Impact at a local level of full-fibre and 5G investments

Prepared for
Broadband Stakeholder Group

12 September 2019

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Contents

Boxes, figures and tables

Foreword from the BSG

Context

Local government is pivotal to the ability of telecoms operators to deploy the networks and infrastructure that will be essential to the UK in both its current and future connectivity needs. The telecoms sector is used to engaging with local authorities the length and breadth of the country and as such understand the competing pressures and obligations that they are under. Their cooperation in playing an active role in deploying our future communications networks is a critical one and whilst the BSG has previously commissioned research[1] into how they can best engage with operators, to date we hadn't set out the 'why' they should.

We know that connectivity is the foundation upon which our digitising economy rests. The successful adoption of Fourth Industrial Revolution technologies from AI to robotics rests on the underlying digital networks. These future networks will be very high capacity, generally considered fixed full fibre and wireless 5G – the defining characteristic will be the ability to deliver Gigabit speeds. Local authorities themselves understand the importance of connectivity but not necessarily the benefits that these networks deliver at the local level. This report seeks to remedy that.

Industry is committed to delivering the Government's stated aims of nationwide Full Fibre by 2033 and 5G to the majority of the population by 2027[2]. These are ambitious timescales under the current policy and regulatory landscape and are intended to be delivered with minimal public funds. The scale of the task should not be underestimated. It needs to be seen for what it is – a strategic civils and digital infrastructure deployment. This upgrade in our national digital infrastructure will not happen without close engagement between Government and the private sector. It will require capital, labour support as well as cooperation with every local authority in the country.

There are a range of reports which estimate the benefits that Full Fibre and 5G can bring to the UK economy. To take just two; the National Infrastructure Commission[3] estimate that the additional use-cases that full fibre enable could deliver from £15-28bn in economic output by 2050 whilst 5G is estimated to generate £173bn of incremental GDP growth between 2020 and 2030[4]. These reports are incredibly useful for making the overall business case for Full Fibre and 5G as well as ensuring that central government plays its role in facilitating this investment. But what does it mean for Manchester, Merthyr Tydfil or the Midlothian hills? Without knowing the answer to this question, it is understandable why there is a disparity amongst authorities in how they engage with and approach builders of digital infrastructure.

Local Benefits

This report sets out a framework, with six different stylised areas, with which local authorities can understand what these economic benefits mean for their locality. The benefits from deployment of these technologies are both indirect and direct to the authority.

Indirect benefits to the local authority come in the form of a more vibrant and attractive business environment.

We have purposefully not set out a large, attention grabbing headline about the economic impact that Full Fibre and 5G can deliver to local areas. Firstly, this is realising that the benefits, whilst always positive, will be different between localities.

[1] http://www.broadbanduk.org/publications/publications/
[2] https://www.gov.uk/government/publications/future-telecoms-infrastructure-review
[3] https://www.nic.org.uk/wp-content/uploads/Benefits-analysis.pdf
[4] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/582640/FCCG_Interim_Report.pdf

Secondly, we're being honest that for 5G in particular, we don't yet have the experiences to always put an accurate figure against it. What we commissioned Oxera to do was develop and build a framework and model into which we've put the best possible data that we have today.

We believe that the true value of this work will be in revisiting the model with better data as empirical evidence and case studies develop alongside the deployment of Full Fibre and 5G. That is not to say that we have not found significant and material benefits for local areas:

Existing businesses will see an increase in productivity which should result in an expected increase in turnover per worker of up to 3.8% per worker per annum.

New businesses will be attracted to the area with a growth in total business of at least 0.4%, rising to 3.2% in other areas. This will result in increased tax and business rates for the local authority.

Both of these benefits will result in **new jobs being created** in the local area. Areas can expect to see 0.7-1.7% more jobs.

As an example of **direct benefits**, York Council have invested in and incentivised full fibre build. They are reaping the benefits as a local authority through their own productivity savings as well as through new applications of technology enabled by their full fibre network such as smart traffic management systems.

How to attract investment

The BSG has worked closely with industry on how to remove barriers to network deployment. Many of the levers for lowering these barriers are held at a local level. All deployments are different but the key for positive engagement between local authorities and telecoms operators remains largely the same. They require leadership at a Cabinet level through to operational support at the official level; this can be in the form of network and local authority planners working in the same physical location through to joint-departmental groups within local authorities.

There is a wealth of guidance for local authorities on the Government's Digital Connectivity Portal[5]. Industry has committed to mirroring this best practice so that local authorities themselves have a consistent experience when dealing with the sector.

Industry needs to continue to review its own processes to ensure a smooth relationship with local authorities. Operators will allocate significant amounts of capital for new digital infrastructure not only where there is an economic return but also where it is easiest to do so.

This report demonstrates that even at this nascent stage of the UK Full Fibre and 5G market there are very real positive benefits for local areas which local authorities should want to take advantage of by ensuring that their locality is easy to invest in and for digital infrastructure to be deployed. We look forward to working with both industry and local authorities to make it easier to deliver the economically essential Full Fibre and 5G networks.

[5] https://www.gov.uk/guidance/resources-for-local-authorities

Deployment

Deployment of local fibre and 5G networks supported by Local Authorities

Mechanisms

Improved availability and take-up of full-fibre broadband and 5G services

Incremental improvements associated with new technology

- Better download and upload speeds
- Improved resilience and reliability
- Achievable speeds less dependent on distance from the cabinet
- Reliable support for a large number of connected devices
- Lower-latency connections

Realisation of benefits through apps and services that will:

- Enable access to new markets
- Improve search and matching
- Improve collaboration
- Lower barriers to entry

Outcomes

Improved employment opportunities

- Increased labour market participation and reduced unemployment
- Increasing employment by between 0.6% and 1.7%

Benefits for existing businesses

- Productivity improvements
- Increasing turnover per worker by up to 3.8%

Benefits to Local Authorities

- Cost savings in the delivery of public services
- Option value

New business start-ups

- Genuinely new businesses
- Migration of businesses into the area, resulting in an increase in the number of businesses of between 0.4% and 3.2%

Private benefits to consumers

- Access to improved and new services
- Improvements in subjective wellbeing

Benefits to wider society

- Greater digital inclusion
- Online access to public services
- Externality impacts

Executive summary

The importance of infrastructure for the future

Infrastructure at both the local and the national level is crucial for enabling interconnection between areas, industries and individuals. It is important for facilitating interaction, collaboration, trade, and the social and economic benefits that come with it. In today's connected world, having up-to-date and future-proof digital and telecommunications infrastructure is a key strategic priority for the UK government.[6]

In 2018 the UK government announced ambitious targets for full-fibre[7] coverage in its Future Telecoms Infrastructure Review: by 2025, 15m premises are to be connected to full-fibre networks, with nationwide coverage to be achieved by 2033.[8] According to the latest Ofcom figures, only 7% of UK premises currently have access to full-fibre services.[9]

The government also wants the UK to be a world leader in 5G, with the majority of the population to be covered by 5G networks by 2027.[10] Some 5G networks have been deployed in a number of UK towns and cities in summer 2019 and early 5G services have become available to customers in these areas. However, much more investment will be needed to cover the entire population within the expected timeframe.

Cooperation between Local Authorities (LAs) and industry will be crucial to enabling deployment of new infrastructure and helping to remove barriers to infrastructure roll-out.[11] This report describes the range of positive impacts on LAs, businesses and consumers at the local level arising from the improvements in connectivity that very high capacity networks—for which full-fibre and 5G are the main (but not sole) delivery technologies—will bring.

The value of full-fibre and 5G connectivity

Full-fibre and 5G networks will bring technological and service quality improvements over previous generations of fixed and mobile networks. They will provide faster and more reliable connectivity, as well as a conduit for new applications and services that can take advantage of the technological improvements these new connections will bring.

These new services and applications will enable new and improved business practices and end-user services such that increased availability and take-up of full-fibre broadband and 5G will lead to positive outcomes for businesses, consumers, local government and wider society.

The evidence from existing empirical studies and reports on the impact of full-fibre and 5G connectivity, and increases in broadband speeds more generally, demonstrates that businesses, individuals, government and wider society are

[6] Department for Digital, Culture, Media & Sport (2018).
[7] Full-fibre or 'fibre to the premises' (FTTP) refers to a telecoms access network that uses optical fibre to provide the connection between the local exchange all the way to the end users' houses or business premises.
[8] National Infrastructure Commission (2018).
[9] Ofcom (2019).
[10] National Infrastructure Commission (2018).
[11] The BSG published a report in July 2018 on 'Lowering barriers to 5G deployment' and the Department for Digital, Culture, Media & Sport's 'Barrier Busting Taskforce' has launched a Digital Connectivity Portal as an online resource for LAs and communications network providers with guidance to support investment in broadband and mobile networks.

all expected to benefit from increased coverage and take-up of full-fibre and 5G:

Benefits for existing businesses

Existing businesses can expect to benefit from business expansion, improved productivity and greater turnover, as a result of improved access to existing markets, entry into new markets enabled though improved communication and distribution channels, and the ability to offer innovative new services.

The evidence shows that, on average, **existing businesses** will see **increased productivity**, with an expected impact of between 0.3% and **3.8% increase** in turnover per worker per annum.[12]

New businesses

Significantly improved connectivity can encourage **new business start-ups**, enabled by easier access to markets, lower barriers to entry and the development of new business models that are digitally dependent and more flexible than established businesses.

At a local level, if speeds are higher relative to other surrounding areas (or similar, competing areas), new or established businesses may also be attracted into the area from elsewhere, thereby boosting the level of business activity in the local area.

The evidence shows an expected impact of between 0.4% and 3.2% **increase in the number of businesses** operating in the area.[13]

Improved employment opportunities

Evidence shows that improved broadband speeds and greater penetration of fibre in an area will lead to increased participation in the labour market and higher employment levels linked to the creation of new jobs.

Furthermore, as a result of improved communication channels and opportunities for remote working, there will be new employment opportunities or a reduction in migration away from the area that might otherwise have been at a disadvantage in terms of broadband availability/speeds (this is referred to as 'safeguarding jobs').

The evidence shows that there could be an **increase in employment** in the area (new jobs, inward migration and safeguarded jobs) of around 0.6–1.7%.[14]

Private benefits to consumers

There will be **private consumer benefits** in terms of access to a greater number of services. These benefits will be reflected in increased consumer surplus, i.e. the difference between willingness to pay (value) and the actual price. Consumer surplus will increase where price declines as a result of increased competition and/or willingness to pay rises as a result of increased connectivity and enables access to new and valuable services.

[12] Upper bound estimates based on the findings of Ipsos MORI (2018), showing the impact of an increase in connection speed of greater than 200 Mbit/s. 0.3% based on SQW (2013), which estimated productivity gains based on an assumption of the impact of a doubling of speed, for which the central estimate is 0.3%.
[13] Ipsos MORI (2018), based on an increase in connection speed of 100–200 Mbit/s; and Hasbi (2017), which estimated the impact of very high speed broadband availability in the local area.
[14] Ipsos MORI (2018); and OECD (2015).

Consumers may also experience improvements in subjective personal wellbeing, for example from the greater range of entertainment or education options or increased social inclusion.

Benefits to LAs

At the local level, public service providers, such as LAs, could benefit from cost savings in the delivery of public services and benefits associated with the improved economic environment.

Increased economic activity can have a number of benefits for a local area, both directly through some additional income (for example through business rates) and indirectly (through assisting with a range of other LA objectives facilitated by increased economic activity such as reduction in antisocial behaviour or deprivation).

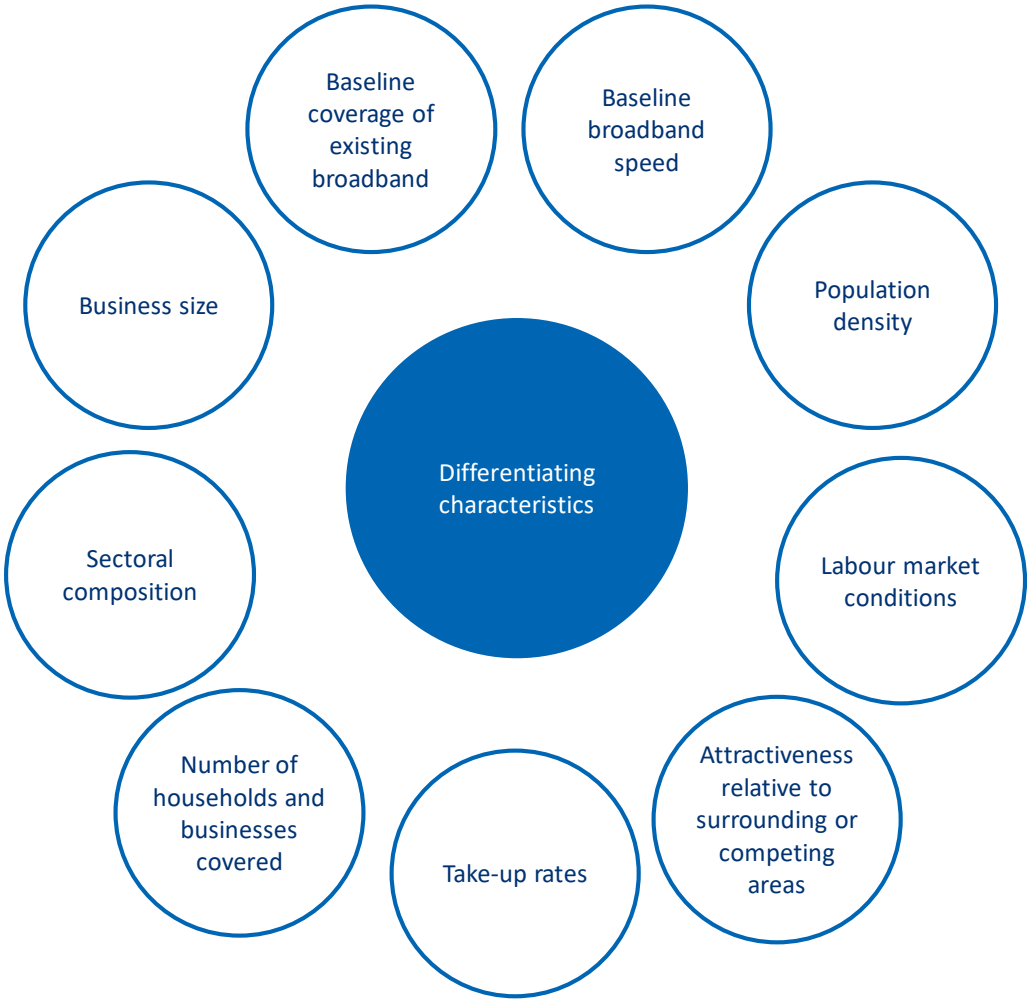
There is also a significant 'option value' associated with deploying physical infrastructure that is 'future-proof', thereby reducing the costs associated with civil engineering in the long run and the trialling of new services in a more cost-effective way.

Benefits to wider society

Wider society may benefit through network externalities, or positive spill-overs. As more people are connected, further developments have a greater impact, and benefits might also accrue more widely than just to the subscribers and producers of such services. This could also deliver important, but often unquantifiable, **social benefits** such as greater social inclusion.

However, these impacts and outcomes will not apply uniformly across all local area types. There will be differences in the impacts and outcomes depending on the specific characteristics of the area, as outlined in the figure below.

Differentiating area characteristics



Source: Oxera.

Conclusions

LAs and the businesses and individuals operating, living and working in a local area stand to experience significant benefits from greater access to very high capacity networks, including full-fibre and 5G, in their area. While the roll-out of new full-fibre and 5G networks may lead to some short-term disruptions, the economic and social benefits that could be realised should provide LAs with the motivation to support and cooperate with operators and help remove any barriers to infrastructure roll-out.

There is a strong case for any investment in full-fibre and 5G networks to be evaluated and assessed for its impact against the key outcomes defined in the framework above. To measure the impact, it is therefore important to ensure that the data necessary to measure these outcomes is collected before, during and after the investment project. Furthermore, data on the local area's characteristics, as identified above, should also be collected to allow future evaluations to compare across area types to distinguish which area characteristics have a significant impact on the relative success of the investment.

The data collected to measure outcomes can then be used to compare changes from before and after the investment for the treatment group (where

the investment has taken place), accounting for how those factors have changed in a control group[15] (where the investment has not taken place).[16]

Conducting evaluations in this way will add new and robust evidence to the literature on the economic impact at a local level of full-fibre and 5G, which can be used to shape future policy.

[15] The more data that is available on the characteristics of the area being investigated, the greater the scope for identifying an appropriate control group (i.e. an area with similar characteristics that has not yet invested in improved connectivity).
[16] Best practice guidance for evaluations is outlined in HM Treasury (2011), 'The Magenta Book Guidance for evaluation', April.

1 Introduction

This report, prepared by Oxera for the BSG, provides a framework to help the BSG and its sponsors inform and educate LAs on the importance of improved connectivity at a local level through greater availability of full-fibre broadband[17] and 5G connectivity.

By demonstrating the benefits that LAs, businesses and consumers can expect to realise through increased availability of full-fibre broadband and 5G connectivity at a local level, the findings of this report can be used to gain cooperation and support from LAs.

This report, and the assessment framework outlined within, draws on the findings from a comprehensive review of existing empirical studies and reports on the impact of full-fibre and 5G connectivity, and increases in broadband speeds more generally, to provide an overview of the benefits that can arise from the improved connectivity.[18]

This is an emerging framework based on the findings of existing literature: the approaches and metrics will need to be updated over time to reflect the latest emerging evidence as it becomes available. This applies to 5G in particular given the very early stages of the commercial deployment of this technology. To this end, the framework can also be used to inform the structure and focus of future evaluations of full-fibre and 5G investment projects, as it outlines the key measures against which outcomes should be assessed and the data that should be collected to support future evaluations. This will help ensure the expansion of a robust evidence base demonstrating the impacts of investment in full-fibre and 5G networks that can be used to inform future investment decisions.

1.1 The importance of infrastructure for the future

Infrastructure at both the local and the national level is crucial for enabling interconnection between areas, industries and individuals, facilitating interaction, collaboration, trade and the social and economic benefits that come with it.

In today's connected world, having up-to-date and future-proof digital and telecoms infrastructure is a key strategic priority for the UK government.[19] The National Infrastructure Commission recognises that digital connectivity is as important as any other essential utility, and its importance is set to increase over time as businesses and homes become increasingly 'smart'—with a growing number of devices being connected to the Internet, and the demand for data, greater speeds and improved reliability of connections forecast to continue to grow.[20]

Therefore, as with any infrastructure project, it is important to consider not only the current requirements and state of the infrastructure but also the future needs. The National Infrastructure Commission articulates this clearly:

> The infrastructure we have now, and the infrastructure we plan to build, will support and sustain us for decades to come. Our quality of life, and our success

[17] Full-fibre or 'fibre to the premises' (FTTP) refers to a telecoms access network that uses optical fibre to provide the connection between the local exchange all the way to the end users' houses or business premises.
[18] An overview of the results from the literature review is provided in Appendix A1 of this report.
[19] Department for Digital, Culture, Media & Sport (2018).
[20] National Infrastructure Commission (2018).

> as an economy in the future, will depend on our infrastructure's ability to respond to future challenges. This will rely on decisions taken now.[21]

Recognising the importance of an improved digital infrastructure, in 2018 the UK government announced ambitious targets for full-fibre coverage in its Future Telecoms Infrastructure Review: by 2025, 15m premises are to be connected to full-fibre, with nationwide coverage to be achieved by 2033.[22] According to the latest Ofcom figures, only 7% of UK premises currently have access to full-fibre services.[23]

The government also wants the UK to be a world leader in 5G, with the majority of the population to be covered by 5G networks by 2027.[24] Some 5G networks have been deployed in a number of UK towns and cities in summer 2019 and early 5G services have become available to customers in these areas. However, much more investment will be needed to cover the entire population within the expected timeframe.

Achieving the ambitious targets set by government will require significantly greater roll-out of new full-fibre networks and significantly more investment in 5G infrastructure and services. Good cooperation between industry and LAs will be crucial to enabling deployment of new infrastructure and helping to remove barriers to infrastructure roll-out.[25]

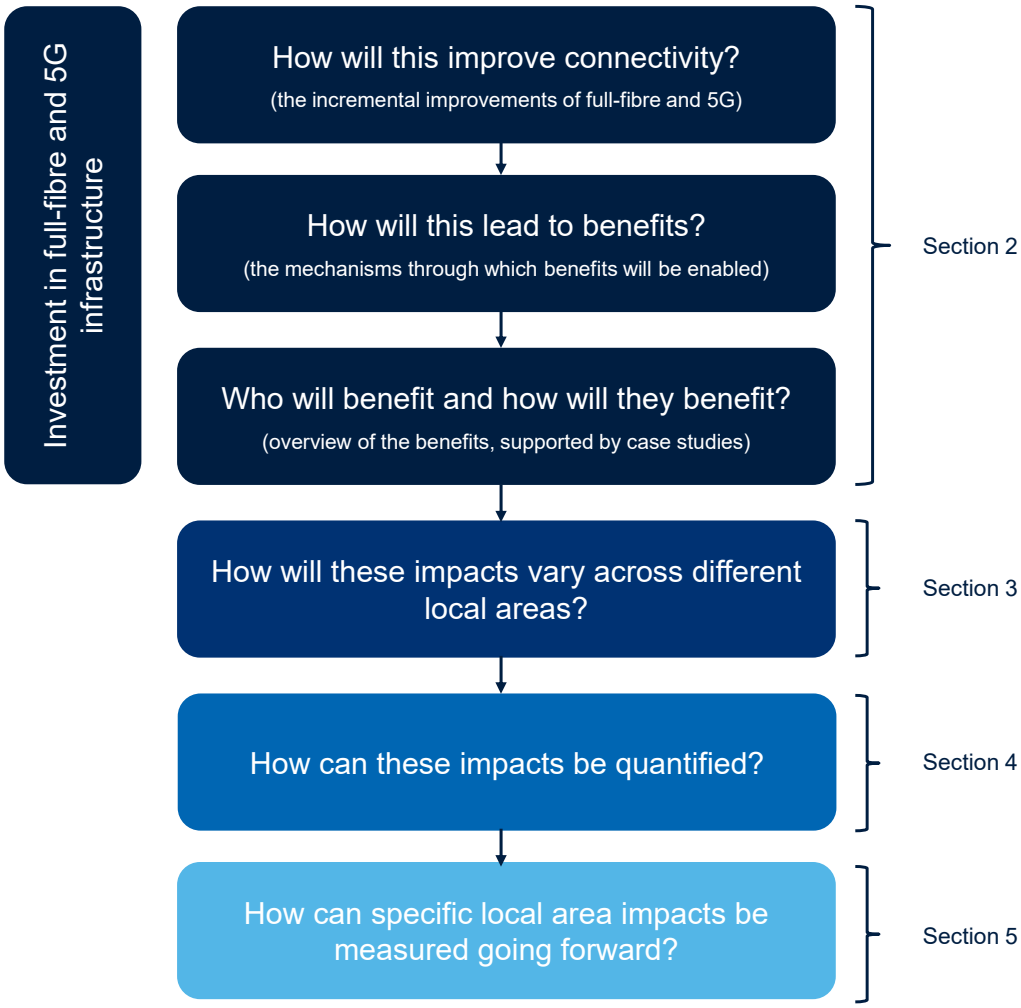
While acknowledging that LAs have a wide range of issues to deal with and the roll-out of new full-fibre and 5G networks may lead to some short-term disruptions, this report demonstrates the range of positive impacts on LAs, businesses and consumers at the local level arising from the improvements in connectivity that very high capacity networks will bring.

1.2 Report structure

The BSG foreword, executive summary and infographic provide a comprehensive and accessible overview of the findings of this research report. The remainder of this report provides the underlying detail supported by the findings from the existing evidence base. The key sections of this report and their contents are illustrated in Figure 1.1 below.

[21] National Infrastructure Commission (2018).
[22] National Infrastructure Commission (2018).
[23] Ofcom (2019).
[24] National Infrastructure Commission (2018).
[25] The BSG published a report in July 2018 on 'Lowering barriers to 5G deployment' and the Department for Digital, Culture, Media & Sport's 'Barrier Busting Taskforce' has launched a Digital Connectivity Portal as an online resource for LAs and communications network providers with guidance to support investment in broadband and mobile networks.

Figure 1.1 Structure of this report



Source: Oxera.

In section 2 we draw on the findings of existing empirical studies and reports to indicate the types of known benefits that will be realised from improved connectivity, and who is likely to benefit from these. We also outline the mechanisms through which these benefits will be realised, acknowledging that the physical infrastructure itself is simply an enabler for the provision of faster and more reliable services, and a conduit for new applications and services that will enable new and improved business practices and end-user services. This section includes case studies that provide some specific examples of how greater availability of full-fibre broadband and 5G can lead to tangible benefits for businesses, consumers and LAs.

In section 3, recognising that the impacts and outcomes will not necessarily apply uniformly across all local area types, we assess the extent to which the relevance and magnitude of these impacts will vary across different LA areas. We show that differences will depend on the specific characteristics of the area, the level of take-up of the new service, and the attractiveness of the area's connectivity offering relative to surrounding or competing areas. We consider how some of these characteristics differ across area types, based on the Office for National Statistics' urban-rural classification of LA areas.

In section 4 we present metrics from previous empirical studies and reports that indicate the expected magnitude of the impacts, and show how these figures could be used to provide an illustrative example of a high-level estimate

of the impact on a local area of improved connectivity facilitated by investment in full-fibre and 5G.

In section 5 we take a forward-looking view, outlining how both investors in full-fibre and 5G projects and LAs could monitor the impacts and outcomes of these investment projects. Robust evaluations of investment projects can support an improved evidence base for the impacts and benefits of greater improvements in connectivity, which will help inform future policy and decision making.

2 The value of full-fibre and 5G connectivity

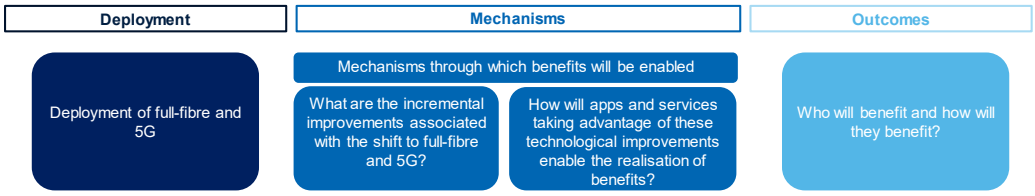
Investment in very high capacity networks—for which full-fibre and 5G are the main (but not sole) delivery technologies—will bring improvements in connectivity for end-users. Full-fibre networks will bring significant improvements to fixed broadband connectivity and facilitate the deployment of improved mobile connectivity (5G). Full-fibre networks will deliver faster broadband speeds and higher quality of service for residential customers and businesses compared with copper broadband and even fibre to the cabinet (FTTC) connections. In addition to delivering faster and better mobile broadband services to customers and businesses relative to existing mobile services, 5G is designed to support innovative new services through its improved capabilities in terms of supporting ultra-low latency connections and a very large number of connected devices.

Full-fibre and 5G networks will provide faster and more reliable connectivity services, as well as a conduit for new applications and services that can take advantage of the technological improvements these new connections will bring, enabling new and improved business practices and end-user services. In turn, this could provide new opportunities for new and existing businesses, lead to productivity improvements and cost savings for businesses and LAs, and allow consumers to access a wide range of new and valuable services.

Therefore, increased take-up of very high capacity networks will result in the improved availability of, or access to, existing services for those who previously had limited access to broadband or poor-quality connections. There will also be transformative impacts associated with all users of these very high capacity networks gaining access to services or applications that were not possible with previous generation connections.

A complete understanding of the impact of investment in improved connectivity at the local level is based on three main elements: investment in the physical network infrastructure (network deployment); the mechanisms through which benefits will be enabled; understanding who benefits and how they benefit. (see Figure 2.1).

Figure 2.1 Deployment–mechanisms–outcomes framework



Source: Oxera.

2.1 Investment in physical network infrastructure

The key input to improvements in fixed connectivity at the local level is the deployment of a full-fibre network, providing a fibre connection all the way to the home or business. Improvements in connectivity will also come from improvements in mobile connectivity through the deployment of 5G networks.

Fixed-fibre networks and 5G are complementary technologies in that the significantly increased data volume that will be carried over mobile networks will mean that data backhaul requirements will be significantly increased—this can only be supported by the improved capacity and capabilities of a full-fibre network.

2.2 Mechanisms through which benefits will be enabled

The presence of the physical infrastructure in itself will not necessarily bring direct benefits. However, these new networks will bring technological and service quality improvements over previous generations of fixed and mobile networks. It is the improvements in the functionality of these networks that is important, not necessarily the underlying technology.

Improvements associated with a shift to full-fibre networks:

- achievable speed less dependent on distance from the street cabinet;
- improved resilience and reliability;
- better download and upload speeds;
- lower latency;
- future-proof digital infrastructure—greater capacity to support the increases in data requirements, providing the basis for future investments in 5G.

Improvements associated with a shift to 5G:

- higher peak and user experienced data rates (download and upload speeds) to support enhanced mobile broadband services;
- lower latency and increased reliability supporting real-time, critical wireless communications;[26]
- greater connection density (allowing support for millions of Internet of Things (IoT) and other connected devices per cell).[27]

In this way, technological and service quality improvements that come from the launch of new and improved connectivity networks will support the development of new services and applications that can take full advantage of the improvements. In other words, full-fibre and 5G connections do not create value single-handedly, but are necessary to unlock future benefits. It is the applications and services that run over these connections that bring benefits (where those services and applications are taken up) and the ability of multiple users to take advantage of the 'bigger pipe' for concurrent usage of existing and new applications, meaning a greater number of people can benefit.

Applications and services that exploit these greater capabilities will enable the realisation of benefits by, for example, improving search and matching, improving collaboration, enabling access to new markets, and lowering barriers to entry, as explained in Figure 2.2 below. More generally, this can be thought of as lowering 'transaction costs' within the economy, which can lead to significant benefits.

[26] Supporting 'ultra-reliable low latency connections', as defined by ITU (2015), 'IMT Vision – Framework and overall objectives of the future development of IMT for 2020 and beyond. Recommendation ITU-R M.2083-0'.
[27] Supporting 'massive machine-type communications', as defined by ITU (2015), 'IMT Vision – Framework and overall objectives of the future development of IMT for 2020 and beyond. Recommendation ITU-R M.2083-0'.

Figure 2.2 How will applications and services exploiting the greater capabilities of full-fibre and 5G networks enable the realisation of benefits?

Improving search and matching By enabling easier and quicker access to information, or improving the ability to find local services, search and transaction costs will be reduced. Applications and services could also improve matching of businesses and suppliers and enable better matching of resources across borders.	**Improving collaboration and communication** Applications or services taking advantage of the improved connectivity could enable greater collaboration through, for example, increased availability, quality and reliability of online tools and video-conferencing services that allow for remote collaboration and access to a wider pool of labour.[28] Increased scope for remote monitoring and maintenance will also be facilitated.[29]
Enabling access to new markets In addition to improving access to existing services, widespread full-fibre and 5G connections will enable access to new markets.[30] It will also enable new, high-capacity applications to gain access to a wider commercial audience (e.g. gaming and VR) as well as the development and launch of new bandwidth-hungry services we cannot yet anticipate.	**Lowering barriers to entry** Businesses will have the opportunity to get easier access to market information, and to take advantage of improved connectivity and digitisation to operate new business models at lower cost and with greater flexibility than traditional businesses. For example, improved access to, and reliability of, cloud-computing services could lower upfront capital costs (relative to investing in physical equipment). It could also lower the ongoing support costs of setting up a new business, and improve flexibility through ease of adjusting capacity in reaction to changing requirements.[31]

Source: Oxera.

2.3 Outcomes: who will benefit and how will they benefit?

Businesses, individuals, government and wider society are all expected to benefit from increased coverage and take-up of full-fibre and 5G.

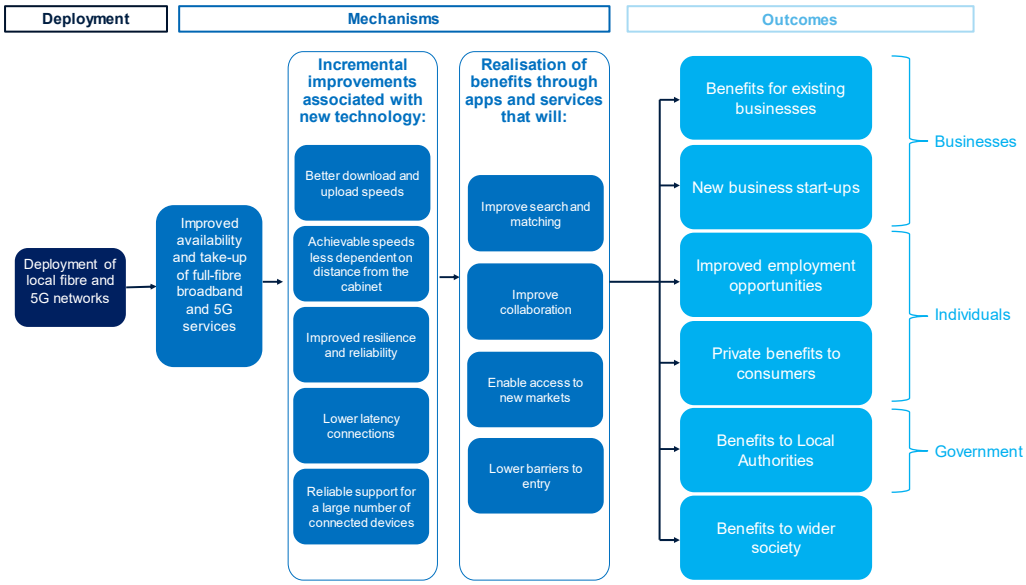
The outcomes for these four groups can be broken down further:

- business impacts will take the form of productivity benefits for existing businesses and the impact on new businesses being created;
- individuals may benefit from improved employment opportunities and in terms of private benefits for consumers taking up the services;
- at the local level, public service providers, such as LAs, may benefit from cost savings in the delivery of public services and benefits associated with the improved economic environment;
- wider society may benefit through network externalities, or spill-overs. As more people are connected, further developments have a greater impact, and benefits might also accrue more widely than just to the subscribers and producers of such services.

[28] Lapointe (2015).
[29] As described in the case study on '5G and the future of manufacturing' in section 2 of this report.
[30] Department for Culture, Media & Sport (2017).
[31] Regeneris (2012).

Figure 2.3 presents a summary of the deployment–mechanisms–outcomes framework. We provide an overview of the economic and social benefits that can be expected to arise in the boxes below.[32]

Figure 2.3 Deployment–mechanisms–outcomes summary



Source: Oxera analysis, based on findings from an extensive literature review.

Existing businesses

Businesses can expect to benefit from business expansion, improved productivity and greater turnover, as a result of improved access to existing markets, entry into new markets enabled though improved communication and distribution channels, and the ability to offer innovative new services.

For example, SMEs reported that faster broadband had the following benefits for their business:[33]

- 86% of SMEs that responded reported that their broadband upgrade had increased their employees' effectiveness;
- 83% reported improved efficiency;
- almost 70% reported increased speed and reliability of delivering goods or services;
- 45% reported that their upgrade had improved their ability to develop new goods or services;
- over 35% reported that their upgrade had generated new sales and provided access to new markets, and 19% reported that their upgrade had an impact on exports.

[32] A full review of the findings from the literature is included in Appendix A1, but we summarise the key messages here.
[33] Department for Culture, Media & Sport (2017).

New businesses

Significantly improved broadband connections can encourage new business start-ups. This is because easier access to markets lowers barriers to entry and greater availability of very high capacity networks can lead to new business models that are digitally dependent and more flexible than established businesses.[34]

At a local level, if speeds are higher relative to other surrounding areas (or similar, competing areas), new or established businesses may also be attracted into the area from elsewhere, thereby boosting the level of business activity in the local area.[35] This might lead to a corresponding reduction in business activity in those other areas.

Employment opportunities

The evidence shows that improved broadband speeds and greater penetration of fibre in an area will lead to increased participation in the labour market and higher employment levels linked to the creation of new jobs.[36]

Furthermore, as a result of improved communication channels and opportunities for remote working, there will be new employment opportunities or a reduction in migration away from the area that might otherwise have been at a disadvantage in terms of broadband availability/speeds (this can be referred to as 'safeguarding jobs').[37]

Some studies have included direct employment impacts arising from network build (i.e. increased employment in the construction sector) in their assessment of the employment impacts.[38] It would be inappropriate to include this within the calculation for benefits at the local level, as these employment changes are likely to be transitory and unlikely to result in genuinely new employment for the local area. Those carrying out the construction works are likely to be employed centrally by a telecoms, engineering or construction company rather than being hired locally, and thus this should not be considered a direct impact on the local area. The exception would be if there were a supporting policy to require that the full-fibre or 5G investment programme provided employment and training to some of the local workforce such that those workers benefited from improved long-term employment prospects.

[34] However, as SQW (2013) noted, this may be at the expense of the decline of more traditional businesses in sectors that are disrupted by the new technology.
[35] Ipsos MORI (2018) found up to 80% of increased turnover and productivity of firms located in postcodes seeing a boost in broadband speeds was driven by the relocation of firms to postcodes with better connections (however, the economic impacts are not driven solely by the relocation of firms, and as discussed above, there is evidence to support the idea that incumbent firms will still benefit from increased turnover per worker). Results from a study in France (Hasbi, 2017) also suggest that very high speed broadband networks enhance the attractiveness of municipalities for companies, and results from Sweden (OECD, 2015) suggest that increases to a municipality's economic attractiveness lead to the establishment of more companies (or the decision of existing ones to stay).
[36] Ipsos MORI (2018); OECD (2015); Singer et al. (2015); Lapointe (2015); Forzati and Mattson (2012); and SERIO et al. (2015).
[37] SQW (2013); and Regeneris (2012).
[38] Regeneris (2018).

Consumers

Consumers will benefit from being able to access new and innovative services, which will be reflected in the value that consumers put on the services. Where the deployment of full-fibre in the area stimulates greater competition, either through infrastructure-based competition between competing networks or by opening the market to significant competition at the retail level (for example, where the new network employs a model of open access), consumers will also benefit in terms of lower (telecoms) prices.[39] These impacts can be captured in estimates of consumer surplus—i.e. the difference between willingness to pay (value) and the actual price paid. Hence, where price declines and/or willingness to pay rises, then consumer surplus will increase.[40]

There can be benefits associated with the increased prospect of working remotely (saving on travel time and increasing leisure time).[41] There is also evidence to suggest that greater access to higher broadband capabilities may have an impact on subjective personal wellbeing.[42] For example, this comes from the greater range of entertainment or education options, increased social inclusion, increased leisure time that improved connectivity could enable.[43] Technology and better connectivity may also reduce loneliness in some cases.[44] It may not all be positive however, as others may suffer from greater social isolation as a result of reduced face-to-face contact, Internet addiction or increased incidence of online crime or other online harms that may lead to lower personal wellbeing.[45]

Local Authorities

Improved connectivity has been shown to lead to cost savings in the delivery of public services (more efficient service delivery through reduced equipment and energy consumption[46]) and the opening of new and improved ways for residents and businesses to interact with local government and public services at a time and method of the customer's choosing and convenience. For example, new methods for monitoring patients and providing remote social care services enabled by fibre technology have been shown to lower costs of service provision for those public service providers taking advantage of the improved connectivity.

There is also a significant 'option value' associated with deploying physical infrastructure that is 'future-proof', thereby reducing the costs associated with civil engineering in the long run. For example, rather than undertaking incremental upgrades to physical infrastructure (which results in cost duplication), laying fibre once has significant value, as it makes some opportunities more cost-effective than would otherwise be the case, thereby improving overall efficiency of service delivery and increasing the likelihood that certain applications will come to market quicker than they otherwise would.

LAs can also obtain benefits from the increased economic activity in the areas directly through some additional income (for example through business rates) and indirectly (through assisting with a range of other LA objectives facilitated by increased economic activity such as reduction in antisocial behaviour or deprivation).

[39] Forzati and Mattson (2012); and Oxera (2017).
[40] This approach was used in Oxera (2017).
[41] SERIO et al. (2015).
[42] The UK Office for National Statistics has reported that: 'Personal wellbeing is a particularly important dimension which we define as how satisfied we are with our lives, our sense that what we do in life is worthwhile, our day to day emotional experiences (happiness and anxiety) and our wider mental wellbeing.'
[43] Simetrica (2018).
[44] Vodafone (2019).
[45] Simetrica (2018).
[46] For example, by using cloud-computing services rather than relying on physical server space.

Wider social benefits

Improved connectivity may also deliver important, but often unquantifiable, social and environmental benefits. For example, there may be wider benefits that arise from improved social inclusion (reducing the digital divide between locations, particularly in rural areas).

Studies have estimated that full-fibre will accelerate new, more flexible ways for students to learn remotely and to use interactive e-learning tools, and that advances in connected health technologies (facilitated by 5G and the IoT) could lead to health improvements through ongoing monitoring of existing conditions and early detection of issues.[47]

Smart cities infrastructure facilitated by full-fibre and 5G is also expected to lead to reductions in energy use, congestion and fuel costs stemming from smart energy and traffic systems.[48]

To account for all of these impacts together would result in 'double-counting'—i.e. the effects overlap such that adding them together would overstate the impacts of the change in connectivity. There are also issues around the robustness of certain metrics or the need to account for any offsetting impacts. Therefore, we must be clear on the key outcomes that LAs and industry should focus on as measurable outcomes against which they can assess the impact of improved connectivity.

- **For existing businesses**, if we measured the impact of greater connectivity as increased turnover, this would capture the effect of both increased productivity and increased employment (since as businesses grow, this results in the need to hire more employees). Because increased employment will also be captured under change in employment opportunities, it is appropriate to focus on **productivity improvements** to existing businesses through metrics such as turnover per employee.[49]
- **For new businesses**, one should consider the net impact, taking into account genuinely new businesses, net migration of business into the area, and any businesses that cease to exist because they are outcompeted by the new or more efficient businesses adopting new, digital business models. Therefore, the focus should be on the **change in the number of businesses** in the local area.
- **For employment**, one should also consider the net impact, taking into account job creation, net migration in the area and any lost jobs as a result of being replaced by technology.[50] Therefore, the focus should be on the **change in the number of people employed** in an area. Although this may not necessarily be the result of a net reduction in unemployment or economic inactivity in the economy as a whole (as employment may be transferred from one area to another), this change in total employment numbers could still be beneficial to the local area in which the investment is focused.[51]

[47] Regeneris (2018).
[48] Regeneris (2018).
[49] Productivity would normally be defined as output per worker, not turnover per worker. As some of the literature uses turnover per worker, we use this definition here.
[50] These individuals who lose their jobs as a result of improvements in technology may be required to re-train to re-enter the workforce.
[51] We acknowledge that skills and capabilities of people who are economically inactive will also be important in determining the extent to which they could expect to move into the labour force, especially for the long-term unemployed, and particularly if the new roles being created are for knowledge-intensive or technology-

- **For consumers**, there are a number of possible ways to measure the consumer benefits considered in the literature, such as increased leisure time, increased house prices and housing wealth, or the value of specific services enabled by the new technology. However, time spent not commuting as a result of increased remote working can either be spent as increased leisure time or increased work time: it cannot be captured as both. To the extent that increased productivity comes from increased hours worked (due to less time travelling), this time is, by definition, not being used for increased leisure. We consider that this is likely to be captured as a benefit to businesses and in productivity measures (defined as output per worker). Furthermore, increases in house prices and housing wealth from an increase in broadband speeds should not be measured in addition to other measures of consumer value and wellbeing, as one way of thinking about the increase in house prices is that it reflects consumers' valuation of that connection.[52] Rather than quantify the benefits of any one particular service, one can instead calculate an aggregate estimate of the consumer surplus impact of all these services taken together.[53] A simple metric for **consumer surplus** can be estimated by comparing the amount that consumers would be willing to pay for a step change in connectivity through upgrades to full-fibre and 5G, and an estimate of the amount that consumers actually pay to purchase this upgrade.[54]
- **For LAs**, one should consider the direct impacts in terms of **cost savings in the delivery of public services**. However, the source of these cost savings should also be considered, as any gains from cost savings achieved through reduced spend with service providers (e.g. businesses supporting the authority with services delivery) will be offset by reduced revenues of those businesses. For benefits arising from the increased economic activity in the local area, such as increased business rates, only the net benefits should be captured to the extent that any addition receipts may simply represent a transfer from businesses to the LA.

As more people become connected, further developments could have a greater impact, and benefits may also accrue more widely than just to the subscribers and producers of such services (referred to as positive spillovers).

The evidence presented above is summarised in the deployment–mechanisms–outcomes framework in Figure 2.4 below.

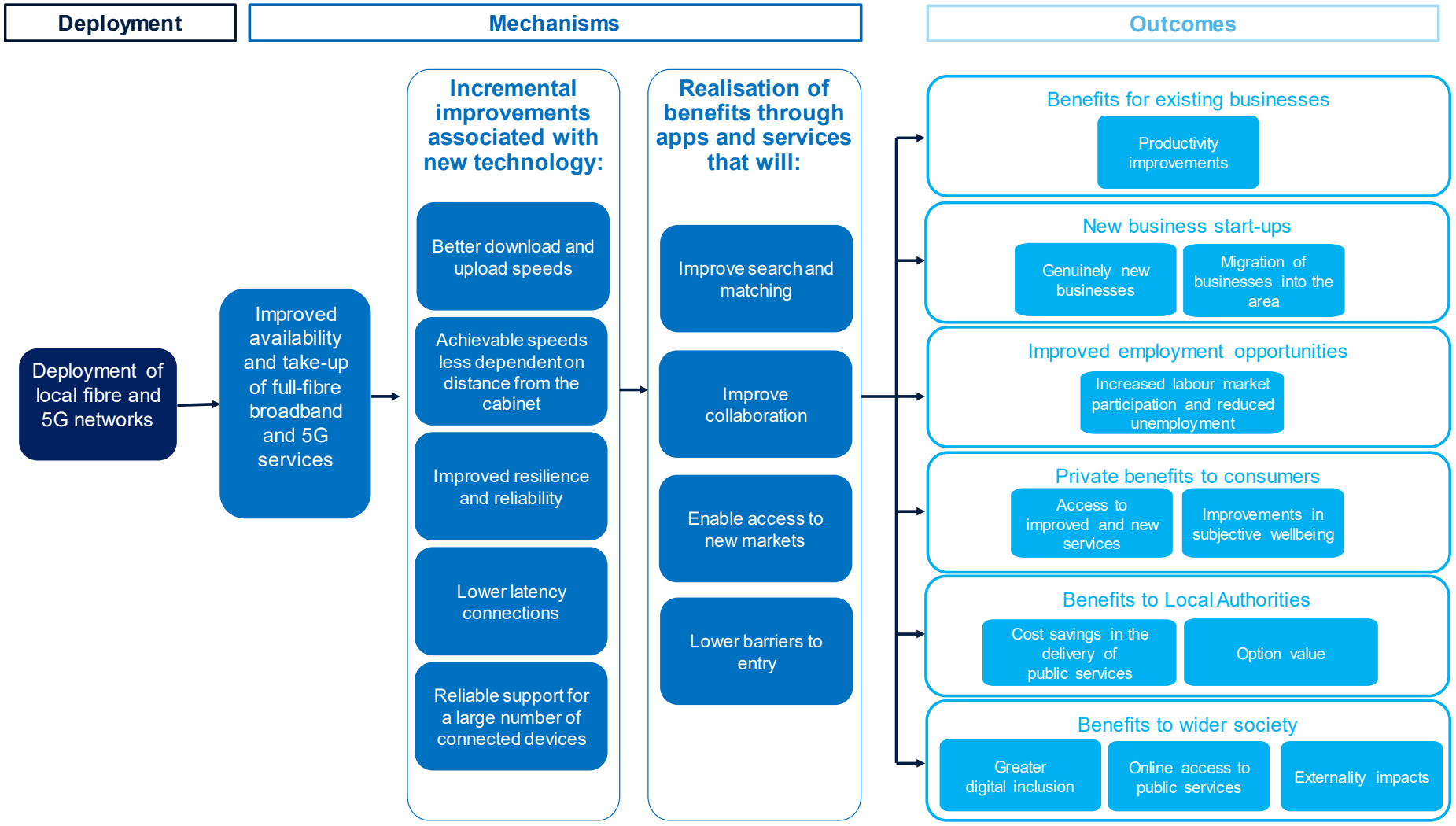
based industries. Complementary policies supporting training and education may be needed to re-train the long-term unemployed to fill the new jobs being created.

[52] Furthermore, there is an inherent risk of endogeneity bias in assessing the impact of broadband/full-fibre availability on house prices. This comes from the fact that areas with higher house prices may be the target of improvements in broadband networks on the expectation of a more wealthy community with a higher willingness to pay. While some studies, including Ahlfeldt et al. (2017) have sought to control for this bias in their estimates, other studies suggesting significant impacts are more focused on correlation, not causality.

[53] The consumer surplus is the net benefit that a consumer receives from consuming a good. It is the difference between a consumer's willingness to pay for a good and the price they actually pay for the good.

[54] For example, this was the approach taken in Oxera (2017) and Oxera (2015).

Figure 2.4 Deployment, mechanisms and measurable outcomes



Source: Oxera analysis, synthesising the findings from a detailed review of the existing literature.

2.4 Demonstrating the impacts of improved connectivity

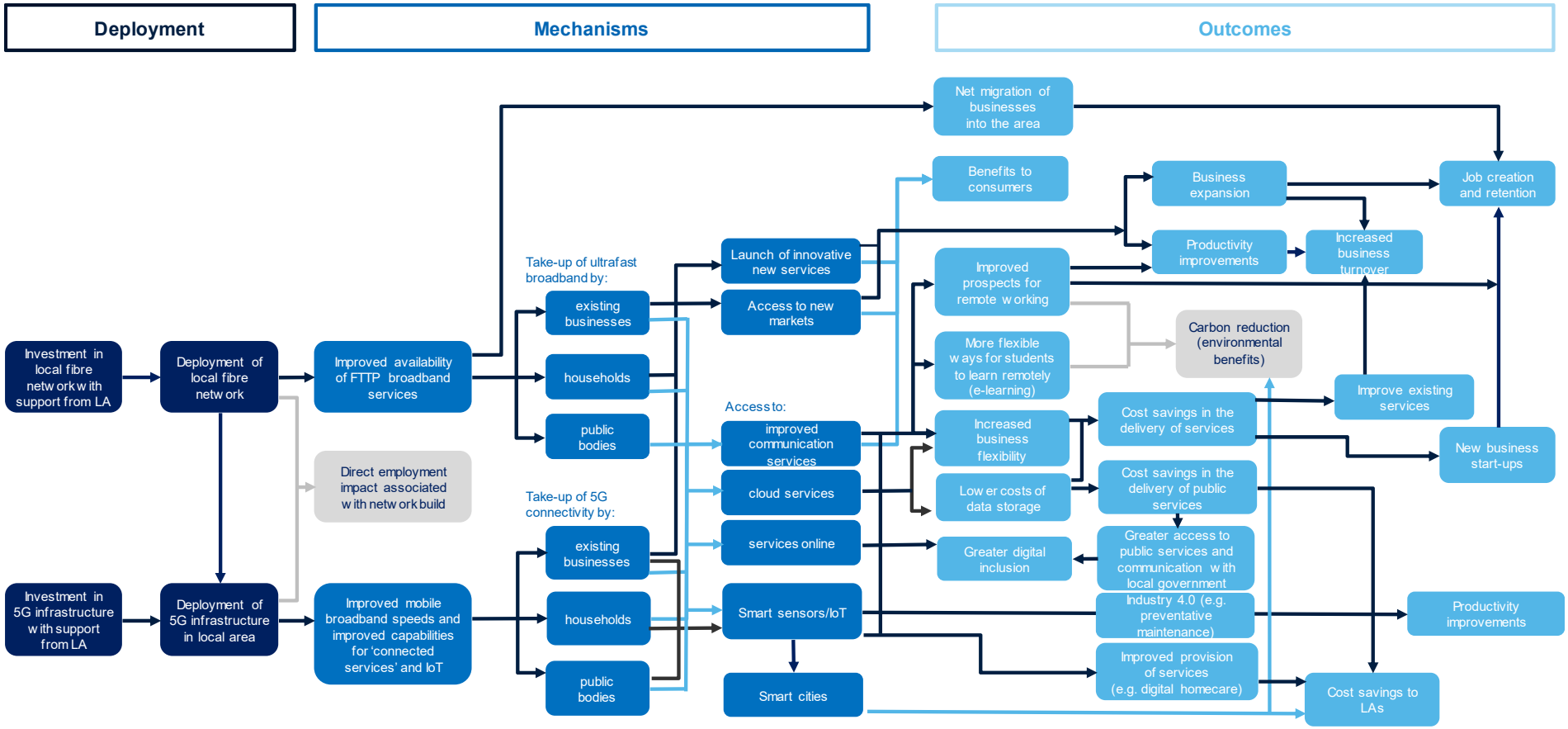
Figure 2.5 below illustrates some of the main expected impacts of investments in full-fibre and 5G, highlighting cases of how the deployment of physical infrastructure can lead to positive outcomes for business, consumers, government and society.

The figure shows that the impacts and outcomes will depend on who takes up the services and how they take advantage of the improved capabilities of these high-speed networks. It provides some tangible examples of how the investment in full-fibre and 5G can help to deliver measurable outcomes and benefits for businesses, individuals and LAs, drawing on existing studies and reports as well as the case studies presented below.

For example, this figure and the case studies below illustrate how take-up of full-fibre and 5G by public bodies could lead to improved communication services, and to the deployment of smart sensors and IoT to improve the provision of home care services, which in turn leads to cost savings. Similarly, the take-up of fibre and 5G by businesses to support smart sensors could lead to productivity improvements through preventive maintenance in an industrial environment.

The examples and flows fit neatly within the simplified deployment–mechanisms–outcomes framework outlined above.

Figure 2.5 Examples of impacts and outcomes associated with investment in full-fibre and 5G



Note: Grey indicates that these impacts will not be accounted for in our assessment. The direct employment impact associated with network build should not be captured as a benefit at a local level, given that employment changes are likely to be transitory and not likely to result in genuinely new employment for the local area. Environmental benefits are outside the scope of this study, which focuses on the economic and social impacts only.

This figure is not comprehensive, but is intended to illustrate a number of the key expected impacts of improved connectivity at a local level.

Source: Oxera analysis, synthesising the findings from a detailed review of the existing literature.

The case studies below give some further specific examples of how the improved capabilities of full-fibre and 5G networks can bring significant benefits.

'Fibre to the home(care)'—fibre-enabled digital homecare services in Sweden

Fibre-enabled digital services aimed at improving health and social care services in the home have been experimented with by several municipalities in Sweden, where full-fibre networks are currently much more widely available than in the UK.

For example, the City of Västerås has introduced four digital services to provide social care—taking advantage of the improved digital connectivity enabled by fibre broadband connections to allow for improved communication with homecare recipients and for remote monitoring of patients. These services reduce the need for physical access to the patient or their living environment. The services include:

- a robot-like, remotely controlled video unit, capable of moving anywhere in the home, allowing improved communication between the homecare recipient, family and care personnel;
- improved communication services for sending and receiving text, voice, image and video messages. This is used to manage the planning, booking and follow-up of services by end-users;
- the use of a night-vision camera to enable the supplementary monitoring of individuals while they sleep, complementing or replacing the physical visit service.

This provides an interesting example of how LAs can take advantage of the improved connectivity to make changes to how they deliver public services. Furthermore, the evidence from Sweden shows that providing services in this way can generate extensive cost savings in service delivery. For example, one study has quantified the cost savings achieved by the authority when these services were deployed for 300 residents in the area (around 10% of homecare users). The cost savings included:

- reduced transport costs (because physical visits could be reduced) = €2.2m saving;
- shorter missions (the project showed that supervised visits via ICT could often be shorter) = €0.28m saving;
- decreased need (the knowledge of being able to contact personnel more easily made users feel safer and not require physical visits to the same degree) = €0.38m saving.

Source: Case study based on material from Forzati and Mattson (2014).

'Build it and they will come': the story of the City of York Council

By investing in improved connectivity, LAs are well placed to take advantage of emerging technologies quickly and effectively, helping them to improve service delivery while lowering operational costs.

The City of York Council is an example of a city that is reaping the benefits of early adoption.

As a review of its telecoms service contracts, in 2008/09 the City of York Council sought a single managed network solution to meet the connectivity needs of all public authority buildings and services at the council level. The proposed solution

involved delivering these services over a fibre network solution and, by 2010, the City of York Council was a full-fibre connected council.

This acted as the catalyst for significant investment in York's infrastructure to serve business and residential users. TalkTalk, Sky and CityFibre worked together to deliver the first stage to connect 14,000 homes, with TalkTalk then leading on the second phase to connect an additional 40,000 homes across a wider area. £55m will have been invested by the end of 2019, delivering 70%+ fibre penetration in York.

While the initial decision to adopt a fibre network solution was not driven by any specific use cases, the City of York Council is starting to reap the benefits of improved connectivity as a result of: a) being 'ready' to use the network capabilities to support new and emerging use cases, and b) the government's industrial strategy that has infrastructure as one of its primary foundations.

York is becoming a digital city through the provision of 'a city wide digital infrastructure to support staff, customer, visitors and residents enabling uptake of developments and technology solutions.'[55]

For example, the fibre network was used to support 'City Centre Wi-Fi', which was originally aimed at enhancing the resident, visitor and student experience in the city. However, the presence of a high-capacity Wi-Fi network has since enabled the council to use this network to support other services that would otherwise require a separate connection. For example, using this network to support the transmission of CCTV images, and to support transport management applications.

This is all made possible because of the high-capacity, reliable backhaul supplied using the fibre network, which is an essential platform to help meet the current and future challenges such as those identified within the UK's future mobility programme.

The City of York Council is also able to take advantage of the existing network to trial new services in a more cost-effective way than would otherwise be the case. For example, with a full-fibre network in place, the connectivity is there to explore a larger number of IoT use cases. This includes using IoT devices to improve the data available to the council, which would allow it to make more informed decisions that lead to cost savings and greater efficiency. Examples of use cases being deployed include:

- roadside sensors—to provide data on road conditions that will inform decisions about where to prioritise the gritting of roads in the winter;
- damp sensors in social housing stock—to gather data that could be used to inform early responses to address these issues;
- investigating use cases for IoT in healthcare—to allow people to return home from hospital earlier, while still being closely monitored.

The City of York has also been awarded £2.85m of government funding for a Smarter Travel Evolution Programme (STEP). Taking advantage of the fibre-optic connectivity in the city, detectors located on traffic lights, bollards and other street furniture will track vehicle movements by anonymous signatures collected from people using mobile data services. This real-time traffic data will then be processed to support analysis on how the council manages the city's roads, from changes to how traffic lights react to traffic flows through to designing junctions and road improvements.

[55] City of York Council.

5G and the future of manufacturing: the Worcestershire 5G consortium

While 5G is still an emerging technology with limited widespread commercial deployments, the manufacturing industry is expected to benefit from its ability to support more reliable low-latency connections and high-capacity communications.

Worcestershire has been taking part in the first phase of the 5G Testbed and Trials Programme, supported by the Department for Digital, Culture, Media & Sport, and is hoping to improve its performance as a connected county. In particular, this testbed is being used to assess how Industry 4.0/Remote Manufacturing will be made possible by 5G, and how this will lead to increased productivity by enabling:

- assisted maintenance using Augmented Reality (AR);
- preventative maintenance using 5G-enabled sensors.[56]

For example, the trial will include tests of an AR headset with built-in HD camera and microphone powered by 5G. This will be used to support a two-way communication stream between the machine manufacturer's service department and the on-site engineer to provide real-time maintenance support (which requires low latency and seamless connectivity provided by 5G). This is estimated to save time and money and provide a level of service that could previously have been achieved only by having a second on-site engineer. Estimates of an increase in productivity of 1–2% have been reported.[57]

The Worcester Bosch factory is deploying 5G-connected sensors to detect and record machine health (e.g. collecting data on temperature, pressure and vibrations). The sensor sends data across the 5G network in real time to a database and is checked against pre-defined limits, alerting an engineer immediately if the machine is close to its limits and allowing intervention before critical failures arise. The real-time nature of this monitoring and data sharing means that issues can be identified immediately. This is expected to lead to improvements in productivity as a result of preventative maintenance through a reduced number of downtime incidents.[58]

'Liverpool is smart when it comes to keeping healthy': Liverpool's 5G Testbed

Liverpool is the centre of a 5G Testbed and Trials Programme to demonstrate how 5G can be used to support improvements in the delivery of health and social care.

'The Liverpool 5G testbed is working to demonstrate the capabilities of a blend of advanced low cost 5G technology and modern applications to provide services that will revolutionise the future delivery of health and social care.'[59]

The objective is to demonstrate how health and social care applications are enhanced and integrated through the advanced capabilities of 5G networks (including high bandwidth and low latency). Therefore, the project is focusing on the trial of bandwidth-intensive applications that require very fast processing (relying on edge or cloud computing).

For example, patients triaged at A&E departments might be sent home with a monitoring device rather than being admitted for observation and taking up a bed in

[56] UK 5G Innovation Network website, 'Worcestershire 5G Consortium Overview', https://uk5g.org/discover/research/worcestershire-5g-consortium-overview/
[57] UK 5G Innovation Network (2019), '5G: The Key to unlocking a brighter future for UK manufacturing.' Testbeds and Trials special issue, pp. 20–23.
[58] UK 5G Innovation Network (2019), '5G: The Key to unlocking a brighter future for UK manufacturing.' Testbeds and Trials special issue, pp. 20–23.
[59] UK 5G Innovation Network website, 'Liverpool 5G Testbed', https://uk5g.org/discover/testbeds-and-trials/liverpool-5g-testbed/

hospital. The hospital can continue to monitor the patient and determine which patients can stay at home and which should be admitted.

Connectivity at home can support Intelligent IoT sensors to aid independent living in the home. For example:

> using detectors on chairs, toilets, mains plugs, taps, doors or other things like fridges, a picture of the daily routine in a service user's house can be built. This generates up to 35,000 data points a day which are sent back to the server where AI software determines baseline normal behaviour. Based on this, any changes in the routine can be detected, such as when a service user takes a little longer than usual to move from sensor to sensor. The system triangulates between data sets collected to produce a wellness score which is then presented to the local authority through a dashboard.[60]

Other services to be trialled include:[61]

- high resolution video and distributed AI for patient event and movement monitoring;
- teleconferencing, AR, VR, etc. to manage loneliness in older adults;
- high resolution video and remote diagnostics, facilitating communication between hospitals and patients.

Allowing people to return home from hospital sooner, or live longer in their own homes before going into care, can improve their wellbeing as well as that of their families. It can also ease a city's budget; the cost of adult social care to the City of Liverpool is around £15,000 per person per annum.[62]

'Putting Rural First—improving connectivity in rural areas': the 5G RuralFirst co-innovation project led by Cisco

The 'RuralFirst' project, which is part of the Department for Digital, Culture, Media & Sport's 5G Testbed and Trials Programme, is seeking to pioneer new approaches to deployment and use of connectivity in rural areas, supporting agriculture, tourism, renewable energy and manufacturing.[63] For example, the programme is testing how 5G can be used for 'Agritech', 'with the aim of improving yield, efficiency and profitability' by focusing on 'achieving high speed connection to autonomous tractors and drones providing high definition image analysis of cross, weeds and soil'.[64]

This project is also hoping to demonstrate the value of high-speed wireless services for the most rural or isolated areas in the UK (focusing on the Orkney Islands), testing use cases that are expected to 'result in many significant benefits for the communities, homes, schools, stores and industries' in the area. 5G in these remote areas is expected to help create 'a more connected rural United Kingdom, tackling the digital divide, enabling (in cases for the first time) digital delivery of public services and working towards a smarter country, and smarter world.'[65]

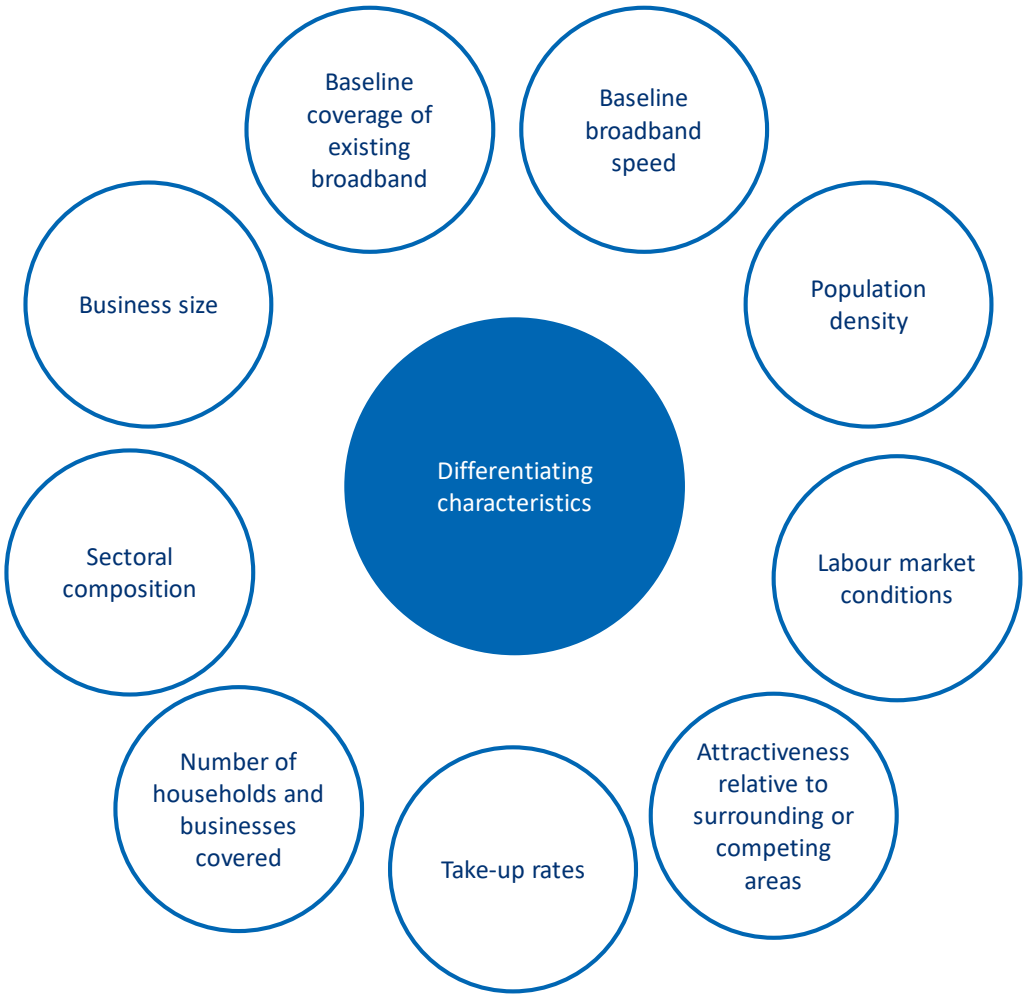
[60] UK 5G Innovation Network (2019), 'Keeping Liverpool Healthy', Testbeds and Trials special issue, pp. 32–35.
[61] UK 5G Innovation Network website, 'Liverpool 5G Testbed', https://uk5g.org/discover/testbeds-and-trials/liverpool-5g-testbed/
[62] UK 5G Innovation Network (2019), 'Keeping Liverpool Healthy', Testbeds and Trials special issue, pp. 32–35.
[63] 5G RuralFirst website, 'About 5G Rural First', https://www.5gruralfirst.org/what-is-5gruralfirst/
[64] 5G RuralFirst website, 'Agritech', https://www.5gruralfirst.org/project/agritech/
[65] 5G RuralFirst website, 'Community and Infrastructure'. https://www.5gruralfirst.org/project/community-and-infrastructure/

3 How will the impacts and outcomes vary at a local level?

3.1 Building a deeper understanding of investment areas

The impacts and outcomes described in section 2 will not necessarily apply uniformly across all local area types, and investors and LAs that are considering how their areas will benefit from fibre and 5G connectivity must understand the differentiating characteristics that could affect the variation of impacts and outcomes across areas.[66] These characteristics are outlined in Figure 3.1 and described in turn below.

Figure 3.1 Differentiating area characteristics



Source: Oxera.

- **Baseline coverage of existing broadband**—if there are a number of customers who currently have little or no broadband, a large-scale investment project in full-fibre or 5G improving digital connectivity will result in the improved availability of or access to existing services for those who had previously had limited or no access to broadband. This could bring social benefits such as improved digital inclusion, in addition to

[66] Where possible we provide references to the existing reports and studies that have explored these issues. However, we acknowledge that quantitative estimates discussed in section 4, do not provide such a fine degree of differentiation. However, as we discuss in section 5, keeping track of these key area characteristics will be important for informing the selection of control groups in future evaluations and allow for further analysis of the quantitative impacts of changes in these characteristics.

transformative impacts associated with all broadband users gaining access to services or applications not possible with previous generation connections.

- **Baseline speeds**—the level of broadband speed already available in the area prior to investment in very high capacity networks will be an important determinant of the magnitude of any benefits. The evidence from the literature suggests that larger changes in broadband speed can lead to larger impacts on productivity and employment.[67]
- **Population density**—areas with low population density without full-fibre connections might be more likely to suffer from long line lengths provided over copper, which will result in lower achievable connection speeds, higher latency and jitter, so the potential for gains from a shift to full-fibre or 5G connections are more significant in terms of increases in achievable speeds and reliability.[68,69]
- **Distribution of business size**—it is possible that many large businesses already have access to high-speed connections that enable them to take advantage of the incremental benefits of fibre connections. This is because they may already have access to business connectivity services known as 'leased lines'.[70] Smaller businesses, which may be more reliant on mass market or business broadband services that are based on standard broadband connections, are more likely to benefit from a step change in broadband speeds and the associated improvements.[71] However, evidence suggests that employment gains are expected predominantly in micro firms (0 to 9 employees), while turnover gains are captured more widely between micro, medium (50–249 employees) and large (250+ employees) firms.[72]
- **Industry type/sectoral composition**—the literature suggests that certain business types are likely to benefit more from improved connectivity than others. For example, knowledge-intensive sectors[73] are shown to benefit

[67] For example, Ipsos MORI (2018) finds that turnover per worker (average) sees larger increases at larger speeds and firm turnover (average) also sees significantly larger increases at greater speeds. The idea of larger returns is also supported by evidence presented by Bai (2017), which shows that an increase in broadband speed from 100 Mbit/s to 1 Gbit/s has a greater impact on country-level employment than increasing speeds from 3 Mbit/s to 100 Mbit/s. Singer et al. (2015) considers that fibre deployment to 100% of a region is associated with an increase in employment of approximately 2.9%. The authors explicitly recognise that 'the positive employment impact is specific to FTTP deployment, and is over and above the employment benefits that arose from previous broadband deployment', implying that there is an incremental impact over standard broadband.

[68] Services provided over a copper connection (even if just over the 'last mile' from the street cabinet to the home) experience degradation of service over distance. Fibre can carry much wider bandwidth over much longer distances without degradation.

[69] We acknowledge that published metrics of population density for an LA area may provide a distorted picture of the density of households within residential areas. For example, for very rural areas, where population may be based in a specific village or hamlet surrounded by large areas of uninhabited land, the population density will be very low, but the population may be clustered in a single area.

[70] Leased lines services are a dedicated broadband connection providing uncontended access to the user. These services are typically high-speed services (as high as 10 GB/s) and have symmetrical upload and download speeds.

[71] The Office for National Statistics reports statistics on proportion of businesses by sizeband that have connections at various speeds. In 2017, only 7.4% of all businesses had a connection of 100 Mbps or more (100 Mbps or more is the highest speed category presented, which could be used as a conservative estimate for those already obtaining a high-speed connection.) However, 65.4% of businesses with over 1,000 employees had such a connection, implying that larger businesses will experience relatively smaller incremental benefits compared with those experienced by smaller businesses. See Table 13: Proportion of UK businesses by maximum contracted internet connection speed, by size of business. Available from Office for National Statistics E commerce tables (2017), available at Office for National Statistics website, 'E-commerce and ICT activity', https://www.ons.gov.uk/businessindustryandtrade/itandinternetindustry/datasets/ictactivityofukbusinesseseecommerceandictactivity

[72] Ipsos MORI (2018).

[73] Industrial classifications J (information and communication), K (financial), M (professional, scientific and technical).

most.[74] Education and health sectors have also been shown to experience larger-than-average productivity impacts of increased connectivity.[75] As demonstrated in the case studies presented in section 2.4, there is also a likelihood for full-fibre and 5G in particular to lead to productivity improvements in industrial and manufacturing settings.

- **Labour market conditions**—in terms of the impact of improvements in connectivity on reducing economic inactivity or unemployment, the potential scope for impact will be larger where these levels are higher.[76] However, the skills and capabilities of people who are economically inactive will also be important in determining the extent to which they could expect to move into the labour force, especially for the long-term unemployed, and particularly if the new roles being created are for knowledge-intensive or technology-based industries. Complementary policies supporting training and education may be needed to re-train the long-term unemployed to fill the new jobs being created.

- **Attractiveness relative to surrounding and competing areas**—in addition to considering the broadband speed in the local area before the investment, the post-investment speeds relative to surrounding areas (or competing areas with otherwise similar characteristics) will be important. Studies have found that regions with higher fibre penetration attract more business registrations and employment and have reduced migration away from rural areas.[77] For example, evidence from the UK suggests that local benefits related to turnover and productivity are supported by the relocation of firms to postcodes with better connections;[78] evidence from France shows that very high-speed broadband networks enhance the attractiveness of municipalities for companies.[79] Furthermore, results from Sweden suggest that increases to a municipality's economic attractiveness lead to the establishment of more companies (or the decision of existing ones to stay).[80]

- **Number of households and businesses covered**—the larger the coverage area (for example, in terms of premises passed), the greater the number of consumers and businesses that have the opportunity to take up the service and the larger the absolute potential impact.

- **Take-up rates**—the availability of the service alone is not sufficient, benefits to businesses or consumers can be realised only by those actually taking up and using the service. Therefore, take-up rates must be accounted for to adjust the total number of premises passed to give a meaningful measure of those that will benefit. Note the take-up rate of FTTH/B in the EU28 is around 38.2%;[81] however, the UK take-up rate is around 13.1% at present.[82] Take-up rates of 5G are not yet available given the nascent nature of 5G services in Europe. However, any complementary policies to encourage

[74] Micus Management (2008).
[75] Ipsos MORI (2018).
[76] Ipsos MORI (2018) found evidence to support the hypothesis of reductions in unemployment in the areas benefiting from superfast broadband programmes relative to those that did not.
[77] As noted in WIK-Consult (2018).
[78] Ipsos MORI (2018).
[79] Hasbi (2017).
[80] OECD (2015).
[81] See ISP (2019), 'UK Finally Joins 2019 FTTH Ultrafast Broadband Country Ranking', https://www.ispreview.co.uk/index.php/2019/03/uk-finally-joins-2019-ftth-ultrafast-broadband-country-ranking.html
[82] See ISP (2019), 'UK Finally Joins 2019 FTTH Ultrafast Broadband Country Ranking', https://www.ispreview.co.uk/index.php/2019/03/uk-finally-joins-2019-ftth-ultrafast-broadband-country-ranking.html

take-up of services where they are available is likely to increase total benefits.

Table 3.1 provides an illustrative overview of the extent to which the core outcomes identified earlier are likely to be relatively larger or smaller as the key characteristics change.

Table 3.1 Influence of area characteristics on expected outcomes of upgrade

Characteristics of the local area	**Existing** businesses (productivity)	**New businesses** (number of businesses operating in the area)	**Employment** (change in number of employed in the area)	**Consumer benefits**	**Local authorities** (cost savings)
Baseline coverage (lower coverage before investment)	↑			↑	↑
Baseline speeds (lower baseline speed before investment)	↑			↑	↑
Business sizes (more micro and SME-focused)	↑		↑		
Industry type (greater share of knowledge-intensive businesses)	↑				
Labour market conditions (high unemployment)			↑		
Greater post-investment speeds and attractiveness relative to surrounding/ competing areas		↑	↑		
Number of businesses and households taking up the service	↑			↑	

Source: Oxera, based on the findings described above.

The realisation of benefits from network deployment take some time for three reasons. Firstly that there will be a period between the network build and the enabling of broadband services. Secondly, the take-up of the new services provided through the networks are likely to take time to increase as people switch to the new network. Thirdly, it will take time for new products and

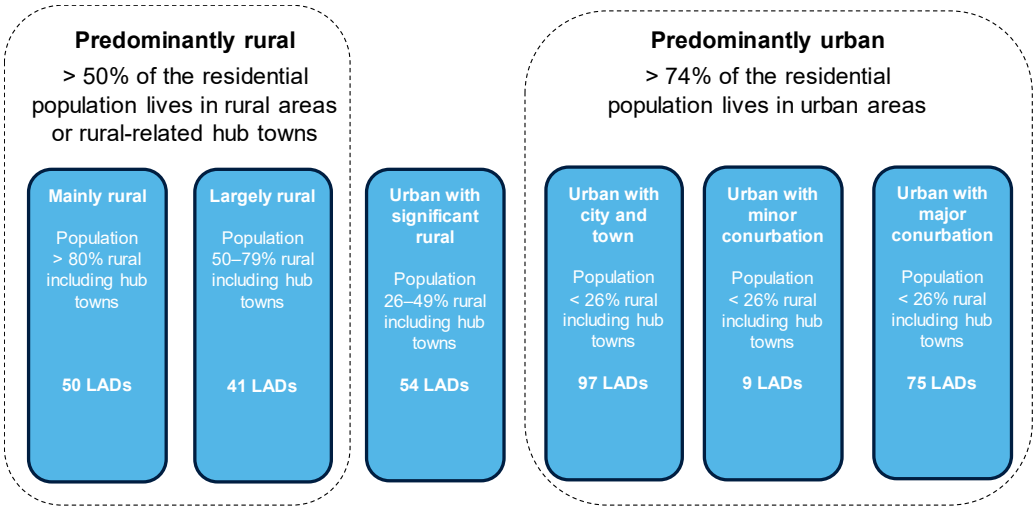
services to be developed that make use of the additional capability of the networks and for consumers, businesses and Local Authorities to change business and other processes to take advantage of these new products and services.

3.2 Impacts for stylised area types

To illustrate the potential scale of the benefits that could be realised in an LA district, in this section we draw on official statistics that can provide a clearer picture of the characteristics of a particular local area.

We have identified data reported at the LA level and, while acknowledging that each LA is different, we summarise the statistics for Local Authority Districts (LADs) by rural-urban classification. This is based on Office for National Statistics classifications of LADs in England[83] as belonging to one of six categories (see Figure 3.2). This is just one of the ways in which the data can be grouped, but it is helpful for providing a broad overview.[84]

Figure 3.2 Overview of stylised area types



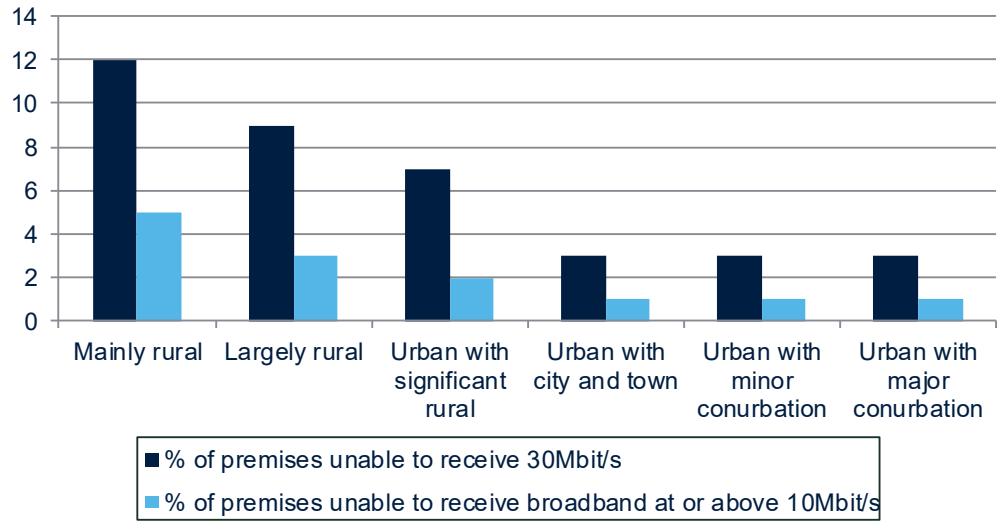
Source: Oxera, based on Office for National Statistics (2011), and other higher-level geographies for statistical purposes.

Based on data collected on the key characteristics identified above we would expect the impact of improved connectivity to vary between different LAD area types.

For example, Figure 3.3 below shows that, on average, rural areas have a larger number of premises without access to broadband speeds at or above 10Mbit/s and 30Mbit/s, implying that there is scope for larger proportional impacts to be achieved from widespread availability of full-fibre and 5G networks in these areas (including through greater social inclusion and improved access to existing and new services).

[83] The Office for National Statistics' rural-urban classification presented here is mapped for LADs in England only. Wales, Scotland and Northern Ireland each have their own rural-urban classification of LA areas in those countries, which could be presented and assessed separately.
[84] Each of the metrics presented in this table are available for all LAs in the UK. This table presents the simple average of the figures for LAs in England that are categorised into each of the six Office for National Statistics rural-urban categories. We acknowledge that there is significant variation within each of these area types, and that the average is only indicative of differences across LAs based on urban-rural classification.

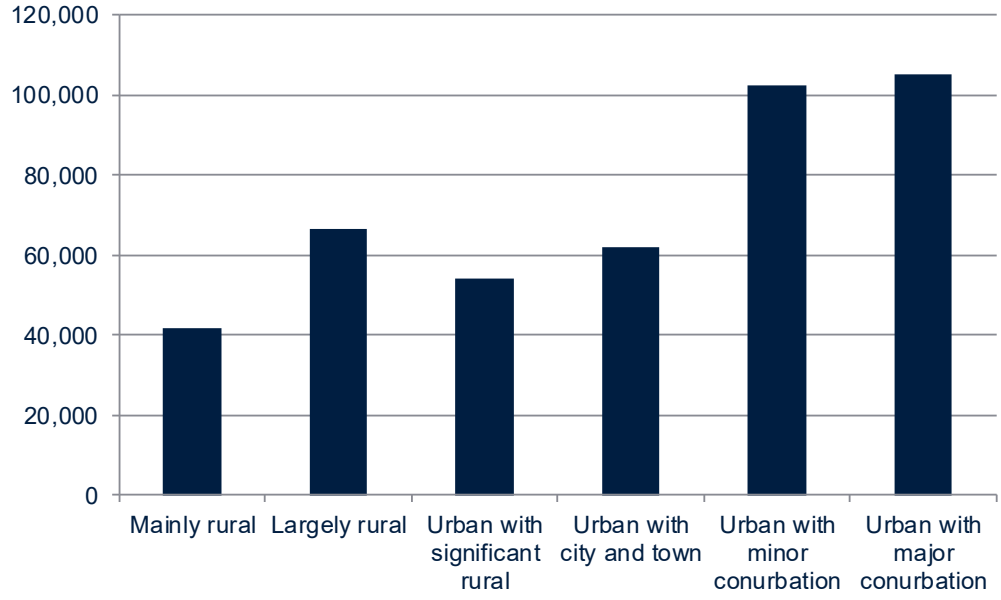
Figure 3.3 Access to broadband by stylised area type (average per LAD)



Source: Ofcom (2019), Connected nations Fixed-LAUA data, Spring, https://www.ofcom.org.uk/research-and-data/multi-sector-research/infrastructure-research/connected-nations-update-spring-2019

LAD in more urban areas tend to have a larger number of households (Figure 3.4) local business units[85] (Figure 3.5) and jobs (Figure 3.6) than those in rural areas. This implies that the number of consumers who could benefit from access improvements in connectivity is greater, and that the gains from even small proportional increases in productivity (turnover per worker) will be larger in absolute terms given the larger number of workers.

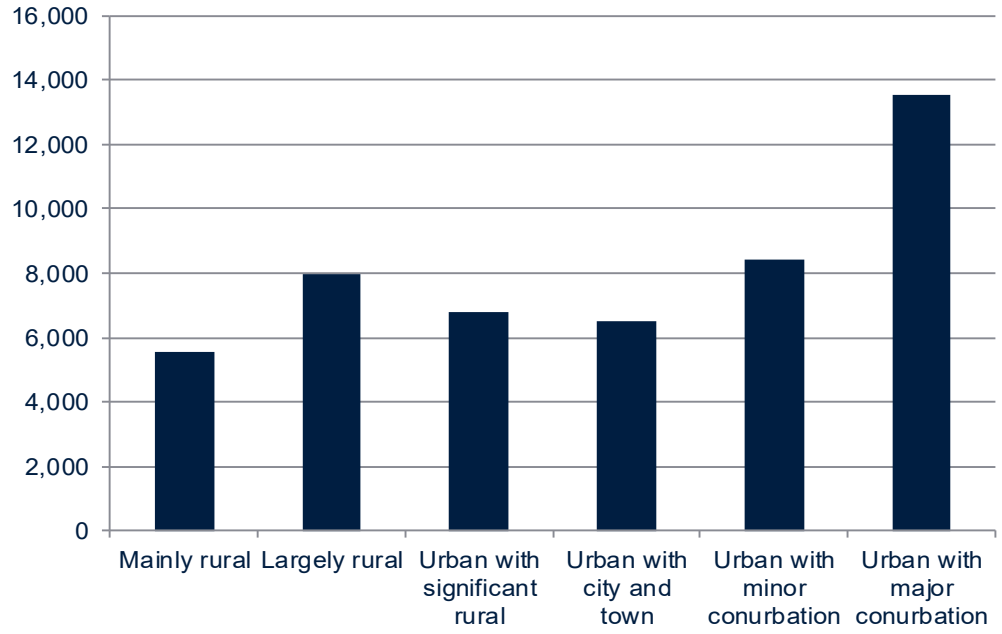
Figure 3.4 Average number of households per LAD



Source: Office for National Statistics (2018), 'Estimated number of households by local authorities of England, 2004 to 2016', June.

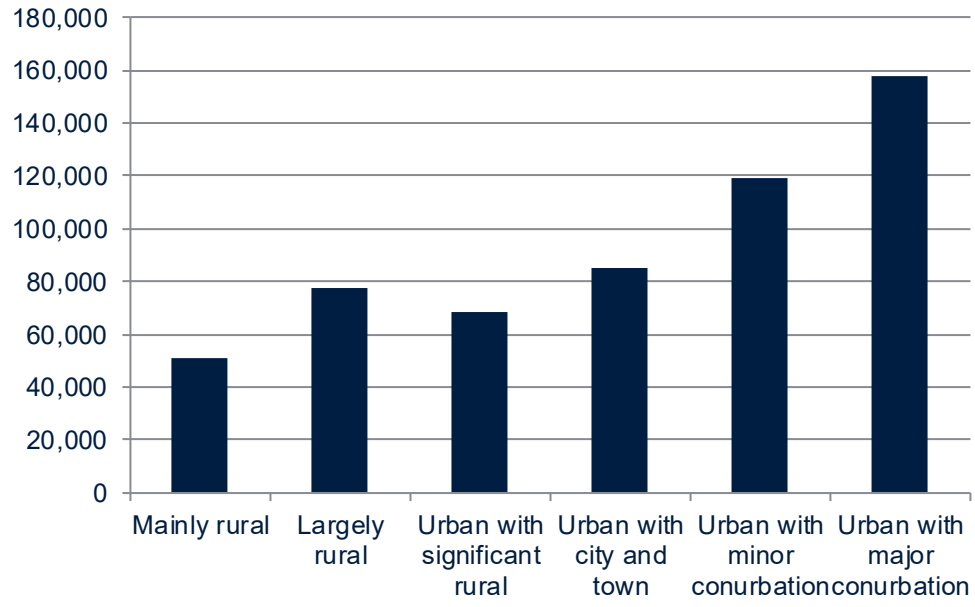
[85] Note that, within these average figures, there does not appear to be any significant variation in distribution of business size (measured in terms of the average number of employees per business) across different area types.

Figure 3.5 Average number of business units per LAD



Source: Office for National Statistics (2018), UK BUSINESS: ACTIVITY, SIZE AND LOCATION - 2018 (Table 16 - Number of VAT and/or PAYE based local units in districts, counties and unitary authorities within region and country by broad industry group (UK, 2018)).

Figure 3.6 Average number of jobs per LAD



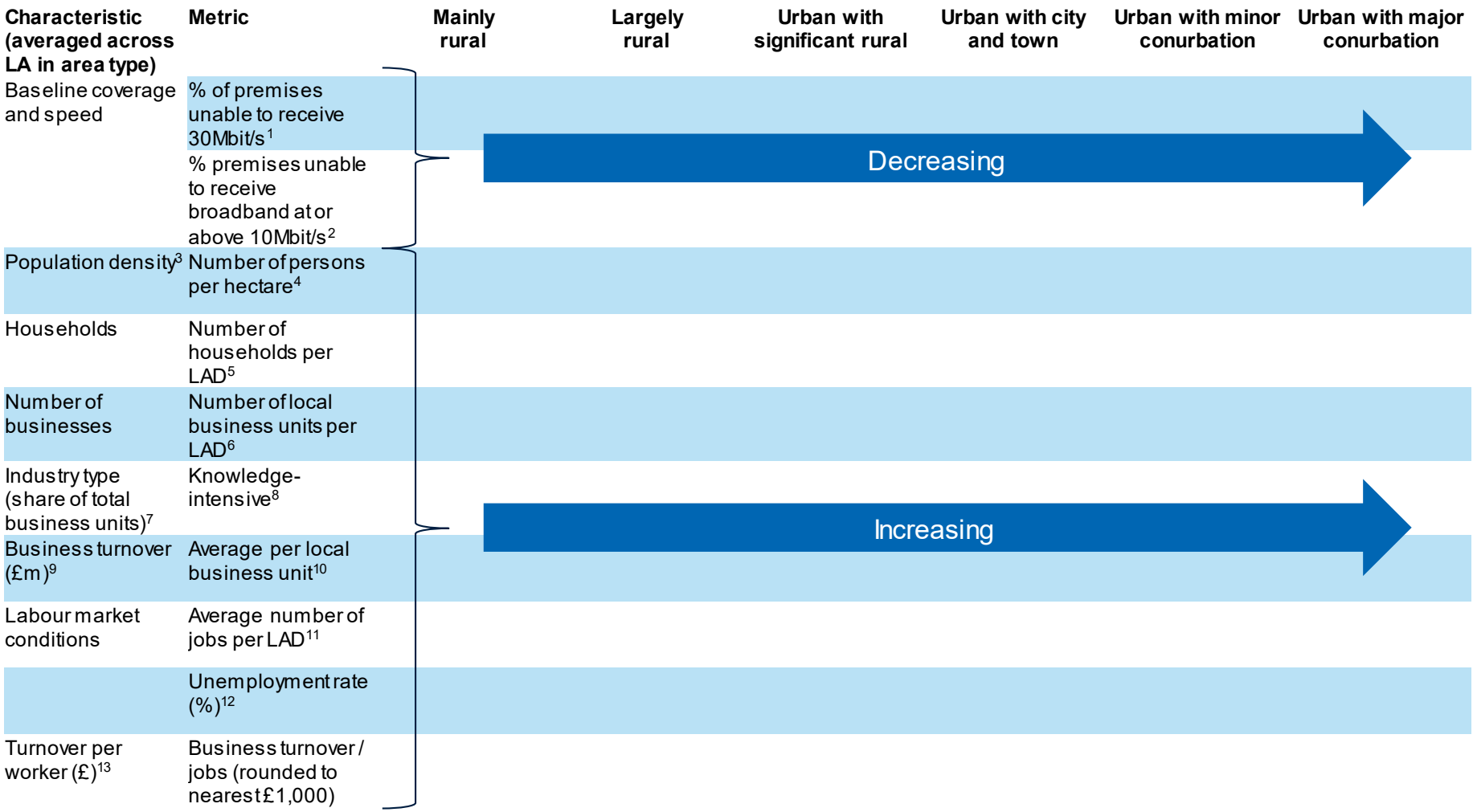
Source: Office for National Statistics, LI01 Regional labour market: Local indicators for counties, local and unitary authorities.

Figure 3.7 below summarises the trends for key statistics that will influence the expected impact of improved connectivity across local areas within these area types (with the full table and statistics included in Appendix A2). For example, in addition to the trends highlighted above, we note urban areas have on average a larger share of firms in knowledge-intensive sectors such as

information and communication; professional, scientific and technical; and business admin and support services compared with rural areas. This implies that the productivity benefits in urban areas may be proportionally larger than those in rural areas. Furthermore, more urban areas have a greater rate of unemployment, suggesting that any increase in the number of jobs available might be more beneficial for urban than rural areas in terms of the greater scope for these jobs to be filled by economically inactive people (consistent with findings in the literature that there is a stronger employment impact in urban versus rural areas).[86]

[86] Ipsos MORI (2018); and OECD (2015).

Figure 3.7 General trends for key statistics for Local Authority area types



Notes: [1] Ofcom (2019), Connected nations Fixed-LAUA data, Spring, https://www.ofcom.org.uk/research-and-data/multi-sector-research/infrastructure-research/connected-nations-update-spring-2019

[2] Percentage of premises that do not have access to download speeds at or above 10Mbit/s and upload speeds at or above 1Mbit/s including non-matched records and zero predicted speeds. Ofcom (2019), Connected nations Fixed-LAUA data, Spring, https://www.ofcom.org.uk/research-and-data/multi-sector-research/infrastructure-research/connected-nations-update-spring-2019
[3] We acknowledge that published metrics of population density for an LA area may provide a distorted picture of the density of households within residential areas. For example, for very rural areas, where population may be based in a specific village or hamlet surrounded by large areas of uninhabited land the population density will be very low, but the population may be clustered in a single area.
[4] Office for National Statistics 2011 census data. Table P04UK 2011 Census: Population density, local authorities in the United Kingdom.
[5] Office for National Statistics (2018), 'Estimated number of households by local authorities of England, 2004 to 2016', June.
[6] Office for National Statistics (2018), UK BUSINESS: ACTIVITY, SIZE AND LOCATION - 2018 (Table 16 - Number of VAT and/or PAYE based local units in districts, counties and unitary authorities within region and country by broad industry group (UK, 2018)).
[7] Office for National Statistics (2018), UK BUSINESS: ACTIVITY, SIZE AND LOCATION - 2018 (Table 16 - Number of VAT and/or PAYE based local units in districts, counties and unitary authorities within region and country by broad industry group (UK, 2018)).
[8] Includes industry types J (Information and communication), K (Finance and Insurance), M (Professional, scientific and technical).
[9] Office for National Statistics (2018), UK BUSINESS: ACTIVITY, SIZE AND LOCATION - 2018 (Table 11 - Number of VAT and/or PAYE based enterprises in districts, counties and unitary authorities within region and country by turnover sizebands (UK, 2018)).
[10] The Office for National Statistics' data presents the number of firms in each LA by turnover sizebands. We estimate the total turnover of businesses in the local area by multiplying the number of businesses inside a particular turnover sizeband and the mid-point of the sizeband, and summing across all sizebands to give an estimated turnover per LA. This relies on a simplifying assumption that firms within each turnover sizeband are uniformly distributed within the band.
[11] Office for National Statistics, LI01 Regional labour market: Local indicators for counties, local and unitary authorities.
[12] Office for National Statistics, M01 Regional labour market: Modelled unemployment for local and unitary authorities (Table name: LA, UA Rates : Unemployment rates in local and unitary authorities) (Rate (%) Jan 2018 - Dec 2018). Unemployment rates calculated as percentage of 16+ economically active population.
[13] Turnover per worker estimated as the average turnover per area type divided by the average number of jobs per area type.

3.3 Variation within stylised area types

The examples described above and the assessment framework provided give a clear basis for LAs to identify the type of benefits that could be expected in their areas, and how those benefits will be realised. However, there is likely to be further variation in individual cities, towns and villages within each of these area types and, therefore, any quantification of benefits based on these average figures would not be helpful to a specific LA. Therefore, any quantification of the expected impacts on specific LA areas would benefit from being assessed on a case-by-case basis. In section 4, we outline how this could be done by drawing on LA-level data on key characteristics and the metrics from the existing literature regarding the impact on productivity, new businesses and employment, and consumer benefits.

4 Quantifying the expected impacts

The data presented in Figure 3.7 is available for all LAs in the UK. Estimates for the impact of improved connectivity on these areas could be calculated using the metrics from the existing literature.

This is an emerging framework based on the findings of existing literature: the approaches and metrics will need to be updated over time to reflect the latest emerging evidence as it becomes available. This will help to build an increasingly accurate business case for improvements in connectivity.

However, indicative quantitative estimates for the direct impacts of improved connectivity on productivity, number of businesses and employment can be estimated as follows:

Productivity (per annum):

*(Turnover per worker of firms taking up full-fibre broadband * estimated percentage increase in productivity) * the number of employees of those firms taking up full-fibre broadband*

Change in number of businesses:

*Number of local businesses * estimated increase in businesses in the area*

Employment impact:

*Number of jobs * estimated impact on jobs in the area*

The key metrics from the literature regarding the impact on productivity improvements, number of new businesses, and the impact on employment are outlined in the tables below.

4.1 Existing businesses (productivity)

The existing literature suggests that productivity (measured by turnover per worker)[87] increases with broadband speed, with a larger impact for a larger change in speed. The average impact ranges from around 0.3% to 3.8% per annum depending on the change in broadband speed. Therefore, the impact on productivity will be felt by businesses not already obtaining full-fibre services that can expect a change in speed and reliability. Firms in sectors such as education, health, manufacturing, and professional services see larger-than-average increases for the same change in speed.[88]

Table 4.1 Summary of metrics supporting an impact on productivity

Metric	Impact of what?	Shape of impact	Period	Beneficiaries	
Productivity measured as turnover per worker	Increase in broadband speed	Larger speed increases result in larger productivity gains: • speed increase from 20Mbit/s to 64 Mbit/s results in **0.32%** increase in turnover per worker • speed increase of 100–200MB/s results in **1.2%** increase in turnover per worker • speed increase > 200mbps results in **3.8%** increase in turnover per worker)	Per annum	Firms experiencing faster connection speeds particularly in sectors with high productivity gains (e.g. education and health)	Impact varies significantly across sectors: • education: 4.7% • health: 3.7% • manufacturing: 0.8% • professional services: 0.7%
	Increase in broadband speed[1]	Doubling of connection speed yields approx. **0.3%** increase in productivity	Per annum (estimated for three years post-upgrade)	Firms experiencing faster connection speeds	

Note: SQW (2013) estimated productivity gains based on an assumption of the impact of a doubling of speed, for which the central estimate is 0.3% (i.e. an increase of 100% in the used speed in a year will lead to a 0.3% uplift in productivity, over the following three-year period). However, this was an input to a model rather than based on findings from an ex post evaluation. The findings from Ipsos MORI (2018), however, are based on findings from an ex post evaluation of the impact of firms upgrading to superfast broadband, tracking the impacts over different changes in speed.

Source: [1] Ipsos MORI (2018); [2] SQW (2013).

[87] Productivity would normally be defined as output per worker, not turnover per worker. As the literature uses turnover per worker, we use this definition here.
[88] The industry-specific impacts presented in this table are for the average change in speed considered (an increase from 20 Mbit/s to 64 Mbit/s on average). However, changes in speed from an upgrade to full-fibre are expected to be significantly more (as indicated by the average figures); therefore, these industry-specific figures could represent a lower bound estimate of the impact of an upgrade to full-fibre broadband for which the increase in speed will be more significant.

4.2 New businesses (number of firms operating in the area)

The evidence from the literature demonstrates a measurable impact of greater speeds and increased fibre penetration on the number of firms in an area.

Table 4.2 Summary of metrics supporting an impact on new business start-ups

Metric	Impact of what?	Scale of impact	Period	Beneficiaries
New business start-ups	Increase in speed	Step change in the number of businesses: • an increase in speed of 100–200Mbp/s leads to a 0.4% increase in number of firms in the area[1]	One-off	Relatively new firms (1–3 years old) may be better placed to exploit the benefits of faster speeds[1] [89]
	Increase in fibre penetration	Step change in the number of businesses: • the presence of a very high speed broadband network leads to 3.2% more businesses operating in a municipality[2] 10% higher fibre penetration leads to 1 additional business opening per 12,000 inhabitants[3] (another study estimates the effect at 0.1%[4])	One-off	The estimated 3.2% average effect of the increase in penetration on the number of businesses varies with the sector considered: • construction: 4.7% • tertiary sector: 2.7% • industrial sector: 1.4%[2]

Source: [1] Ipsos MORI (2018); [2] Hasbi (2017); [3] OECD (2015); and [4] Lapointe (2015).

[89] Ipsos MORI (2018) notes that its results indicated that many of the incoming firms were relatively young—around 1 to 3 years old. This could suggest that these smaller firms are better able to exploit these speeds to their advantage, at least at present.

4.3 Employment (number of people employed in the area)

The literature that focuses on change in employment includes both new jobs and jobs as a result of inward migration due to the improved attractiveness of the area. The local jobs market may also be protected by reduced migration away from areas (safeguarding jobs).[90] Urban areas are shown to benefit more than rural areas.

Table 4.3 Summary of metrics supporting an impact on employment

Metric	Impact of what?	Scale of impact	Period	Beneficiaries	
Employment	Increase in speed	Step change in employment rate: • speed increase from 20Mbp/s to 64Mbp/s results in employment rise of 0.8% on average[1]	One-off	Workers	The effect of speed change on employment increase depends on urbanisation • 1.3% in urban areas • 0.6% in rural areas* Classification based on Office for National Statistics: an Output Area (OA) is treated as urban if it is allocated to a 2011 'built-up area' with a population of 10,000 or more people
	Increase in fibre penetration	Step change in employment: • fibre deployment to 100% is associated with an increase in total employment of approx. 2.9%[3] • a 10% increase in fibre penetration results in a 0.1% increase in total employment[4] Change in employment rate:[91] • 10% higher fibre penetration is correlated with 1.1% higher employment rate[2]	One-off	Workers	The effect of penetration on employment rate can vary by urbanisation level. The effect of 10% increase in penetration: • 1.1% in low urbanisation area • 0.7% in medium urbanisation area • 1.7% in high urbanisation area[2]

Source: [1] Ipsos MORI (2018); [2] OECD (2015); [3] Singer et al. (2015); and [4] Lapointe (2015).

[90] For example, Xiong (2013) found that fibre penetration in Sweden had a significant impact on the population's evolution, especially the net amount of migration into a municipality, which indicates the attractiveness of municipalities per se. OECD (2015) also suggests that higher employment could be explained through increases to a municipality's economic attractiveness, leading to the establishment of more companies (or the decision of existing ones to stay) and greater efficiency of the labour markets. Similarly, Forzati and Mattson (2012), in their study of FTTP in Swedish municipalities, found that an increase in roll-out of FTTP was linked to both higher migration and a positive change in employment.

[91] Note that this study focuses on the employment rate, the ratio of the employed to the working age population, rather than changes in total employment level as per the other studies listed here.

Box 4.1 Quantifying the impacts on productivity, new businesses and employment: a worked example

Suppose the LA area has:

- 9,000 local business units;
- 90,000 jobs;
- 60,000 households;
- Turnover per worker (average) = £80,000.

Impact on productivity (per annum)

As shown in Table 4.1, the *average* impact of increased speed on productivity ranges from around 0.3% to 3.8% per annum, with the upper bound of this range related to the increase in speed that can be expected to be a reasonable estimate for the speed increase that could be achieved with an upgrade to a full-fibre connection.[92]

Therefore, on average, the productivity gain to a firm taking up a full-fibre connection can be estimated as:

*Turnover per worker of firms taking up the service * 3.8%*

Assuming turnover per worker for each firm taking up full-fibre is £80,000 per annum, each firm can expect to see an increase of turnover per worker of around **£3,040 per annum**.

To estimate the aggregate impact for the local area, we must scale this up by the number of employees working for those businesses taking up the services.

Assuming a take-up rate of around 13% (the average take-up rate for FTTH/B in the UK in 2019),[93] and the average of 10 jobs per business, the total expected benefit will be approximately **£3.5m per annum**.[94] This will increase as take-up increases.

Change in number of businesses

As shown in Table 4.2, taking a conservative estimate, the average impact of increased speed on the number of firms operating in the area is 0.4%, but may be as large as 3.2%.

In our example, this implies an increase of between **36 and 288 businesses** in the area as a result of increased connectivity.

Employment impact

As shown in Table 4.3, the average impact of increased speed on employment is 0.8%, but could be higher for an urban area at 1.3%.

This implies between 720 and 1,170 new jobs in the area as a result of increased connectivity. We have not monetised these impacts as they are likely to overlap with

[92] Ipsos MORI (2018) identified that a speed increase of >200mbps would result in a 3.8% increase in turnover per worker.
[93] Note the take-up rate of FTTH/B in the EU28 is higher at 38.2%. See ISP (2019), 'UK Finally Joins 2019 FTTH Ultrafast Broadband Country Ranking', https://www.ispreview.co.uk/index.php/2019/03/uk-finally-joins-2019-ftth-ultrafast-broadband-country-ranking.html
[94] If this is scaled up to give an impact over several years, a discount rate must be applied to calculate the net present value of the impact. This should follow the guidance presented in the Green Book, which uses a discount rate based on the 'social time preference rate' (STPR). It is defined as the rate at which society values the present compared with the future. The STPR used in the Green Book is set at 3.5% in real terms.

the increased number of businesses: on the basis that more businesses are likely to, at least to some extent, rely on newly employed people to work in them.

Source: Oxera calculations, using metrics from the literature.

4.4 Impact on consumers

For consumers, the value of improved connectivity can be estimated using consumer surplus—i.e. the difference between willingness to pay (value) and the actual price.

There is some evidence in the literature regarding willingness to pay for enhanced or superfast broadband services over and above legacy broadband services. For example, in the regulatory context of incentivising fibre broadband roll-out, Plum Consulting assumed a price premium of €5 per month for fibre to the curb and €10 for fibre to the home.[95] For these price premia to hold, the increment in consumer willingness to pay would need to be higher than €5 and €10 respectively. WiK estimated that the gross willingness to pay for cable-based services in 2011 was €82 per month, while for incumbent-based copper services it estimated €68–€77.[96] This would imply a willingness to pay for an upgrade from incumbent-based copper services to cable-based services of between €5 and €14. Survey evidence from the UK in 2012 suggested that consumers might be willing to pay approximately £15 per month more for enhanced services.[97]

While providing a guide to consumers' willingness to pay for improved connectivity, these studies are relatively old and are unlikely to reflect the value of the services that full-fibre and 5G could bring today (and in the future). Therefore, estimates of consumer willingness to pay would be a valuable area for further research. We also note that the number of applications and services taking advantage of the improved capabilities of full-fibre and 5G is likely to grow over time, which may lead to greater willingness to pay for access to these new technologies in the future, reflecting the greater value to consumers. However, as an illustrative estimate of the benefits to consumers based on the existing willingness to pay estimates, we will use an assumption of around £15 per month as the willingness to pay for faster broadband services over legacy services.

The price premium for upgrade to the faster broadband service must be subtracted from the willingness to pay assumption to give an estimate of consumer surplus, which is then multiplied by the number of consumers taking up these services. For fixed full-fibre broadband services, we express the results in terms of the impact on households taking up the service.

[95] Plum Consulting (2011).
[96] WiK Consult (2011).
[97] thinkbroadband.com (2012).

Impact on consumers

*Households taking up the service * (willingness to pay for full-fibre/5G per month – price for full-fibre/5G services per month)*

If full-fibre broadband is £5–£10 per month more expensive than the average broadband connection in the area and there is a willingness to pay an extra £15 per month to obtain a fibre connection, the consumer surplus value would be £5–£10 per month per consumer, or approximately £60–£120 per annum.

If the area has **60,000 households** and we assume a take-up rate of around 13% (the average take-up rate for FTTH/B in the UK in 2019),[98] then approximately 7,800 households will benefit.

This amounts to a benefit of **£0.5m–£0.9m per annum**.[99]

Source: Oxera calculations, using metrics from the literature.

4.5 Impact on Local Authorities

The impact on LAs will depend on the specific uses of the fibre network and how the council uses the improved connectivity to help with its service delivery. However, where efficiency improvements and cost savings come from changing interactions with end-users to digital or connected services, the improved availability and take-up of these new technologies broadens the scope for this more efficient service delivery.

For example, in section 2.4 we presented case studies showing the benefits to LAs of using the increased connectivity to support delivery of home care and other healthcare services in such a way that could improve efficiency of delivery and lead to cost savings.

Furthermore, there may be additional indirect benefits to the LA arising from the increased economic activity facilitated by the greater availability of full-fibre broadband and 5G. Increased economic activity can have a number of benefits to a local area, both directly through some additional income (for example through business rates) and indirectly (through assisting with a range of other LA objectives facilitated by increased economic activity such as reduction in antisocial behaviour or deprivation).

The evidence base regarding the quantification of direct and indirect impacts on LAs is small, and at present appears to be focused on a small number of specific use cases. Therefore, further data on the benefits to LAs should be collected as part of future evaluations of investment projects after roll-out. This will help to strengthen the evidence base to support a greater understanding of the quantitative value of the impacts on LAs.

[98] Note the take-up rate of FTTH/B in the EU28 is higher at 38.2%. See ISP (2019), 'UK Finally Joins 2019 FTTH Ultrafast Broadband Country Ranking', https://www.ispreview.co.uk/index.php/2019/03/uk-finally-joins-2019-ftth-ultrafast-broadband-country-ranking.html

[99] If this is scaled up to give an impact over several years, a discount rate must be applied to calculate the net present value of the impact. This should follow the guidance presented in the Green Book, which uses a discount rate based on the 'social time preference rate' (STPR). It is defined as the rate at which society values the present compared with the future. The STPR used in the Green Book is set at 3.5% in real terms.

5 Improving the evidence base: an evaluation framework

Much of the literature to date has focused on retrospective assessments of projects; the quantification has largely focused on the private benefits arising from improved connectivity in terms of the impact on productivity, new businesses and employment.

However, given the relatively low levels of full-fibre and 5G investment in the UK to date, information and data should be collected alongside any new investment projects in order to allow for more robust and meaningful evaluations in future. As noted in HM Treasury's 'Green Book', 'The role of appraisal and evaluation is to provide objective analysis to support decision making'.[100]

While tracking some metrics for the affected area and doing a simple 'before and after' comparison may give some indicative results,[101] it does not provide a robust evaluation. Therefore, such approaches should be accompanied by data generated from quantitative evaluations.

In line with guidance from the 'What Works Centre for Local Economic Growth', using before and after data, combined with a suitable control group against which to assess changes, is a key building block of a robust evaluation.[102] A robust evaluation will allow for the assessment of 'net economic impact' from the investment.

The net economic impact is the value of economic effects over and above any impact that would have arisen if the project/investment had not gone ahead (the counterfactual). In the case of full-fibre or 5G investment, the net impact reflects the impact on users and wider society compared with what they would have experienced without the investment. This principle is illustrated in the figure below.

Figure 5.1 Illustration of net impact

Note: The top bar represents the total benefits that might have been expected to accrue had the investment in full-fibre or 5G not taken place; the bottom bar represents the total gross economic benefits observed as a result of the local investment; and the middle bar (representing the difference between these points) therefore shows the net economic impact or benefit of the project.

Source: Oxera.

[100] HM Treasury (2018), 'The Green Book – Central Government Guidance on Appraisal and Evaluation'.
[101] Supported by qualitative approaches such as interviews with consumers, businesses and LAs taking up the service.
[102] What Works Centre for Local Economic Growth (2016), 'How to evaluate local growth programmes', April, https://whatworksgrowth.org/blog/how-to-evaluate-local-growth-programmes-all-our-guidance-in-one-place/

Therefore, it is important to be clear on what metrics should be tracked (how to define and measure the impact of the investment) and what factors should be taken into account for defining a relevant counterfactual.

5.1 Defining the impact of the investment

When evaluating specific projects or investments it is important to consider what effects the investment project is expected to have and how these could be measured.

In this report, we have specified the key categories of impact that can be taken as variables for measuring the impact, at a local level, of investment in full-fibre and 5G.[103] In particular, the focus should be on the 'outcomes' identified in our assessment framework:

- **impact on existing businesses taking up the service**—measured by impact on productivity;
- **impact on new businesses in the area**—measured by change in the number of businesses in the area;
- **impact on employment**—measured by change in the number of people employed in the area (controlling for changes in the population of working age);
- **impact on consumers taking up the service**—measured by willingness to pay compared with prevailing retail prices;
- **impact on LAs**—measured by cost savings in service delivery.

5.2 Identify the data needed to measure the impact

To measure the impact, it is therefore important to ensure that the data necessary to measure the 'outcomes' defined above (e.g. data on who takes up the service, measures of productivity, business start-ups, etc.) is collected before, during and after the investment project for both the treatment and control groups.

Further, as outlined earlier,[104] there are a number of differentiating area characteristics that could have an impact on the extent to which impacts will vary.

Gathering data on these local area characteristics will be important for two main reasons:

- it will allow future evaluations to compare across area types to distinguish which area characteristics have a significant impact on the relative success of the investment;
- the more data that is available on the characteristics of the area being investigated, the greater the scope for identifying an appropriate control group (i.e. an area with similar characteristics that has not yet invested in improved connectivity).

Therefore, we have identified two groups of data that should be captured before, during and after the investment to ensure an effective evaluation of the investment:

[103] See section 2.3.
[104] See section 3.1.

- the differentiating characteristics (which will also help inform the control group);
- data to measure the 'outcomes' defined above (e.g. data on who takes up the service, measures of productivity, business start-ups, etc.)

We have identified the following metrics to be monitored (some of which are available from regularly published data sets published by the Office for National Statistics, Ofcom, or other public authorities).

Table 5.1 Differentiating characteristics

Category	Example metrics	Availability
Baseline coverage and speed	SFBB availability (% of premises)[105] UFBB availability (% of premises)[106] % of premises unable to receive 30Mbit/s % of premises unable to receive 10Mbit/s[107]	Ofcom Connected Nations Report, presented at LA level (updated regularly)[108]
Households	Number of households in the area	Office for National Statistics figures up to 2016, reported at LA level[109]
Population density	Number of persons per hectare (10,000 square meters)	Census data, presented at LA level (last updated 2011)[110]
Business (number)	Number of 'local business units'. Where a local unit is an individual site (e.g. a factory or shop) associated with an enterprise. It can also be referred to as a workplace[111]	Office for National Statistics, reported at LA level[112]
Business (by size)	'Local business units' by employment sizebands: 0–4 employees 5–9 employees 10–19 employees 20–49 employees 50–99 employees 100–249 employees 250+ employees	Office for National Statistics, reported at LA level[113]

[105] Percentage of premises that have superfast broadband (30Mbit/s to less than 300Mbit/s) coverage.
[106] Percentage of premises that have ultrafast broadband (300Mbit/s or higher) coverage.
[107] Percentage of premises that do not have access to download speeds at or above 10Mbit/s and upload speeds at or above 1Mbit/s including non-matched records and zero predicted speeds.
[108] Ofcom (2018), Connected nations Fixed-LAUA data, Spring, https://www.ofcom.org.uk/research-and-data/multi-sector-research/infrastructure-research/connected-nations-update-spring-2019
[109] Office for National Statistics, 'Estimated number of households by local authorities of England, 2004 to 2016': https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/families/adhocs/008604estimatednumberofhouseholdsfortheunitaryauthoritiesofengland2004to2016
[110] Office for National Statistics 2011 census data. Table P04UK 2011 Census: Population density, local authorities in the United Kingdom.
[111] Office for National Statistics, UK Business Counts Datasets, https://www.nomisweb.co.uk/articles/764.aspx
[112] Office for National Statistics (2018), UK BUSINESS: ACTIVITY, SIZE AND LOCATION - 2018 (Table 22 - Number of VAT and/or PAYE based local units in districts, counties and unitary authorities within region and country by employment sizebands (UK, 2018)).
[113] Office for National Statistics (2018), UK BUSINESS: ACTIVITY, SIZE AND LOCATION - 2018 (Table 22 - Number of VAT and/or PAYE based local units in districts, counties and unitary authorities within region and country by employment sizebands (UK, 2018)).

Category	Example metrics	Availability
Industry type of those businesses	'Local units' by standard industry classification	Office for National Statistics, reported at LA level[114]
Turnover of businesses	Annual turnover	Accurate figures provided in the Office for National Statistics Business Structure Database (available only to government bodies and LADs)[115] Estimates from Office for National Statistics data, reported at LA level[116]
Labour market conditions	Job numbers[117]	Office for National Statistics, reported at LA level[118]
Labour market conditions	Unemployment rate	Office for National Statistics, reported at LA level[119]

Source: Oxera.

[114] Office for National Statistics (2018), UK BUSINESS: ACTIVITY, SIZE AND LOCATION - 2018 (Table 22 - Number of VAT and/or PAYE based local units in districts, counties and unitary authorities within region and country by employment sizebands (UK, 2018)).
[115] This data set is only available to government bodies and relevant LADs and is not available for commercial use.
[116] Office for National Statistics (2018), UK BUSINESS: ACTIVITY, SIZE AND LOCATION - 2018 (Table 11 - Number of VAT and/or PAYE based enterprises in districts, counties and unitary authorities within region and country by turnover sizebands (UK, 2018)). The Office for National Statistics data presents the number of firms in each LA by turnover sizebands. We estimate the total turnover of businesses in the local area by multiplying the number of businesses inside a particular turnover sizeband and the mid-point of the sizeband, and summing across all sizebands to give an estimated turnover per LA. This relies on a simplifying assumption that firms within each turnover sizeband are uniformly distributed within the band.
[117] This is the number of jobs in the area rather than the number of employed living in the area, which would include those living in the area but working in another LA area.
[118] Office for National Statistics, LI01 Regional labour market: Local indicators for counties, local and unitary authorities.
[119] Office for National Statistics, 'Regional labour market: Modelled unemployment for local and unitary authorities (Table name: LA, UA Rates : Unemployment rates in local and unitary authorities) (Rate (%) Jan 2018 - Dec 2018)'.

Table 5.2 Measuring outcomes

Category	Metric	Availability
Existing businesses	Productivity – turnover per worker	Accurate figures provided in the Office for National Statistics Business Structure Database (available only to government bodies and LADs)[120] Data may be collected alongside investment project
New businesses	Change in the number of businesses in the area	Office for National Statistics, reported at LA level[121]
Impact on employment	Change in number of employed in area (controlling for changes in the population of working age)	Office for National Statistics figures on number of jobs per LA[122]
Impact on consumers	Willingness to pay compared with prevailing prices	Data to be collected alongside investment project
LAs	Cost savings in service delivery	Data to be collected alongside investment project

Source: Oxera.

5.3 How to use this data

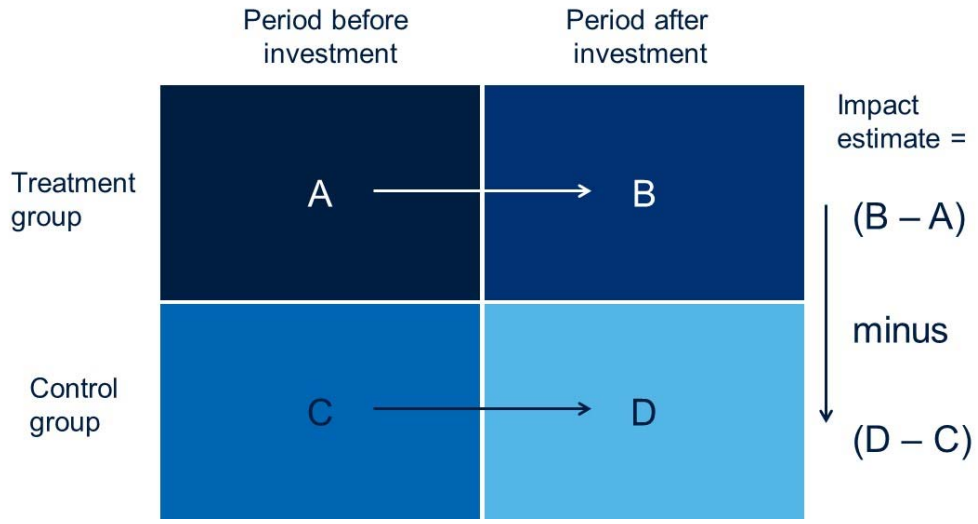
The data on differentiating characteristics can be used to define the control group, i.e. a similar area (as defined by the area characteristics discussed above) not undertaking the kind of project being evaluated.

The data collected to measure outcomes can then be used to compare changes from before and after the investment for the treatment group (where the investment has taken place), accounting for how those factors have changed in the control group (where the investment has not taken place).[123]

While the control group is unlikely to be perfect, any remaining differences in observable characteristics should be controlled for as part of the (econometric) analysis. This form of analysis, known as difference-in-differences estimation is illustrated in the figure below.

[120] This data set is only available to government bodies and relevant LADs and is not available for commercial use.
[121] Office for National Statistics (2018), UK BUSINESS: ACTIVITY, SIZE AND LOCATION - 2018 (Table 22 - Number of VAT and/or PAYE based local units in districts, counties and unitary authorities within region and country by employment sizebands (UK, 2018)).
[122] Office for National Statistics, LI01 Regional labour market: Local indicators for counties, local and unitary authorities.
[123] Best practice guidance for evaluations is outlined in HM Treasury (2011), 'The Magenta Book Guidance for evaluation', April.

Figure 5.2 Difference-in-differences approach



Source: Oxera.

Conducting evaluations in this way will add new and robust evidence to the literature on the economic impact at a local level of full-fibre and 5G, which can be used to shape future policy and gain further support for investments in these new technologies.

A1 Summary of findings from literature review

In gathering information for the report, we conducted a wide-reaching literature review. Where possible, we focused on studies that assess the benefits of investment and roll-out of full-fibre (FTTP) networks or 'ultrafast' networks at the local level, both internationally and in the UK, and the expected impacts from the availability of 5G.

For studies relating to fixed broadband, we recognise that the evidence base surrounding the impact of full-fibre is more limited than that used for studies assessing the benefits of access to increased broadband speeds (e.g. upgrades to superfast broadband) and the presence of broadband more generally. However, we have identified a number of studies that do focus on FTTP roll-out. Separate from the impact of improvements in fixed broadband, we also sought evidence or case studies on the expected benefits of 5G.

Many of the studies described below present quantitative estimates of each of the main impacts. While some of these studies are based on ex post assessments of superfast broadband programmes (e.g. the various BDUK schemes in the UK), others have focused explicitly on the impacts of increased FTTH penetration or on 5G. In terms of applicability to our study, we put more weight on the findings relating directly to FTTH deployment and 5G; however, the evidence base for the impacts of superfast broadband provides valuable indicative metrics where FTTH studies fall short.

An overview of the studies reviewed is given below. A full bibliography is provided in Appendix A3 of this report.

A1.1 Impacts on existing businesses

Access to improved connectivity opens up opportunities to existing businesses to improve the quality of existing services, the efficiency of their provision, the ability to offer new services, and improved market access. For example, Regeneris (2018) outlined the opportunities for existing businesses to expand, innovate and open new markets, thereby generating productivity improvements and allowing businesses to operate more efficiently and to develop new products and services enabled by access to full-fibre broadband.

Oxera (2017) considered the benefits of investment in enhanced business broadband services for small businesses in terms of being able to communicate through videoconferencing and to collaborate in real time on projects using cloud-based services. This could help to reduce costs through improvements in multitasking and perhaps reduced number and size of business premises.

Deloitte (2015) found that increased adoption of the cloud, big data analytics and IoT devices (facilitated by full-fibre and 5G) could stimulate new business models. The adoption of the cloud facilitates remote working, and accessing products through websites will also result in time savings and allow businesses to extend their market reach (e.g. internationally).

Several studies include surveys of businesses benefiting from significant improvements in broadband speeds as a result of access to newly deployed superfast or fibre broadband. Existing businesses report a wide range of benefits attributable to improved broadband access. For example, SERIO et al. (2015) investigated the impacts of new superfast broadband networks in Cornwall and found that businesses reported that faster connections:

- saved them time and/or money;
- enabled them to work in new and different ways;
- allowed them to grow;
- helped them to develop new goods and services; and generate new sales or access new markets.

Department for Digital, Culture, Media & Sport (2017) also found that SMEs reported that faster broadband had the following benefits for their business:

- 86% of SMEs that responded reported that their broadband upgrade had increased their employees' effectiveness;
- 83% reported improved efficiency;
- almost 70% reported increased speed and reliability of delivering goods or services;
- 45% reported that their upgrade had improved their ability to develop new goods or services;
- over 35% reported that their upgrade has generated new sales and provided access to new markets, and 19% reported that their upgrade had an impact on exports.

Rural England and SRUC (2018) found that survey respondents reported several benefits from their digital take-up, facilitated by better broadband services. Benefits most frequently mentioned included improving access to customers/suppliers; improving business efficiency; improving data storage and security; and enabling more business flexibility.

Ipsos MORI (2018) found that firms located in postcodes seeing a boost in broadband speeds benefit from increased turnover and improvements in productivity approximated by turnover per worker, compared with areas that did not benefit from the scheme.

SQW (2013) found that the bulk economic impact from upgrades to broadband infrastructure comes from improvements in the productivity of broadband-using firms. While Regeneris (2012) considered that knowledge-based industries, and the places where they are most concentrated, are expected to exploit faster broadband most effectively and generate the greatest impacts.

There may also be significant benefits to firms being able to make use of new services that improve their business processes and improve productivity. For example, 5G is capable of facilitating millions of connected devices that could be used for more advanced asset tracking, remote control, predictive maintenance and sensor-enabled optimisation of processes, allowing for increased in productivity across sectors (see Deloitte, 2018). One often-cited example is of the agricultural sector benefiting from 'smart farming' applications through the integration of sensor networks facilitated by 5G technologies.[124] Manufacturing sectors are also expected to benefit through 5G-enabled remote control and monitoring of factory equipment to bring operational benefits and increased productivity.[125] For example, Regeneris (2018) considered that increased manufacturing productivity would be enabled by a digital revolution

[124] For example, Ericsson (2018); EPRS (2016); and Little (2017).
[125] For example, 5GPP (2015); Little (2017); and Ericsson (2018).

in manufacturing ('Industry 4.0') and connected IoT devices facilitated by full-fibre and 5G.

Table A1.1 Summary of metrics supporting an impact on productivity

Change in speed/penetration	Impact on	Magnitude of increase
Doubling of broadband speed[1]	Productivity	0.30%
Increase in speed		
from 20 Mbit/s to 64 Mbit/s (average)	Turnover per worker (average)	0.32%
of around 100–200Mbit/s	Turnover per worker (average)	1.20%
of >200Mbit/s	Turnover per worker (average)	3.80%
from 20 Mbit/s to 64 Mbit/s (average)	Turnover per worker (education sector)	4.70%
	Turnover per worker (health sector)	3.70%
	Turnover per worker (manufacturing)	0.80%
	Turnover per worker (professional services)	0.70%

Source: [1] SQW (2013), and used by a number of other studies. All other data taken from Ipsos MORI (2018).

Note: SQW (2013) estimated productivity gains based on an assumption of the impact of a doubling of speed, for which the central estimate is 0.3% (i.e. an increase of 100% in the used speed in a year will lead to a 0.3% uplift in productivity, over the following three-year period). However, this was an input to a model rather than based on findings from an ex post evaluation. The findings from Ipsos MORI (2018), however, are based on findings from an ex post evaluation of the impact of firms upgrading to superfast broadband, tracking the impacts over different changes in speed.

Table A1.2 Summary of metrics supporting an impact on firm turnover

Change in speed/penetration	Impact on	Magnitude of increase
Increase in speed from 20 Mbit/s to 64 Mbit/s (average)	Firm turnover (average)	1.20%
	Firm turnover (urban)	1.40%
	Firm turnover (rural)	1.20%
Increase of around 100–200Mbit/s	Firm turnover (average)	1.20%
Increase of > 500Mbit/s	Firm turnover (average)	5.80%

Source: Ipsos MORI (2018).

Table A1.3 Summary of metrics supporting an impact on GVA

Change in speed/penetration	Impact on	Magnitude of increase in
Upgrade to superfast broadband[1]	GVA of area (rural)	0.30%
	GVA of area (town)	0.50%
	GVA of area (city)	0.40%
	GVA of area (capital city)	0.50%
Presence of broadband[2]	GVA per firm (manufacturing and construction)	0.14%
	GVA per firm (knowledge-intensive)	0.58%
	GVA per firm (other services)	0.32%

Source: [1] Regeneris (2012); [2] Micus Management (2008).

A1.2 Impact on new business start-ups

A large number of studies have considered the impact of improved broadband and access to fibre networks on the number of businesses in a local area. Increases may arise from genuinely new business start-ups capitalising on gigabit broadband or from attracting established businesses to move into the area (at the expense of the areas they move from). For example, Regeneris (2018) considers that access to gigabit capabilities will facilitate new businesses operating new digital-dependent business models at lower cost and more flexibly than established businesses. However, as SQW (2013) noted, this may be at the expense of the decline of more traditional businesses in sectors, which are disrupted by the new technology.

SQW (2013) found that faster broadband also helps to support the creation of new businesses, as the easier access to market information reduces barriers to entry. Regeneris (2012) corroborates this, outlining that superfast broadband is expected to help greater numbers of new businesses emerge by reducing barriers to entry. There are several ways in which this can occur, and Regeneris (2012) considered that cloud computing is perhaps the most significant, as it would sharply reduce the upfront capital and ongoing support costs of setting up a new business, and support flexible growth.

Ipsos MORI (2018) found up to 80% of increased turnover and productivity of firms located in postcodes seeing a boost in broadband speeds was driven by the relocation of firms to postcodes with better connections. Results from a study in France (Hasbi, 2017) also suggest that very high speed broadband networks enhance the attractiveness of municipalities for companies, and results from Sweden (OECD, 2015) suggest that increases to a municipality's economic attractiveness lead to the establishment of more companies (or the decision of existing ones to stay). Hasbi (2017) found that companies from the tertiary sector, which rely more on ICT, are more likely to be attracted by very high speed networks and found that, on average, very high speed broadband networks have a positive impact on the creation of small businesses.

Table A1.4 Summary of metrics supporting an impact on new business start-ups

Change in speed/penetration	Impact on…	Magnitude of increase
Increase in speed of around 100–200Mbit/s[1]	Number of firms located in postcode area	0.40%
Presence of a very high speed broadband network[2]	Number of companies operating in a municipality	3.20%
10% increase in the percentage of households with access to fibre Internet[3]	Number of companies operating in a municipality	0.10%
10% higher fibre penetration[4]	Additional companies per 12,000 inhabitants	1

Source: [1] Ipsos MORI (2018); [2] Hasbi (2017); [3] Lapointe (2015); [4] OECD (2015).

A1.3 Employment impacts

Expansion of existing businesses or the creation of new ones can lead to increased participation in the labour market and higher employment levels in areas benefiting from better fixed broadband access.[126] Better broadband will

[126] During the quantification exercise, it will be important to ensure that there is no double-counting of benefits, for example, through capturing the benefits of new employment for both businesses and customers.

also improve opportunities for remote working and the safeguarding of employment in areas that might otherwise have been at an disadvantage in terms of broadband availability/speeds, as noted in SQW (2013).

Ipsos MORI (2018) found evidence to support the hypothesis of reductions in unemployment in the areas benefiting from superfast broadband programmes relative to those that did not.

Singer et al. (2015) considered that fibre deployment to 100% of a region is associated with an increase in employment of approximately 2.9%. The authors explicitly recognise that 'the positive employment impact is specific to FTTP deployment, and is over and above the employment benefits that arose from previous broadband deployment', implying that there may be increasing returns to speed. The idea of increasing returns is also supported by evidence presented by Bai (2017), which shows that an increase in broadband speed from 100 Mbit/s to 1 Gbit/s has a greater impact on country-level employment than increasing speeds from 3 Mbit/s to 100 Mbit/s.

The local jobs market may also be protected by reduced migration away from areas (safeguarding jobs). For example, Xiong (2013) found that fibre penetration in Sweden had a significant impact on the population's evolution, especially the net amount of migration into a municipality, which indicates the attractiveness of municipalities per se. OECD (2015) also suggested that higher employment could be explained through increases to a municipality's economic attractiveness, leading to the establishment of more companies (or the decision of existing ones to stay) and greater efficiency of the labour markets. Similarly, Forzati and Mattson (2012), in their study of FTTP in Swedish municipalities, found that an increase in roll-out of FTTP was linked to both higher migration and a positive change in employment.

Regeneris (2012) considered that widespread availability of superfast broadband will allow much more flexible working patterns, opening up new employment opportunities and enhancing the productivity of existing staff. This was supported by findings from SERIO et al. (2015) on the introduction of superfast broadband in Cornwall, which reported that superfast broadband had allowed employees to work remotely and/or more efficiently from home, and that superfast was an important factor in the decision of some participants to work from home more. SQW (2013) also found benefits to better broadband from productivity-enhancing time savings for teleworkers. To the extent that increased productivity comes from more hours being worked due to less time traveling, this time is, by definition, not being used for increased leisure; as such, only one of these impacts should be accounted for in the benefits assessment.

Regeneris (2018) considered that the rise in flexible working practices could be further enhanced through full-fibre roll-out by enabling gigabit cloud, file transfer and communications/conferencing applications, which could also deliver additional productivity benefits.

Note that increased employment in one area might be offset by reductions of employment in other businesses, either within or outside the intervention area, so such findings must be interpreted with care when assessing net impacts.

In some cases, there are also reports of direct employment impacts arising from network build (i.e. increased employment in the construction sector). However, we consider that it would be inappropriate to include this within the calculation for benefits at the local level, as these employment changes are likely to be transitory and unlikely to result in genuinely new employment for

the local area. Those carrying out the construction works are likely to be employed centrally by a telecoms, engineering or construction company rather than being hired locally, and thus this should not be considered a direct impact on the local area. The exception would be if there were a supporting policy to require that the full-fibre of 5G investment programme provides employment and training to some of the local workforce such that those workers benefit from improved long-term employment prospects.

Table A1.5 Summary of metrics supporting an impact on employment

Change in speed/penetration	Impact on	Magnitude of increase
Increase in speed from 20 Mbit/s to 64 Mbit/s (on average)[1]	Employment (average)	0.80%
	Employment (urban)	1.30%
	Employment (rural)	0.60%
10% higher fibre penetration[2]	Employment (average)	1.10%
	employment (low urbanisation municipality)	1.10%
	Employment (medium urbanisation municipality)	0.70%
	Employment (highly urbanised municipality)	1.70%
100% fibre deployment in the region[3]	Employment	2.90%
10% increase in the proportion of households with access to fibre Internet[4]	Employment	0.13%
10% increase in the proportion of population living within 353 metres of a fibre-connected premises[5]	Employment	0.20%
Upgrade to superfast broadband[6]	Jobs created per connected business (average)	0.18 net FTE
	Jobs safeguarded per connected business (average)	0.42 net FTE

Source: [1] Ipsos MORI (2018); [2] OECD (2015); [3] Singer et al. (2015); [4] Lapointe (2015); [5] Forzati and Mattson (2012); [6] SERIO et al. (2015).

A1.4 Private benefits to consumers/households

Some studies have considered the benefits to consumers in terms of lower prices resulting from increased competition. For example, Oxera (2017) considered that introducing a new high-speed network into an area (alongside an existing network) could introduce network competition to an area for the first time—for example, where consumers and businesses previously had access only to services provided over the incumbent's network. Further evidence shows that this competition puts downward pressure on prices for a given level of service, resulting in cost savings, and thus a monetary benefit to consumers. For example, Smith et al. (2013) found that a 10% increase in the market share of a non-DSL competitor was associated with a 1.6% fall in price in that market.

These benefits are likely to emerge only where the deployment of full-fibre in the area does stimulate greater competition, either through infrastructure-based competition between competing networks, or by opening the market to significant competition at the retail level (for example, where the new network employs a model of open access).

There may also be significant benefits to consumers from being able to access innovative services. This will be particularly relevant to benefits associated with 5G, as services previously unavailable over existing technologies will come to market (for example, a wider range of IoT devices and smart devices and services enabled by 5G). Deloitte (2017) noted possible examples of new consumer devices and services, including immersive media and entertainment, new healthcare wearables, and connected vehicles.

A large number of studies have also considered private household benefits in terms of increases in house price and housing wealth. For example, Regeneris (2018) and FTTH Council Americas (2015) both considered that access to fibre increases a home's value. Ahlfeldt et al. (2017) also found a causal effect of broadband speed on property prices, and that the increase in value is greater when starting from relatively slow connections.

SQW (2013) considered the value of household savings associated with additional teleworking and the value of leisure time saved through increased teleworking. However, we note that any measure of increased leisure time as a result of less travel time to work cannot necessarily be counted in addition to impacts associated with improved productivity as a result of working from home. To the extent that increased productivity comes from increased hours worked (due to less time travelling), this time is, by definition, not being used for increased leisure. We need to be careful to avoid double-counting the benefits arising from increased flexible working practices.

There is emerging evidence to suggest that greater access to higher broadband capabilities may have an impact on subjective personal wellbeing.[127] For example, Simetrica (2018) found that this may be as a result of the greater range of entertainment or education options, increased social inclusion, increased leisure time that improved connectivity could enable. However, it may not all be positive as greater social isolation as a result of reduced face-to-face contact, Internet addiction or increased incidence of online crime may lead to lower personal wellbeing.[128]

Rather than quantify the benefits of any one particular service being provided over the full-fibre or 5G connection, measures of consumer value and wellbeing can instead be calculated using an estimate of the consumer surplus impact of all these services taken together.[129] A simple metric for **consumer surplus** can be estimated by comparing the amount that consumers would be willing to pay for a step change in connectivity through upgrades to full-fibre and 5G with an estimate of the amount that consumers actually pay to purchase this upgrade. This was an approach taken in Oxera (2017), where it was estimated that customers were willing to pay an extra €10 per month for fibre to the home connectivity and enhanced services (based on a review of literature and survey evidence). This was then compared against the additional amount that consumers would have to pay for improved connectivity, to provide an estimate for consumer surplus.

A1.5 Benefits to local authorities and local service provision

Few of the studies reviewed as part of this research have focused explicitly on the benefits to LAs. This is an area where evidence is lacking and further work

[127] The Office for National Statistics has reported that: 'Personal wellbeing is a particularly important dimension which we define as how satisfied we are with our lives, our sense that what we do in life is worthwhile, our day to day emotional experiences (happiness and anxiety) and our wider mental wellbeing.'
[128] Simetrica (2018).
[129] The consumer surplus is the net benefit a consumer receives from consuming a good. It is the difference between a consumer's willingness to pay for a good and the price they actually pay for the good.

is needed to improve the evidence base, supported by more evaluation projects of local fibre investments (including, for example, the Department for Digital, Culture, Media & Sport's Local Full-fibre Networks Programme).

Greater access to faster broadband speeds facilitated by fibre investments could bring cost savings in the delivery of public services. For example, Regeneris (2018) reported that 'full-fibre will allow residents and businesses to interact with local government and public services in a more seamless way as full-fibre opens additional means of delivering public services.' However, no further details or evidence was provided to explain the mechanism through which this could be achieved.

Forzati and Mattson (2012) considered the example of Stockholm fibre network, and described how schools and hospitals have introduced functions that are possible only with a fibre connection (without providing explicit details). The authors suggested that, in the medium to long term, public administrations will benefit from a number of effects, including increased efficiency and cost reductions in relation to improvements in e-government and e-health services, for example.

Forzati and Mattson (2012) also estimated cost savings to the city and county council as a result of access to the FTTP network, partly due to increased efficiency (reduced equipment, energy consumption, and footprint per unit of transmitted information), and partly to the fact that fibre networks with high capacity allow for more competition. For instance, in Stockholm there are about 90 different operators on the open fibre network. However, we acknowledge that competition benefits arising from an open access fibre model may not be directly applicable to local areas in the UK if the investment is initially carried out by a private investor.

5G could be a key enabler of smarter infrastructure and public services leading to more efficient and secure service delivery. For example, improvements to traffic management systems and energy grids could be enhanced by 5G. In its literature review, Deloitte (2018) noted:

> Significant attention has been devoted to 'smart cities', with many cities establishing smart city strategies. 5G in expected to be a key enabler of low-cost, mMTC-capable smart public infrastructure. This is expected to lead to a number of wider impacts, such as increased public safety, lower costs, higher revenues and environmental benefits, although further analysis is needed to quantify the net benefits for municipalities.

Regeneris (2018) also considered that smart cities infrastructure facilitated by full-fibre and 5G could lead to reductions in energy use, congestion and fuel costs stemming from smart energy and traffic systems.

Although difficult to quantify, there may also be an option value associated with having future-proof technology in place. For example, even if we do not know the exact applications that will run in future, there will be some value to having the capacity on the network ready to meet the needs of these services as soon as they become available.

A1.6 Wider social/public benefits

There are potentially much wider-reaching impacts of improvements in fibre and 5G connectivity that could be considered as social benefits—for example, arising from improved social inclusion (reducing the digital divide between locations) and externality impacts in terms of improved health, wellbeing, environmental benefits, and the 'smart' transformation of local areas.

Ipsos MORI (2018) looked at the benefits that access to superfast broadband can provide in terms of connecting people to others. This could also be important in terms of digital and social inclusion, reducing the digital divide between locations. SERIO et al. (2015) found that greater access to superfast broadband in Cornwall did lead to greater digital inclusion, with surveys indicating that those who were previously isolated were able to become engaged.

Ipsos MORI (2018) also considered the role of the Internet in accessing educational content, which is becoming increasingly important. Regeneris (2018) estimated that full-fibre will accelerate new more flexible ways for students to learn remotely and to use interactive e-learning tools, and that advances in connected health technologies (facilitated by 5G and the IoT) could lead to healthcare benefits.

Environmental benefits may arise through carbon reduction. While environmental benefits are outside the scope of this study, we note them for completeness. For example, OECD (2015) found that increased fibre penetration leads to less car use as a result of more tasks being done remotely, reducing the need for transport (for example, including online shopping and teleworking). SERIO et al. (2015) found evidence of a reduction in business travel among some businesses after upgrading, and proposed that the carbon-abatement potential of the superfast broadband project in Cornwall far outweighs the carbon impact. SQW (2013) also explored the routes to environmental impacts associated with improved broadband capabilities in a local area through increased teleworking, reduced business travel, and increased cloud computing.

A1.7 Further comment on 5G

Many of the studies referred to above focus on the benefits of fixed broadband; however, improvements in connectivity also relate to changes in mobile connectivity related to the launch of 5G services.

Where studies assessing the impacts of 5G are available, they are necessarily more speculative in nature, given the limited deployment of commercial 5G and a large unknown as to the actual use cases for 5G that might materialise in the future beyond improvements in mobile broadband capabilities (referred to as ‘enhanced mobile broadband’).

With capabilities for significant improvements in reliability, capacity and peak data rates provided over mobile broadband, 5G may also lead to many of the same benefits as those expected from improvements in fixed broadband speeds, and are captured within our framework for assessing improvements in connectivity. This may be especially relevant to those areas where roll-out of fibre broadband may be less commercially attractive than providing a wireless solution over 5G.

However, 5G could bring further incremental benefits by enabling new services to be provided, and creating opportunities that could benefit specific industries or businesses within a local area. For example, many studies focus on the expected impacts of specific use cases for 5G that rely on its capability to support:

- massive machine-type communications—connectivity of millions of devices to enable the IoT, asset tracking, smart agriculture, smart home devices, remote monitoring;

- ultra-reliable, low-latency communications—resilient, instantaneous connectivity to facilitate/enable use cases such as autonomous vehicles, smart grids, remote patient monitoring, industrial automation.[130]

Many of the studies we identified have attempted to assess the potential benefits by considering specific use cases. Typically, they focus on four 'verticals' (automotive, healthcare, transport, utilities) and four 'environments' (smart cities, non-urban areas, smart homes, and smart workplaces).[131] We have discussed some of these examples in the case studies provided in the main report.

For illustrative purposes we present a small number of use cases that might be relevant at a local level, and the range of expected impacts in the table below.

Table A1.6 Example 5G enabled use cases and benefits estimates

Beneficiary	Use case	Impacts
Consumers	5G-enabled smart grids and smart metering	£145 off consumer energy bills[1]
	Connected rubbish collection through smart bins	£66 off council bills[1]
Manufacturing sector	Remote control and monitoring	3% increase in production output[2]
	Use of 5G-enabled IoT, cyber-physical systems' and 'additive manufacturing'	Savings of 15% to 50% on the operations process[3]
Healthcare providers	IoT-based health sensors	Savings of 10% in healthcare costs[4]
Wider society	Smart traffic management systems	10% reduction in congestion (of which 50% could be associated with 5G dynamic data exchange capabilities)[5]

Source: [1]Juniper Research (2018); [2] Ludgren et al. (2017); [3] Little (2016); [4] McKinsey (2013); [5] Tech4i2 et al. (2014).

[130] These examples are referred to in a large majority of the literature, based on key usage scenarios for 5G identified by the ITU in 'IMT Vision – Framework and overall objectives of the future development of IMT for 2020 and beyond. Recommendation ITU-R M.2083-0', accessed 12 April 2019.
[131] For example, the 5GPP published a number of case studies in 2015 including: '5G and e-Health', '5G and the Factories of the Future', '5G and energy', and '5G Automotive Vision'.

A2 Key statistics for stylised Local Authority area types

Table A2.1 Key statistics for Local Authority area types

Characteristic (averaged across LA in area type)	Metric	Mainly rural	Largely rural	Urban with significant rural	Urban with city and town	Urban with minor conurbation	Urban with major conurbation
Baseline coverage and speed	% of premises unable to receive 30Mbit/s[132]	12	9	7	3	3	3
	% of premises unable to receive broadband at or above 10Mbit/s[133]	5	3	2	1	1	1
Population density[134]	Number of persons per hectare[135]	1.2	2.0	3.7	18.6	12.8	41.6
Households	Number of households per LAD[136]	41,694	66,644	54,072	61,798	102,567	105,021
Number businesses	Number of local business units per LAD[137]	5,561	7,985	6,800	6,518	8,434	13,553
Business size[138] (share of total local business units)	0–4 employees	72.9%	72.2%	71.8%	68.6%	68.3%	73.3%
	5–9 employees	13.4%	13.2%	13.1%	13.8%	13.7%	12.1%
	10–19 employees	7.3%	7.4%	7.5%	8.3%	8.4%	7.0%
	20–49 employees	4.4%	4.7%	5.0%	5.7%	6.0%	4.6%
	50–99 employees	1.3%	1.5%	1.5%	2.0%	2.0%	1.7%

[132] Ofcom (2019), Connected nations Fixed-LAUA data, Spring https://www.ofcom.org.uk/research-and-data/multi-sector-research/infrastructure-research/connected-nations-update-spring-2019
[133] Percentage of premises that do not have access to download speeds at or above 10Mbit/s and upload speeds at or above 1Mbit/s including non-matched records and zero predicted speeds. Ofcom (2019), Connected nations Fixed-LAUA data, Spring https://www.ofcom.org.uk/research-and-data/multi-sector-research/infrastructure-research/connected-nations-update-spring-2019
[134] We acknowledge that published metrics of population density for an LA area may provide a distorted picture of the density of households within residential areas. For example, for very rural areas, where population may be based in a specific village or hamlet surrounded by large areas of uninhabited land the population density will be very low, but the population may be clustered in a single area.
[135] Office for National Statistics 2011 census data, Table P04UK 2011 Census: Population density, local authorities in the United Kingdom.
[136] Office for National Statistics (2018), 'Estimated number of households by local authorities of England, 2004 to 2016', June.
[137] Office for National Statistics (2018), 'UK BUSINESS: ACTIVITY, SIZE AND LOCATION - 2018 (Table 16 - Number of VAT and/or PAYE based local units in districts, counties and unitary authorities within region and country by broad industry group (UK, 2018)).
[138] Office for National Statistics (2018), 'UK BUSINESS: ACTIVITY, SIZE AND LOCATION - 2018 (Table 22 - Number of VAT and/or PAYE based local units in districts, counties and unitary authorities within region and country by employment sizebands (UK, 2018)).

Characteristic (averaged across LA in area type)	Metric	Mainly rural	Largely rural	Urban with significant rural	Urban with city and town	Urban with minor conurbation	Urban with major conurbation
	100–249 employees	0.6%	0.8%	0.9%	1.1%	1.1%	0.9%
	250+ employees	0.2%	0.3%	0.3%	0.5%	0.4%	0.4%
Industry type[139] (share of total business units)	Knowledge-intensive[140]	19%	22%	25%	24%	19%	29%
	Health	4%	5%	5%	6%	6%	6%
	Education	2%	2%	2%	3%	3%	2%
	Production[141]	6%	6%	6%	6%	7%	5%
Business turnover (£m)[142]	Average per local business unit[143]	3,140	5,083	4,714	4,799	5,995	11,275
Labour market conditions	Average number of jobs per LAD[144]	51,022	77,821	68,471	85,054	119,222	157,587
	Unemployment rate (%)[145]	3.0	3.3	3.4	4.1	5.0	4.6
Turnover per worker (£)[146]	Business turnover / jobs (rounded to nearest £1,000)	62,000	65,000	69,000	56,000	50,000	72,000

[139] Office for National Statistics (2018), 'UK BUSINESS: ACTIVITY, SIZE AND LOCATION - 2018 (Table 16 - Number of VAT and/or PAYE based local units in districts, counties and unitary authorities within region and country by broad industry group (UK, 2018)).
[140] Includes industry types J (Information and communication), K (Finance and Insurance), M (Professional, scientific and technical).
[141] Includes industry types B, D and E (Mining, quarrying and utilities) and C (manufacturing).
[142] Office for National Statistics (2018), UK BUSINESS: ACTIVITY, SIZE AND LOCATION - 2018 (Table 11 - Number of VAT and/or PAYE based enterprises in districts, counties and unitary authorities within region and country by turnover sizebands (UK, 2018)).
[143] The Office for National Statistics data presents the number of firms in each LA by turnover sizebands. We estimate the total turnover of businesses in the local area by multiplying the number of businesses inside a particular turnover sizeband and the mid-point of the sizeband, and summing across all sizebands to give an estimated turnover per LA. This relies on a simplifying assumption that firms within each turnover sizeband are uniformly distributed within the band.
[144] Office for National Statistics, LI01 Regional labour market: Local indicators for counties, local and unitary authorities.
[145] Office for National Statistics, M01 Regional labour market: Modelled unemployment for local and unitary authorities (Table name: LA, UA Rates : Unemployment rates in local and unitary authorities) (Rate (%) Jan 2018 - Dec 2018). Unemployment rates calculated as percentage of 16+ economically active population.
[146] Turnover per worker estimated as the average turnover per area type divided by the average number of jobs per area type.

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