and sensitivity – the designated Areas of Outstanding Natural Beauty (AONBs) in particular – plus important cultural and heritage assets. There are many designations and only so much land can be physically developed on. Therefore, there is a need to be innovative and take a strategic approach to new developments, given the limited capacity. This will include increasing densities on development sites to intensify land use and thus use it more efficiently and the increased use of previously used and brownfield land, such as surplus MoD land across the County.

Figure 5.5 shows the key strategic environmental assets in the region. There are two AONB located to the south and west of the region. In addition, the Oxford Green Belt is a designation that prevents the enlargement of Oxford City. Environmental constraints (such as flood risk) and Green Belt policy restricts the number of development sites within the region.

Protecting and enhancing Oxfordshire's built heritage and natural environment will be important for safeguarding its future as a prosperous attractive destination. Therefore any economic development plan set out within the Oxfordshire Industrial Strategy must work within this constraint.



Source: Natural England, 2018

Figure 5-5 Oxfordshire's Strategic Environmental Assets

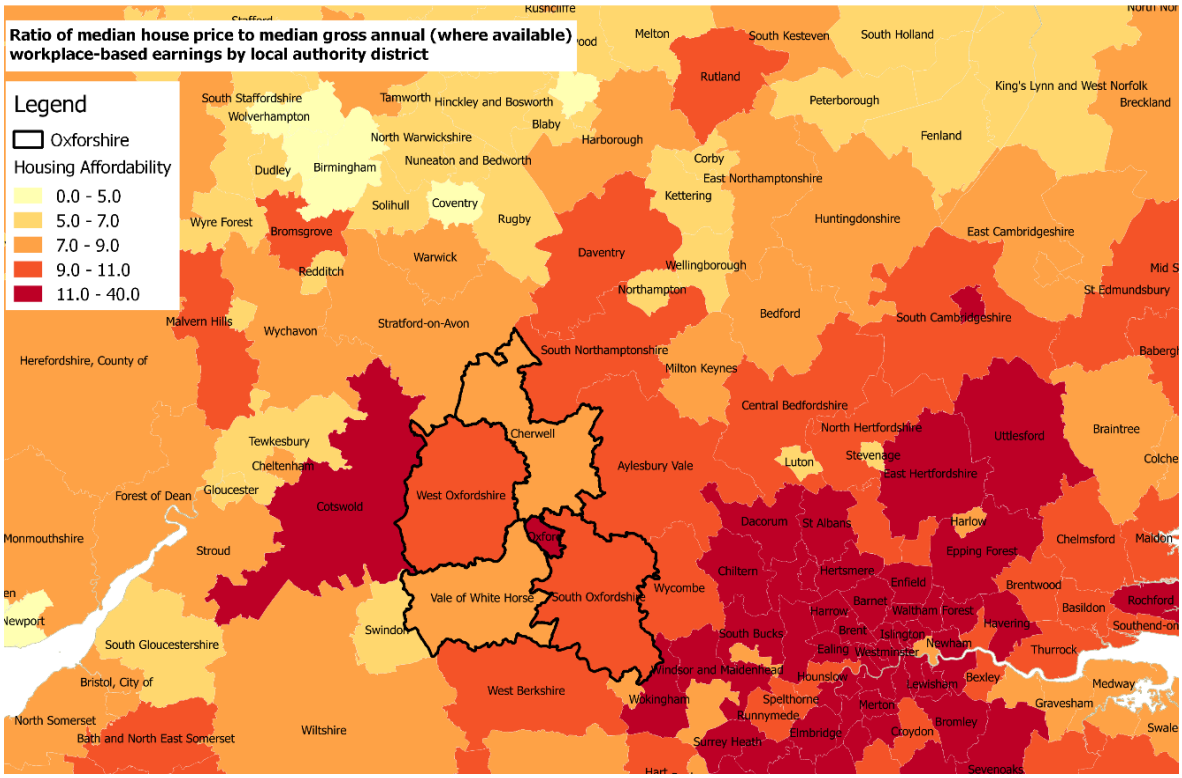
3. LAND AND RESOURCE

Oxfordshire is facing significant land and resource constraints including the availability of affordable housing, water, power supply and grid capacity which need to be addressed to deliver sustainable economic growth.

Housing affordability

Across wider Oxfordshire, there is substantial need for new housing and subsequently buying and renting housing is becoming increasing unaffordable which Local Plans are taking steps to support. Increased use of custom build housing on new development sites should enable a progressive reduction in build costs, enabling more affordable housing as a result. Figure 5.6 shows the housing affordability by each Local Authority area calculated by dividing house prices by annual earnings. Areas with a high value and hence a darker red show more unaffordable areas where house prices are proportionally high. The UK average affordability ratio is 7.8, which has increased by 2.4% from 2016 to 2017. By comparison the South East has an average

affordability ratio of 10.3. Oxford City has a greater ratio than both of these averages at 12. The more affordable districts within the region are Cherwell and Vale of White Horse.



Source: ONS Housing affordability in England and Wales: 2017
Figure 5-6 Ratio of median house price to median gross annual workplace-based earnings by local authority district.

Energy Infrastructure

Oxfordshire's energy network is heavily constrained, both for additional load and for new generator connections. Meeting the scale of demand will require multiple sources and technologies delivered at a strategic, community and business / household scale. It is critical that Oxfordshire's energy infrastructure can support future economic growth, changing energy requirements and the needs of energy-intensive research and scientific national assets and institutions. However, attention should be made to accelerating the move to a sustainable low carbon network. Higher building standards and the use of more energy efficient modular construction would progressively reduce energy demand.

Digital Infrastructure

Fixed digital connectivity in Oxfordshire is significantly improved in recent years. Oxfordshire recently undertook the Better Broadband for Oxfordshire programme which has enabled over 96% of premises across the County have access to superfast broadband. However only 7% of premises have full fibre connectivity, which despite being twice the national average, is well behind many other competing global innovation ecosystems and presents a risk of this becoming an inhibitor to international competitiveness. This will influence the ability of Oxfordshire to roll out the new 5G network, which will be critical for Oxfordshire to remain at the forefront of innovation.

5.7 SUMMARY OF EXISTING INFRASTRUCTURE AND DEVELOPMENT CONSTRAINTS

Oxfordshire is a location with many spatial constraints (connectivity, the physical environment and land and resources). Therefore, the LIS will need to identify how these factors can be overcome to create a strategy which enhances the local environment. It will be critical to improve existing transport networks between the network of existing sites. This will unlock growth within the area.

In accelerating the future development of Oxfordshire's industry-leading science and technology clusters, it will be important to take into account key spatial constraints and identify measures for addressing these. Key considerations that will need to be addressed include the following areas:

Settlement pattern: Oxfordshire faces considerable challenges relating to living costs. A constrained housing supply has increased the price of housing to buy and rent, which could affect Oxfordshire's future ability to attract the global talent that is required to fuel its knowledge-based economy. Oxford's Green Belt boundary is drawn extremely tightly around the urban area. In addition, flooding and other constraints limit the options for growth beyond the existing boundaries. It will be important to consider how the design and development of new communities (such as Garden Towns and Garden Villages) will help to address this challenge.

Capacity of science and technology based clusters: Stakeholder interviews with some of the major science parks (including Harwell, Culham and Begbroke) revealed that they are struggling to respond to demand for new premises from both new and scaling businesses. Whilst the major science parks are developing plans to create new facilities, it is perceived that due to a range of factors, such as adequate financing, planning process, and land ownership complexity, that new developments may not come forward at a pace that will be in line with Oxfordshire's economic ambition.

Connectivity: Given the largely rural nature of the region, there is a heavy reliance on car travel to get between housing and employment locations. This has contributed to severe traffic congestion, particularly on key routes, such as the A34 and A40, which not only affects workplace productivity but also prospective investment in the region. Future initiatives will need to consider ways to alleviate pressure on the road infrastructure and encourage a shift towards more sustainable patterns of travel.

Environment and heritage: Oxfordshire's natural capital and its cultural offer is distinctively rich and diverse and is an important part of what makes the region an attractive place to live and work. Future development will need to be designed and delivered in even more innovative ways to meet economic demand, whilst sustaining and capitalising on Oxfordshire's exceptional high quality natural and cultural environment.

Energy infrastructure: The electricity network across Oxfordshire is already constrained, both for additional load and for new generator connections. Meeting the scale of demand will mean using multiple sources and technologies. Innovative energy and low carbon projects are planned for the Garden Towns.

Digital infrastructure: Ensuring that digital infrastructure is fit for purpose and can sustain the needs of new industries will be critical for Oxfordshire's future economic success. Although improvements have been made over recent years, Oxfordshire still lags behind other global innovation ecosystems in terms of full fibre connectivity.

6 APPENDICES

6.1 APPENDIX A: GLOSSARY

Agglomeration: An agglomeration exists where a large number of companies, services and industries are clustered together. Agglomeration economies refer to the benefits derived from having people, output and housing in close proximity. These advantages include better supply networks, a larger pool of skilled and trained workers, infrastructure for certain industries and transport links. In these areas, firms are often able to reduce cost and improve efficiency while people have a greater choice of jobs and recreational activities.

Enterprise: As defined by the ONS…**"**an enterprise is a statistical unit, defined as the smallest group of legal units (generally based on VAT or PAYE) within an enterprise group (where one exists) that have a certain degree of autonomy or control. An enterprise is essentially a business. It is generally located at the main operating site or the head office."

Fourth Industrial Revolution: According to BEIS, the fourth industrial revolution "… is characterised by a fusion of technologies that are blurring the lines between the physical, digital, and biological spheres. "What distinguishes this revolution from its predecessors is the speed of technological breakthroughs – this has no historical precedent".

Gazelle: A company that has been increasing its revenues by at least 20% annually for four years or more.

GVA: Gross Value added measures the contribution to the economy of each producer, industry or sector. It is the value of the amount of goods and services which have been generated in the production process once all the inputs and raw materials involved in the production have been accounted for.

Inefficiency/Efficiency: Inefficiency refers to the case in which firms fail to produce to their maximum potential, given the inputs they have used to generate production. On the other hand, efficiency is when resources are optimised. Often, firms that are efficient are also productive as there is limited waste of resources, such as time, when completing a task.

Location Quotient (LQ): This is a way to show which corporate sectors or industries have much larger concentrations across the county relative to the UK. LQ's are computed as an industry's share of Oxfordshire's total employment divided by the same industry's share of the United Kingdom's total employment. An LQ above 1 indicates that a highly concentrated industry.

$$LQ = \frac{\left(\frac{\text{Employment of Industry X in Oxfordsahire}}{\text{Total Employment in Oxfordshire}}\right)}{\left(\frac{\text{Employment of Industry X in the UK}}{\text{Total Employment in the UK}}\right)}$$

NUTS3: Nomenclature of Territorial Units for Statistics (NUTS) are EU codes that are categorised into 3 levels. NUTS1 (12 regions within the State and as a country of the UK, with 9 such regions in England), NUTS2 (40 areas) and NUTS3 (174 subdivisions).

Productivity: In our analysis, we measure productivity as the Gross Value Added of each economic region divided by the total number of hours worked per year. It is a measure of how well a region can use its labour force to generate economic growth.

SIC code: Standard Industry Classifications (SIC) is a way of classifying industry areas. The SIC codes are grouped into sections which categorise similar trade classifications. For instance, within an ‘Agriculture, Forestry and Fishing’ group, there are 40 SIC codes which give more specific forms of agriculture.

Stochastic Frontier Analysis (SFA): It is an economic approach that is used to calculate how inefficient firms are. It involves estimating the optimal production (the frontier) of a firm in the case in which it uses all of its resources in an efficient way and compares this to the actual production observed. It also takes into account how random shocks, beyond the control of the firm, can influence realised production and excludes this from the estimates of inefficiency.

Unicorn: A start-up that holds a market value of over US$1 billion.

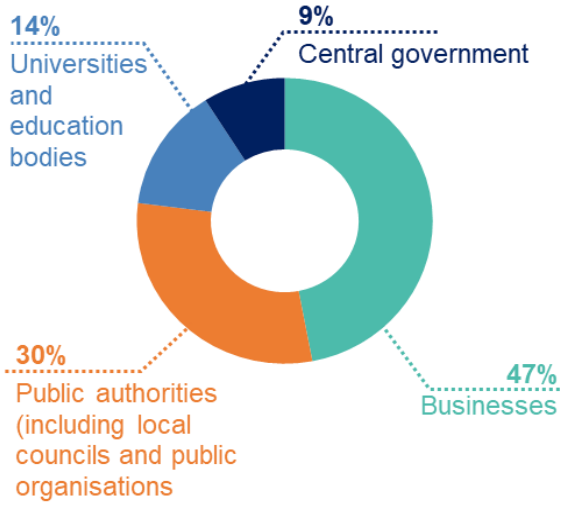
6.2 APPENDIX B: STAKEHOLDER ENGAGEMENT

In preparing for this review, and the subsequent reports that follow, we have undertaken a comprehensive programme of stakeholder engagement. OxLEP and partners in their work to date (developing the 2016 Strategic Economic Plan and 2017 Science and Innovation Audit) have established broad networks that span a range of different sectors and industries. Using these networks we have reached over 150 stakeholders and partners from across Oxfordshire, including Oxfordshire start-ups and spin-outs, global businesses in Oxfordshire, the universities, national and international science and research organisations, education bodies, land owners and developers, estate agents, local authorities, and central government.

Engagement events conducted so far include:

- Fortnightly meeting with the Oxfordshire Local Industrial Strategy Steering Group
- Science and Innovation Audit group meeting
- Joint Statutory Spatial Plan and Local Industrial Strategy workshop, with the JSSP lead officers from each Local Authority
- Meetings with senior teams of Harwell, Culham and the University of Oxford
- OxLEP Board and Sub-groups workshop, bringing together over fifty members of the OxLEP family, and the local authorities and businesses they represent
- Future of Oxfordshire workshop, bringing together over fifty stakeholders primarily from Oxfordshire's business community

It should be noted that this is not an Independent Economic Review and therefore we have not instigated a broader public consultation. Neither did the engagement focus solely on the economic baseline review – views which were expressed and are relevant to this stage of work are set out in this section. Finally, it should also be mentioned that while there has been engagement with various Government officials, the opinions set out are not reflective of any official or unofficial HMG positions.



Purpose of engagement sessions

Each stakeholder engagement session was tailored to the specific group attending, but all shared the central purposes to:

Develop the evidence base:

- Understand the policy context in Oxfordshire and how the baseline economic review, which will underpin the evidence base for the Oxfordshire Local Industrial Strategy, supports existing and future work. This was particularly relevant for the Science and Innovation Audit and Joint Statutory Spatial Plan (JSSP) sessions.
- Explore initial results from analysis to understand Oxfordshire's existing strengths, economy, global competitors and potential for growth.

Develop a broad base of stakeholder support for the Economic Review and future work

- Encourage stakeholders to think disruptively and innovatively about Oxfordshire's future economy, opportunities and barriers to growth.
- Encourage stakeholders to start thinking ambitiously about future policy proposals that could be included in the Oxfordshire Local Industrial Strategy.

Start to develop policy interventions for the Oxfordshire Local Industrial Strategy

- Identify catalytic interventions that will enable Oxfordshire to achieve its ambition to be a top three global innovation ecosystem, that can form a part of the Oxfordshire Local Industrial Strategy.
- Begin thinking about investment and delivery of intervention options for the Oxfordshire LIS.

Outputs and key conclusions

The discussions and thoughts shared in each session were collected and have been used as key inputs into the development of the baseline review, and will continue to be used as inputs for the development of the Oxfordshire Local Industrial Strategy.

In the next pages we set out the key findings from the early stakeholder engagement. The main conclusions are that Oxfordshire stakeholders:

1. Support the vision to develop the LIS and JSSP
2. Believe future growth will be driven by the breakthrough technology industries
3. Suspect growth has been constrained by spatial factors
4. Are confident that Oxfordshire's attractiveness as a place to work is constrained by the high cost of living
5. Feel positive about the economic outlook for Oxfordshire

Stakeholders fully supported the decision to develop the LIS and JSSP using a common economic evidence base

This is a key decision which is well supported by stakeholders. They believe it will help to accelerate strategic alignment between different parts of the Oxfordshire system. As noted, it is also clear that spatial planning and industrial planning need to be more closely aligned in Oxfordshire if going to achieve its full growth potential in coming years.

Stakeholders generally believe that future growth will be driven by the breakthrough technologies and industries but recognise that future plans need to deliver clear benefits for the cornerstone industries

Recent work such as the Science and Innovation Audit is well understood and supported by a wide range of stakeholders. This work identifies four transformative technologies that Oxfordshire has a distinct set of capabilities to develop and starts to outline how they could be applied in different industries. Stakeholders were clear: they want to pursue a strategy which delivers transformative growth (but not growth at any cost); they want to this strategy to play to Oxfordshire's distinctive capabilities (i.e. to focus on the breakthrough); equally they want this to create new opportunities for cornerstone businesses and to address long term challenges such as social and economic inequality.

Stakeholders suspect that Oxfordshire's economic growth to date has been constrained by spatial factors

In different engagement sessions, a range of anecdotal evidence was presented about the challenges that spatial constraints were currently creating e.g. some companies have left or not expanded in Oxfordshire because the right facilities (or facilities with the right access) could not be created in a reasonable timeframe. Stakeholders are clear that they want to preserve Oxfordshire's outstanding natural beauty and historic assets – but equally they want future spatial planning to be more closely aligned to the scale of growth ambitions.

The infrastructure challenges in Oxfordshire were a popular theme which was regularly discussed in the sessions convened. It is clear that stakeholders would like to see investment in this area accelerated to help create opportunities for growth and productivity improvements.

Stakeholders are confident that Oxfordshire's attractiveness as a place to work (and for postgraduate research) has been constrained by the high cost of living.

The evidence around Oxfordshire's cost of living challenge is well documented in this review and other local reports. Oxfordshire now has an unwanted reputation as being one of the most expensive places to live in the UK. Stakeholders have clearly voiced that they feel this is a factor which is having a material impact on their research and business activities in Oxfordshire. Stakeholders have suggested this is deterring individuals from considering local roles – and this in turn is impacting innovation, research and productivity levels (and therefore, ultimately Oxfordshire's GVA and future potential). Individual organisations, such as the University of Oxford, are now seeking to explore putting in place their own measures which will help to address this challenge for their key personnel (in this case, postgraduate researchers).

Stakeholders have also suggested that this problem (to date) has not been taken seriously enough in planning and policy discussions at a local and national level.

Overall, stakeholders are very positive about the economic outlook for Oxfordshire and are excited about the opportunity to contribute to the current strategy development process

Stakeholders feel momentum has been genuinely building over the last few years and that the Oxfordshire proposition is growing with clarity. While feelings about projects such as the Arc are mixed (some are optimistic, others show cautious enthusiasm, some feel it is a distraction), all agree that the immediate focus should be on setting a strategy which will underpin future growth and development across Oxfordshire. Stakeholders from across sectors and public authorities have shown a real desire to contribute and collaborate as part of this strategy planning process.

Finally stakeholders have been clear that they want to work on something which is distinctive, ambitious and transformative. They have brought into the emerging vision to position Oxfordshire as a top three global innovation system and want to understand more about what this will mean. They have rigorously engaged with the work to date and will continue to hold all involved in this strategy development process to account.

6.3 APPENDIX C: DISTRICT OVERVIEW

CHERWELL

Key Sectors

With approximately 75,000 jobs, Cherwell accounts for 20.8% of the total employment in Oxfordshire, the second highest percentage after Oxford. The largest industry group by employment share is “Wholesale, retail, distribution, accommodation & foods services”, which constitutes 32.5% of the total employment in Cherwell; this sector also leads in employment share in West Oxfordshire. Other substantial sectors are “Public services” and “Professional & Business services”, accounting for 21.3% and 19.9% of the total employment respectively.

Employment has increased by 4.6% (2016 vs. 2015), significantly above the Oxfordshire overall growth rate of 1.6%; this was mainly driven by a significant 25% increase in “Professional & Business Services” jobs. A GVA analysis paints a similar story, with Cherwell contributing 20.7% of the total GVA of Oxfordshire, second after Oxford, with 29.9%. The workforce in Cherwell is also a highly skilled one, with 44.5% of Cherwell’s working age population hold qualification levels of NVQ4+. Well above the UK average and

The industries with the highest GVA are two of those with the highest employment share - “Wholesale, retail, etc.” and “Public services” – with the third place being occupied by “Manufacturing”

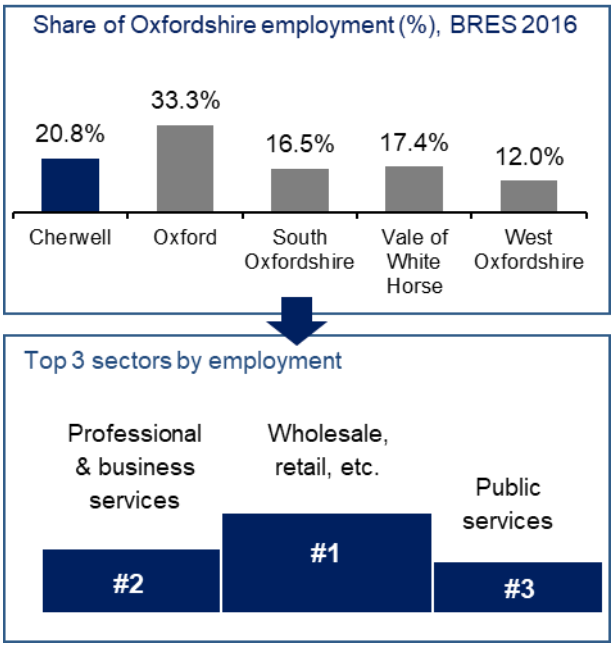
Distribution of Enterprises by size band

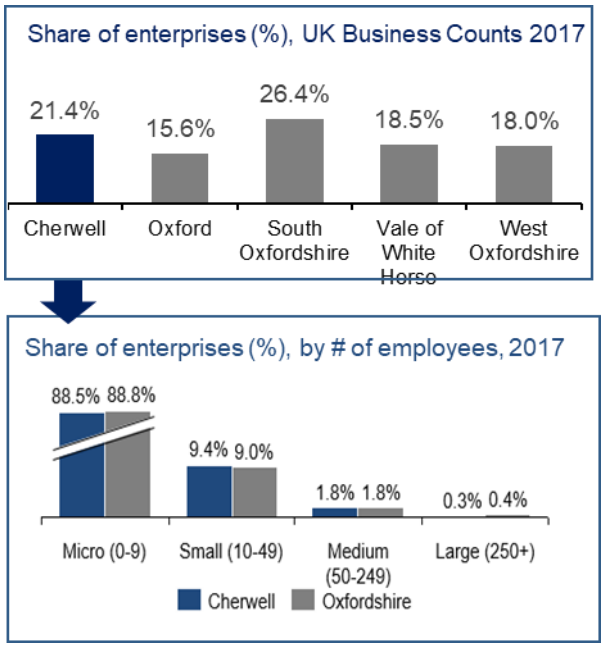
Cherwell has 6,675 enterprises -the second most after South Oxfordshire - which represents 21.4% of the total number of enterprises in Oxfordshire. 28.1% the firms are in the “Professional & Business Services” sector, more than in any other industry group, in line with what is seen in the other districts.

The proportion of enterprises by employees band is very similar to the average for Oxfordshire, with the percentage of small enterprises being slightly above average, and the percentage of micro enterprises slightly below between 2010 and 2017, the number of enterprises across all employee number bands have either remained constant or increased, with the overall increase being 11.8%.

Largest firms

The largest three companies by turnover are “DCS INC Limited” (Wholesale trade), “Airbus Helicopters UK Limited” (Repair and installation of machinery and equipment) and “Karcher (U.K.) Limited” (Wholesale trade). The largest 3 companies by number of employees are Palico Limited, KL Ventures Limited and Bansols Beta Limited, with the first operating in “Other personal services” and the other two in the “Food and accommodation services”.





CITY OF OXFORD

Key Sectors

With approximately 121,000 number of jobs, Oxford contributes with a third of the total employment in Oxfordshire, the highest of all districts. It also holds the highest percentage of skilled workers in Oxfordshire with 63% of the working population holding an NVQ4+ education level.

The largest industry group by its employment share is Universities, which constitutes 49.3% of the total employment in Oxford; the striking size of this sector is unique to Oxford within the five Oxfordshire districts.

Other substantial sectors are “Professional & Business services” and “Wholesale, retail, etc.”, accounting for 16.9% and 14% of the total employment, respectively.

Employment has increased by 0.4% (2016 vs. 2015), the lowest growth in Oxfordshire; while professional & business services employment has gone up by 13.3%, decreases in “Information and comms.” and “Wholesale, retail, etc.” have balanced this out.

In terms of GVA, Oxford contributed with 29.9% of the total Oxfordshire GVA in 2015, a proportion slightly lower than its employment share, due to slightly lower productivity.

The industry with the highest GVA is, unsurprisingly, “Public services”. The second place is taken by “Wholesale, retail, etc.” and the third one by “Manufacturing”, despite its relatively low employment of 4,500 (~4% of total Oxford employment).

Distribution of enterprises by size band

Despite its high employment and GVA, Oxford has the lowest number of enterprises in Oxfordshire.

30.8% the firms are in the “Professional & Business Services” sector, more than in any other industry group, in line with what is seen across Oxfordshire.

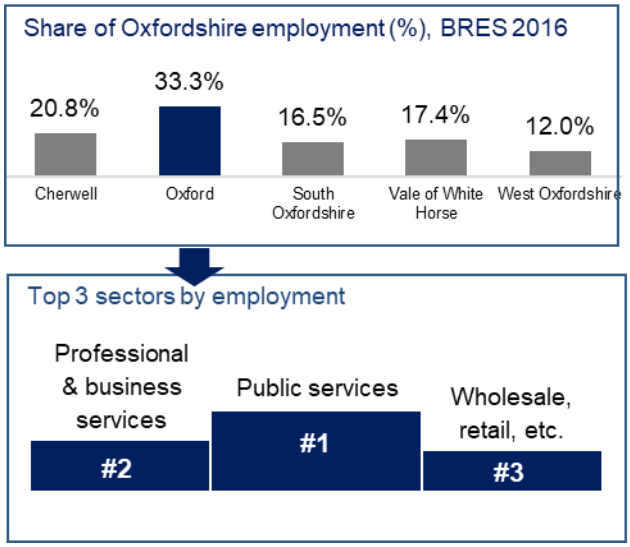
The split of enterprises by employees band is distinct, with a lower proportion of micro firms and greater presence of medium and large enterprises than in all the other four districts in Oxfordshire.

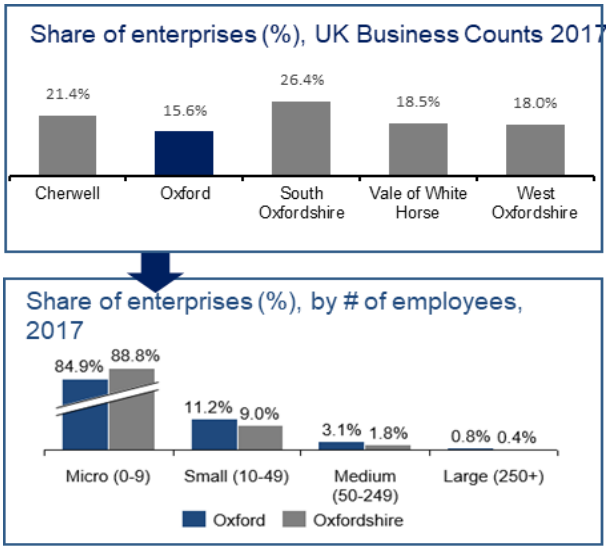
Between 2010 and 2017, the number of enterprises has increased by 25%, the highest jump amongst all five districts

Largest Firms

The largest 2 companies by both turnover and number of employees are “Amey UK PLC” (Activities of head offices / management consulting) and “Unipart Group of Companies Limited” (Business support services).

“Oise Holdings Limited” (Education) has the third most employees and Harley-Davidson Europe Limited (Wholesale) has the third highest revenues.





SOUTH OXFORDSHIRE

Key Sectors

With approximately 59,900 jobs, South Oxfordshire contributes 16.5% of the total employment in Oxfordshire, the second lowest percentage except West Oxfordshire, with 48.6% of these workers holding an NVQ4+ education level. The largest sector by its employment share is “Professional & business services”, which accounts for 28.3% of the total employment in the local authority; this sector is also the lead employer in the Vale of White Horse.

Other substantial sectors are “Wholesale, retail, etc.” and “Public services”, making up 28.2% and 17.5% of the total employment respectively. Employment has been relatively flat, having increased by 0.9% (in 2016 vs. 2015), slightly below the Oxfordshire overall growth rate of 1.6%.

Looking at GVA, South Oxfordshire contributed 17.6% of the total GVA of Oxfordshire, in line with its employment share ranking; however, South Oxfordshire has seen the largest ten-year GVA growth out of the five districts (52.5% from 2005 to 2015). The industries with the highest GVA are also those with the highest employment share, with the order of the first & second place from the former interchanged: “Wholesale, retail, distribution, accommodation & foods services”, “Professional & business services” & “Public services”.

Distribution of enterprises by size band

South Oxfordshire has 8,210 enterprises – most in Oxfordshire - which represents over quarter of the total number of enterprises in the county.

32.8% the firms are in the "Professional & Business Services" sector, more than in any other industry group, in line with what is seen in the other districts.

The enterprises' profile based on their number of employees is skewed towards micro companies – their proportion is the higher in South Oxfordshire than in the other four districts; small, medium and especially large enterprises are less frequent.

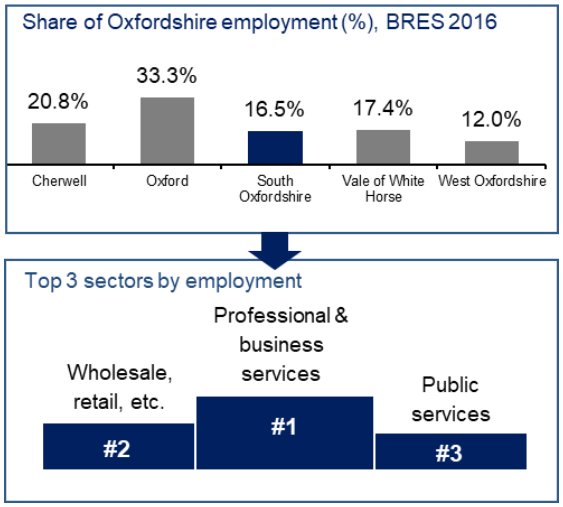
•Between 2010 and 2017, the number of enterprises across all employee number bands have increased, with the overall growth rate being 16%, second only to Oxford.

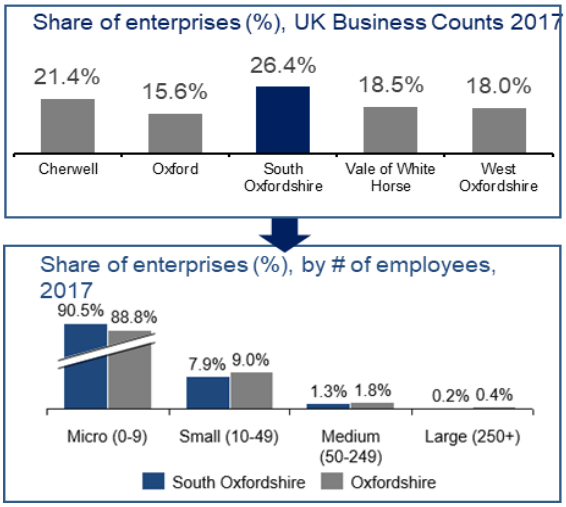
Between 2010 and 2017, the number of enterprises has increased by 25%, the highest jump amongst all five districts.

Largest Firms

The largest company by both turnover and number of employees is "Thame And London Limited" (Office administrative and support activities).

"Kubota (U.K.) Limited" and "Concha Y Toro UK Limited" are the second and third largest enterprises by revenue and are both falling into the Wholesale trade classification; "Harrison SD Holdings Limited" (Food and beverage services) and "Grundon Waste Management Limited" (Waste collection, etc.) are the second and third largest companies by number of employees.





VALE OF WHITE HORSE

Key Sectors

With approximately 62,900 jobs, Vale of White Horse contributes with 17.4% of the total employment in Oxfordshire, which is in the middle of all districts, 47.7% of Vale of the White Horse working population also hold a minimum NVQ4+ education level.

Just as in South Oxfordshire, the largest industry group by its employment share is "Professional & business services", accounting for 25.4% of the total employment in Vale of White Horse.

Other substantial sectors are "Public services" and "Wholesale, retail, etc.", each contributing with 22.7% of the total employment.

Employment has increased by 1.1% year-on-year (in 2016 vs. 2015), the third highest growth in Oxfordshire, after Cherwell and West Oxfordshire.

Vale of White Horse contributed18.4% of the total Oxfordshire GVA in 2015, consistent with its employment proportion and its relative ranking; it has seen the second largest ten-year GVA growth in the county (51.4% from 2005 to 2015), similar to South Oxfordshire.

The industries with the 3 highest relative GVA are “Public services”, “Professional and business services” and “Information and comms”; the latter is a remarkable entry in the “top 3 sectors”, unique among the Oxfordshire districts.

Distribution of enterprises by size band

The proportion of Oxfordshire enterprises based in Vale of White Horse is 18.5%, almost identical with the local authority’s GVA contribution (of 18.4%).

31% the firms are in the “Professional & Business Services” sector, more than in any other industry group, in line with what is seen across Oxfordshire.

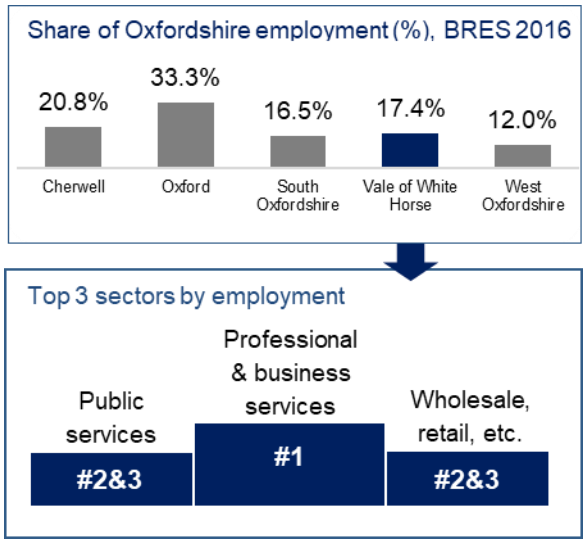
The distribution of enterprises by employees band is very similar with the Oxfordshire average, with the only notable variation being in the percentage of large companies: 0.6% vs. the county’s average of 0.4%.

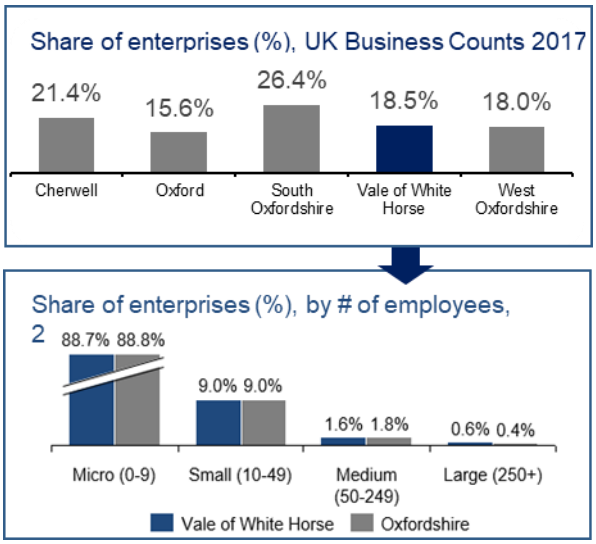
Between 2010 and 2017, the number of enterprises has increased by 14.1%, similar to the 14.6% growth in the total number of enterprises in Oxfordshire.

Largest Firms

The top 3 companies by turnover are in the manufacturing sector: “Infineum International Limited” (Manufacture of chemicals), “Williams Grand Prix Holdings PLC” (Manufacture of motor vehicles) and “Inter Rested Limited” (Manufacture of other general-purpose machinery).

Looking at the top 3 by number of employees adds “Orchid Cellmark Ltd” (Technical testing and analysis) to the list of the largest firms in Vale of White Horse.





WEST OXFORDSHIRE

Key Sectors

With approximately 43,400 jobs, West Oxfordshire contributes with 12% of the total employment in Oxfordshire, the lowest of all districts.

The largest industry group by employment share is “Wholesale, retail, etc.”, which constitutes 30.3% of the total employment in West Oxfordshire; this sector also leads in employment proportion in Cherwell.

Other substantial sectors are “Public services” and “Professional & business services”, accounting for 19.4% and 16.1% of the total employment, respectively.

Employment has increased by 1.6% year-on-year (2016 vs. 2015), the second highest growth in Oxfordshire, after Cherwell; this was primarily driven by a ~20% growth in “Professional & business services employment. 44.1% of the working population in West Oxfordshire hold a minimum NVQ4+ education level.

Due to its smaller size, West Oxfordshire also contributed least to the county’s total GVA (13.3% in 2015) - this proportion is above its employment share, due to its slightly higher than average productivity, as indicated before.

The industries with the highest GVA are “Wholesale, retail, etc.”, “Public services” and “Manufacturing,” in this order.

Distribution of enterprises by size band

In spite of having lower employment figures and GVA, West Oxfordshire has 18% of the enterprises in Oxfordshire, marginally behind Vale of White Horse.

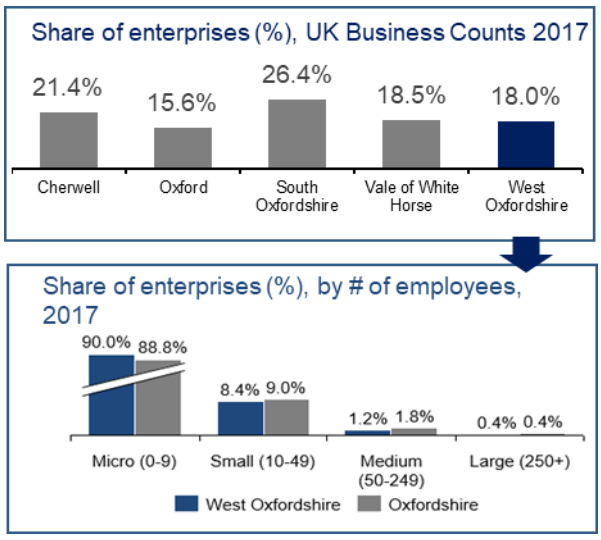
26.7% the firms are in the “Professional & Business Services” sector, more than in any other industry group, in line with what is seen across Oxfordshire.

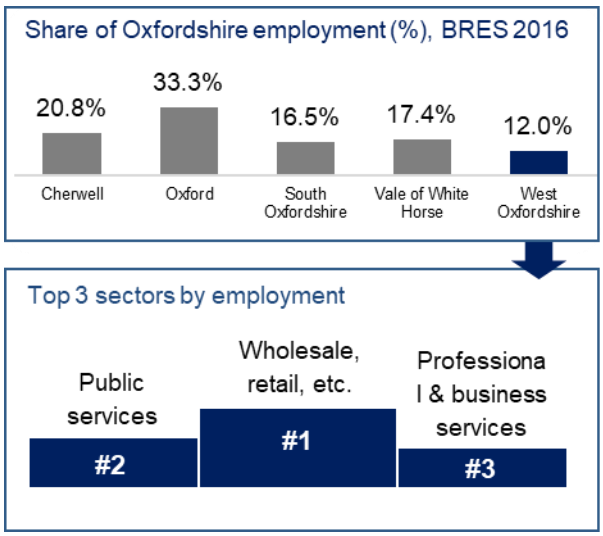
The distribution of enterprises by employees band is similar to that of South Oxfordshire, with a higher proportion of micro firms; however, the percentage of large firms is in line with the Oxfordshire average.

Between 2010 and 2017, the number of enterprises has increased by 8.5%, the lowest growth amongst all five districts.

Largest Firms

The largest three firms, by both turnover and number of employees are: “Hook 2 Sisters Limited” (Animal production), “Canaveral Holdco Limited” (Activities of holding companies) and “P. D. Hook (Group) Limited” (Animal production).





6.4 APPENDIX D: STOCHASTIC FRONTIER ANALYSIS

In this section of the Appendix, we describe our methodological approach and set out the results of Stochastic Frontier Analysis (SFA) which we have undertaken to understand the distribution of firm inefficiency across the UK, but with particular emphasis on the Oxfordshire region. We also describe the methodology and results for the supplementary high-level analysis we have undertaken to understand the drivers of firm efficiency.

Purpose of the analysis

The aim of Oxfordshire's LIS is to boost productivity and growth in the Oxfordshire region.

In order to do this, an intimate understanding of the local economy and the type, productivity and location of businesses throughout the region is essential. Studying levels of firm efficiency can help to inform the LIS with regards to firm productivity. For instance, it allows for the identification of areas within Oxfordshire that are relatively inefficient compared to the rest of the UK. Such areas have potential for catch up and hence may be targeted by the LIS for development, In addition, efficiency analysis can also help to locate efficient areas which by connecting, either physically with transport interventions, or digitally through targeted business interventions could unleash further growth.

SFA is the primary tool used by economists to undertake efficiency analysis

It uses firm-level data to estimate an efficient production "*frontier*" representing the maximum attainable economic output attainable given a set of inputs. Such a frontier can then be used to estimate a firm-specific level of economic output with which, if a given firm was fully efficient, it could attain given the current levels of its production inputs. Having estimated this frontier, any non-random component of the difference between actual economic output and the frontier for a given firm can be deemed to be down to production inefficiency relative to other firms included in the data sample. Such estimates of firm inefficiency are useful and can inform the compilation of Oxfordshire's LIS as they identify the current state of businesses inefficiency across Oxfordshire relative to the inefficiency of other businesses across the UK.

Estimated inefficiencies

While useful in their own right, can also be used to understand what drives firm efficiency. This allows the estimates generated from the SFA to have a second purpose in respect of the LIS as they can identify what potential policy interventions may be useful to implement to increase firm efficiency in the Oxfordshire region.

For this work, we have been innovative and have used a UK-wide panel dataset of firm level information to conduct SFA to understand the relative inefficiency of Oxfordshire firms to those in the rest of the UK. We have then conducted further statistical analysis to understand what policy relevant variables explain differing levels of inefficiency across firms.

This analysis is inherently valuable when forming the LIS for two key reasons. Firstly, it allows for the understanding of business efficiency in a single measure across geographies, taking into account production input levels, how well these are used by firms and how they work together to produce output - rather than analysis which relies purely on trends in production inputs (labour, capital etc) in situ. In addition, it allows for quantification and testing of the relative importance of the effects of different policy interventions on business efficiency levels.

This appendix sets out the theoretical underpinnings of SFA, before discussing the data we used in our analysis and our approach to estimating firm inefficiency. We then set out our approach to identifying significant drivers of such efficiency before presenting the results of our analysis.

An important caveat to our analysis to make at this point is that businesses, typically newly formed start-ups, which do not produce particularly large amounts of output yet, but may have large output in the future will not be accurately captured by this analysis as it only considers current output. Therefore, when interpreting our results it should be noted that particularly hubs of innovation such as educational institutions or science parks are likely to be presented as more inefficient than they actually are due to the omission of such businesses.

Technical Inefficiency and Stochastic Frontier Analysis

Classical microeconomic theory of the firm describes a firm as an entity that transforms a selection of inputs to create economic output.

This is formalised by the notion of a theoretical production function, $f(.)$**,** which takes a set of inputs $\boldsymbol{x_{it}}$ for firm *i* and time *t* and parameters $\boldsymbol{\beta}$ and maps these to the economic output, y_{it} of firm, *i* at time, *t* (where bold is used to indicate a vector of numbers):

$$y_{it} = f(\boldsymbol{x_{it}}; \boldsymbol{\beta})$$

As is often the case with economic analysis, this comes with some assumptions.

What it is important to note at this point is this mathematical representation of a firm's activities assumes the firm is perfectly efficient. That is, that the firm produces the maximum amount of economic output that can be achieved given (i) the inputs it has to use, $\boldsymbol{x_{it}}$ and (ii) the production technology it has access to (the function, $f(.)$ and parameters, β). This explains why the level of output specified by the equation above is often referred to as the efficient production *frontier*. It therefore, does not allow for divergences from this efficient level of production due to: (i) technical inefficiency of the firm (e.g. due to less than optimal use of resources by management, or not employing best practises) and/or (ii) random, or stochastic, disturbances which perturb economic output from its efficient level (e.g. factors beyond firm managements control, such as weather conditions for agricultural firms).

Recognising that it is unlikely all firms produce at their respective efficient levels, the Stochastic Frontier Approach proposed by Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977), takes account of the two reasons for divergences from the efficient production frontier of a firm set out above. Therefore, these authors argue a more realistic representation of firm activities is:

$$y_{it} = f(\boldsymbol{x_{it}}; \boldsymbol{\beta}).\, TE_{it}.\, e^{v_{it}}$$

Where the additional terms, TE_{it} and v_{it} are the technical efficiency of firm, *i* in time *t* and a random, stochastic disturbance term respectively. Technical efficiency captures non-random factors which cause actual economic output of the firm to diverge from the efficient level when no stochastic shocks take place (i.e. when v_{it} =0). Therefore, by definition, the value of TE_{it} must sit within the range (0,1] as actual output, in the absence of shocks must be less than or equal to the efficient level. In contrast the stochastic disturbance term can take any value and be positive or negative. However, given that it is stochastic, i.e. it is a random variable and not a number like technical efficiency, it is usually assumed to have a symmetric distribution. This production function is also normally log-linearised and presented in the form shown below

$$\ln(y_{it}) = \ln(f(\boldsymbol{x_{it}}; \boldsymbol{\beta})) - u_{it} + v_{it}$$

Where; ln is the natural logarithm and $u_{it} = -\ln(TE_{it})$ is a firm's technical <u>in</u>efficiency in a given time period (where by definition $u_{it} > 0$).

This additive separation of actual output into efficient output, technical inefficiency and stochastic effects is shown in Figure D.1 for a hypothetical firm relative to its firm-specific efficient production frontier.

As shown in Figure D.1, actual output diverges from the efficient level due to technical inefficiency, u_{it}, and a stochastic shock, v_{it}. In this particular case, for ease of explanation we have assumed the stochastic disturbance term, v_{it}, is mean zero and has a symmetric distribution, as indicated by the bell-shaped curve in the diagram. This means that the random, or stochastic, part of output is centred at the output level that would be achieved if technical inefficiency was the only factor preventing output being at its efficient level (i.e. $\ln(f(\boldsymbol{x_{it}};\boldsymbol{\beta})) - u_{it}$). As shown actual output is below the level it would be, absent the stochastic shock, due to the negative realisation of the shock. Hence, the specific firm, if the two effects were not separated from one another would look more inefficient than it actually is (clearly given other realisations of the stochastic shock, this could work in the opposite direction as well). The task of SFA is to separate the shortfall shown between actual and efficient output into the component parts of technical inefficiency and stochastic shocks.

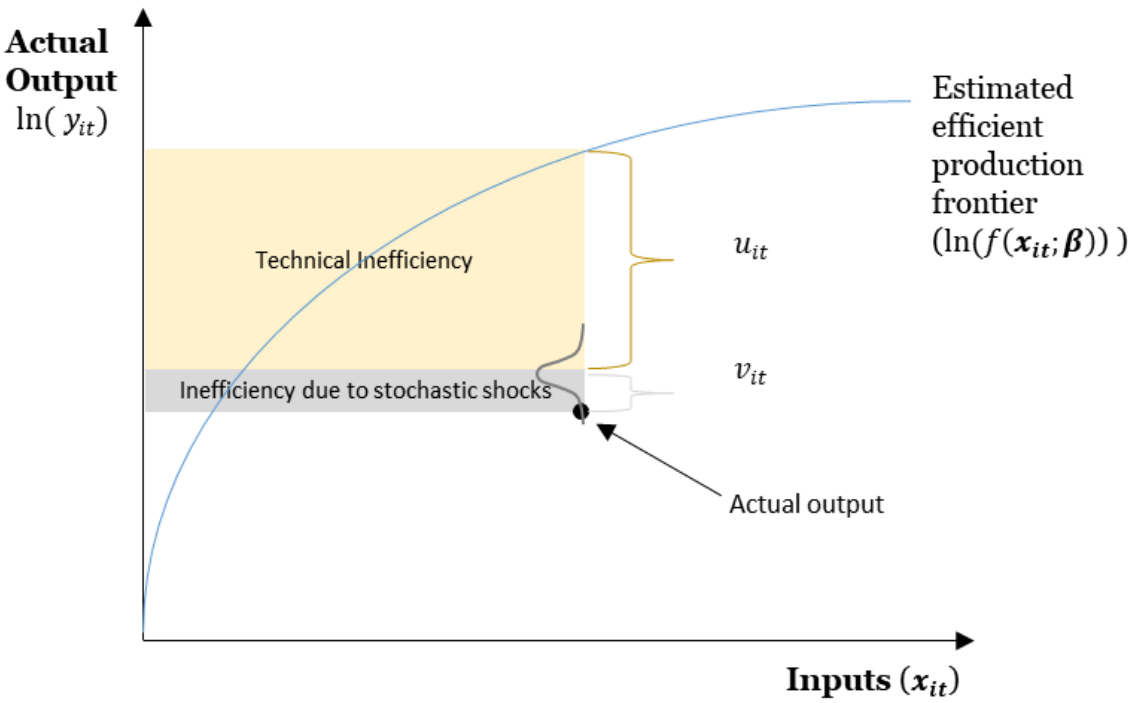


Figure D.1: Technical inefficiency and stochastic effects relative to the production frontier

Estimating efficiency

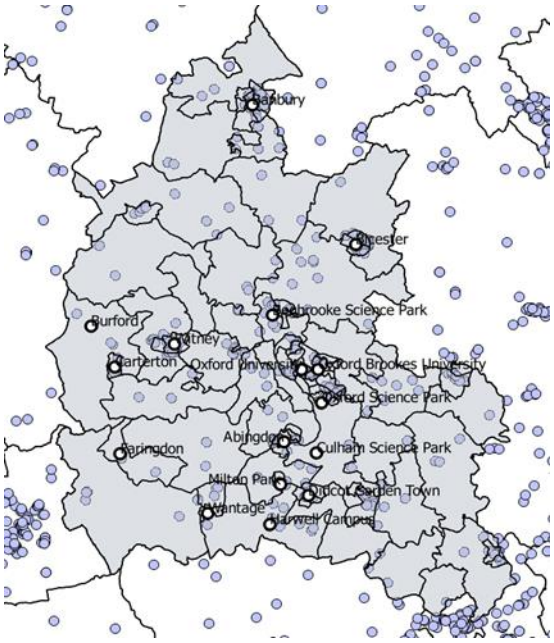
Using SFA to estimate firm-specific levels of technical inefficiency, based on a theoretical production function as set out above, represents the first stage in our econometric analysis for the LIS. In our second stage of analysis we then transform these estimates of inefficiency to each firm's level of technical efficiency and regress this on policy relevant variables to understand whether, and if so, how such variables explain firm-specific levels of technical efficiency.

Data used in the analysis

Studies concerning efficiency analysis and the application of SFA use firm level data to estimate the firm production function and derive associated inefficiency estimates on a per firm basis (Greene, 2008). Use of such data has several statistical advantages over aggregated data, say at the regional level, in addition to the theoretical consistency of estimating a firm production function and firm-specific levels of inefficiency. Indeed, Griliches and Mairesse (1995) have identified several advantages of using firm level data over data at a geographic level. These include greater data variability, avoidance of aggregation bias and better representation of firms' optimising behaviour.

Of the notable data sources containing firm level data, FAME (Financial Analysis Made Easy) has often been used to estimate production functions in different contexts. For example, see Graham (2007), Rizov and Croucher (2011), and Rizov and Walsh (2005) among others. FAME is a data set published by Bureau Van Dijk (BvD), a company specializing in company information and business intelligence. At the time of writing (August 2018), FAME covered over 11 million companies that are or were in existence in the UK and Ireland, with 2 million of these being in detailed format, 280,000 in summary format, as well as basic information for 1.3 million that are not required to or have yet to file accounts.

It is worth noting that a number of weaknesses have been identified with FAME in other contexts. Principal among these is that FAME only includes registered companies, this means we cannot consider universities and public sector organisations such as research institutes, which have a great deal of importance in Oxfordshire.



Source: FAME, PwC

Figure D.2: FAME Firm trading addresses in Oxfordshire

However, it remains the workhorse dataset for analysis of production functions in the UK (and Europe more generally, where the Europe-wide AMADEUS database is in place). For this analysis we have extracted data on nearly 200,000 companies across the UK for ten years

(2008-2017). The locations of firm data we use in Oxfordshire are set out in Figure D.2 below where dots indicate firms based on their trading address post code as listed in FAME.

- Greene, W.H., 2008, “The Econometric Approach to Efficiency Analysis” in eds. H.O. Fried., K. Lovell and P. Schmidt, The Measurement of Productive Efficiency and Productivity Change, Ch. 2
- Griliches, Z., & Mairesse, J., 1995, . “Production Functions: The Search for Identification2, NBER Working Power No. 5067
- Graham, D. J., 2007, Variable returns to agglomeration and the effect of road traffic congestion. Journal of Urban Economics 62, 103–120
- Rizov, M., & Croucher, R., 2011, The impact of the UK national minimum wage on productivity by low-paying sectors and firm-size groups. Report for the Low Pay Commission
- Rizov, M., & Walsh, P. P., 2005, Linking Productivity to Trade in the Structural Estimation of Production within UK Manufacturing Industries. IIIS Discussion Paper No. 98

We have extracted the following variables listed in Table D.1 below for each firm for use in the SFA:

Model variable	Proxy (if any)	Derivation / Remarks	Source
Output	Turnover of the firm	A firm’s output is usually sold in the marketplace, and therefore its real revenue (i.e. revenue adjusted for CPI) can be interpreted as a measure of the value of its products at market prices relative to the mean national price level. This is not a value-added measure (which would have required subtracting intermediate materials input from this figure). This is our dependent variable.	FAME
Capital input	Total fixed assets	Total fixed assets of a company	FAME
Labour input	Number of employees	We use employment as the main proxy for labour input. This effectively assumes that types of labour input do not vary geographically.	FAME

Model variable	Proxy (if any)	Derivation / Remarks	Source
Intermediate materials input	Cost of goods sold minus wages and salary	We aim to obtain a pure materials measure by subtracting the cost of direct labour from the cost of goods sold, with the former proxied by wages and salary. However, if a significant portion of a firm's employment cost is categorised as 'selling, general, and administrative' (SG&A), then this approach may understate the amount of materials consumed. Harris and Li (2008) used this measure as their proxy for materials.	FAME
Inflation	UK Consumer Price Index (CPI)	It does not enter any of our models as an explanatory variable. Instead, we adjusted all monetary items in our dataset for inflation by CPI.	FAME, PwC

Table D.1: Data extracted from FAME for use in the SFA

In addition to the firm level data drawn from FAME, which we use in the SFA to estimate firm-specific levels of inefficiency, we also use a number of indicators drawn from a variety of sources when we look to analyse – at a high-level – the factors that drive firm efficiency. Such indicators we have used in this second stage of the analysis and their associated sources are listed in Table D.1.[33] It should be noted when reviewing such indicators, that we have not looked to compile an exhaustive list of indicators which we believe affect firm efficiency to estimate a predictive model. Rather we have sought to compile a list of indicators that yield useful inference for particular policy prescriptions within Oxfordshire's LIS.

Model variable	Proxy (if any)	Derivation / Remarks	Source
Technical Efficiency	n/a	Estimated from the SFA.	FAME, PwC
Market competition	Local Authority District Birth/Death of enterprise ratio	Ratio of enterprise births to deaths per year per Local Authority District.	ONS, FAME
Export competitiveness	Turnover from foreign sales (as % of total turnover)	Derived from each company's registered accounts in FAME.	FAME

33 Harris, Richard and Qian Cher Li, 2008, "Evaluating the Contribution of Exporting to UK Productivity Growth: Some Microeconomic Evidence". *The World Economy*, 31(2), 212-235.

Model variable	Proxy (if any)	Derivation / Remarks	Source
Maturity of the firm	Firm age	Time elapsed, in years, since company's date of incorporation.	FAME
Business R&D intensity	Business enterprise R&D expenditure per NUTS2 region	Intramural business enterprise R&D expenditure per NUTS 2 region per year at 2005 constant prices, matched to firms using their trading address.	Eurostat, ONS, FAME
Gov't R&D intensity	Gov't sector R&D expenditure per NUTS2 region	Intramural government sector R&D expenditure per NUTS 2 region per year at 2005 constant prices, matched to firms using their trading address.	Eurostat, ONS, FAME
Gov't business support	Gov't grants offered by postcode	Government grants offered per postcode, matched to firms using their trading address.	Innovate UK, FAME
Agglomeration	PwC (2015) Agglomeration index	Weighted average of employment in every LSOA in the UK around a given LSOA, weighted by road travel journey time. The methodology for calculating this was proposed by Graham et al. (2009) and has been produced by PwC independently and is matched to firms by their trading address.	ONS, ESRI ArcGIS, PwC
Sector dummies	n/a	Dummy variables generated from sic codes in FAME, to correspond to 6 broad sector definitions as used in Graham (2007): Agriculture, Construction, Manufacturing, Business Services, Consumer Services and other.	FAME, PwC

Table D.2: Data used to assess drivers of firm efficiency

Specifying the production function

This section sets out our methodological approach to (i) the SFA and (ii) the analysis of the drivers of business efficiency using the outputs of the SFA.

As set out previously, the theoretical SFA model is as shown below:

$$ln(y_{it}) = ln(f(\boldsymbol{x_{it}}; \boldsymbol{\beta})) - u_{\boldsymbol{it}} + v_{it}$$

The first step in setting out the methodology used for the Stochastic Frontier Analysis is to specify the theoretical production function, $f(.)$, to be used in the analysis.

Cobb-Douglas

The most prevalent of production functions to be used in this type of analysis is the so-called "Cobb-Douglas" production function (Greene, 2008). Given the production inputs we have been able to gather data on from FAME in this specific case this takes the form:

$$ln\big(f(\boldsymbol{x_{it}};\boldsymbol{\beta})\big) = \beta_k\, ln(k_{it}) + \beta_l\ ln(l_{it}) +\ \beta_m\, ln(m_{it})$$

Where $\mathrm{k_{it}}$, $\mathrm{m_{it}}$ and $\mathrm{l_{it}}$ are firm i's factor inputs (capital, intermediate materials and labour respectively) at time t and all β coefficients are parameters to be estimated in the analsyis. Furthermore, in this form all β coefficients can be interpreted as output elasticities, such that, for example with capital, "a 1 percent increase in the capital input used by firm i at time t leads to a β_k percent change in firm i's output level." However, it is important to note that the coefficients to be estimated are restricted in this form to be constant acorss all firms, no matter their size, sector etc.

Given this analysis, we shall use a UK-wide dataset. It is possible that due to different production processes across firms of different size that these coefficients may vary significantly. Therefore, in addition to the Cobb-Douglas specification we will also specify and estimate a model using a quadratic production function, which is specied below:

$$\ln\big(f(\boldsymbol{x_{it}};\boldsymbol{\beta})\big) = \beta_k \ln(k_{it}) + \beta_l\ \ln(l_{it}) +\ \beta_m \ln(m_{it}) + \beta_k \ln(k_{it})^2 + \beta_l\ \ln(l_{it})^2 +\ \beta_m \ln(m_{it})^2$$

Where, in addition to log-levels of capital, labour and intermediate materials, each of these enters in squared terms as an additional variable. This specification allows for the production function to be different for small and large firms by allowing the elasticity between each input and efficient output to vary depending on the absolute amount of a given input a firm uses. For example, in the case of capital the elasticity, ε_k, can be shown to be:

$$\varepsilon_k = \frac{\partial f(x_{it};\beta)}{\partial k_{it}} . \frac{k_{it}}{f(x_{it};\beta)} = \beta_k + 2\beta_{k2} \ln(k_{it})$$

Using our results, each firm can be shown to have it's own bespoke output elasticity for each of the factor inputs and as such allows us to take into account that a larger firm with bigger capital stock will have a very different output elasticity than a firm which uses little capital.

Given that we shall be looking across several sectors which use inputs in different intensities together, it is important to specify a third type of production to take into account interaction effects between inputs. Therefore, we shall also estimate a model using the so-called "translog" production function

$$\begin{aligned}\ln\big(f(\boldsymbol{x_{it}};\boldsymbol{\beta})\big) = \beta_k \ln(k_{it}) + \beta_l\ \ln(l_{it}) +\ \beta_m \ln(m_{it}) + \beta_{k2} \ln(k_{it})^2 + \beta_{l2}\ \ln(l_{it})^2 +\ \beta_{m2} \ln(m_{it})^2 \\ +\ \beta_{kl} \ln(k_{it}) . \ln(l_{it}) + \beta_{lm}\ \ln(l_{it}) . \ln(m_{it}) +\ \beta_{km} \ln(k_{it}) \ln(m_{it})\end{aligned}$$

The translog production function includes the squares and cross-products of the factor inputs. The inclusion of these terms gives the translog production function an even more flexible functional form than the standard Cobb-Douglas production function and the quadratic form as it does not assume the elasticity is (i) constant (as in the Cobb-Douglas form), or (ii) only a function of the amount of the particular input used. Indeed, under a translog function, the estimated elastcity of each input on output depends on the current level of all inputs that have already been committed. For example, the elasticity of capital under a Translog function would be:

$$\varepsilon_k = \frac{\partial f(\boldsymbol{x_{it}};\boldsymbol{\beta})}{\partial k_{it}} . \frac{k_{it}}{f(\boldsymbol{x_{it}};\boldsymbol{\beta})} = \beta_k + 2\beta_{k2}\, ln(k_{it}) + \beta_{kl}\, ln(l_{it}) + \beta_{km}\, ln(m_{it})$$

Approach to SFA

Having specified the three variants of production function that will be used in this analysis, the next step in the estimation methodology is to outline the approach we take to estimate the efficient production frontier in the presence of (i) Technical Inefficiency and (ii) Stochastic shocks.

Approaches to SFA with Panel Data

Given the dataset to be used in this analysis is a panel following a number of firms over several years a number of methodological approaches are available for undertaking SFA. As set out in Greene (2008), the distinguishing feature between the classes of methods available is the assumption of whether firm-specific technical inefficiency is fixed over time, as in Battese and Coelli (1988) or Pitt and Lee (1981) for example, or whether it is allowed to vary over time as in Battese and Coelli (1992) or Kumbhakar (1990).

On the face of it, allowing for time-varying inefficiency would seem a more flexible approach to taken given we have access to panel data in this analysis. However, we have elected to assume inefficiency is fixed over time for our work for the following two reasons:

(i) In order to understand how firm inefficiency evolves over time, if it is indeed time varying, the dataset needs to be fairly large in the time dimension. However, in this analysis we have dataset with a very large number of companies (circa 200,000) but relatively small amount of time periods (ten years) making identification of changes in efficiency over time for a given firm difficult; and

(i) The leading methodologies which allow for time varying firm-specific inefficiency tend to be relatively restrictive in how they specify inefficiency can evolve over time. In particular, these approaches tend to impose a functional form on this inefficiency such that it is explicitly related to time. For example, Battese and Coelli (1992) assume that inefficiency decays (i.e. is forced to decline) at an exponential rate over time.

- Battese, G. and T. Coelli, 1988, “Prediction of Firm-level Technical Efficiencies with a Generalized Frontier Production Function and Panel Data,” Journal of Econometrics, 38, pp. 387-399.
- Pitt, M., and L. Lee, 1981, “The Measurement and Sources of Technical Inefficiency in the Indonesian Weaving Industry,” Journal of Development Economics, 9, pp. 43-64.
- Battese, G., and T. Coelli, 1992, “Frontier Production Functions, Technical Efficiency and Panel Data: With Application to Paddy Farmers in India,” Journal of Productivity Analysis, 3, pp. 153-169.
- Kumbhakar, S., 1990, “Production Frontiers and Panel Data, and Time Varying Technical Inefficiency,” Journal of Econometrics, 46, pp. 201-211.

The approach of Battese and Coelli (1988):

We recognise that confining ourselves to time invariant inefficiency estimates may discard important intertemporal mechanisms that affect firm inefficiency and will mean we are not able to determine if and how firm inefficiency changes over time. Therefore, as a sensitivity test to our estimates, later in this appendix we set out work we have undertaken which analyses the presence of time varying-inefficiency.

Given that we assume firm-specific technical inefficiency is fixed over time, we have then elected to employ the methodology of Battese and Coelli (1988). We have chosen this approach as it represents the most flexible approach to SFA in this class of models, given it imposes the most flexible distributional assumptions. For example, and as discussed below this approach does not restrict inefficiency to have a zero mean, as in Pitt and Lee (1981). Nevertheless for robustness, we also consider the Pitt and Lee (1981) approach later in this appendix as a sensitivity to our analysis.

Battese and Coelli (1988) consider a restricted version of the theoretical SFA model set out above, with technical inefficiency only varying by firm and not time:

$$\ln(y_{it}) = \ln(f(\boldsymbol{x_{it}}; \boldsymbol{\beta})) - u_{\boldsymbol{i}} + v_{it}$$

They then proceed to estimate firm-specific technical inefficiency as specified in the equation above by using Maximum Likelihood Estimation.

Maximum Likelihood Estimation

In order to do this they therefore, need to first make assumptions on the distributions of the unknown quantities of (i) technical inefficiency, $u_{\boldsymbol{i}}$, and (ii) the stochastic disturbance term, v_{it}. Starting with the latter, they specify, as is common in many SFA models (Greene, 2008), that the stochastic disturbance term is independent and identically distributed (i.i.d.) normal with zero mean and variance, σ_v^2, i.e. $v_{it} \sim N(0, \sigma_v^2)$. Then, recalling that technical inefficiencies, $u_{\boldsymbol{i}}$, are by definition non-negative, they specify a truncated normal distribution for technical inefficiencies where each $u_{\boldsymbol{i}}$ is assumed to be i.i.d. and drawn from the positive half of a normal distribution with mean, μ, and variance, σ_u^2, i.e. $u_i \sim N(\mu, \sigma_u^2)$ with the following probability density function for a single realisation of u_i being:

$$pdf(u_i) = \frac{\exp\left(-\frac{\frac{1}{2}(u_i - \mu)^2}{\sigma_u^2}\right)}{(2\pi)^{1/2}\sigma_u\left[1 - \boldsymbol{\varphi}\left(-\frac{\mu}{\sigma_u}\right)\right]}, \quad u_i > 0$$

Where: $\boldsymbol{\varphi}(.)$ denotes the cumulative distribution function of the standard normal distribution.

Calculating the firm inefficiencies

The approach to estimate parameters, $\boldsymbol{\beta}$ and calculate firm-specific levels of inefficiency, u_i is t maximise the joint Likelihood function (which is formed by multiplying each individual density function) subject to (i) the constraint that u_i must be positive and (ii) the definition of u_i as a residual component of the theoretical SFA model. Or more formally, the problem is:

$$\max_{\beta} \quad \prod_{i=1}^{N} pdf(u_i)$$

$$s.t.$$

$$(i) \quad u_i > 0$$

(ii) $\ln(y_{it}) = \ln(f(\boldsymbol{x_{it}}; \boldsymbol{\beta})) - u_{\boldsymbol{i}} + v_{it}$

Such a maximisation problem is inherently non-linear, and so to solve this we utilise numerical optimisation methods contained within the statistical software STATA rather than calculus.

This procedure is undertaken for each specification of the production function outline above. We then choose our preferred model by utilising frequently used measures of statistical fit for the production functions, the Akaike Information Criterion (AIC) and the Bayes Information Criterion (BIC).

Approach to understanding the drivers of firm efficiency

Once we have obtained the estimates of technical inefficiency, we then carry out a second exercise using these estimates to understand what factors, other than factor inputs drive firm levels of technical efficiency, TE_{it}, and, in particular, we look to understand, at a high-level what policy relevant variables are associated with more efficient firms.

To do this we first transform the estimates of technical inefficiency from the SFA by multiplying them by -1. This is necessary as set out above, $u_{it} = -\ln(TE_{it})$. Therefore, conducting this transformation means the dependent variable for our analysis is easier to interpret, being the log of technical efficiency. Having done this we then regress this score on policy relevant variables using the following empirical specification:

$$-u_i = \alpha_0 + \alpha_1 \ln(MktComp)_{it} + \alpha_2 \ln(ExportComp)_{it} + \alpha_3 Age_{it} + \alpha_4 \ln(\mathrm{BusR\&D})_{it}$$
$$+\alpha_5 \ln(Gov'tR\&D)_{it} + \alpha_6 \ln(Grant)_{it} + \alpha_7 \ln(Agglo)_{it} + \alpha_8 Agri_{it}$$
$$+\alpha_9 Cons_{it} + \alpha_{10} Manu_{it} + \alpha_{11} CSer_{it} + \alpha_{12} Bser_{it} + \omega_{it}$$

Where $MktComp,\ ExportComp$, Age , $BusR\&D,\ Gov'tR\&D$, $Grant$, $Agglo,\ Agri,\ Cons,\ Manu,\ CSer,\ BSer,$ are market competitiveness, export competitiveness, business R&D intensity, Government sector R&D intensity, Government business support, agglomeration, an agriculture dummy, construction dummy, manufacturing dummy, consumer services dummy and business services dummy (as set out above) respectively, ω_{it} the regression error term and $\alpha's$ parameters to be estimated. Note here businesses in the “Other” sector are the base group (i.e. the Other sector dummy variables has been excluded to avoid the so-called “dummy variable trap”).

Approach to understanding the drivers of firm efficiency

Recalling that the dependent variable itself is in log form, the coefficients in this regression, other than for Age and the sector dummies, can be interpreted as elasticities with respect to technical efficiency, TE_{it}. For example, in the case of agglomeration, “a 1 percent increase in the level of agglomeration in a given LSOA where firm *i resides* at time *t* is associated with a α_7 percent change in firm *i*'s level of technical efficiency” – such a statistic is also approximately equivalent to the percentage change in technical efficiency that would be associated with a 1% decrease in UK-wide road journey travel times. Note though as Age and the sector dummies enter in levels form only, we have to interpret them differently. In particular, for Age, we can interpret α_3 as “for every one year a firm is older its level of technical efficiency changes by 100xα_3 percent”.

To estimate this equation, we use a Pooled OLS approach rather than utilising a Fixed Effects panel data method. The rationale for this is as follows. Some explanatory variables, such as the level of agglomeration and our dependent variable are time invariant. This means use of a Fixed Effects methodology at the firm level to control for potential omitted variable bias is impossible,

as the estimator cannot be computed. Further, since many variables at the firm level have values shared by several firms, due to being specified at a higher level of geographical aggregation (e.g. per Local Authority District or NUTS 2 region), a Fixed Effects approach based on time fixed effects cannot be used for the same reason.

Given the restriction we face in our estimation procedure for this equation, our analysis may suffer from potential omitted variable bias, as there are other variables which could explain firm inefficiency levels, and that may be correlated with variables we have included in this analysis. Hence, caution should be taken in causally interpreting the precise level of the coefficients estimated. Nevertheless though, the estimated coefficients still have value in terms of the statistical significance and sign.

It is also noteworthy that we have also chosen to use clustered standard errors at the firm level, rather than a Random Effects panel data structure to correct for standard error size given that clustered standard errors allow for much wider levels of autocorrelation and heteroscedasticity.

Finally, as is standard econometric practise, we employ a general-to-specific approach (a'la David Hendry) whereby by we estimate the specified equation above, successively removing groups of insignificant variables to ensure precision of estimation. We present our final model in the next section of this appendix.

Core estimation results: Setting out the findings from analysis.

Dependent variable	Log(Turnover)		
	Cobb-Douglas	Quadratic	Translog
Log(Fixed assets)	0.0349***	0.0272***	0.0704***
	(0.000907)	(0.00175)	(0.00264)
Log(Employment)	0.327***	0.346***	0.721***
	(0.00207)	(0.00524)	(0.00570)
Log(Intermediate materials)	0.467***	-0.165***	-0.0324***
	(0.00130)	(0.00376)	(0.00344)
[Log(Fixed assets)]^2		0.0000616	0.00275***
		(0.000136)	(0.000147)
[Log(Employment)]^2		-0.00826***	0.0379***
		(0.000596)	(0.000676)
[Log(Intermediate materials)]^2		0.0414***	0.0589***

Dependent variable	Log(Turnover)		
	Cobb-Douglas	Quadratic	Translog
		(0.000236)	(0.000234)
Log(Fixed assets) x Log(Employment)			0.00245***
			(0.000508)
Log(Fixed assets) x Log(Intermediate Materials)			-0.00979***
			(0.000318)
Log(Employment) x Log(Intermediate Materials)			-0.0866***
			(0.000632)
Constant	7.983	9.657	7.758
	(9.48)	(14.63)	(26.09)
Number of observations	93967	93967	93967
AIC	-4698.174	-31823.69	-55938.85
BIC	-4632.019	-31729.19	-55815.99

Source: PwC

Table D.3, Results:

Key to table: Standard errors in parenthesis; coefficients are statistically significant at the * 5% level; ** 1% level; *** 0.1% level

As discussed in the previous section we have used Maximum Likelihood Estimation following Battese and Coelli (1988) to estimate firm-level technical inefficiency for three variants of production function: the Cobb-Douglas production function, the quadratic production function and the translog production function. Estimation results for each of these is set out in Table D.3.

Core estimation results review

Cobb Douglas Specification

We can see firstly that the estimated coefficients of the Cobb-Douglas specification are of the theoretically expected sign with each factor input, statistically significant at the 1% level confidence level and positively contributing to output. Of particular interest is that the coefficients for intermediate inputs and labour are an order of magnitude larger than that for fixed assets. This may indicate that on average businesses in the UK operate with a fairly small capital base

relative to labour and intermediate inputs. However, this is unlikely to be true for some larger firms, as well as capital intensive industries It is more likely that the Cobb-Douglas specification does not capture capital's impact on other factors of production accurately.

Quadratic Specification

Moving to the quadratic specification that allows us to take account of the absolute size of firms we see that each factor input has a different estimated shape to its output elasticity. In particular, for fixed assets, or capital, the quadratic term is statistically insignificant indicating the capital elasticity does not vary between different firms. In contrast, the signs on coefficients of labour indicate that the output elasticity of labour decreases as the absolute amount of labour employed increases for a given firm. In addition the sign of the coefficients on intermediate inputs suggest the opposite, such that the larger amount of intermediate materials used the greater the output elasticity.

Trans-log specification

In contrast, the translog specification shows that interaction effects are very important. First of all, their inclusion (i) means we can more precisely identify the quadratic capital term, which is now statistically significant and (ii) the inclusion of interaction terms clarifies the sign of the squared labour term which is now positive. Both of these changes can be explained by the omission of significant negative interaction terms between capital and intermediate inputs and labour and intermediate inputs in the quadratic form. In particular, as these negative effects were not specified separately, they would be captured in the level and quadratic terms, biasing the estimated coefficient down to insignificance in the case of capital and in labour's case leading to a negative estimated quadratic coefficient. The negative interaction terms between capital and intermediates and labour and intermediates indicate that increases in intermediates reduce both the capital and labour output elasticities. Such a finding indicates substitutability between intermediates and capital and labour which is reasonable. In contrast, labour and capital have positive effects on each other's elasticities indicating both factors benefit from having more of the other to work with.

Core estimation results review

If we now look across the models the translog is our preferred model as: (i) it allows for a more interactions between inputs, that are shown to be important in the estimation; and (ii) it has lower values of information criteria (AIC and BIC) indicating a much better fitting model to the data. Therefore, all proceeding estimates of technical inefficiency discussed below, either for the whole sample, by sector or for the efficiency driver analysis use the translog specification.

Sector estimation results: In addition to our core model for the entirety of firms in the UK for our sample, we have also ran separate models for key sectors to unpack the rationale behind levels of inefficiency across Oxfordshire. Our results for each of these are set out in Table D.4

As shown in the Table D.4, the sign and significance of different coefficients is remarkably similar between the sectors with most coefficients highly statistically significant. Most interestingly, and perhaps intuitively are the size of the coefficients on the log-levels of each input when compared across models. In particular, business and consumer services and manufacturing have much larger coefficients than construction and agriculture regarding the elasticity of output with respect to labour (not including interaction and firm size effects). This makes sense as business and consumer services are driven by labour input as they are by nature service industries, and manufacturing in the UK as a tends to be highly specialised, requiring a good amount of skilled labour input. Likewise the coefficient on capital in the models for construction and agriculture is

much higher, indicating on average higher elasticities of output (not including interaction and firm size effects) with respect to capital for these sectors. Again this is reasonable as these are much more capital intensive sectors.

Dependent variable	Log(Turnover)				
	Agriculture	Construction	Manufacturing	Consumer Services	Business Services
Log (Fixed assets)	0.263***	0.189***	-0.00961	0.0346***	0.0710***
	(0.0227)	(0.00905)	(0.00678)	(0.00382)	(0.00631)
Log (Employment)	0.479***	0.657***	0.959***	0.731***	0.809***
	(0.0532)	(0.0218)	(0.0137)	(0.00831)	(0.0148)
Log (Intermediate materials)	-0.292***	0.0984***	-0.172***	0.00579	-0.0348***
	(0.0377)	(0.0121)	(0.00839)	(0.00526)	(0.00844)
[Log(Fixed assets)]^2	0.00158	0.00711***	0.0000864	0.00122***	0.00364***
	(0.00106)	(0.000458)	(0.000298)	(0.000201)	(0.000412)
[Log(Employment)]^2	0.0295***	0.0478***	0.0516***	0.0389***	0.0340***
	(0.00528)	(0.00262)	(0.00169)	(0.000984)	(0.00194)
[Log(Intermediate materials)]^2	0.0763***	0.0621***	0.0768***	0.0567***	0.0564***
	(0.00277)	(0.000941)	(0.000617)	(0.000322)	(0.000660)
Log(Fixed assets) x Log(Employment)	-0.00776	0.00113	0.00733***	0.00374***	0.00510***
	(0.00571)	(0.00175)	(0.00115)	(0.000765)	(0.00135)
Log(Fixed assets) x	-0.0250***	-0.0280***	-0.000969	-0.00486***	-0.0114***

Dependent variable	Log(Turnover)				
	Agriculture	Construction	Manufacturing	Consumer Services	Business Services
Log(Intermediate Materials)	(0.00268)	(0.00116)	(0.000889)	(0.000450)	(0.000827)
Log(Employment) x Log(Intermediate Materials)	-0.0518***	-0.0891***	-0.131***	-0.0897***	-0.0901***
	(0.00620)	(0.00267)	(0.00196)	(0.000928)	(0.00175)
Constant	6.353***	5.231	6.608	6.928	7.839
	(0.293)	(12.81)	(7.394)	(12.47)	(24.79)
Number of observations	1331	7769	23503	32917	13539

Source: PwC

Table D.4: Sectoral Estimation results

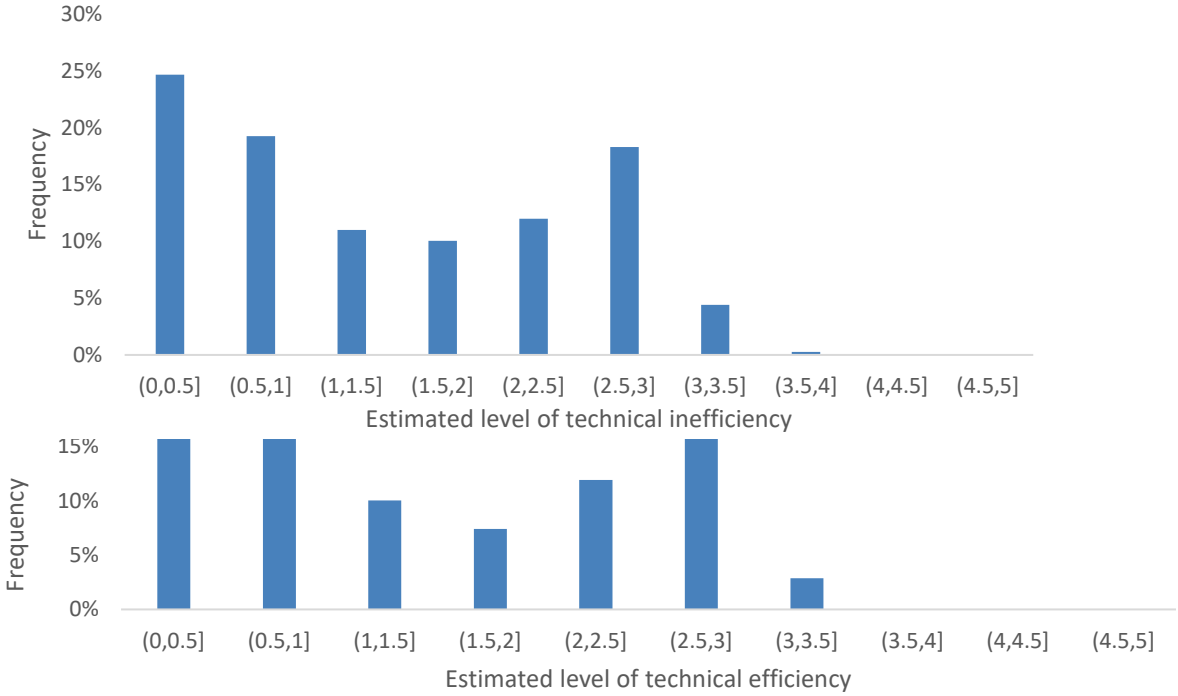
Key to table: Standard errors in parenthesis; coefficients are statistically significant at the * 5% level; ** 1% level; *** 0.1% level

Discussion of inefficiency estimates and implications for the LIS

Using our preferred production function, we have generated firm-specific estimates of technical inefficiency based upon our core model. We have also generated estimates of inefficiencies on a per sector basis using the sector models discussed above for cross comparison with the core results.

Distributions of inefficiency

Figures C.3 and C.4 set out the estimated frequency distributions of firm-specific technical inefficiency for both the UK as a whole and for Oxfordshire only. It is important to note here that the ranges of values correspond to estimated technical inefficiency parameters, with increasing sizes indicating more inefficient firms.



Source: PwC

Figure D.3 and C.4: Frequency distribution of technical inefficiency for the UK

Discussion of inefficiency estimates and implications for the LIS

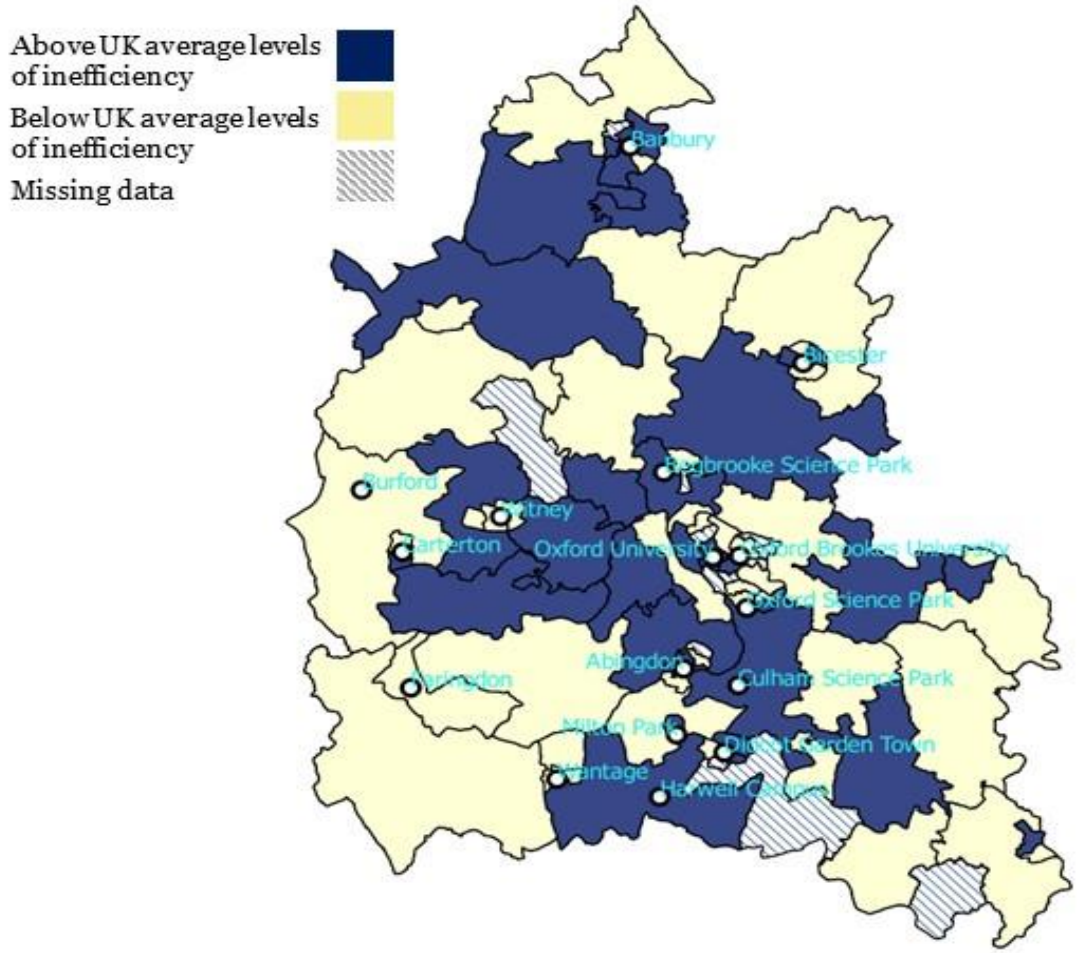
Figures C.3 and C.4 show the frequency distribution in both the UK and Oxfordshire are very similar and roughly resemble a truncated normal distribution, with non-zero and positive mean, as would be expected given the estimation procedure adopted in this analysis. However, upon comparison, firms in Oxfordshire tend to polarise the distribution, in that Oxfordshire has both (i) a higher proportion of firms with the lowest efficiency score than can compared to the UK, while (ii) also having a higher proportion of firms in the highest frequency bin, (2.5,3], than in the UK. If firms of similar efficiency levels are in the same sector and/or clustered geographically this may mean Oxfordshire itself is also likely to be polarised, in that, it is likely to have areas of very efficient activity and other areas of very inefficient activity.

It is important to note that the figures in these frequency distributions cannot be readily interpreted in this form as they need to be multiplied by negative 1 and exponentially transformed to have meaning. If this was to be undertaken the resulting figure would be an estimate of Technical Efficiency, the multiplicative constant described earlier in this appendix. For example, the mean inefficiency estimate of 1.5 for the UK (and Oxfordshire) corresponds to a technical Efficiency parameter of 0.22. Such a figure is quite low and indicates a high degree of technical inefficiency in UK firms in general. However, it should be recognised that in undertaking this analysis we have only estimated a theoretical production function with three factor inputs so that, in the second stage of our analysis, we are able to understand what factors may be related to technical efficiency, having only taken into account these core inputs.

The geographical distribution of inefficiency

To investigate the geographical distribution of technical inefficiency, we have averaged each firm's inefficiency estimate with other firms within its MSOA to produce the following map of inefficiency scores by MSOA for Oxfordshire.

As shown in Figure D.5, areas shaded in blue represent areas with high levels of technical inefficiency (relative to the UK average) while areas in yellow indicate relatively more efficient areas.



Source: PwC SFA

Figure D.5: Distribution of inefficiency in Oxfordshire

From this map, several interesting observations can be made about different geographical areas of Oxfordshire. These are summarised over the following pages.

Oxford

The City of Oxford itself is characterized as an area with low levels of business inefficiency, but as can be seen in Figure D.5 above there are pockets of relatively high inefficiency around the University of Oxford itself. Though perhaps surprising, when cross-referencing the core results to the sector results we see that this area has low inefficiency business services firms, but a high number of inefficient consumer businesses. That Oxford has particularly efficient business

services firms is unsurprising and intuitive as they would be the most likely type of firms to benefit from the being in close proximity to the University of Oxford due to its leading research and pool of skilled labour. Such intuition is confirmed when considering which efficient companies are located here. For example, specialised consulting, data and analytics firms such as Frost & Sullivan, Epic Data, Numerical Algorithms Group are among the most efficient firms in the area.

Cherwell

The area to the north of the city of Oxford presents a mixed picture of efficiency with large areas characterized by above average business inefficiency. However, there are pockets of efficiency in Bicester where a cluster of relatively efficient consumer businesses are located in the vicinity of Bicester village. In addition, there are a collection of efficient firms, such as chemical manufacturing firm Energetics Europe Ltd who operate close to Begbroke Science Park. Therefore, there is evidence that initiatives to cluster similar firms has helped to ensure business efficiency. In contrast, Cherwell also has large swathes of greenbelt land and so it unsurprising that the particular areas are populated by efficient agricultural businesses.

West Oxfordshire

The area to the west of the City of Oxford has much higher levels of technical inefficiency relative to all other areas within the county. This is unsurprising, given we have shown earlier in this report that West Oxfordshire seems to stand out as an area lagging behind the rest of Oxfordshire, characterised by a declining working age population, relatively high levels of household poverty and lower numbers of enterprise creation when compared to other districts. This area is also not very agglomerated which limits knowledge sharing and other spillover benefits between firms in the locality and with firms across the UK. In respect of particular sectors, the area is highly inefficient in respect of business services and construction. However, there are pockets of efficient activity related to agriculture and manufacturing. For instance in Whitney, efficient specialised manufacturing companies such as Meech International Ltd account for the lion’s share of the inefficiency score in this area.

Vale of White Horse

Similar to the South of Oxfordshire, the Vale of White Horse is on average a very efficient part of the county with consumer services and manufacturing being standout sectors. With regards to particularly efficient businesses, Williams Motorsport stands out as highly efficient which is unsurprising given its proximity more broadly to other leading motorsport bases in Oxfordshire, Buckinghamshire and Northamptonshire.

South Oxfordshire

This area is characterised by a large density of efficient businesses, particularly in the South-East tip of the county as high levels of agglomeration related to the proximity of the area to Reading and London benefit businesses. However, it is perhaps surprising that the MSOA containing the historic Culham Science Park is inefficient. Upon further investigation, this is perhaps misleading as there are a distinct lack of companies in our dataset located in close proximity to the science park, which is perhaps not surprising given the largest notable institution in the area is the UK Atomic Energy Authority which is a public entity, not captured within FAME data.

Lack of efficiency

Of these observations, perhaps the general lack of efficiency in the West of Oxfordshire is most pertinent for the LIS. In particular, this analysis implies that the area to the west of the City of Oxford has a larger potential for productivity improvement that could be unleashed by initiatives

in the LIS. In addition, important lessons for the LIS can be learnt from efficient areas within the county which tend to be characterised by either:

i) close proximity to agglomerated areas, such as in the South East tip of the county or

ii) significant density of related businesses to leading research hubs and institutions such as the cluster of efficient businesses services firms close to the University of Oxford.

On the basis of this evidence, the LIS should leverage this experience by ensuring good transport connectivity and encouraging the location of new businesses close to related research hubs and science parks.

Drivers of firm efficiency

Our analysis of firm inefficiency in Oxfordshire has been useful in that it has (i) helped to identify areas for potential catch up in terms of productivity and (ii) helped to identify lessons from efficient areas. In relation to the latter though, our analysis of the drivers of firm specific technical efficiency is useful in shedding light on potentially effective policies that could be implemented as part of the LIS.

As set out in the previous section, we have estimated a model used Pooled OLS estimation to understand the relationships between policy relevant variables and firm inefficiency. In Table D.5 below we present our final econometric estimation results of this equation having followed a general to specific procedure.

As shown, of the initial list of variables considered, five variables have been found to have a significant estimated relationship with technical efficiency as well as most of the sector dummies. The interpretation and policy implications of each of the estimated relationships is set out below.

Dependent variable	Log(Technical Efficiency)
	Final model
Log(Export Competitiveness)	0.0381***
	(0.00485)
Age	-0.00627***
	(0.000450)
Log(Market Competition)	0.403***
	(0.0243)
Log(Business R&D intensity)	0.0358***
	(0.00916)
Log(Agglomeration)	0.0475***
	(0.0104)

Dependent variable	Log(Technical Efficiency)
	Final model
Agriculture	-0.145
	(0.0911)
Construction	-0.147**
	(0.0620)
Manufacturing	-0.230***
	(0.0316)
Business Services	0.190***
	(0.0354)
Consumer Services	-0.177***
	(0.0313)

Source: PwC

Table D.5: Drivers of firm-level efficiency

Key to table: Standard errors, clustered at the firm level, in parenthesis; coefficients are statistically significant at the *5% level; ** 1% level; *** 0.1% level

Export competitiveness

Increases in the proportion of turnover sold abroad is associated with increasing firm efficiency. In particular a 1% increase in the proportion of turnover sold abroad from its current level is associated with increasing firm inefficiency by 0.4%. Given firms in Oxfordshire have a higher average proportion of turnover sold abroad than the rest of the UK, the LIS should look to build on this to continue to encourage the export of products and services abroad, while looking to retain businesses in the region. To support businesses in this, the LIS could look to, for example, establish joint representative offices overseas or matching companies with export credit insurance firms.

Drivers of firm efficiency

Age

The age distribution of firms in Oxfordshire is relatively more polarised than the UK as a whole. Oxfordshire has a higher proportion of firms that are 50 years and a smaller proportion of firms that are less than ten years old. Given the higher proportion of older firms it will be important for

the LIS to look to encourage new business growth as our results indicate that for every extra year a business has been running, this is associated with decreasing business efficiency by 0.6%.

Market Competition

As shown, an increase in market competition measured by the ratio of enterprise birth to deaths per Local Authority district by 1% from its current level is associated with increasing firm efficiency by 0.04%. This is intuitive and suggests that the LIS should ensure that entry barriers for new businesses are kept low to encourage entrepreneurship and innovation. On the other hand, where possible, the LIS should also avoid propping up inefficient and/or failing enterprises to avoid distorting investment incentives.

Business R&D Intensity

Increases in business R&D expenditure are shown to be associated with increasing firm efficiency, with a 1% increase in spend per NUTS2 region being associated with increase in efficiency of 0.04%. Oxfordshire has a higher average level of business R&D intensity than the UK nationally for all years in our sample. In addition, it also has a higher proportion of persons employed in Business Services (32%) rather than on average in the UK (20%). Therefore, encouraging business R&D further by setting up matching schemes and/or providing infrastructure support may represent an effective method to achieve big productivity and growth gains to the region.

Agglomeration

Increases in the level of agglomeration within Oxfordshire are found to be associated with increasing technical efficiency, in that, a 1% increase in the level of agglomeration in a given LSOA where a particular firm resides is associated with a 0.05% increase in its technical efficiency. As stated before, this is approximately equivalent to the percentage change in technical efficiency that would be associated with a 1% decrease in UK-wide road journey travel times. Given this association, the LIS should devote some focus to investment in targeted transport infrastructure interventions that better connect Oxfordshire's economic conurbations to each other and cities through the UK. An example of this could be the proposed East-West rail link between Oxford and Cambridge.

Sector Dummies

Implicit in the estimation results above is that the base sector used is Other – this means that when interpreting the estimated coefficients in respect of sectors, the sign of coefficients indicates whether firms in particular sectors on average, having taken into account the other variables in our model, are more or less efficient than firms in the Other sector. As shown, the coefficient on Agriculture is insignificant which provides evidence of a similar level of inefficiency for firms in this sector when compared to those in Other. Business Services meanwhile is unsurprisingly comparatively more efficient and construction, manufacturing and consumer services are less efficient. Given Oxfordshire has a higher than UK average level of employment in the comparatively most efficient sector, business services, this suggests the LIS should look to encourage further growth in this sector.

Sensitivity Analysis

In this final section of this Appendix we set a number of sensitivity tests that we have undertaken to ensure the robustness of our approach to SFA. Each of these are set out in turn.

Dependent variable	Log(Turnover)
Log(Fixed assets)	0.0643***
	(0.00326)
Log(Employment)	0.714***
	(0.00727)
Log(Intermediate materials)	-0.0144***
	(0.00422)
[Log(Fixed assets)]^2	0.00286***
	(0.000189)
[Log(Employment)]^2	0.0330***
	(0.000884)
[Log(Intermediate materials)]^2	0.0576***
	(0.000290)
Log(Fixed assets) x Log(Employment)	0.00431***
	(0.000645)
Log(Fixed assets) x Log(Intermediate Materials)	-0.00998***
	(0.000398)
Log(Employment) x Log(Intermediate Materials)	-0.0831***
	(0.000804)
Constant	7.708
	(15.55)
Number of observations	60898

Source: PwC

Table D.6: Estimation results of firms without multiple trading addresses

Key to table: Standard errors in parenthesis; coefficients are statistically significant at the * 5% level; ** 1% level; *** 0.1% level

Excluding firms with multiple trading addresses

The FAME dataset used in this analysis identifies each company in England and Wales with its registered address, which may not be the only location at which a company operates. This creates concern that firm revenue allocation may not be accurate. For example, The Co-operative Group operates thousands of different branches across the country, and it would not be appropriate to assign all its revenue and productivity to Manchester, where it is registered. Therefore, we have re-ran our core SFA model having purged the dataset of all companies with more than one trading address from our main model. The results of this sensitivity test are set out in Table D.6

As shown, when compared to the core estimation results above estimated coefficients are very similar and as a result, the distribution of estimated level of technical inefficiency are virtually identical. As such we do not expect this potential issue to impact our core estimates and their implications materially.

Exploring other time invariant SFA approaches

In this analysis we have chosen to use the Battese and Coelli (1988) approach to estimate levels of firm inefficiency. While we believe this is the most flexible approach to take in terms of distributional assumptions, we think it is useful to contrast our results against a different methodology. In particular, we have estimated inefficiencies based on the Pitt and Lee (1981) approach. Such an approach is very similar to that used by Battese and Coelli (1988), but assumes a half normal distribution of inefficiencies with a zero population mean. The results of the SFA when using this approach are set out in Table D.7.

Similar to the previous sensitivity test, again estimated coefficients are similar as well as the resulting distribution of estimated inefficiencies. This perhaps unsurprising as when allowing the mean to be non-zero using the Battese and Coelli (1988) approach, areas of high frequency in the sample distribution of inefficiency estimates for the sample is close to zero.

Time varying inefficiency

A fundamental assumption made in this analysis is that firm inefficiency is constant over the time period studied. To test this assumption we initially looked to estimate the time varying inefficiency model of Battese and Coelli (1992). This specifies that while inefficiencies can vary over time, they have to decay (i.e. decrease over time) at an exponential rate.

Dependent variable	Log(Turnover)
Log(Fixed assets)	0.0635***
	(0.00257)
Log(Employment)	0.723***
	(0.00561)
Log(Intermediate materials)	-0.0949***
	(0.00411)

[Log(Fixed assets)]^2	0.00451***
	(0.000115)
[Log(Employment)]^2	0.0418***
	(0.000606)
[Log(Intermediate materials)]^2	0.0638***
	(0.000267)
Log(Fixed assets) x Log(Employment)	0.000893*
	(0.000437)
Log(Fixed assets) x Log(Intermediate Materials)	-0.0103***
	(0.000309)
Log(Employment) x Log(Intermediate Materials)	-0.0912***
	(0.000629)
Constant	5.758***
	(0.0231)
Number of observations	84892

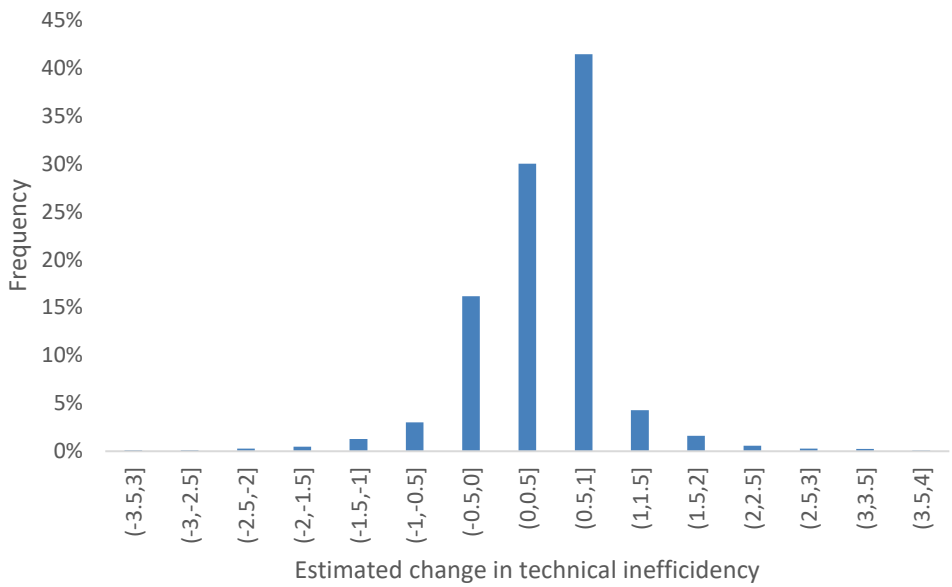
Table D.7: Estimation results assuming half normal distribution of inefficiencies

Source: PwC

Key to table: Standard errors in parenthesis; coefficients are statistically significant at the * 5% level; ** 1% level; *** 0.1% level

However, when attempting to run these type of models we found that the Maximum Likelihood Estimation procedure was not regular and a global maximum was never found by our numerical optimisation methods. Therefore, we chose to split the panel dataset we have into two periods, 2008-2012 and 2013-2017 and estimate separate models using our core approach to look at average levels of inefficiency over the two time periods for firms present over the whole period of study.

Figure D.6: below shows the outcome of the two split panel models, presenting the frequency distribution of the difference in firm efficiency scores between the two periods. It is useful to note when interpreting this that positive values indicate that firms have become relatively more inefficient over time while negative values indicate the opposite.



Source: PwC

Figure D.6:Frequency distribution of the difference in firm efficiency between the two periods

As shown, while there is a significant mass of frequency of firms with little or no inefficiency change (i.e. at or around zero) the peak of the frequency distribution is positive. This indicates that the average level of UK firm inefficiency has, if anything, increased over time. While such a finding casts some doubt on our assumption of time invariant inefficiency, it is important to note that the peak of the distribution is itself close to zero and the positive skew may be due to sampling error. Nevertheless, the positive skew in the data does help to explain why using the Battese and Coelli (1992) methodology was problematic. In particular, we were unable to estimate the model accurately as the numerical optimisation methods we used tried to fit a decreasing structure to firm inefficiency that was actually reasonably constant, if not increasing over time in the data.