Evaluation of the Superfast Broadband Programme

Technical Appendix 3: Economic & Social Impacts

February 2023

Ipsos

Contents

Glossary

ADSL	Asymmetric Digital Subscriber Line - a technology that facilitates fast data transmission at a high bandwidth on existing copper wire telephone lines to homes and businesses.
Exchange Only Lines	Premises connected directly to the telephone exchange, rather than to a cabinet that is connected to the telephone exchange. These premises tend to be either very close to the telephone exchange or at long distances in remote locations.
FTTC	Fibre to the Cabinet – a technology involving the installation of fibre optic lines to connect the cabinet to the service exchange, with premises connected to the cabinet using the copper network.
FTTP	Fibre to the Premises – a technology delivering very fast broadband speeds, using fibre optic connections across the full connection between the premises and the Exchange.
Gigabit capable coverage	Refers to any technology able to provide download speeds of 1Gbit/s or faster.
NGA	Next Generation Access – broadband technologies capable of delivering superfast speeds, including Wireless, Fibre-to-the-Cabinet, Fibre-to-the-Premises, and cable.
OMR	Open Market Review – a process completed by Local Bodies to obtain information on the commercial plans of network providers to invest in superfast broadband infrastructure.
SCT	Speed and Coverage Template – a template developed by Local Bodies describing which postcodes or premises are eligible for subsidised coverage. The network provider completes the template as part of the tendering process to define which postcodes or premises they plan to upgrade as part of the proposed network build.
White area	Premises or postcodes identified as unlikely to receive commercial deployments of superfast broadband infrastructure within 3 years, through the Open Market Review and consultation process.

Acknowledgements

The authors would like to thank Dr Martin Foureaux Koppensteiner for his helpful comments on the methodology and interpretation of results as part of the peer review of this report.

1 Introduction

This Technical Appendix provides quantitative estimates of the economic and social impacts of subsidised broadband coverage delivered through the Superfast Broadband Programme between 2012 and 2021. The analysis is based on econometric analysis of a variety of administrative and secondary datasets providing longitudinal data at a small area level. The results of the analysis are combined to provide an assessment of the net social costs and benefits of the programme.

1.1 Aims and objectives

The Superfast Broadband Programme aims to provide gap funding to network providers to extend superfast broadband services to rural areas that would not benefit from commercial deployments. This Appendix provides a quantitative assessment of the economic and social benefits of the programme between 2012 and 2021. The analysis seeks to address the following questions defined by Building Digital UK (BDUK) in its overall evaluation plan for the Superfast Broadband Programme:

- What are the outcomes of the scheme?
- Was the investment cost-effective?

The analysis also seeks to address questions defined in the common methodology for State aid evaluation relating to the indirect impacts of the intervention (namely – has the scheme had spill-over effects on other firms or geographical regions?). [1] This Appendix considers the impacts of the programme in four key areas – its effects on businesses and the performance of local economies, workers, households, and the performance of public services (linked to the BDUK Benefits Realisation Framework below).

Table 1.1: Coverage of the BDUK Benefits Realisation Framework

Benefit type	Benefit	Coverage in this report
Productivity growth	Increased business productivity	Section 4
	New businesses established	Section 4
	Increased ICT skills and wider educational attainment	Section 7 (educational attainment)
Employment	Employment (safeguarded or new)	Section 4
Public sector efficiency	More efficient delivery and increased access to public services	Section 7
	Cross-Government learning for large procurement programmes	Not covered
Digital Divide	Reduced digital divide	Covered in Technical Appendix 1
Public Value	Improved quality of life and well-being	Section 5 (incomes), Section 6 (house prices)
	Consumer savings	Not covered
Reducing impact on the environment	Reduced impact on the environment	Not covered

Source: BDUK Benefits Realisation Framework. Note that benefits for 'Stimulating the Broadband Market' are not included in the table but are addressed by the State aid evaluation report.

[1] European Commission (2014) Common methodology for State aid evaluation (Commission Staff Working Document). Available at: https://ec.europa.eu/competition/state_aid/modernisation/state_aid_evaluation_methodology_en.pdf (accessed August 2020).

1.2 Methodology

The results set out in this paper have been produced by linking records of the delivery of the programme to administrative datasets providing longitudinal measures of the outcomes of interest at a postcode or small area level. A discussion of the datasets deployed in the analysis, data processing steps taken, and implications for interpretation of results are provided in the introductory passages of each section.

Estimates of the causal effects of subsidised coverage have been derived from econometric models comparing those areas benefitting from the programme in earlier years to those benefitting at later stages (a 'pipeline' design). [2] This approach will provide robust estimates of the impacts of the programme if there are no systematic differences between areas benefitting at different points in time that are also linked to the outcomes of interest (e.g. the capacity of areas to accommodate additional economic growth). Further details of the rationale for this approach, including tests of the underpinning assumptions) are set out in Section 3.

1.3 Key issues

The following issues should be borne in mind when reviewing the results presented in this Appendix:

- **Nature of results:** The results set out in this paper identify the effects of making superfast broadband infrastructure available. No data was available on the take-up of subsidised broadband infrastructure at an individual or firm level because take-up of subsidised infrastructure is monitored at the level of overall contracts rather than at the level of individual premises. As such, it was not possible to explore how far the impacts of the programme were driven by take-up of newly enabled superfast broadband services.

- **Additionality:** The findings in this paper focus on the economic and social impacts of subsidised coverage. As the analysis compares areas that did and did not have access to superfast coverage at different points in time, the estimates will account for the possibility that some users may have otherwise been able to substitute superfast broadband for other technologies (e.g. using mobile data services in place of fixed lines). However, they do not account for the possibility that network providers would have extended their networks without public funding (deadweight). This aspect of additionality is explored in Technical Appendix 1 (Reducing the Digital Divide), which provides estimates of the share of subsidised coverage that would not have come forward in the absence of the programme. Results from these parallel analyses are incorporated in the cost-benefit analysis presented in the final chapter, where the focus is on the net costs and benefits of the programme.

- **Differences across Phases:** Most premises upgraded by the programme received subsidised coverage under Phase 1 of the programme which was delivered between 2012 and 2016. These contracts primarily involved the delivery of Fibre-to-the-Cabinet (FTTC) solutions. Later phases of the programme were smaller in scale (in terms of premises upgraded) and involved a greater focus on Fibre-to-the-Premises (FTTP), which can offer substantially faster upload and download speeds. Where possible, estimates of the relative effects of different technologies have been provided though it should be noted that the more recent delivery of FTTP coverage means that less time has passed for impacts to accumulate.

- **Focus of the cost-benefit analysis:** A cost-benefit analysis of the Superfast Broadband programme is provided in the final section of this Appendix. This analysis focuses exclusively on Phase 3

[2] The analysis has been completed using both R & Stata. Stata was the primary software package for the modelling.

contracts (i.e. those funded under the 2016 to 2020 UK National Broadband Scheme) in line with the principal focus of this evaluation.

- **Population dynamics:** Some of the outcomes of interest – for example, the impacts of superfast broadband on residents' experiences of public services – could plausibly be driven by changes in the composition, or growth of, the resident population. These issues will be explored as part of the evaluation programme using small area data taken from the regular Office for National Statistics (ONS) Census of Population (which takes place every ten years). However, at the time of writing, only national level results from the 2021 Census were available.

- **COVID-19 pandemic:** The data deployed in this analysis covers the period in which social distancing restrictions were in place to manage the COVID-19 pandemic. The government introduced a substantial programme of universal and sector-specific economic support measures to mitigate against the adverse economic consequences of enforced closures of significant sectors of the economy during this period. However, the results of the analysis will partly capture the contributions of the programme to national resilience (for example, by enabling remote working or the delivery of public services e.g. General Practice consultations). Modelling has sought to control for the COVID-19 pandemic using dummy variables for specific lockdown periods and the overall period by the pandemic.

1.4 Structure of this report

The remainder of this report is structured as follows:

- **Section 2** provides an overall analytical framework for the study – describing the anticipated causal processes through which subsidised broadband coverage would be expected to deliver its intended social and economic impacts.

- **Section 3** provides a theoretical justification for the methodological approach adopted.

- **Section 4** provides an analysis of the impact of the programme on businesses and local economies.

- **Section 5** provides an analysis of the impact of the programme on workers.

- **Section 6** provides an analysis of the impact of the programme on households.

- **Section 7** provides an analysis of the impact of the programme on the performance of public sector services.

- **Section 8** provides a cost-benefit analysis of Phase 3 of the Superfast Broadband Programme (contracts awarded as part of the 2016-2020 UK National Broadband Scheme).

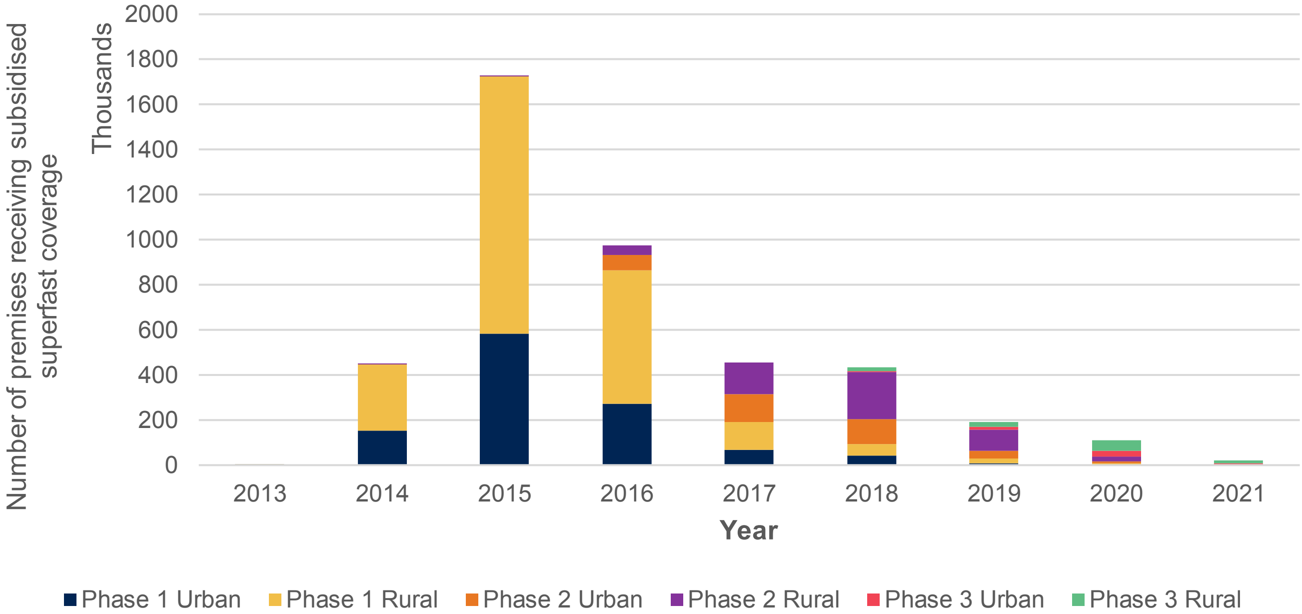
2 Analytical framework

This section provides an overarching analytical framework for the assessment of the economic and social benefits of the Superfast Broadband Programme. This explains how the anticipated outputs of the programme (i.e. increased availability of superfast broadband services) can be expected to lead to downstream impacts in the four key areas under consideration in this study. This is intended to provide an organising framework for the empirical analysis that follows, setting out the key hypotheses to be tested and giving guidance on interpretation.

2.1 Superfast Broadband Programme

The Superfast Broadband Programme aims to provide gap funding to network providers to extend superfast broadband services to rural areas that would not otherwise benefit from commercial deployments. The figure below provides an overview of the number of premises receiving subsidised coverage between 2013 and 2021, under Phase 1, 2 and 3 of the programme. While the programme was notionally aimed at rural areas, eligible areas included all areas market as 'white' as part of the Open Market Review and Public Consultation process resulting in some delivery in areas classed as 'urban'.

Figure 2.1: Number of premises receiving superfast (30Mbit/s[3]) coverage subsidised by BDUK between 2013 and September 2021, Phase 1, Phase 2, and Phase 3[4]



Source: C3 reports, Ipsos analysis. Note that delivery has been assigned to the period covered by the relevant annual Connected Nations report and do not always cover a 12-month period.

2.2 Impacts on businesses and local economic performance

The impact of the programme on businesses is expected to involve the following processes:

- **Take-up:** It is expected that the benefits of the programme will be realised – in the first instance – by firms taking up superfast broadband connections. Incentives to adopt the technology could be limited to firms for which it would be profitable to take-up superfast connectivity (relative to basic or slower broadband speeds), but who are not so dependent on bandwidth that they faced incentives

[3] 24MBits for Phase 1 and Phase 2

[4] Data allocated to Connected Nation years and not calendar or financial years (distinction provided above in data section)

to obtain faster connectivity through lease[5]d lines or by relocating to areas where faster speeds were already available. This creates an expectation that the primary users of the superfast coverage made available will be small and medium-sized or new enterprises (SMEs) making use of asymmetric subscriber lines – rather than large firms with the scale needed to make leased lines commercially viable or digitally intensive firms where faster and more reliable connectivity is central to the underlying business model. The shift in emphasis from FTTC to gigabit capable technologies in Phase 3 of the programme may alter these incentives – making faster speeds (and symmetric connections) available may increase the number and types of firms that could potentially benefit from the programme.

- **Usage:** Faster and more reliable connectivity can potentially enable several productivity or growth enhancing investments. A 2018 review[6] of the benefits of ultrafast network deployment highlights several potential business applications of faster connectivity:

  - **Access to new markets:** On-line channels to market are becoming an increasingly important source of revenues to businesses in the UK, rising to £688bn in 2018 from £375bn in 2009.[7] A 2010 Government review highlighted that the use of ICT and broadband can enable small businesses to access to new markets.[8] A 2016 review of the impact of fibre connectivity on SMEs in the South West of England, provides numerous examples of how superfast connectivity has reduced barriers to entering export markets.[9]

  - **Cloud computing:** Cloud computing offers opportunities for businesses to raise their efficiency by moving to ‘on-demand’ computer system resources (such as data storage and computing power) and realise economies of scale by sharing those resources with other users via off-site servers. This can reduce the costs associated with maintaining physical servers on site and the scale of internal IT support requirements. One case drawn out in the Ofcom review highlighted that retailers would need to set their IT requirements to accommodate busy periods (e.g. during the holiday season), resources that would lie idle during normal periods.[10] Cloud computing services allow retailers to scale their usage to demand on an on-going basis, raising productivity. Cloud computing solutions typically require both high upload and download speeds.

  - **Internet of things**: The internet of things describes products, applications and services that are driven by devices that collect data from sensors and communicate with each other through local or wide area networks. This creates opportunities to realise efficiencies through automation and analytics by enabling more rapid and effective decision making.[11] One example is the energy efficiency savings that are possible using smart meters to manage energy and heat consumption in industrial contexts. Another example would be efficiency gains from knowing exactly where along the production line a good may be or the reduced maintenance time required for equipment if regular maintenance is enabled through sensors after a certain condition is met e.g. actions performed for assembly equipment. Again, as these applications are data intensive, higher capacity networks are needed to enable their implementation.

[5] BSI (2010) Britain’s Superfast Broadband Future
[6] Ofcom (2018) The Benefits of Ultrafast Network Deployment
[7] ONS (2018) E-commerce and ICT activity
[8] BSI (2010) Britain’s Superfast Broadband Future
[9] Plymouth Business School (2016) The Impact of Fibre Connectivity on SMEs: Benefits and Business Opportunities.
[10] Ofcom (2018) The Benefits of Ultrafast Network Deployment
[11] OECD (2016) Seizing the Benefits and Addressing the Challenges

In turn, making superfast connectivity available would be expected to have the following direct economic impacts:

- **Productivity gains:** Numerous studies have shown that faster broadband stimulates productivity growth. Adoption of superfast broadband could raise the productivity of local firms in several different ways. As noted, these improvements may take time to arise, and complementary business investments may be required to take advantage of higher speeds.

- **Turnover:** The adoption of superfast broadband may also aid firms to expand their sales directly by opening new channels to market, e.g. through enabling them to integrate into global supply chains. Sales may grow indirectly if any productivity gains resulting from the adoption enable them to lower their prices, raise quality and claim market share from their competitors.

- **Employment:** Where firms expand their sales, they may also increase their demand for workers (or other inputs), creating jobs in the local economy. This may have differential effects across occupational groups. For example, past research indicates the availability of higher skilled workers is a key factor determining the degree to which firms can exploit the benefits of faster broadband (as flagged below).

However, these direct impacts may lead to a range of indirect effects:

- **Displacement:** The expansion of firms may lead to offsetting effects elsewhere in the economy. Firstly, firms may take market share from domestic competitors, causing them to reduce their levels of output (GVA) and employment (product market displacement).

- **Crowding out:** Expansion of demand may also place upward pressure on local wages and prices, potentially encouraging other firms locally to reduce their output (crowding out).[12] The Superfast Broadband Programme may also crowd out private investment in superfast broadband in infrastructure – this possibility is explored in Technical Appendix 1.

- **Sorting effects:** The programme may also result in local economic benefits through the spatial reallocation of economic activity. Several studies[13] have illustrated that the availability of broadband makes economic activities more viable in less central locations, with the employment impacts associated with the availability and adoption of broadband often found to be stronger in rural or less central locations than in metropolitan urban areas:

  - **Relocation of firms:** This suggests the programme could lead to 'sorting effects' in which the areas benefitting attract firms located elsewhere, resulting in positive local economic impacts (though little, if any, change at a national level).

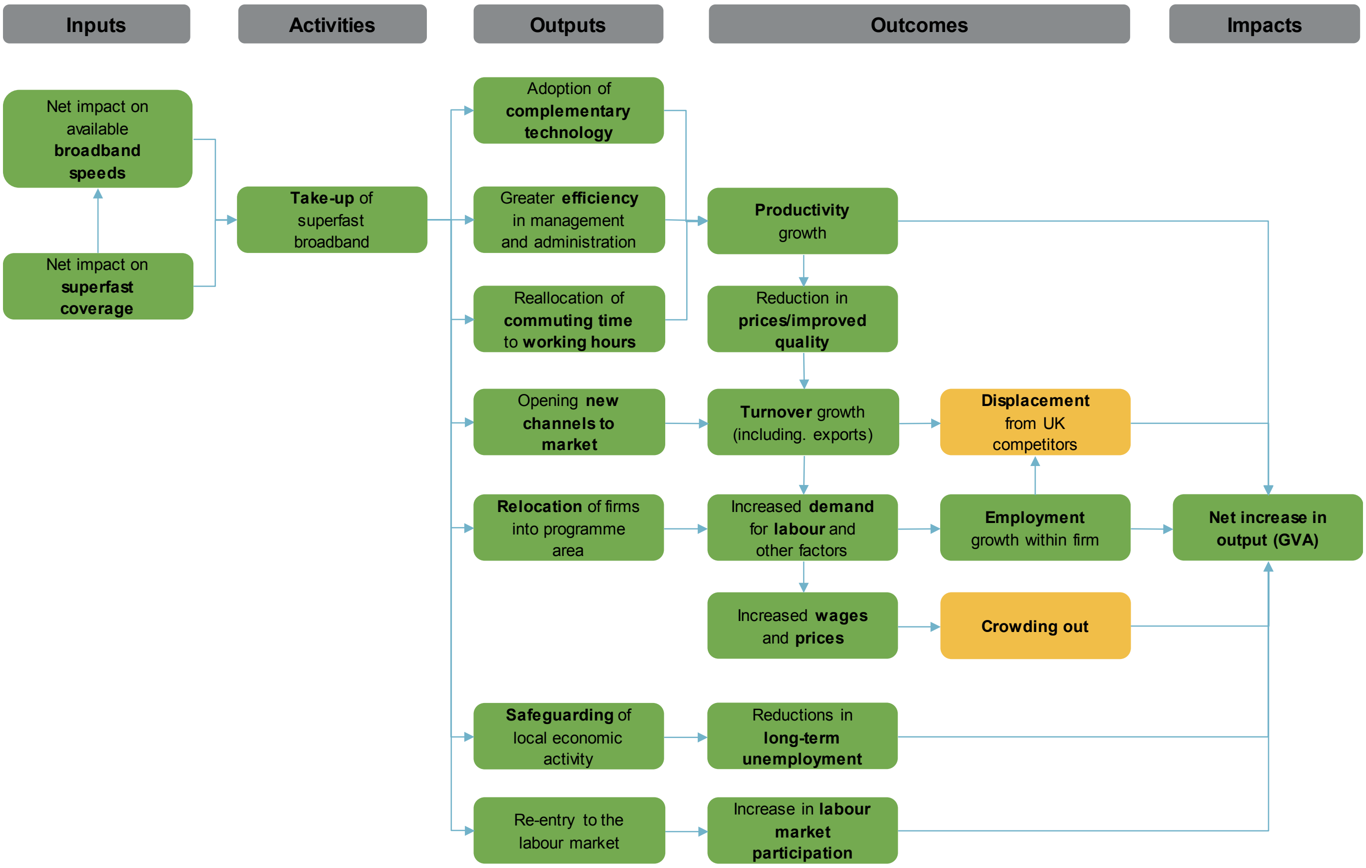
  - **Agglomeration and disagglomeration:** Such a process could also trigger in-migration of skilled labour, encouraging further concentration of economic activity in areas benefitting from upgraded broadband infrastructure, and enabling firms to benefit from the efficiency gains associated with being located in proximity to customers and suppliers (agglomeration effects). While this would produce positive benefits to the areas benefitting from the programme, it is

[12] In light of these issues, the HM Treasury Green Book recommends that the focus of economic appraisal should be on increases in the productive capacity of the economy, rather than on short term demand side effects.
[13] Whitcare et al. (2014) Broadband's contribution to economic growth in rural areas: Moving towards a causal relationship

important to note that there would be corresponding 'disagglomeration' effects in other areas that would offset these impacts.

- **Crowding out:** The attraction of firms from other areas also has the potential to place upward pressure on local prices through increased demand for inputs such as labour. In turn, this may encourage lower productivity firms to reduce their output or relocate to lower cost locations. Many of these effects could be expected to play out over the medium term.

Figure 2.2: Business, local economic performance and worker impacts of superfast broadband



2.3 Impacts on workers

The programme may also have the following effects on workers:

- **Teleworking:** Faster connectivity also has the potential to transform the nature of work by enabling efficient remote working. While this also relies on residential upgrades, a range of studies have estimated that increased teleworking can produce productivity gains – both reducing working hours lost to commuting delays and by improving work-family balance and job satisfaction. [14] Prior to the pandemic in 2019, the ONS estimated that around 4m (12 percent) of the total workforce had worked from home in the week prior to interview, using the Annual Population Survey (APS) and the Labour Force Survey (LFS). However, research does not always suggest that teleworking has positive benefits. For example, a 2018 review of teleworking in the public sector indicated that public servants experienced negative effects from teleworking – including greater professional isolation and less

[14] For a summary of recent evidence for the UK context see: UK Parliament POST (2022) POSTbrief 49 The impact of remote and hybrid working on workers and organisations Available at: https://researchbriefings.files.parliament.uk/documents/POST-PB-0049/POST-PB-0049.pdf

organisational commitment on the days they worked entirely from home. [15] Similar findings were also obtained in a study of US federal Government workers. [16] The COVID-19 pandemic also resulted in a substantial expansion in teleworking which appears to have led to persistent effects on working patterns (although a number of studies have identified disadvantages for some groups of workers).[17]

- **Wage impacts:** Classical economic theory would suggest that the productivity gains associated with broadband adoption would be shared between the firm (via greater profits), the broadband supplier (through additional profits earned through the supply of services[18]) and potentially the land owner (to the degree that they can extract any productivity gains associated with superfast availability through increasing rents – which depend on how such gains arise and the extent to which commercial property markets are competitive). However, workers may also benefit from enhanced wages to the degree that the programme enables them to become more productive – either by enabling more productive working practices or by stimulating investments in training. These wage gains may reflect their increase in productivity and could differ across occupational groups (e.g. if the programme results in reduced demand for unskilled workers). [19]

- **Labour market participation impacts:** The provision of superfast broadband in low connectivity areas could also have further economic benefits through increasing labour supply. However, it is plausible that labour supply effects could occur through other mechanisms. For example, those in (or on the verge of) retirement may re-enter the labour market if they can telework from the location in which they chose to retire. Equally, if superfast broadband enables previously unviable economic activities to be provided in rural or other types of low connectivity areas, then the jobs created may have features (higher wages, greater flexibility, better working conditions) that are attractive to residents that are economically inactive. Such benefits may be particularly significant for some groups with high inactivity rates – such as by enabling carers or those with disabilities to enter the labour market through teleworking.

- **Skills issues:** The availability of superfast broadband may enable the adoption of complementary data intensive technologies that would not have been viable at lower speeds, e.g. precision farming applications in agriculture. The extent to which these effects are realised will be in part dependent on the ability of firms in subsidised areas to absorb the technology. For example, evidence from the US has suggested that broadband tends to raise productivity only in areas where there is strong supply of highly skilled workers. [20] Additionally, firms in some sectors appear less able to exploit the availability of broadband to raise productivity, particularly the manufacturing sector.[21][22] The economic performance of rural areas has also been shown to be linked to the adoption rates of broadband, with areas less able to absorb the technology seeing declines in employment. [23] As such, there are questions as to the significance of any skills shortages or gaps created by superfast broadband access and how firms respond to those issues – e.g. how far they seek to meet these

[15] De Vries et al (2018) The Benefits of Teleworking in the Public Sector: Reality or Rhetoric?
[16] Caillier (2012) The Impact of Teleworking in a US Federal Government Agency
[17] Subel et al. (2022) How Shifts in Remote Behavior Affect Employee Well-Being
[18] Though note that the programme has been designed to equalise the IRR on the project with the suppliers Weighted Average Cost of Capital, so in principle, suppliers will not earn excess profits on their investments.
[19] Wages could also rise if the programme stimulates demand for workers with locally scarce skills (creating wage inflation) or if firms choose to share any productivity benefits with workers, for the purposes of retention.
[20] Mack, E., and Faggian, A (2013) Productivity and Broadband: The Human Factor
[21] Haller, S.A., and Lyons, S. (2014) Broadband adoption and firm productivity: Evidence from Irish manufacturing firms,
[22] Ivus, O., and Boland, M, (2013) The Employment and Wage Impact of Broadband Deployment in Canada
[23] Whitcare et al. (2014) Broadband's contribution to economic growth in rural areas: Moving towards a causal relationship

skills challenges through training existing staff or recruitment, and what happens to workers that do not have the skills required.

- **Safeguarding of economic activity in previously low connectivity areas:** Improved broadband infrastructure may help some areas retain economic activity that would have otherwise been lost to other high connectivity areas (though there will be offsetting effects for the areas that would have otherwise benefitted). While many workers may be able to adjust to such local economic shocks by relocating, retraining, or commuting to more buoyant local economies, some may be unable to do so. This might occur, for example, if workers are unable to bear the costs of relocating. These types of problem could produce local issues of long-term unemployment and permanent losses of output (i.e. hysteresis effects) as these workers would not be redeployed elsewhere in the economy – costs that could be averted by subsidised coverage. [24]

2.4 Impacts on households

The previous section describes the potential impacts of the programme on workers. However, households may also benefit from the technology through their consumption of the technology (though there are also a range of possible disbenefits that may arise), as outlined below:

- **Consumption benefits:** Improved access to faster broadband may produce a range of consumption benefits for households arising through improved choice, quality, and time savings. Most obviously, faster broadband speeds will allow consumers to access a range of entertainment and media services that depend on high bandwidths (e.g. streaming services or smart devices). Benefits may also arise from access to more extensive on-line marketplaces that allow consumers more choice or to obtain savings – and potentially free up time that would have otherwise been spent travelling to retail or other centres. It should be noted that a shift to on-line consumption patterns could be accompanied by disbenefits if it reduces the commercial viability of in-store retail services. The loss of retail outlets may reduce the vibrancy of town centres (reducing the well-being of residents of those communities) as well as produce digital exclusion issues amongst those that are unable to take advantage of increased digitalisation (because they are unable to pay or because they do not have the skills to do so). Such effects may not be permanent if town centres can adjust to changing consumption patterns - in the long run, these effects could be expected to lead to reduced commercial rents, encouraging the redeployment of those spaces for alternative uses. The COVID-19 pandemic has clearly accelerated these trends as the closure of non-essential retail has forced households to shift their consumption on-line (and there are signals that this shift may have some permanence).

- **Teleworking and leisure time:** Greater opportunities for teleworking may produce benefits that exceed any effect on the productivity of the worker and associated wage income. Households newly able to work remotely may derive additional benefits from extra leisure time gained from reduced commuting times and travel costs. The well-being gain may not always be positive, however, if superfast connectivity encourages workers to engage with work outside of normal working hours. These types of issues are being explored by BDUK in on-going work to understand the public value impacts of the programme.

- **Social interaction:** Faster broadband may also open new modes of communication between residents. While use of email and social media may not be dependent on higher bandwidths (and can be straightforwardly used via mobile telecommunications networks), the COVID-19 pandemic

[24] Individuals that are not in employment, but looking for work.

temporarily popularised the use of video conferencing (previously used for remote meetings in a business context) as a mode of interpersonal communication. This technology requires greater bandwidths and subsidised coverage has the potential to improve well-being by supporting more extensive social interactions within and beyond the communities in which residents live (potentially reducing social isolation for some). However, there are some questions as to how far this mode of communication will endure now social distancing restrictions have largely been removed.

- **Social costs:** Greater on-line social interaction may not always be positive. There is evidence that for some groups, greater use of social media is associated with lower levels of self-esteem. Internet addiction (i.e. compulsive desire to use the internet) has also been an area of recent clinical investigation – and has been found to be associated with depression and self-esteem. The direction of causality is unclear – i.e. internet addiction may be a symptom of underlying emotional disorders, rather than a cause – but it should be at least acknowledged that improved broadband connectivity has the potential to produce negative subjective well-being effects in some users. [25]

- **Perceptions of inequity:** The Superfast Broadband Programme also has the potential to address perceptions of inequity relating to the locations of major investments in infrastructure. For example, focus groups undertaken by University College London revealed a perception that recent investments in infrastructure have exacerbated disparities in amenities and mainly benefitted those that were already affluent. [26] Although clearly the programme cannot tackle these issues in their entirety, bringing superfast broadband coverage to rural areas that would not have otherwise been covered by commercial deployments has the potential to at least alleviate these types of public concerns. However, consideration may need to be given to the possibility that the programme exacerbates these perceptions in some areas (e.g. in cases where communities have not been included in the build plans of local schemes).

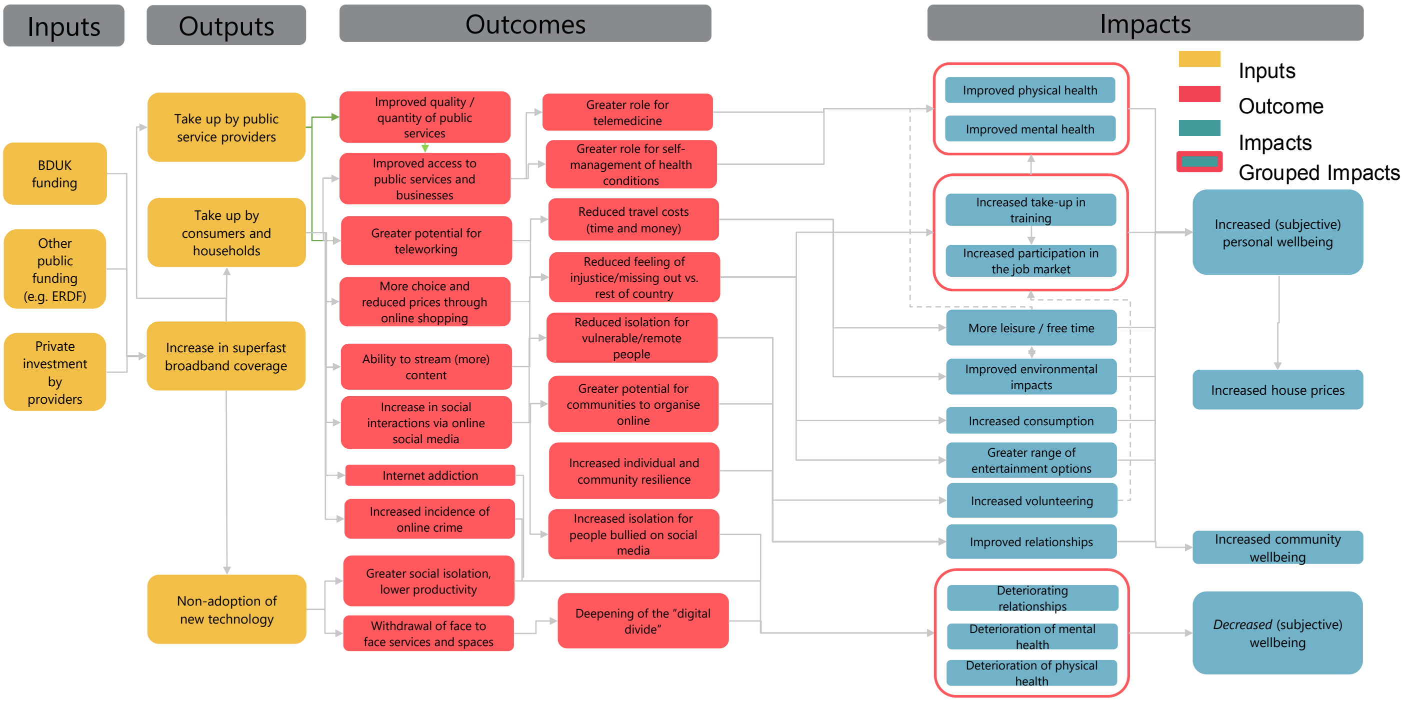
- **Technology induced disagglomeration:** As highlighted above, improved superfast broadband connectivity may encourage the relocation of firms to rural areas. This may require their workforces to make relocation decisions to avoid episodes of unemployment, maintain their incomes, or reduce commuting times. In these cases, the well-being impact of superfast broadband coverage may not be positive (and may indeed be negative).

- **Rural population growth:** Migration of population to rural areas could also lead to pressures on local housing markets. This could also have a negative impact on the well-being of residents for example, if it increases equilibrium rents or stimulates house building activity on previously undeveloped land (creating disamenities for existing residents). Additionally, rural population growth could feed through into pressures on public services (if supply does not expand to meet demand, as discussed below) or create other negative externalities such as greater congestion on rural road networks (and associated impacts on air quality). The movement of people to rural areas may also relive some pressure on urban areas and their local housing markets and services.

- **Composition of local populations:** Finally, while increased social connectivity may promote greater community cohesion, migration of population to rural areas could have the opposite effect if it disrupts settled patterns of community life.

[25] Pantic (2014) Online Social Networking and Mental Health, Cyberpsychology, Behaviour and Social Networking
[26] Natarajan et al (2020) Civil Society Perspectives on Inequality: Focus Group Research Finding, Submission to UK2070 Commission.

Figure 2.3: Household impacts of superfast broadband



2.5 Impacts on public sector service delivery

Finally, the programme may also have a range of direct and indirect effects on the delivery of public sector services:

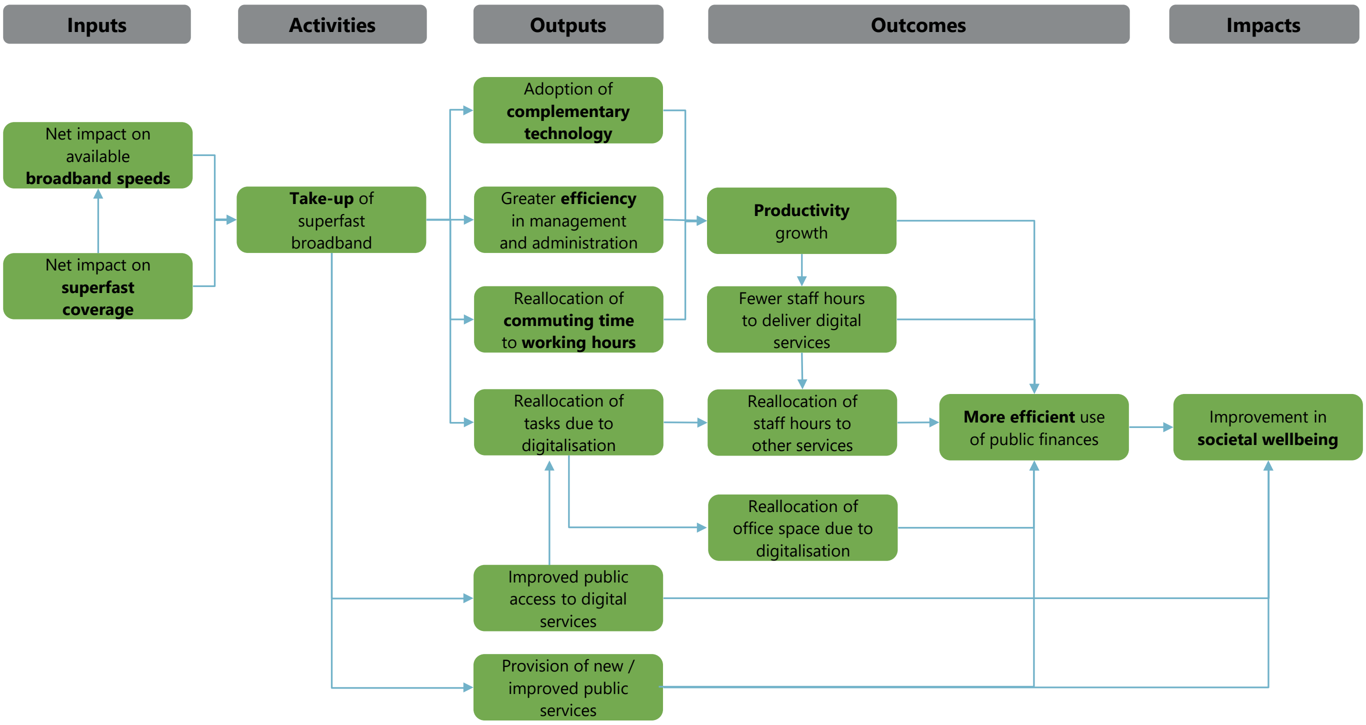
- **Direct efficiency gains:** Subsidised coverage may allow public sector organisations to benefit from the faster broadband connectivity. This will potentially allow these organisations to realise efficiency gains from the adoption of similar technologies to those described above in relation to the private sector (e.g. cloud computing). Public sector productivity may also arise to the degree that adoption of such technologies allows public sector workers to work more flexibly – for example, through allowing working from home and reducing commuting time. In principle, the savings and efficiencies arising could also be channelled into improved quality of service delivery (and potentially feeding through into enhanced quality of life for residents).

- **Service transformation:** Perhaps more consequentially, improved connectivity may also facilitate the digitalisation of public services (also enabled by improved service delivery). The range of possible applications are extensive. These might include enabling simple transactions to be undertaken on-line (payment of bills, booking systems for leisure facilities, renewal of prescriptions). However, higher bandwidths will also enable more sophisticated transformational changes in which public services are delivered remotely. E-health applications have figured prominently in recent years that typically seek to drive efficiency through remote diagnosis of health conditions – such as via telemedicine platforms (e.g. the GP at Hand service developed by Babylon Health), diagnostic or therapeutic smart-phone applications (e.g. the Changing Health diabetes management application), or using remote sensors to provide real-time information to clinicians to support patient management. However, the COVID-19 pandemic has also illustrated how other forms of public services – such as education – can be effectively provided through on-line learning platforms.

- **Digital divide issues:** Digitalisation of public services can produce social benefits – not just through reducing the cost of delivery but also via improving choice and widening access. However, the ability of resident populations to benefit from digitalisation of public services will partly depend on the extent to which they can access digital services. If they do not take up faster broadband services or if they do not have the confidence or skills to use online platforms, then some residents may be locked out of new modes of service delivery. This also risks negative distributional impacts if physical modes of delivery are withdrawn or scaled back.

- **Population growth:** Subsidised coverage may also have indirect effects on public services if it induces the migration of population to rural areas. If the supply of public services does not expand to accommodate the additional demand this may bring, this could place pressure on public services (leading to greater rationing and reduced access, rather than a widening of access). Once again, there is the possibility that rural population growth removes pressures in urban areas with the opposite effects.

Figure 2.4: Public service delivery impacts of superfast broadband



3 Methodological framework

The results set out in this paper have been generated using a common methodological framework. This section provides a theoretical outline of the methodology employed and its limitations.

3.1 Challenges in for an impact evaluation

The design of a credible approach to the assessment needs to address the following challenges:

- **Longitudinal data:** Any assessment of the impacts of the programme will require observations of the outcomes of interest (such as total employment) before and after the provision of subsidised broadband infrastructure. This is needed to demonstrate that that the desired changes in local socio-economic conditions have arisen.[27] Sources of longitudinal data to support the analysis are described in full in the opening passages of the following sections.

- **Counterfactual:** Evidence that local conditions have changed in the desired manner are clearly insufficient to demonstrate that these changes were brought about by the programme. For example, employment may have grown in areas benefitting from the programme because of external factors (e.g. wider economic growth).

  As such, a credible assessment of impact also requires comparisons between areas that benefit from the programme to areas that do not, to identify what may have transpired in the absence of the programme. These comparisons will only provide a reasonable estimate of impact if the comparator areas can be considered equivalent to those areas benefitted from subsidised broadband coverage. If there are systematic differences between areas that do and do not benefit from the programme that are also causally related to the outcomes of interest, then this could lead to a biased estimate of the impact of interest. The nature of the programme and its design raises two concerns that such distortions could arise when comparing areas benefitting from the programme to other areas. These stems from choices made by Local Bodies and network providers in defining the target area for the programme:

  - **Reverse causality:** Reverse causality is typically a central challenge in the evaluation of the impacts of infrastructure projects. Areas often benefit from enhanced infrastructure investment *because* they are expected to grow in the future. Comparing areas that do and do not benefit from enhanced infrastructure tends to overstate the effects of investment, as areas receiving the investment would be expected to grow more rapidly anyway (i.e. growth causes the investment, rather than the reverse). In the case of the Superfast Broadband Programme, some Local Bodies refined the target area for the programme by limiting the scope of procurements to eligible premises (i.e. residential or non-residential properties) in areas that aligned with broader spatial development priorities. However, this problem is generally less acute than in other contexts (e.g. in relation to investments in new road infrastructure), as it was designed to address inclusion objectives (i.e. enabling areas of the UK to obtain superfast broadband services that were being delivered on a commercial basis to denser urban areas) rather than to address specific spatial development priorities.

[27] By extension, impacts inferred from cross-sectional comparisons between areas that do and do not benefit from the programme after the programme has been delivered can be expected to produce misleading results. For example, if areas benefitting from the programme may be associated with lower economic density than other areas, these types of comparison could lead to the incorrect conclusion that provision of superfast broadband infrastructure caused lower levels of employment.

- **Selection by network providers:** Potentially more problematic, suppliers chose which premises to upgrade from a list of eligible premises identified as 'white' (i.e. not covered by the commercial plans of network providers over the next three years). Comparisons between areas that did and did not benefit from the programme could also lead to biased results if those areas that suppliers chose to upgrade differed in systematic ways to those that they excluded from their build plans. It would not be unreasonable to assume that the suppliers chose these premises to maximise their expected returns from investment. This could imply a focus on areas with higher levels of demand density and lower costs associated with delivering superfast broadband infrastructure. This could distort comparisons between those areas that benefitted from the programme and other eligible areas that did not. For example, areas of higher economic density may offer firms superior access to the skilled labour needed to exploit enhanced connectivity (either locally or via better connections to other centres). These features may have enabled these areas to grow more rapidly than areas that did not benefit from the programme regardless of the broadband infrastructure delivered, leading to comparisons that overstate the impacts of the investment.

3.2 Pipeline design

The issues identified above were handled by exploiting the long timeframes over which the programme was delivered. Residential and non-residential premises receive the intervention (an upgrade to broadband infrastructure allowing the occupants to obtain superfast broadband services) at different points in time. As such, premises that benefitted from the programme first can be compared to those that received the intervention later (with those receiving subsidised coverage at later stages acting as a comparison group for those that receive the intervention earlier).

Comparisons in this set-up are only made between premises that eventually receive the intervention. By excluding any premises that do not receive subsidised coverage, results should not be distorted by systematic differences between premises that do and do not benefit from subsidised broadband coverage (i.e. problems caused by reverse causality or selection by network providers). This can be expressed as in terms of the following econometric model:

$$y_{it} = \alpha + \beta T_{it} + \varepsilon_{it}$$

This model links the outcome of interest for premises *i* in period *t* (y_{it}) to whether the premises has benefitted from subsidised coverage in period *t* (T_{it} - taking the value of 0 before the upgrade has been delivered and the value of 1 after the upgrade has been delivered). The coefficient β captures the effect of subsidised coverage on the outcomes.

This model will only produce an unbiased estimate of the impact of the programme if there is no systematic link between the order in which premises are upgraded and the underlying outcomes of interest. For example, if network providers tended to prioritise upgrades to premises in areas with greater growth potential, then this model will tend to overstate the economic impacts of the programme (specific examples of these threats are given further discussion below). To probe the robustness of these findings, it is also possible to progressively add further controls as follows:

$$y_{it} = \alpha + \beta T_{it} + \gamma t X_{i2012} + \alpha^{i} + \alpha^{t} + \varepsilon_{it}$$

This augments the model described above to control for unobserved but time invariant characteristics of premises (α^i) that could bias results and unobserved but time specific shocks (α^t) affecting all premises (i.e. this design is also known as a two-way fixed effects model with staggered treatments).[28] These findings could still be biased by unobserved differences but time varying between premises receiving upgrades at different times. To mitigate this risk, it is possible to further control for differential trends across premises with different baseline characteristics (tX_{i2012} where t is a linear time trend), such as local industrial structure.[29] These controls are added progressively to the baseline model to probe the stability of the estimated effect of the programme under more stringent controls.

The discussion above assumes that both the treatment and outcome can be observed at the level of the premises. However, while data on the delivery of the programme is available at the premises level, data on outcomes were only available at higher levels of aggregation. This requires a corresponding aggregation of data describing the delivery of the programme and the approach described above was adapted as follows:

- **Postcode:** Where information on outcomes was available at the postcode level, the modelling approach described above was implemented by assuming that a postcode received the intervention at the point the first premises on the postcode was upgraded. This implies an assumption that all premises on the postcode benefit from the availability of enhanced broadband coverage at the same time. As illustrated in Technical Appendix 1, there were around 12 premises per postcode in the target area for the programme. These would generally have received upgrades collectively when the serving cabinet was upgraded to FTTC, and network providers will also upgrade adjacent properties to FTTP simultaneously to take advantage of scale economies.

- **Output Area:** While data describing individual firms or workers was available via the ONS Secure Research Service, these observations only included the Output Area of the business or individual concerned. An Output Area is a statistical unit used for reporting small area statistics, the majority of which (80 percent) comprise 110 to 139 households. This makes it impossible to identify whether a specific firm or individual occupies premises benefitting from subsidised coverage at a particular time. To address this issue, data on outcomes and the delivery of the intervention were aggregated to the level of the Output Area.

  This introduces a complication in that an assumption that all premises in the area receive enhanced connectivity when the first property is upgraded is less reasonable at the level of Output Areas, owing to variance in both (a) temporal variation in the share of premises that receive upgrades and (b) the share of premises locally that ultimately receive upgrades.[30] To address this, the models were adapted by redefining the treatment variable in the equation above to represent the cumulative number of premises (T_{it}) upgraded. This provides sensitivity to temporal variation in the volume of premises upgraded and implies a 'dose-response' relationship. This relationship is also assumed to be linear - i.e. each additional premises upgraded has an equal additive effect on the outcomes of interest. It should be noted that comparisons between this approach and prior results generated using postcode level data were provided in the 2020 State aid evaluation of the UK National

[28] All models have been estimated with standard errors clustered at the level of unit of analysis (postcode, Output Area or LSOA).

[29] Noting that the fixed effects specification would account for (fixed) differences in baseline characteristics, while including controlling for time varying features of the areas could introduce problems with endogeneity (e.g. if the programme caused changes in local industrial structure).

[30] Note that areas that did not benefit from subsidised upgrades were not included in the analysis, in line with the principles of the pipeline design.

Broadband Scheme and indicated that the two approaches generated consistent results for the period 2012 to 2016.

Reconfiguring the analysis at the level of Output Areas also implies some differences in interpretation as findings should in principle provides estimates of the net effect of the programme at the very local level. This would account for any locally important offsetting displacement or crowding out effects (e.g. if the programme encouraged firms to relocate from nearby postcodes without enhanced broadband infrastructure, there would be no net increase in employment at the local level).

- **LSOA:** In one case (unemployment claimant numbers), data was only available at the LSOA level. These are larger areas containing an average of 650 households. The larger areas exacerbate the issues described above, and a variety of approaches were adopted to model the intervention as described in the relevant section.

3.3 Limitations

There are some methodological limitations to this approach:

- **Robustness:** The pipeline design will produce robust estimates of the impact of subsidised coverage if the order in which the premises receive upgrades can be considered effectively random in relation to the outcomes of interest. Three factors have the potential to influence the timing of upgrades:

  - **Timing of procurement:** The timing of the procurement exercise will be partly determined by the Local Body. It is possible that completing the tendering exercise more rapidly may reflect unobserved managerial characteristics of the Local Body (e.g. greater efficiency and/or internal resources). In turn, this could be reflected in other aspects of the performance of the area. This most obviously would be connected to the performance of public services, but also potentially to economic development outcomes if this reflects the ability or willingness of the Local Body to invest in the promotion of local growth. This could lead to an overstatement of the programme's effects.

  - **Order of upgrades:** The network provider selects the order in which postcodes benefit from subsidised upgrades. If they adopt a profit maximising strategy, it would be anticipated that they would deliver to the profitable postcodes first. in Phase 3, network providers appeared to prioritise lower density areas where competitors were less likely to have a presence nearby. If lower demand density is positively correlated with underlying economic performance or other outcomes of interest, then this could lead to an overstatement of the impacts of the programme.

  - **Timeliness of delivery:** Finally, the order in which postcodes benefit from subsidised upgrades will be influenced by how rapidly the network provider brings forward delivery. This could potentially be linked to the capacity of the local economy to provide the necessary resources (e.g. skilled labour) to do so. Constrained capacity could reflect the wider growth of the local economy. If so, the economies of those areas upgraded later may have been more likely to expand in the absence of subsidised coverage (in which case, the pipeline design would understate the impacts of the programme).

  Attempts to mitigate these issues have been made by controlling for the observed characteristics of the areas benefitting from the programme as well as unobserved characteristics that do not change with time. However, there may be time varying but unobserved characteristics of the areas benefitting from the programme that have not been controlled for in the analysis e.g. working travel patterns or local business clusters. As such, the design does not involve quasi-random allocation between the treatment and comparison groups and the results should be considered to attain Level III on the Maryland Scale.

- **Direct and indirect effects:** The model does not discriminate between the direct and indirect effects of superfast broadband coverage on the outcomes of interest. This will not create problems with biased results but can create some challenges for interpretation. As an example, superfast broadband connectivity may have a direct impact on primary care by enabling GPs to open new channels to patients and offer new technology driven services (e.g. on-line consultations). However, superfast broadband connectivity may also have indirect impacts through bringing faster speeds to surrounding residential areas. This may make primary care services more accessible to patients (leading to greater demand) or alter the composition of local populations (via the housing market). The data available does not always allow these different effects to be separated.

3.4 Validity of the pipeline design

For the pipeline design to produce unbiased estimates of the programme impact, there must not be any systematic differences between areas receiving investment earlier and those receiving investment later that are also correlated with the outcomes of interest. For example, if subsidised broadband is rolled out to areas experiencing higher productivity growth first, then this will overstate the impact of the programme. The suitability of the pipeline approach for use throughout the analysis utilising this approach in this paper was tested by comparing the characteristics of the areas receiving upgrades at various times.[31]

Significant differences in the key observable characteristics of areas benefitting from the programme over time would indicate that the order in which the intervention was rolled out was not random. As highlighted above, this could lead to biased estimates of impact if those differences were also correlated with the outcomes of interest (and greater need to control for differences in area characteristics). An absence of observable differences also does not imply an absence of unobservable differences.

The postcodes first receiving subsidised coverage in each year between 2014 and 2021 were first of all compared using the Business Structure Database (BSD). This allows for the comparison of these areas in terms of their economic performance (see section 4.1.1 for more detail on the BSD). This did not identify many differences between the areas upgraded at different times in terms of the sizes and sectors of local firms. The average turnover generated in Output Areas (OA) upgraded in 2016 was, however, lower than the average across areas upgraded in other years.

[31] Pairwise significant testing has been used to highlight those years that appear significantly difference from the base year (2014). Across a large number of annual averages, a number of statistically significant differences would be expected even without the presence of systematic differences over time. Additionally, the underlying mechanics of the approach (i.e. controlling for both unobserved area level differences and time specific shocks) will mitigate against the risk of biases driven by these systematic differences.

Table 3.1: Comparison of the economic performance of areas receiving coverage in each year between 2014 and 2021

	Year postcode was first upgraded							
	2014	2015	2016	2017	2018	2019	2020	2021
Economic activity in the local area (Output Area)								
Average total employment within OA	218.3	207.3*	201.8*	218.7	209.0*	212.1*	208.5*	217.8*
Average total turnover of firms located in OA (£,000)	31,679.7	33,162.8	27,389.7*	33,698.7	28,984.6*	32,499*	26,841.0	33,024*
Average turnover per worker of firms located in OA (£,000/worker)	90.1	91.0	89.0	88.6	87.4	86.4	92.8	90.3
Share of local units in OA by size:								
Micro	78.9%	80.2%	80.2%	79.4%	79.2%	77.8%	77.8%	77.0%
Small	7.9%	7.8%	7.5%	7.7%	7.4%	7.6%	7.3%	7.5%
Medium	2.7%	2.5%	2.5%	2.6%	2.6%	2.4%	2.4%	2.5%
Large	10.5%	9.4%	9.8%	10.4%	10.8%	9.1%	9.5%	10.1%
Share of local units in OA by sector:								
C (Manufacturing)	13.4%	14.4%	15.2%	14.1%	12.1%	14.0%	14.7%	13.7%
DE (Infrastructure)	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%
F (Construction)	13.2%	13.1%	13.4%	12.4%	13.4%	12.7%	13.0%	12.0%
G (Retail)	15.4%	14.0%	13.8%	14.1%	13.6%	13.6%	13.4%	13.7%
H (Transportation)	4.0%	4.0%	4.1%	4.8%	4.7%	3.9%	4.0%	4.7%
I (Accommodation and food)	6.4%	5.7%	5.9%	6.0%	6.0%	5.5%	5.7%	5.8%
J (IT)	4.9%	5.1%	5.3%	5.5%	6.2%	4.9%	5.1%	5.3%
K (Financial)	1.4%	1.3%	1.3%	1.4%	1.6%	1.3%	1.3%	1.4%
LMN (Service sector)	23.8%	25.2%	24.9%	24.6%	25.0%	24.4%	24.2%	23.9%
O (Public admin)	1.2%	1.1%	1.1%	0.9%	1.0%	1.1%	1.1%	0.9%
P (Education)	3.1%	3.1%	2.9%	3.1%	2.9%	3.0%	2.8%	3.0%
Q (Health)	6.3%	6.1%	6.2%	6.4%	6.4%	5.9%	6.0%	6.2%
RS (Arts & other)	6.3%	6.3%	6.2%	6.0%	6.5%	6.1%	6.0%	5.8%

*Source: Business Structure Database; C3 Reports; Ipsos analysis; * indicates value is significantly different from the equivalent in the first available year at the 95 percent level of confidence.*

A similar exercise was undertaken comparing the characteristics of the employees working at firms located in the areas upgraded at varying times using the Annual Survey of Hours and Earnings (ASHE – see section 5.1.1). This did not highlight many significant differences that would threaten the validity of the approach. Only comparisons between employees located in postcodes upgraded earliest and latest would cause concern and sample sizes in these years were relatively small.

Table 3.2: Characteristics of employees working in areas receiving coverage in each year between 2013 and 2021

	Year postcode was first upgraded								
	2013	2014	2015	2016	2017	2018	2019	2020	2021
Gender (% female)	48%	48%	49%	49%	49%	53%*	51%	47%	48%
Proportion full-time	0.65	0.69	0.71*	0.71*	0.71*	0.72*	0.70*	0.71*	0.71*
Hourly earnings (pence)	1,145.0	1,208.2	1,442.6*	1,298.9	1,321.9*	1,413.2*	1,372.5*	1,294.6	1,483.5*
Total hours worked	31.90	32.99*	33.73*	33.69*	33.95*	33.85*	33.62*	34.13*	33.89*
Occupation:									
Managers and senior officials	7.6%	7.8%	7.9%	7.5%	7.7%	7.4%	7.5%	7.7%	7.8%
Professional	10.4%	11.5%	13.8%	13.8%	13.8%	17.4%*	10.3%	11.4%	13.7%
Associate professional and technical	10.6%	11.8%	12.3%	11.3%	11.7%	11.6%	10.5%	11.7%	12.2%
Administrative and secretarial	12.6%	13.9%	13.9%	14.6%	13.1%	14.5%*	12.5%	13.8%	13.8%
Skilled trades	8.7%	8.4%	7.7%	7.8%	7.9%	6.6%	8.6%	8.3%	7.6%
Personal service	9.4%	8.9%	8.6%	9.2%	8.5%	9.0%	9.3%	8.8%	8.5%
Sales and customer service	13.4%	13.1%	12.1%*	12.3%	12.1%	12.2%	13.3%	13.0%	13.2%
Process, plant and machine operatives	8.3%	8.0%	8.0%	8.1%	8.2%	7.1%	8.2%	7.9%	7.9%
Elementary	18.9%	16.6%	15.8%	15.5%	16.9%	14.3%*	18.7%	16.4%	15.6%
SIC 2007 (1-digit)[32]:									
1	4.3%	4.7%	5.0%	4.3%	4.9%	3.7%	4.3%	4.7%	5.0%
2	5.9%	7.2%	7.6%	7.7%	8.2%*	6.5%	5.8%	7.1%	7.5%
3	3.2%	3.3%	3.4%	3.4%	4.9%	3.3%	3.2%	3.3%	3.4%
4	26.1%	27.6%	26.0%	25.4%	25.9%	24.1%*	25.8%	27.3%	25.7%
5	12.8%	9.7%*	8.9%*	9.3%*	8.9%*	7.2%*	12.7%	9.5%*	10.5%*
6	8.0%	8.5%	7.7%	7.6%	6.8%	8.8%	7.9%	8.4%	7.6%
7	10.2%	8.1%	7.0%	6.4%	6.3%	6.1%	10.1%	8.0%	6.9%
8	25.0%	27.4%	30.9%*	32.5%*	31.0%*	37.3%*	24.8%	27.1%	23.43%*
9	4.4%	3.5%	3.6%	3.4%	3.1%	2.9%	4.4%	3.5%	3.6%

*Source: Annual Survey of Hours and Earnings; C3 Reports; Ipsos analysis; * indicates value is statistically significant from the equivalent in the first available year*

Comparisons were also made between GP surgeries in postcodes upgraded at different times. In general, GP practices upgraded at different times were similar, however those upgraded in 2017 appear to have been in more rural locales and showed a lower intensity of online service use.

[32] See https://www.ons.gov.uk/methodology/classificationsandstandards/ukstandardindustrialclassificationofeconomicactivities/uksic2007 for more detail on the SIC codes and the corresponding industry sectors.

Table 3.3: Characteristics of GPs in areas receiving coverage in the year before upgrade, 2016 to 2018

	Year before postcode was upgraded				
	2016 (Upgraded in 2017)	2017 (Upgraded in 2018)	2018 (Upgraded in 2019)	2019 (Upgraded in 2020)	2020 (Upgraded in 2021)
Registered patients	8,310.01	8,332.25	8,415.57	8,582.22	8,668.04
GPs FTE	4.46	3.92	3.96	4.04	4.08
Nurse FTE	2.45	2.45	2.47	2.52	2.55
Non-clinical FTE	9.08	9.76	9.86	10.05	10.15
Proportion of patients booking appointments online	7.9%	10.2%	10.3%	10.5%	10.6%
Proportion of patients ordering repeat prescriptions online	11.5%	16.7%*	16.9%*	17.2%*	17.4%
Proportion of patients accessing medical records online	1.4%	2.7%*	2.7%*	2.8%*	2.5%*
Proportion Rural	35.1%	24.2%*	24.4%*	24.9%*	25.2%*

*Source: NHS Digital, GP Patient Survey; C3 reports; Ipsos analysis; * indicates value is statistically significant from the equivalent in the first available year*

In the case of schools, a trend is apparent in so far as schools benefitting from subsidised upgrade later (e.g. in 2017) tended to show higher shares of pupils with English as an Additional Language (EAL), eligibility for Free School Meals (FSM) and Special Educational Needs (SEN). This does raise questions as to the applicability of this approach to the analysis of education outcomes.

Table 3.4: Characteristics of schools in areas receiving coverage in the year before upgrade, 2013 to 2020

	Year before postcode was upgraded								
	2013	2014	2015	2016	2017	2018	2019	2020	2021
Number of pupils	196.28	172.80*	181.16	185.00	267.07*	239.43*	198.32	207.34	179.35
Percentage of pupils with EAL	3.26	2.97	5.36*	5.10*	7.16*	5.90*	6.43*	6.27*	6.16*
Percentage of pupils with FSM	10.61	9.07*	8.89*	8.68*	18.72*	9.78*	10.67*	10.40*	10.22*
Percentage of SEN pupils	4.38	3.53*	6.98*	7.72*	12.03*	7.68*	8.38*	8.17*	8.03*

*Source: DfE school database; C3 reports; Ipsos analysis; * indicates value is statistically significant from the equivalent in the first available year*

4 Impacts on businesses

This section provides an assessment of the impacts of subsidised superfast broadband coverage on businesses. This section draws on administrative data and other secondary data on the performance of businesses located in the areas covered by the build plans of local schemes. The analysis considers the direct effects of superfast broadband coverage on the performance of firms and other issues relating to the local and national economic impacts of the programme.

4.1 Data

The following analyses made use of the following datasets.

4.1.1 Business Structure Database

The Business Structure Database (BSD) is an annual snapshot of the Interdepartmental Business Register (IDBR). The database contains longitudinal observations of employment and turnover at an enterprise and workplace level and was accessed through the Office for National Statistics (ONS) Secure Research Service (SRS). [33]

The data also provides the industry sector and the Output Area associated with each workplace, enabling tracking of relocations and the opening of new locations. The underlying data on employment and turnover are assembled from PAYE and VAT returns or from Annual Business Survey or Business Register of Employment Survey[34] returns if the firm is included in the sample. These arrive with different lags and are recorded as and when data arrives. Known issues with the data include the fact that some records are thought to be up to two years out of date, and some caution is urged by ONS in using the BSD in evaluating policy interventions over short time horizons.[35] Annual cross sections from 2012 to 2021 were used for the following analyses.

The BSD incorporates 'live' local units. Between 2012 and 2021, a total of 5,463,832 unique live local units were present with the number present in each yearly cross section in the table below. All other local units were removed from the cross sections where a death date was present.

[34]See: https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/employmentandemployeetypes/methodologies/businessregisterandemploymentsurveybres#bres-quality-and-methods

[35] The ONS urges caution relating to potential time lags in the BSD data. The VAT and PAYE records can in some cases be up to two years old which would pose significant constraints in analysing effects over one or two years. As this analysis examines aggregate effects on an area level and not individual firms, these rare cases should not be a significant issue.

Table 4.1: Number of live local units in yearly cross sections

Year	Number of live local units
2012	2,759,355
2013	2,772,002
2014	2,883,556
2015	2,974,482
2016	3,077,227
2017	3,201,395
2018	3,216,459
2019	3,235,642
2020	3,274,975
2021	3,238,284

Source: Business Structure Database

The BSD research data consists of annual cross-sections at the enterprise and local unit level (i.e. one enterprise may have multiple local units if it operates from more than one site). Employment is observed at the level of local units, while turnover is recorded at the level of the overall enterprise. To provide local measures, turnover was apportioned to each local unit based on their share of employment in the overall enterprise. This implicitly assumes that all local units are equally productive and could have a distortionary effect on findings if the provision of subsidised broadband coverage alters relative productivity of local units (i.e. if the productivity of local units benefitting from subsidised coverage increases in response to the upgrade, then this effect will be diluted by the apportionment process). Measures of turnover were deflated using the HM Treasury Gross Domestic Product (GDP) deflator and expressed in 2021 prices. [36]

The most granular geographical identifier of individual local units was the Output Area (the postcodes of local units were withdrawn in 2019).[37] The BSD dataset was aggregated to the Output Area giving measures of the total employment and turnover of firms located in the Output Area, the total number of live local units active in the area. Measures of turnover per worker (tpw) were calculated by dividing through the total turnover of firms located in the Output Area with the total employment. The final panel dataset comprised 704,287 observations across 72,738 Output Areas. In addition, two further panel datasets were generated focused on subgroups of the firms of interest:

- **Spatially stable:** Local units which remain situated in the same output area between 2012 and 2021. These local units were identified by comparing the output area for each local unit across each cross section. Where these areas remained the same across the period, the local unit was marked as 'spatially stable'. The interest in this group of firms was motivated by the possibility that local economic impacts were driven by firms relocating to areas benefitting from subsidised coverage, implying a corresponding loss of economic activity elsewhere (displacement). Focusing the analysis solely on those firms that did not relocate provides greater confidence that the productivity gains associated with the programme represent improvements in efficiency rather than improvements in local productivity driven by the relocation of more productive firms to the relevant areas. [38] Of the

[36] Note that the BSD does not provide details of VAT paid by firms so it was not possible to remove this from turnover values as per the guidance in the Green Book (as this is considered a transfer payment). It is assumed that the programme did not change the marginal VAT rate paid by firms and therefore changes in turnover reflect changes in underlying GVA.

[37] Output Areas for England, Wales, Scotland as well as Small Areas for Northern Ireland were present in the data.

[38] While firms may have moved within the OA to exploit enhanced connectivity, this will not distort measures of growth or productivity when measured at the level of the OA

5,463,832 unique local units covered by the BSD, 4,582,193 (84 percent) were marked as spatially stable. 1,103,952 (20 percent) were both spatially stable (i.e. did not move location) and present in each cross section between 2012 and 2021 (new start-ups established or business closing since 2012 would not appear in this latter figure).

- **Single site:** Enterprises that operate from one site. These were identified through analysis of the total number of live units falling under each enterprise reference. Where this equalled one, the local unit was marked as a single site. The interest in these firms was as a way to provide a cross-check against the process of apportioning turnover across local units. Therefore ensuring that the apportioning process did not result in misleading results. However, it should also be noted that single site firms are not representative of the overall business population and will typically be smaller operations. Of the 5,463,832 unique local units covered by the BSD, 4,735,748 (87 percent) were marked as single site.

4.1.2 C3 reports

Claimed delivery of superfast coverage was taken from the C3 reports provided to BDUK by contractors. An aggregated dataset was produced by BDUK and supplied to Ipsos. The C3 report captures the address of each premise the contractor claimed they had upgraded and provides predicted download and upload speeds. C3 reports to end of quarter 2 2021/22 were used to support the analyses reported below, providing details of some 6.4m premises that were claimed by providers. As the focus of the analysis was on the impact of subsidised coverage on economic performance, all claimed delivery was retained for the purposes of analysis - delivery of sub-superfast coverage and coverage delivered in grey, black, and ineligible areas were included. The C3 reports covered a total of 478,532 postcodes in the UK (29 percent of the 1,625,197 postcodes in the UK). [39] These were spread over 727,380 Output Areas.

4.2 Overview

Figures 1.1 and 1.2 provide an overview of trends in economic activity in the programme area between 2012 and 2021 (using data from the BSD). These show that the employment, turnover and turnover per worker of firms located in areas receiving subsidised coverage grew over the period covered by the analysis. However, there were differences in the economic density of areas benefitting from Phase 1 of the programme and those benefitting in Phase 2 and 3. Areas benefitting from Phase 1 contracts were associated with lower levels of employment and turnover (and were apparently less productive) than areas covered by later contracts.

This would be consistent with a greater focus on residential suburban zones in Phase 1 as opposed to rural town centres (with denser clusters of businesses). As most areas benefitting from the programme (81 percent) received coverage under Phase 1, these areas dominate whole programme averages. This has possible implications for the pipeline approach to the degree that areas with greater and lower business density have seen divergent growth paths over the course of the period (issues that would be partly addressed by the inclusion of area fixed effects)

[39] As covered in the 2021 Ofcom Connected Nations data

Figure 4.1: Average employment and turnover per output area, outputs areas benefitting from subsidised coverage (2021 prices)

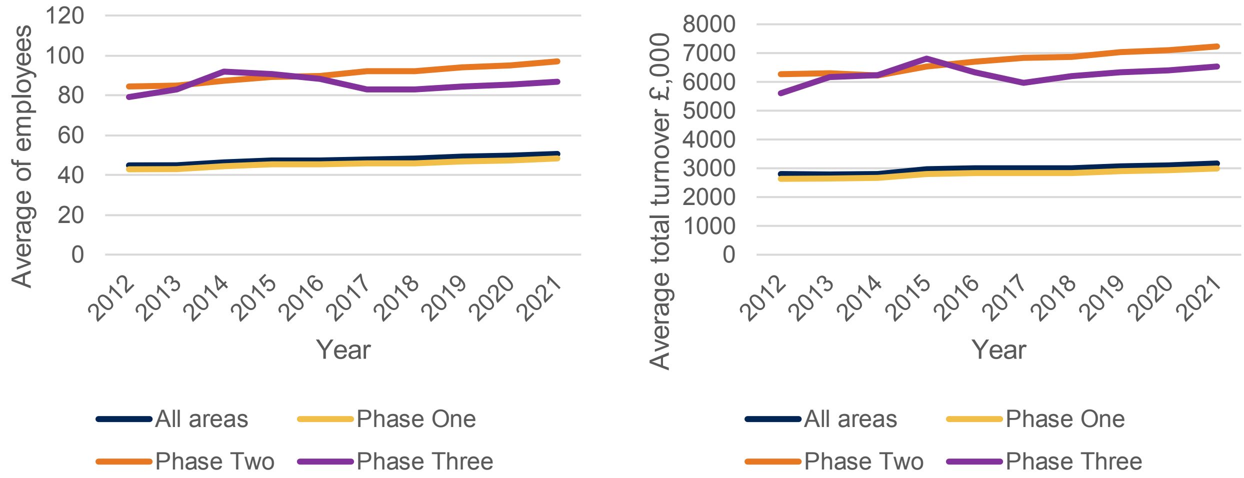
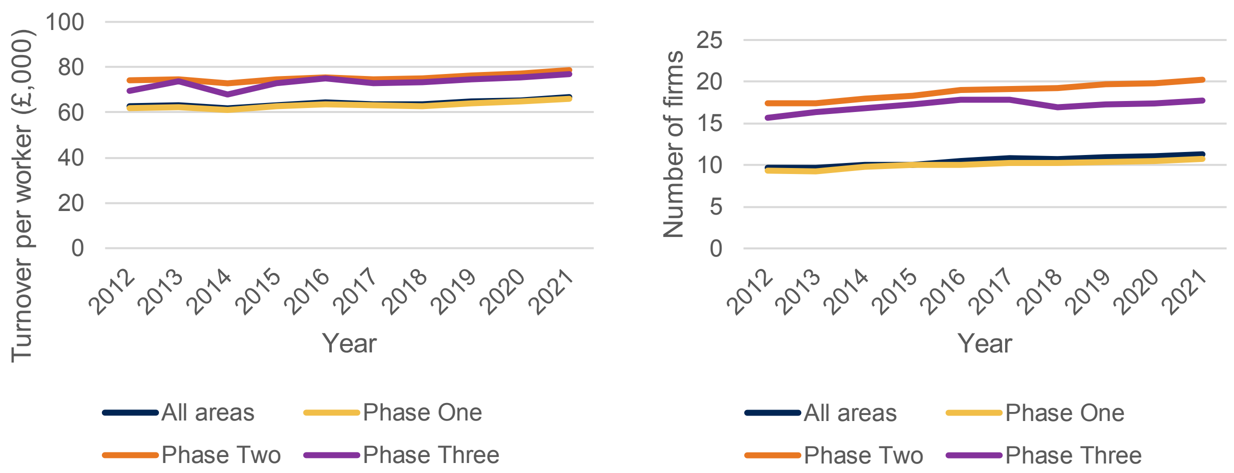


Figure 4.2: Average turnover per worker and average number of firms per output area, output areas benefitting from subsidised coverage (2021 prices)



Source: Ipsos analysis of Business Structure Database (2012 to 2021)

4.3 Results

4.3.1 Business Structure Database

The following fixed effects model was then implemented using the aggregated data (implementing the pipeline approach described in the Section 3):

$$y_{it} = \alpha + \beta T_{it} + \gamma X_{i,t=2012}t + \alpha^i + \alpha^t + \varepsilon_{it}$$

In this model, the outcomes of interest in output area *i* in period *t* (Y_{it}) is determined by whether the area has benefitted from subsidised coverage (T_{it}), and the parameter β gives an estimate of the effect of interest. The treatment variable was defined as the cumulative number of premises upgraded in the Output Area by the end of period *t*.

The models also controlled for general trends at the national level (t) and allows for differential trends across different sectors of the economy and businesses of different employment size bands ($X_{i,t=2012}t$). Here, $X_{i,t=2012}$ represents the share of employment in each sector and size-band in 2012, which was interacted with time to capture unobserved trends affecting different sectors and sizes of firms that would determine growth in the Output Area. The model also controls for any time invariant unobserved differences between output areas (αi). To mitigate against the risk of possible biases driven by unobserved differences between areas benefitting from the programme and areas that were not, the sample was restricted to the 72,738 Output Areas that received subsidised coverage at some point between 2012 and 2021 (i.e. including areas that had not yet benefitted from subsidised upgrades).

Local economic impacts

The table below provides estimates of the overall effects of the Superfast Broadband Programme on employment, turnover and turnover per worker of firms located in Output Areas benefitting from subsidised coverage. The econometric models provided an estimate of the percentage effect on total employment, turnover, turnover per worker and the number of firms in the area per premises upgraded (the first row of Table 4.3). The implied effect at the Output Area level was estimated by multiplying these results by the average number of premises upgraded per Output Area by 2021.

The results indicated that the programme has had a positive impact on the employment and turnover of firms located in Output Areas benefitting from subsidised coverage. The effect on turnover (1.2 percent) was larger than the effect on employment (0.6 percent), implying that the productivity of local firms rose in response to subsidised coverage (0.5 percent, using turnover per worker as a proxy variable). Finally, the number of firms located in the area increased – suggesting that the programme encouraged firms to relocate to areas benefitting from enhanced coverage.

Table 4.2: Estimated impact of subsidised coverage on employment, turnover, and turnover per worker, 2012 to 2021, all firms located in Outputs Areas receiving subsidised coverage

Outcome	Employment	Turnover	Turnover per Worker	Number of firms
Estimated effect per premises upgraded (approximate %)				
All areas upgraded by March 2021	0.000075***	0.000142***	0.000064***	0.000055***
All Phase 3 areas upgraded by March 2021	0.000088***	0.000164***	0.000079***	0.000038***
Implied effect at the Output Area level (approximate %)				
All areas upgraded by March 2021	0.619***	1.173***	0.529***	0.454***
All Phase 3 areas upgraded by March 2021	0.726***	1.355***	0.653***	0.314***
No. of observations	727,380	727,380	727,380	727,380
R-squared	0.315	0.653	0.597	0.328

Source: Ipsos analysis. The outcome variables were expressed in the form of natural logarithms and the coefficients can approximately be interpreted as the marginal percentage effect of subsidised coverage on the outcome of interest.[40] *All models were estimated with time and area fixed effects, allowing for differential across sectors and size-band (based on the Output Areas share of employment by sector). Effects were aggregated to the level of OA by multiplying the estimated effect per premises by the average number of subsidised upgrades in areas benefitting by March 2021 (83.9). This approach assumes that the relationship between the number of premises upgraded and the effect at the area level is linear.*

[40] The percentage effect is exactly equal to the exponentiated value of the coefficient minus 1. However, as the estimated coefficients are small (less than one percent in all cases), these can be treated as approximately equal to the percentage effect.

Impacts by Phase

The results suggested that the economic impacts of the programme tend to decay over time, with earlier Phases of delivery producing smaller long-term impacts than more recent Phases of delivery. While all Phases of the programme appear to have driven expansions in employment, turnover, and turnover per worker (partly through attracting new firms to the relevant areas), the effects of Phases 2 and 3 appear stronger than those of Phase 1 (delivered between 2012 and 2016). However, as these comparisons are not made over consistent timescales, the results would also be consistent with diminishing effects over time. The decline in the impact by Phase is statistically significant.

Table 4.3: Estimated impact of subsidised coverage on local employment, turnover and turnover per worker per premises upgraded (approximate %), by Phase (2012 to 2021)

Outcome	Employment	Turnover	Turnover per worker	Number of firms
Phase 1 (2012 – 2016)	0.000051**	0.000085**	0.000031*	0.000011*
Phase 2 (2015 – 2018)	0.000188***	0.000222***	0.000044*	0.000175***
Phase 3 (2018 - present)	0.000223***	0.000295***	0.000067**	0.000142***
Overall	**0.000075*** **	**0.000142*** **	**0.000064*** **	**0.000055*** **
No. of observations	727,380	727,380	727,380	727,380

*Source: Ipsos analysis. '***', '**', and '*' indicate whether the estimated coefficient was significant at the 99, 95 and 90 percent level of confidence. All models were estimated with fixed effects, allowing for unobserved trends at the national level, and at the sector and size-band (based on the Output Areas share of employment by sector).*

Evidence on the rate at which the impacts of subsidised programme coverage appear to decay was probed further focusing solely on areas that had benefitted from the programme by March 2016 and estimating the impact of subsidised coverage to each year between 2014 and 2021. The results are summarised in the following figure.

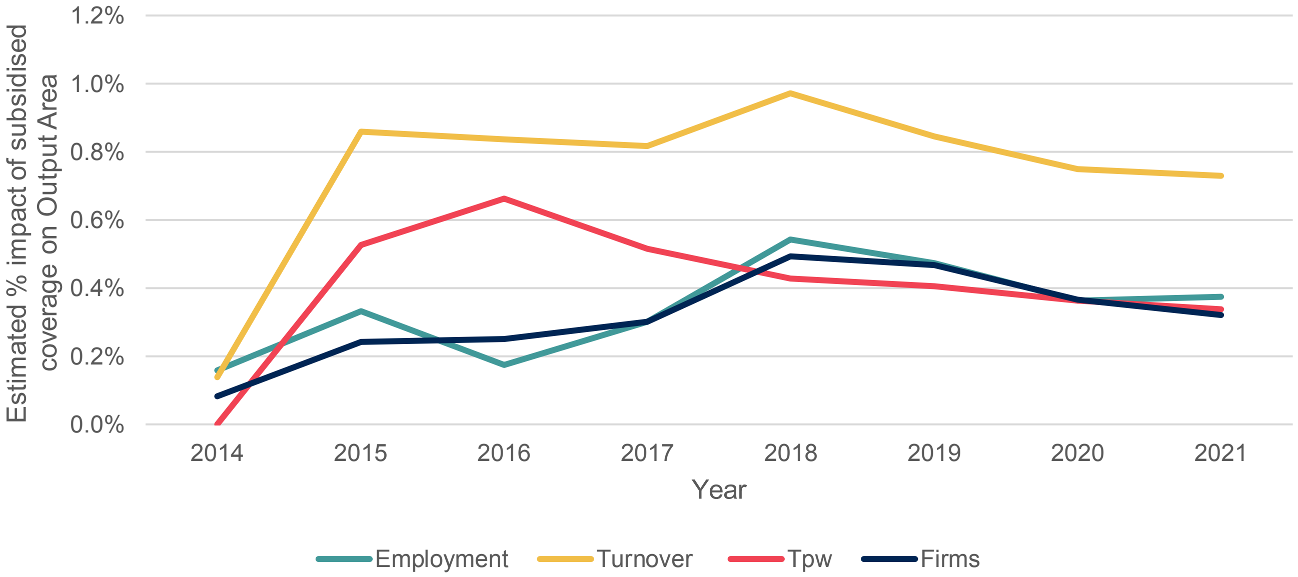
The findings show:

- **Timescale to impact:** Delivery of Phase 1 began in 2013, but the programme had no significant effect on local economic performance until 2015. This suggests that subsidised coverage takes time to produce local economic impacts and may be too early to expect the impact of coverage brought forward under Phase 3 (and to some degree Phase 2) to be visible at this stage.

- **Relocations:** The impact of subsidised coverage on the number of firms located in the areas benefitting appears to strengthen with time up to a point. By 2018/2019 the effect reached its peak and began to fall back. This indicates enhanced broadband infrastructure is an important component of local competitiveness and the ability of areas to attract external investment.

- **Persistence of productivity effects:** The effect of subsidised coverage brought forward by 2016 on turnover per worker peaked in 2016 and got smaller in successive years. The rate of decay was around 20 percent per annum.

Figure 4.3: Impact of subsidised coverage delivered by March 2016 on employment, turnover, turnover per worker and number of local firms, by year (2014 to 2021)



Source: Ipsos analysis. Figure displays the estimated coefficients of the fixed effects models described above. Estimates were derived by restricting the sample to those areas receiving subsidised coverage by 2016. Effects by year were estimated by excluding subsequent years from the sample.

Spatially stable firms

The results above capture the overall effect of the programme on the Output Areas benefitting from the programme. While these findings implicitly account for displacement and crowding out at the local level, they do not represent net economic impacts at the national level and as such cannot be included in a cost benefit analysis. As noted, a share of the local effect is driven by incoming firms and there will be corresponding losses in economic activity elsewhere. To obtain clearer estimates of the economic impacts of the programme, a set of analyses were completed focusing on firms that did not change location between 2012 and 2021.

The findings of these analyses are set out in the table below:

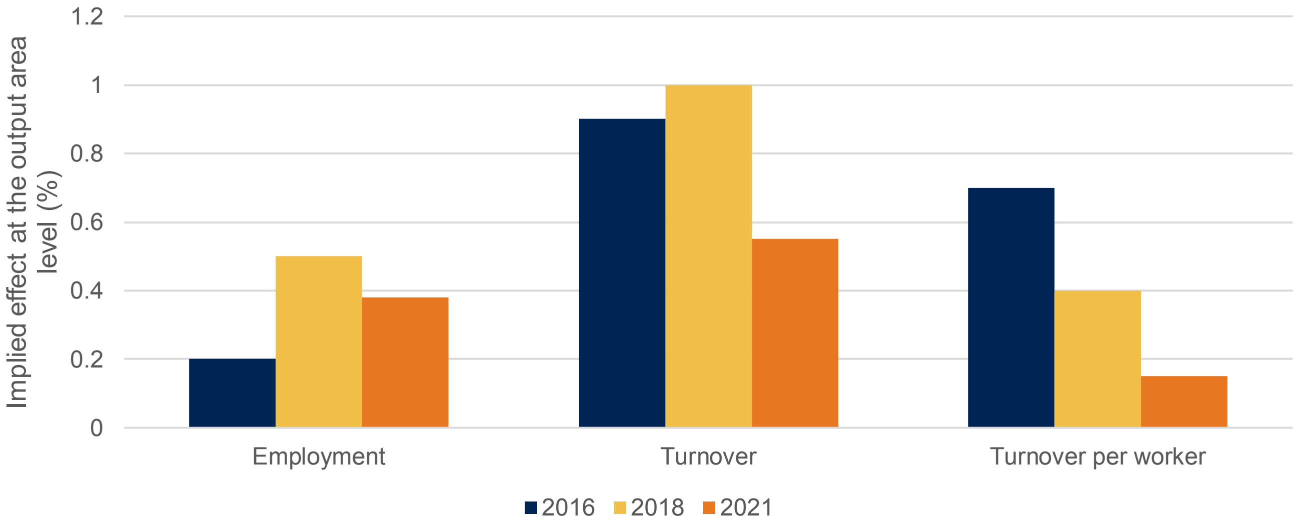
- **Overall impacts:** Across all areas upgraded by March 2021, subsidised coverage increased the average employment of spatially stable firms by 0.38 percent and their turnover by 0.55 percent. The estimated effect on turnover per worker was 0.18 percent.
- **By Phase:** Effects were largest for areas upgraded in Phase 3 with those for Phase 1 smallest by 2021 with no significant effect on turnover per worker for these areas. This would suggest that effects decay over time.
- **Decay over time:** Previous iterations of the evaluation have produced estimates of the employment, turnover and productivity effects up to 2016 and 2018. Figure 4.4 below combines these with the overall results up to 2021 and indicate a declining trend across all outcomes.

Table 4.4: Estimated impact of subsidised coverage on employment, turnover, and turnover per worker, 2012 to 2021, spatially stable firms located in Outputs Areas receiving subsidised coverage

Outcome	Employment	Turnover	Turnover per Worker
Areas upgraded by March 2021 – analysis from 2012 to 2021			
Estimated effect per premises upgraded (approximate %)			
All areas upgraded by March 2021 (approximate %)	0.0000460***	0.0000666***	0.0000184**
Areas upgraded in Phase 1	0.0000367***	0.0000485***	0.0000121**
Areas upgraded in Phase 2	0.0000452***	0.0000689***	0.0000263**
Areas upgraded in Phase 3	0.0000538***	0.0000733***	0.0000205*
Implied effect at the output area level (approximate %)			
All areas upgraded by March 2021 (approximate %)	0.38	0.55	0.15
Areas upgraded in Phase 1	0.30	0.40	0.10
Areas upgraded in Phase 2	0.37	0.57	0.22
Areas upgraded in Phase 3	0.44	0.61	0.17
No. of observations	727,380	727,380	727,380
R-squared	0.187	0.392	0.377

Source: Ipsos analysis. The outcome variables were expressed in the form of natural logarithms and the coefficients can approximately be interpreted as the marginal percentage effect of subsidised coverage on the outcome of interest. All models were estimated with time and area fixed effects, allowing for differential across sectors and size-band (based on the Output Areas share of employment by sector). Effects were aggregated to the level of OA by multiplying the estimated effect per premises by the average number of subsidised upgrades in the Output Areas receiving subsidised coverage by the relevant period.

Figure 4.4: Employment, turnover and productivity effects over time, all areas upgraded



Single site firms

The analyses set out above could potentially be distorted by multi-plant firms owing to the need to apportion turnover measures across individual sites. This was examined further by restricting the analysis to firms with a single site. As highlighted in the table below, the estimated effects of the programme on firms with a single site did not differ in a significant way to those estimated across all firms. This suggests that the presence of multi-plant firms in the sample of firms does not materially influence the results.

Table 4.5: Estimated impact of subsidised coverage on employment, turnover, and turnover per worker, 2012 to 2021, single site firms located in Outputs Areas receiving subsidised coverage

Outcome	Employment	Turnover	Turnover per Worker
Single site firms – estimated effects from 2012 to 2021 (approximate %)			
Estimated effect per premises upgraded, areas upgraded by March 2021	0.000071***	0.000122***	0.000052**
No. of observations	727,380	727,380	727,380
R-squared	0.268	0.521	0.602
All firms – estimated effects from 2012 to 2021 (approximate %)			
Estimated effect per premises upgraded, areas upgraded by March 2021	0.000075***	0.000142***	0.000064***

*Source: Ipsos analysis. '***', '**', and '*' indicate whether the estimated coefficient was significant at the 99, 95 and 90 percent level of confidence. All models were estimated with fixed effects, allowing for unobserved trends at the national level, and at the sector and size-band (based on the Output Areas share of employment by sector).*

Impacts by technology type and speed

C3 reports describe the characteristics of the technologies (i.e. FTTC, FTTP, and wireless) used to provide subsidised coverage as well as their predicted speeds. These details were used to estimate the relative economic impacts by type of technology and predicted speeds. The findings are set out in the following table and suggest:

- **Technology type:** FTTC was the dominant technology type used in the delivery of the programme and the estimated impacts of FTTC coverage broadly aligned with overall impacts of the programme. The findings also indicated that both FTTP and wireless solutions had the potential to deliver larger impacts (though while the estimated coefficients were generally larger than for FTTC, few estimates were statistically significant – particularly for wireless solutions). There was also evidence that ultrafast connectivity (download speeds exceeding 100Mbit/s) had larger effects on employment, turnover and turnover per worker than superfast connectivity. These findings could also potentially be explained by the phasing of the programme (e.g. as earlier phases involved substantially greater shares of FTTC delivery, this may be a signal of initial effects decaying over time).

- **Importance of basic broadband:** The findings partly suggested that there were diminishing returns to the predicted speed of the connection available. The effects of moving up to speeds still below 24Mbit/s were estimated to be between 2 and 2.5 times larger than the impacts of superfast connectivity (on employment, turnover and turnover per worker). [41] This indicates the absence of basic broadband being a more potentially severe impediment for businesses and releasing businesses from this constraint can have significant economic impacts.

- **Locational attractiveness:** While the delivery of basic broadband speeds appeared to have a larger effect on the performance of local firms, it did not have any effect in terms of attracting new firms to the area. The results appeared to suggest that the availability of superfast connectivity was a key differentiating factor in enabling local areas to compete for inward investment.

[41] Note that the analysis included premises upgraded where the predicted speeds were lower than superfast speeds.

Table 4.6: Estimated impact of subsidised coverage on local employment, turnover and turnover per worker per premises upgraded, by technology type and predicted speed (2012 to 2021)

Outcome	Employment	Turnover	Turnover per worker	Number of firms
Effects by type of technology (approximate %)				
FTTC	0.000061***	0.000105***	0.000042***	0.000061***
FTTP	0.000132**	0.000193**	0.000063*	0.000049**
Wireless	0.000340*	0.000492*	0.000132	0.000324
Effects by predicted speed of connection (approximate %)				
Basic (<24Mbit/s)	0.000134***	0.000228***	0.000093***	0.000015
Superfast (>24Mbit to 80Mbit/s)	0.000067***	0.000110***	0.000038***	0.000088***
Ultrafast (>80Mbit/s)	0.000143**	0.000201*	0.000053*	0.000043**

*Source: Ipsos analysis. '***', '**', and '*' indicate whether the estimated coefficient was significant at the 99, 95 and 90 percent level of confidence. All models were estimated with fixed effects, allowing for unobserved trends at the national level, and at the sector and size-band (based on the Output Areas share of employment by sector).*

Impacts by urban and rural areas

The analysis was also completed for urban and rural areas separately. [42] The table below provides the estimated impacts for urban and rural areas. The findings suggest that the estimated magnitude effects (per premises upgraded) on employment and turnover was larger in urban areas than in rural areas.

It should be noted that the economic density of rural Output Areas benefitting from the programme was higher than urban areas (i.e. at 47.7 jobs per rural Output Area in comparison to 38.1 jobs per urban Output Area). This indicates that urban areas benefitting from the programme tended to be in more residential suburban zones. As such, this indicates that rural delivery of the programme will have raised the productivity of more workers on average, leading to larger economic impacts in absolute terms than delivery in urban zones.

Table 4.7: Estimated impact of subsidised coverage on local employment, turnover and turnover per worker per premises upgraded, by urban and rural areas (2012 to 2021)

Outcome	Employment	Turnover	Turnover per worker	Number of firms
Urban	0.000143***	0.000274***	0.000128**	0.000145***
Rural	0.000084***	0.000188***	0.000102***	0.000196***

*Source: Ipsos analysis. '***', '**', and '*' indicate whether the estimated coefficient was significant at the 99, 95 and 90 percent level of confidence. All models were estimated with fixed effects, allowing for unobserved trends at the national level, and at the sector and size-band (based on the Output Areas share of employment by sector).*

Total local economic impacts

The table below aggregates the estimates of the overall economic impacts of the Superfast Broadband Programme over the number of areas benefitting from the programme by applying the estimated effects

[42] Urban areas were defined as A1 to C2 in England and Wales (https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/239478/RUC11user_guide_28_Aug.pdf), 3 to 8 in Scotland (https://www2.gov.scot/Topics/Statistics/About/Methodology/UrbanRuralClassification#:~:text=Scottish%20Government%203%20fold%20Urban%20Rural%20Classification&text=Areas%20with%20a%20population%20of%20less%20than%203%2C000%20people%20and,settlement%20of%2010%2C000%20or%20more) and _ in Northern Ireland. All other areas were classified as rural

to the average total employment and turnover of firms located in the Output Area in 2012. The results indicated that by 2021, the subsidised coverage led to the following estimated impacts:

- **Jobs:** The number of workers employed in Output Areas benefitting from the programme increased by 23,700 jobs due to the subsidised coverage (compared to 17,600 by 2018 and 7,500 by 2016).[43] This accounts for any offsetting but localised displacement or crowding out effects – e.g. if firms benefitting from subsidised coverage claim market share from competitors in the neighbourhood, then the associated impact on jobs will be captured in Output Area totals.

- **Turnover:** Subsidised coverage led to an increase in the annual turnover of firms located in relevant areas of £2.5bn (compared to £1.9bn in 2018 and £1.8bn by the end of 2016). Again, this is net of any offsetting but localised displacement or crowding out effects.

- **Additional turnover from efficiency gains:** The total increase in the annual turnover of firms driven by apparent efficiency gains was estimated at £1.2bn by 2021 compared to £845m by the end of 2018 and £1.4bn by 2016.[44]

These should not be considered estimates of the net economic impacts of the Superfast Broadband Programme. While the results are robust to offsetting localised displacement and crowding out effects, subsidised coverage encouraged the relocation of firms to areas benefitting from the programme and there will be corresponding losses of economic activity elsewhere. Additionally, the expansion of firms benefitting from enhanced broadband infrastructure may also come at the expense of loss of market share for firms located outside the programme.

Table 4.8: Estimated local economic impacts of the Superfast Broadband Programme by 2021

Outcome	Average in 2012 (per Output Area)	Estimated % impact	No. of Output Areas receiving subsidised coverage by March 2021	Estimated total impact (jobs/£m per annum) by 2021	Estimated impacts by March 2018 *	Estimated impacts by March 2016 **
All Phases						
Employment	43.4	0.75	72,738	23,676	17,634	7,459
Turnover (£m per annum)	2.5	1.42	72,738	2,582	1,916	1,868
Turnover per worker (£,000 per worker)	60.2	0.64	72,738	1,216	845	1,430
Phase 3 only						
Employment	79.1	0.88	8,994	6,261	-	-
Turnover (£m per annum)	5.61	1.64	8,994	827	-	-
Turnover per worker (£,000 per worker)	69.6	0.79	8,994	391	-	-

*Source: Ipsos analysis. * As estimated in DCMS (2021) State aid evaluation of the Superfast Broadband Programme, ** As estimated in DCMS (2018) Economic and Public Value Impacts of the Superfast Broadband Programme.*

[43] Note that this differs from prior estimates of the impact of the programme to 2016 (49,000 jobs) as the findings are configured at the level of the Output Area rather than the postcode. As highlighted in the previous study, displacement effects were likely to be significant.
[44] This is calculated as the turnover per worker in 2012 x % impact of subsidised coverage x number of workers employed in 2012.

5 Impacts on workers

This section provides an assessment of the impacts of subsidised superfast broadband coverage on workers. This section draws on administrative data on and wages of workers located in the areas covered by the build plans of local schemes. The analysis considers the direct effects of superfast broadband coverage on workers earnings and hours worked as well as on the number of local residents claiming unemployment benefits.

5.1 Data

The following analyses made use of the following datasets.

5.1.1 Annual Survey of Hours and Earnings

To explore the effects of subsidised coverage on employees' wages, records of premises upgraded were linked to the details of the location of the employer of employees surveyed in the Annual Survey of Hours and Earnings (ASHE) dataset compiled by the ONS and accessed through the SRS. The ASHE is an annual survey of the pay and hours worked of employees in the UK economy, and provides data on the levels, distribution and make-up of earnings and hours worked for UK employees. Using evidence at the level of individual employees should eliminate the possible effects of changes in worker composition at the firm level, providing a clearer measure of the productivity gains involved. The survey covers approximately 300,000 employees in the economy each year, with the sample drawn in such a way that many of the same individuals are included from year to year with the remainder randomly selected. Data on wages are compiled from PAYE records collected by HMRC and alongside a mandatory survey in which firms are required to provide details of usual hours worked by workers that are sampled in the survey. The ASHE is designed to provide information on the levels, distribution and make-up of earnings and paid hours worked for employees in all industries and occupations.

The ASHE is designed to collect data on the structure of earnings for various industrial, geographical, occupational and age-related breakdowns. As such, the survey aims to be representative of employees in the UK economy. However, the sample frame is not able to identify the self-employed and does not fully cover firms that are registered for VAT but not PAYE. In addition, there are likely to be cases in which a firm has a PAYE scheme which does not cover all employees (predominantly in the hotels and catering sectors). Whilst workers employed by VAT but not PAYE registered firms were found by the ONS to be similar to those registered for both, reducing concerns in relation to the representativeness of the data collected.

Records of subsidised areas were linked to the ASHE using the Output Area associated with the premises upgraded. Only employees' main jobs were included where employees had more than one job and to reduce the potential distortionary effects of unbalanced panels, individuals were only kept if data was observed both before and after their employers' area received coverage. In addition, individuals were required to have remained employed in the same output area before and after upgrade (to ensure that the results were not distorted by the movement of workers across locations).

A total of 29,476 Output Areas benefitting from subsidised coverage between 2012 and 2021 were linked to at least one local unit containing a sampled employee between these years. A total of 127,187 employees were associated with firms located in subsidised areas providing a total of 621,738 annual observations of wages and pay.

5.1.2 Claimant Count

Experimental data on the claimant count was taken from NOMIS. [45] This captures the number of people claiming Jobseeker's Allowance plus those who claim Universal Credit and who are required to seek work and be available for work. [46] This has replaced the number of people claiming Jobseeker's Allowance as the headline indicator of the number of people claiming benefits principally for the reason of being unemployed. Data between 2013 and 2021 was downloaded at the LSOA level for England and Wales and the Data Zone level for Scotland (being the smallest census geography areas available). There were a total of 41,729 areas with claimant count data available.

It is important to note that Scottish Data Zones are smaller in area than LSOAs in England and Wales. This would potentially distort attempts to explore the effects of the programme in terms of its impact on the absolute numbers of claimants, as numbers of claimants in Scottish Data Zones are smaller than in LSOAs. Additionally, using these figures will also conflate effects on unemployment driven by the installation of superfast broadband connectivity (e.g. civil engineering jobs created) with longer term effects of the programme in stimulating local economic activity. It is assumed that the former effect will largely be temporary, and the primary focus of the following analysis is on persistent reductions in unemployment that are more likely to be attributable to the longer term local economic impacts of the programme.

In this case, while unemployment is observed at a small area level, the delivery of subsidised superfast broadband coverage—the 'treatment' of interest for these analyses—is observed at a premises level through the C3 reports. As described in Section 3, to define a measure of the 'treatment' for the purposes of these analyses, premises level data required aggregation to the LSOA level. Three measures of the treatment were developed to support the investigation of the programme's effects on unemployment:

- An indicator defining whether an LSOA or Data Zone received any BDUK subsidy at all
- Percentage of postcodes within the LSOA or Data Zone receiving subsidised superfast coverage
- Number of premises within the LSOA or Data Zone receiving a subsidised superfast coverage—this measure is considered least sensitive to differences in the size of LSOA and Data Zones, as it will reflect the size of the area.

All premises reported in the C3 reports were included in these measures. This includes premises claimed by providers but which did not receive a superfast coverage (perhaps because the building was too distant from the cabinet). Premises claimed outside of white postcodes were also included on the assumption that most of these premises would have been enabled as a by-product of upgrading those cabinets serving white postcodes (and the premises concerned may well have employed workers residing in the subsidised areas). While these premises upgraded would have been ineligible for payments under the contracting model, it is considered appropriate to include them in an analysis of the economic impacts of the programme.

The expectation was that the programme would reduce unemployment through its effects in retaining or attracting businesses to those locations benefitting from enhanced broadband coverage (or facilitating the expansion of incumbents). To understand the effects of the programme with greater precision, it would have ideally been possible to refine the focus solely to non-residential premises that have received

[45] See https://www.nomisweb.co.uk/sources/cc

[46] This differs from the Government's preferred measure of unemployment based on the International Labour Organisation's definition, which is collected through the Annual Population Survey/Labour Force Survey. This is only available at the local authority level and is insufficiently granular for the purposes of this analysis.

subsidised coverage. However, this is not captured in the available data, and residential and non-residential premises upgraded are combined in core measures of the treatment variable. This may not be problematic—upgrading residential premises may also support reductions in unemployment—for example, through enabling teleworking or through widening job search strategies. An approach to addressing this issue was through constructing an estimate of the number of residential and non-residential premises receiving subsidised coverage. This involved apportioning observed delivery volumes at a postcode level based on the share of residential and non-residential premises on the postcode in 2013. This approximation involves an assumption that residential and non-residential premises had an equal probability of receiving upgraded broadband coverage. These estimates have been used to test the relative importance of residential and non-residential premises upgraded in reducing the exposure of low connectivity areas to the risks of unemployment, and to shed some light on which of the hypothesised mechanisms are most significant.

5.1.3 C3 Reports

As above, claimed delivery of superfast coverage was taken from the C3 reports provided to BDUK by contractors.

5.2 Results

5.2.1 Wage impacts

The following model was implemented using the data compiled from the ASHE (implementing the pipeline approach described in the Section 3):

$$y_{it} = \alpha + \beta T_{kt} + \partial X_{it=2012}t + \gamma Z_{jt=2012}t + \alpha^k + \alpha^t + \varepsilon_{it}$$

In this model, the outcomes of interest for individual worker *i* in period *t* (Y_{it}) is determined by whether the Output Area in which the worker was employed had benefitted from subsidised coverage in period t (T_{kt}), and the parameter β gives an estimate of the effect of interest.

In this case, while the Output Area associated with the location of employment was known, evidence on wages and hours worked were not available for all workers within an Output Area (making it challenging to provide reasonable estimates at an Output Area level and to adopt the dose response approach outlined in Section 3). For simplicity, the treatment variable for these regressions were defined as *a* dummy variable (taking the value of 1 after the first premises in the Output Area was upgraded and 0 otherwise - represented by T_{kt}).[47]

The models also controlled for linear trends across baseline worker characteristics (age, gender, and occupation, $X_{i,t=2012}t$) and baseline characteristics of the employing firm *j* (sector and size, $Z_{j,t=2012}t$). The model also controls for any time invariant unobserved differences between the Output Areas in which employing firms were located (α^k). As with other analyses, to mitigate against the risk possible of biases driven by unobserved differences between individuals in areas benefitting from the programme and those in areas that did not, the sample was restricted to those individuals employed in Output Areas that received subsidised coverage at some point between 2012 and 2021.

[47] This will result in some workers employed by firms that did not receive subsidised coverage being classed as 'treated'. This would not necessarily distort findings as the ASHE sample is drawn randomly though may lead to an understatement of average effects owing to the inclusion of untreated firms in the treatment group.

Overall effects

The table below provides estimates of the overall effects of the Superfast Broadband Programme on both hourly earnings and total hours worked for individuals employed by firms located in Output Areas benefitting from subsidised coverage. The results found a positive impact on the hourly wage of employees in the OA of around 0.7 percent per worker following the first upgrade (although there was no effect on hours worked). This provides further confidence that the effects on turnover per worker can be treated as a productivity gain.

However, it should be noted that these effects were not statistically significant in models that were restricted to individuals whose wages were observed in each year between in 2013 and 2021 (though it is important to note that the restrictions placed on this model reduced the sample size substantially to just over 5000 observations).

Table 5.1: Impact of subsidised coverage on hourly earnings and total hours worked, 2012 to 2021 (approximate % effects)

	Model 1	Model 2
Fixed effects	Yes	Yes
National time trends	Yes	No
Individual and occupation time trends	Yes	Yes
Firm/individual controls	Yes	Yes
Model specification	OLS	OLS
Individuals present in all periods	No	Yes
Average impact following the first premises upgraded		
Hourly wage (£, ln[48])	0.00688***	0.00413
Total hours worked (hrs, ln)	0.000683	-0.00395
Number of observations	604,374 – 618,493	5,103
Adjusted R-squared	0.218-0.383	0.213-0.292

*Source: Ipsos analysis. '***', '**', and '*' indicate whether the estimated coefficient was significant at the 99, 95 and 90 percent level of confidence.*

Results broken down by Phase indicate broadly similar effects on wages across all Phases of between 0.6 and 0.8 percent as illustrated in the table below (again, the small size of the longitudinal samples available likely limited the statistical power of Model 11).

[48] Outcome variables for wages and hours were log transformed. Therefore, coefficients can be interpreted as approximate % effects as highlighted above.

Table 5.2: Impact of subsidised coverage on hourly earnings by Phase, 2012 to 2021 (approximate % effects)

Outcome	Model 3	Model 4
Fixed effects	Yes	Yes
National time trends	Yes	No
Individual and occupation time trends	Yes	Yes
Firm/individual controls	Yes	Yes
Model specification	OLS	OLS
Individuals present in all periods	No	Yes
Average impact following the first premises upgraded - Hourly wage (£, ln)		
Phase 1	0.00572***	0.00473
Phase 2	0.00693***	0.00665
Phase 3	0.00828*	0.00739

*Source: Ipsos analysis. '***', '**', and '*' indicate whether the estimated coefficient was significant at the 99, 95 and 90 percent level of confidence.*

Effects by occupation

Isolating effects by occupation showed varying impacts depending across occupations:

- **Professional occupations:** For professional occupations (such as scientists, health professionals, teaching professionals and business, media, and service professionals), the estimated effect of subsidised coverage on hourly earnings was shown to be similar to those found overall at 0.7 percent. Subsidised coverage was also estimated to have led to a decrease in the number of hours worked of 0.9 percent.

- **Skilled trades:** Skilled trades also saw an increase in wages of around 0.6 percent. Once again, a similar sized reduction in hours worked was also observed for these occupations at 0.6 percent fewer total hours worked.

- **Sales and customer service:** The largest increase in wages was found for sales and customer service employees at a 1.2 percent increase, however in this case no corresponding reduction in hours was observed.

- **Elementary occupations:** Finally, elementary occupations saw a 0.8 percent rise in wages as a result of subsidised coverage.

Table 5.3: Impact of subsidised coverage on hourly earnings and total hours worked by occupation group (SOC10), 2012 to 2021

Outcome	Hourly wage (£, ln)	Total hours worked (hrs, ln)
Fixed effects	Yes	Yes
National time trends	Yes	No
Individual and occupation time trends	Yes	Yes
Firm/individual controls	Yes	Yes
Model specification	OLS	OLS
Individuals present in all periods	No	Yes
Effects per premises upgraded		
Managers and senior officials	0.00010	-0.00438*
Professional	0.00740***	-0.00879***
Associate professional and technical	-0.00111	-0.00117
Administrative and secretarial	0.00422	-0.00024
Skilled trades	0.00605*	-0.00616*
Personal service	0.00408	-0.00282
Sales and customer service	0.01183***	-0.00040
Process, plant and machine operatives	-0.00167	-0.00664*
Elementary	0.00832***	0.00340
Number of observations	48,791 – 90,664	48,973 – 90,683
Adjusted R-squared	0.133-0.274	0.156 – 0.318

*Source: Ipsos analysis. '***', '**', and '*' indicate whether the estimated coefficient was significant at the 99, 95 and 90 percent level of confidence.*

5.2.2 Unemployment impacts

To examine the effects of the programme on the number of individuals claiming unemployment benefits (claimant count), it was necessary to aggregate the available data to an LSOA level. This enabled the following econometric model to be estimated:

$$y_{it} = \alpha + \beta T_{it} + \gamma X_{it=2013} + UC_{it} + \alpha^i + \alpha^t + \varepsilon_{it}$$

Here, the number of claimants in area i in period t (Y_{it}), is determined by its exposure to BDUK subsidies (T_{it}) and the characteristics of the area in 2013 (X_i,2013). The parameter β provides an estimate of the impact of subsidised coverage on the number of claimants. As the characteristics of areas could have been influenced by the programme, only trends across baseline characteristics are controlled for to avoid possible issues with endogeneity that could cause estimates of impact to be biased. Given the potentially distortionary effect of the spatially variable rollout of Universal Credit on observed claimant numbers, some models also control for its introduction locally (UC_{it}, taking the value of 0 pre-rollout and 1 afterwards).

Overall effects

The overall effects on the number of people claiming unemployment benefits were estimated by starting with a baseline pooled OLS model with no controls and progressively adding fixed effects and controls described presented below:

- Models 1 and 2 provide baseline pooled OLS results with no fixed effects (though controlling for 2013 area characteristics). These models suggest the programme led to a reduction of between 0.4

and 1 claimants per LSOA receiving upgrades (with the estimated effect falling once the introduction of Universal Credit is controlled for).

- Model 3 adds area fixed effects specification with no controls aside from a dummy for universal credit and finds much higher effects. These are tempered by the introduction of time fixed effects in Model 6 and then travel to work area level trends on top in Model 4. The most robust model (Model 4) implies a reduction of 0.5 claimants on average per LSOA upgraded.

These models were run with and without a Universal Credit dummy variable to test the robustness of the models to the timing of universal credit rollout. From here forward the models implemented include this control to account for the differing times UC was implemented across areas.

Table 5.4: Impact of subsidised coverage on the claimant count, 2013 to 2021

Outcome	Model 1	Model 2	Model 3	Model 4
2013 controls	Yes	Yes	No	No
UC control	No	Yes	Yes	Yes
Time FE	No	No	Yes	Yes
Area level trends	No	No	No	Yes
Model specification	OLS	OLS	FE	FE
Dummy treatment variable (equal to 0 before year of upgrade and 1 after)				
Claimant count (number)	-1.023***	-0.389***	-0.588***	-0.549***
Number of observations	184,234	184,234	195,655	195,655
Adjusted R-squared	0.354	0.495	0.427	0.501

*Source: Ipsos analysis. '***', '**', and '*' indicate whether the estimated coefficient was significant at the 99, 95 and 90 percent level of confidence.*

Dose response models

The models presented here are not sensitive to the overall quantity of premises upgraded within an LSOA, therefore an LSOA with a single upgraded premise is treated equivalently to an LSOA with a large number of premises upgraded. This may be misleading in so far as areas upgraded with multiple premises might expect to see larger impacts.

Refining this approach, the table below uses alternative treatment variables defined as the cumulative proportion of postcodes in an LSOA upgraded (Model 5) and the overall number of premises upgraded within the LSOA (Model 9). Both these take the form of a difference-in-differences specification and are, in principle, robust to time invariant differences between LSOAs.

The results of model 6 below indicated that for every 10,000 premises upgraded, the number of unemployed claimants fell by 29 over subsequent years. The results with the cumulative percentage of postcodes in the LSOA/Data Zone receiving subsidised coverage as the treatment also indicated that for every percentage point increase in postcodes of the area upgraded there were 0.25 fewer claimants. This would equate to 2.8 fewer claimants per 10 percent additional coverage of the postcodes within an LSOA/Data Zone.

Table 5.5: Impact of subsidised coverage on the claimant count, dose-response models, 2013 to 2021

Outcome	Model 5	Model 6
Areas controls (2013)	Yes	Yes
Time FE	Yes	Yes
Area level trends	Yes	Yes
Model specification	FE	FE
Treatment variable	Cumulative % of postcodes receiving subsidised coverage	Number of premises upgraded
Claimant count (number)	-0.2524***	-0.00294***
Number of observations	195,030	195,535
Adjusted R-squared	0.419	0.548

*Source: Ipsos analysis. '***', '**', and '*' indicate whether the estimated coefficient was significant at the 99, 95 and 90 percent level of confidence.*

Models 5 and 6 were also repeated using only areas treated in each Phase individually to explore differential impacts over time. The results in the table below show that the estimated effects remain similar to the overall across each Phase. They imply a small degree of decay in effect size over time with Phase 1 effects slightly smaller than both Phase 2 and Phase 3.

Table 5.6: Impact of subsidised coverage on the claimant count, dose-response models, 2013 to 2021

Outcome	Model 7	Model 8
Areas controls (2013)	Yes	Yes
Time FE	Yes	Yes
Area level trends	Yes	Yes
Areas included	Treated only	Treated only
Model specification	FE	FE
Treatment variable	Cumulative % of postcodes receiving subsidised coverage	Number of premises upgraded
Outcome - Claimant count (number)		
Phase 1	-0.1947***	-0.00227***
Phase 2	-0.2749***	-0.0032***
Phase 3	-0.2946**	-0.00343**

*Source: Ipsos analysis. '***', '**', and '*' indicate whether the estimated coefficient was significant at the 99, 95 and 90 percent level of confidence.*

Residential vs non-residential effects

An adapted version of Model 8 above was reapplied to explore the potential for differences in the magnitude of the effect on the claimant count based upon the degree to which premises upgraded in LSOAs were residential or non-residential. This found:

- **Residential upgrades:** Residential upgrades were associated with reductions in the number of claimants. This equated to an estimated 30 fewer claimants per 10,000 residential premises upgraded.

- **Non-residential upgrades:** In comparison, the results suggested that effects from non-residential upgrades were larger at 298 fewer claimants per 10,000 non-residential premises upgraded. This would support the hypothesis that productivity gains are largely driven by commercial use of superfast broadband connectivity.

Table 5.7: Impact of subsidised coverage on the claimant count, residential vs non-residential effects, 2013 to 2021

Outcome		Model 9
	Areas controls (2013)	Yes
	Areas included	Treated only
	Unobserved area effects	Yes
	Unobserved area trends	Yes
	Model specification	FE
	Treatment variable	Number of premises upgraded
	Residential coefficient	**Non-residential coefficient**
Claimant count (number)	-0.00299***	-0.0298***
	Number of observations	79,125
	Adjusted R-squared	0.446

*Source: Ipsos analysis. '***', '**', and '*' indicate whether the estimated coefficient was significant at the 99, 95 and 90 percent level of confidence*

6 Impacts on house prices

This section provides estimates of the effects of the Superfast Broadband Programme in creating value for consumers. The analysis employs a hedonic pricing analysis exploring the degree to which the value created by the programme is reflected in house prices.

6.1 Key issues

Understanding the benefits of the programme for households (over and above the economic benefits described in the preceding chapters) involves several challenges:

- **Direct effects on well-being:** The direct effect of making superfast broadband infrastructure available can be expected to arise from consumption of superfast broadband services. This will include consumption for leisure purposes but also potentially for working purposes (i.e. by enabling teleworking). While this will involve benefits for the consumer (e.g. in the form of increased choice or leisure time) it will also involve costs. The consumer will incur costs in the form of additional spending on broadband services. However, there may be other costs – for example, those relocating on the expectation that they will be able to commute less often may also be faced with longer commutes. As such, it is important to focus on the net benefits of making superfast broadband infrastructure available (i.e. the well-being indicator should measure the consumers' surplus). [49]

- **Income effects:** As illustrated in the previous two chapters, the superfast broadband programme has led to higher incomes for workers. Higher incomes will contribute to higher levels of well-being and unless this is controlled for, analyses risk conflating the economic benefits of the programme with the broader consumer benefit arising from consumption of superfast services.

- **Indirect effects on well-being:** As with the location decisions of firms, subsidised coverage can be expected to lead to 'sorting effects' where improved connectivity influences the location decisions of individuals. As such, the well-being of residents of an area may also be influenced indirectly:

  - If new residents are attracted to an area (or replace existing residents), then differences in the underlying well-being of incoming and incumbent residents will influence the results. This issue could be handled if it was possible to track individuals as they move between locations, though the data available for the following analyses did not permit this. As such, the results that follow focus on the impact of superfast coverage on the well-being of residents of the areas benefitting.

  - If superfast coverage encourages the migration of households to rural areas then this may stimulate population growth. In turn, this could place pressure on public services, lead to greater congestion and/or result in other disbenefits for existing residents (e.g. disamenities arising from pressure to develop land, or disruption to community cohesion or traditional patterns of life). Such population effects could also result in both benefits (reduced congestion) and disbenefits (social dislocation) to communities elsewhere.

  - Greater superfast coverage could also lead to negative indirect impacts on some groups if it accelerates the digitalisation of public and private services. If greater take-up of superfast broadband makes it efficient for services to be moved online, the closure of physical service delivery points will have negative impacts on those without access (or the skills) to access those

[49] This can be understood as the difference between what consumers would have been willing to pay for superfast broadband services and what they actually paid.

services online. Closure of services may also have negative effects on the vibrancy of town centres, which may also have offsetting effects on the well-being of residents.

- **Observability of well-being:** Finally, the welfare or utility of individuals cannot be directly quantified or monetised in the same way as the economic impacts described earlier. As such, alternative approaches are needed to estimate the value of benefits to the consumer.

A revealed preference approach to explore the value of superfast connectivity is adopted below, in which the impact of superfast broadband coverage on house prices is explored (on the basis that the benefits arising from superfast broadband consumption will be capitalised into house prices). A detailed discussion of how far impacts on house prices can be interpreted as a welfare gain is provided in Section 8. A second approach based on stated preferences will also be implemented at a later date, using measures of subjective well-being collected through surveys.

6.2 Impacts on house prices

This section examines the impact of the Superfast Broadband Programme on house prices. This attempts to estimate the social value of superfast broadband services based on prices observed in secondary markets. The underlying assumption is that if households place a value on superfast connectivity, this will be reflected in an increase in what they are willing to pay to obtain access to the asset. The price premium paid for houses with superfast connectivity should in principle represent the present value of the future net benefit they expect to gain from access to faster internet services (though there are a number of caveats to this as outlined in Section 8).

6.2.1 Data

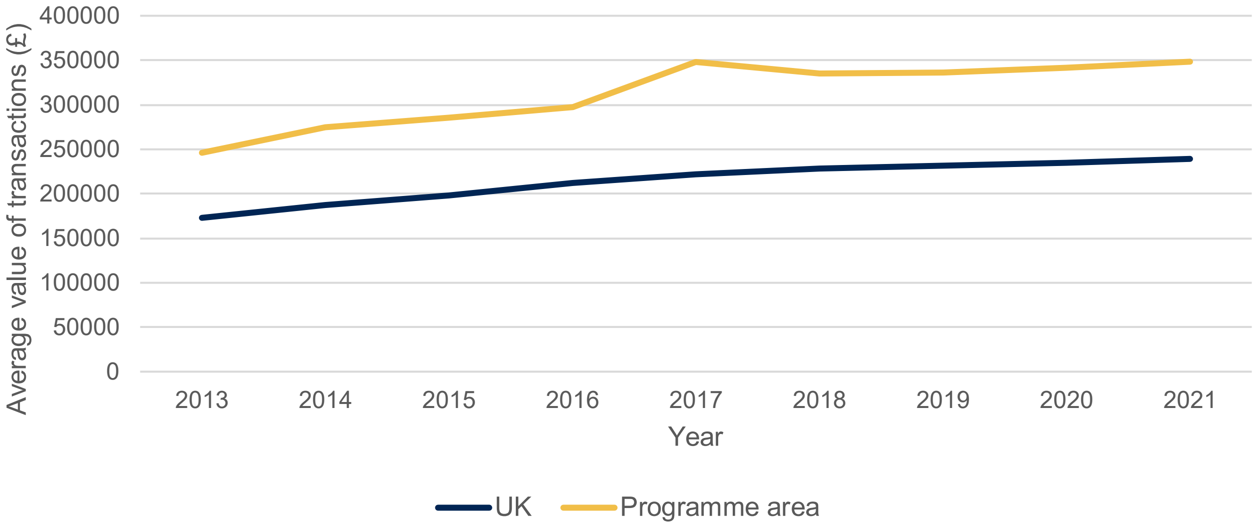
The primary dataset used for the analysis was the transaction level data on houses sold compiled by HM Land Registry. This provides a variety of data on individual housing transactions, including:

- Postcode and address of the house sold
- Sale price agreed
- Date of completion, and
- Some basic information on the characteristics of the property – including tenure (freehold or leasehold) and type (detached, semi-detached, terrace, or flat/maisonette)

This data was linked to both the C3 reports and the build plans defined in the Speed and Coverage Templates to identify properties sold on postcodes that benefitted from subsidised upgrades. This process identified 1,527,144 homes sold on postcodes that benefitted from subsidised coverage at some point between 2013 and 2021, and a further 96,283 homes sold on postcodes defined in the build plans for contracts awarded through the programme but which have not been upgraded yet. Around 682,793 (45 percent) of these transactions took place before the postcode was upgraded. Information on the start date of the relevant contract was also appended to the data to provide a proxy for the announcement date of the scheme (to test for anticipation effects).

The figure below provides an overview of changes in (unweighted) average house prices between 2012 and 2021 in areas covered by the build plans of contracts awarded through the programme and the UK overall. House prices in the programme area increased quickly over the period (rising by 37 percent over the period), mirroring national trends.

Figure 6.1: Evolution of house prices in the UK and programme areas, 2013 to 2021



Source: Land Registry HPI, SCTs, Ipsos analysis

On average, the prices of houses sold in the programme area were 46 percent higher than those sold nationally (£312,524 versus £213,735). This does not account for differences in the types of houses traded, and there were also differences in the composition of characteristics of houses sold in the programme area when compared to the national average, as illustrated in the table below. Given these differences in composition, Figure 6.1 should not be taken to imply that the areas benefitting from the programme are necessarily characterised by higher levels of wealth. For example, between 2013 and 2021, detached house sales in build areas were sold for an average of £369,163 compared to £383,312 for such houses sold across England and Wales in the same period. The same pattern is evident across each of the home types presented below with the average price paid over the period for those in target areas of each type being lower than the equivalent national average.

Table 6.1: Distribution of houses sold by type, programme areas and UK, 2012 to 2021 (percentage of transactions)

Type of home	Programme area	England and Wales overall[50]
Detached	38%	24%
Semi-detached	24%	26%
Terraced	22%	24%
Flat	10%	20%

Source: Land Registry, SCTs, Ipsos analysis

The dataset was enriched with a further set of controls derived from the DfT Journey Time Statistics (previously Accessibility Statistics) between 2012 and 2017. [51] These provided LSOA estimates of the average journey times (by road, public transport, and walking and cycling) to a variety of amenities that may also influence house prices. These amenities included centres of employment, education, healthcare services, town centres, and transport hubs. In the absence of estimates for years post 2018, journey times were assumed to be constant from 2017 onwards.

[50] Taken from the March 2020 Price Paid Data update. See: https://www.gov.uk/government/news/march-2020-price-paid-data

[51] The publication of 2018 journey time statistics (due in August 2020) was cancelled due to the COVID-19 pandemic.

6.2.2 Econometric model

The following econometric model was adopted to investigate the impacts of subsidised coverage on house prices:

$$y_{it} = \alpha + \beta T_{it} + \gamma P_{it} + \delta X_{it} + \alpha^i + \alpha^t + \varepsilon_{it}$$

Two approaches to investigating the impact of the programme were explored. The first linked the average prices of the property sold (y_{it}) to a binary measure of whether the premises had been upgraded in period t (taking the value of 1 after the first premises and 0 otherwise - represented by T_{it}). This approach assumes that prices respond to the delivery of the upgrade and that consumers do not factor in future expectations of superfast connectivity into their valuations. In this model, postcodes that are yet to benefit from subsidised coverage act as the comparison group (in line with the general pipeline model adopted elsewhere).

This will lead to downward bias in the estimates of the impact of the programme if consumers are aware of plans to upgrade local infrastructure and factor this into their valuations. A second approach was adopted in which the availability of superfast broadband was capitalised into house prices from the point at which the scheme was announced (taken as the start date of the contract). Here, the treatment effect applied to all postcodes in the build plans of superfast contracts, and the variable T_{it} took the value of 1 from the point at which the scheme was announced and 0 in preceding years. Effects are identified in these models from the staggered start dates of contracts within and across all Phases of the programme.

All models implemented controlled for number of properties sold of difference types (i.e. detached, semi-detached, terraced or flat/maisonette), represented by the vector P_{it}. Models also allowed for unobserved characteristics of the postcode (α^i) that do not vary over time – this would capture the effect of any locally important but unobserved features influencing local house prices (e.g. proximity to parks). Controls were also added in some models for journey times to local amenities (X_{it}), and unobserved time specific shocks in house prices at a national level (α^t).

6.2.3 Results

The findings of these models are presented in the following tables. Fixed effects models pointed to implausibly strong effects on the average prices of houses sold by 17.7 percent.[52] However, controlling for national trends in house prices reduced this estimate to 1.4 percent, implying that models accounting only for unobserved differences between areas are associated with a simultaneity problem (i.e. the delivery of the programme is correlated with general growth in house prices). Allowing for time-specific shocks or journey times to local amenities likely to influence house prices reduced the estimated effect further to approximately 0.6 percent.

Applying these to the average price of houses sold in the programme area between 2012 and 2021 (£311,472 in 2021 prices), gives a plausible range for the average impact on house prices of £1,700 to £4,400. For Phase 3, the corresponding range for the house price premium was £1,900 to £4,600 (based on an average sold price of £312,524).

When broken down by Phase, the most robust models indicated that effects were strongest for Phase 3 areas followed by Phase 2 and then Phase 1. However, these differences across Phase are relatively

[52] In this case, the coefficient (0.163) is of a magnitude that it can no longer be interpreted as a percentage effect (i.e. $e^{0.163} - 1 = 0.177$)

small implying that the effects on house prices do not decay significantly, at least over the course of the time period studied.

This indicates that buyers were willing to pay a premium to obtain homes that had been upgraded. These estimates also compare to results of a previous study estimating the per household benefit of upgrading rural areas of the UK to FTTC of £3,145 (based on an analysis of the impact of upgrading local exchanges to ADSL during the 2000 to 2010 period). [53] It should be noted, however, that there are several challenges in interpreting the increase in house prices attributable to the programme as a measure of social welfare which are described in more detail in Section 8.

Table 6.2: Impact of subsidised coverage house prices, 2013 to 2022

Outcome	Model 9	Model 10	Model 11	Model 12
Fixed effects	Yes	Yes	Yes	Yes
Unobserved national trends	No	Yes	No	No
Time fixed effects	No	No	Yes	No
Controls for journey times to local amenities	No	No	No	Yes
Model specification	FE	FE	FE	FE
Effects per premises upgraded (postcode level results)				
Average price of houses sold (£, natural logarithm)	0.163***	0.0142***	0.0055***	0.0063***
Number of observations	1,195,119	1,195,119	1,195,119	1,195,119
Adjusted R-squared[54]	0.07 (0.835)	0.08 (0.817)	0.09 (0.883)	0.08 (0.881)
Effects applying from scheme announcement date (postcode level results)				
Average price of houses sold (£, natural logarithm)	0.132***	0.0203***	0.0130***	0.0071***
Number of observations	1,195,119	1,195,119	1,195,119	1,195,119
Adjusted R-squared	0.06 (0.80)	0.07 (0.81)	0.08 (0.84)	0.07 (0.85)

*Source: Ipsos analysis. '***', '**', and '*' indicate whether the estimated coefficient was significant at the 99, 95 and 90 percent level of confidence.*

Table 6.3: Impact of subsidised coverage on house prices, 2013 to 2022

Outcome	Model 9	Model 10	Model 11	Model 12
Fixed effects	Yes	Yes	Yes	Yes
Unobserved national trends	No	Yes	No	No
Time fixed effects	No	No	Yes	No
Controls for journey times to local amenities	No	No	No	Yes
Model specification	FE	FE	FE	FE
Effects per premises upgraded (postcode level results)				
Average price of houses sold (£,natural logarithm)				
Phase 1	0.1467***	0.0128***	0.0050***	0.0057***
Phase 2	0.1712***	0.0149***	0.0058***	0.0066***
Phase 3	0.1793***	0.0156***	0.0061**	0.0069**
Effects applying from scheme announcement date (postcode level results)				
Average price of houses sold (£, natural logarithm)				
Phase 1	0.1188***	0.0183***	0.0117***	0.0064***
Phase 2	0.1386***	0.0213***	0.0137***	0.0075***

[53] Gabriel Ahlfeldt (2014) Speed 2.0 Evaluating Access to Universal Digital Highways

[54] Figures in brackets are generated using areg in Stata and therefore include the share of the overall variance absorbed by group effects. This method is analytically identical to xtreg.

Phase 3	0.1452**	0.0223**	0.0143**	0.0078**

*Source: Ipsos analysis. '***', '**', and '*' indicate whether the estimated coefficient was significant at the 99, 95 and 90 percent level of confidence.*

7 Impact on public services

This section examines the impact of the Superfast Broadband Programme on the performance of public services in two areas: primary care services and education. The analyses that follow draw on the GP Patient Survey published by NHS England, and data on school expenditure and performance published by the Department for Education. The available data only permitted a partial exploration of the effects of the programme on healthcare and education services.

7.1 General practice

This section provides an analysis of the impact of the Superfast Broadband Programme on General Practice.

7.1.1 Background

The potential for digital technologies to reduce pressures on general practice has attracted significant policy interest. NHS England has identified a variety of ways in which digital technologies could streamline processes in primary care, including using questionnaire based on-line consultations, online triage, and remote consultations via video-conferencing. Video conferencing has attracted substantial policy interest as it has the potential to disrupt the dominant form of remote consultation used in general practice (telephone) which has drawbacks in that it does not allow the GP to capture non-verbal cues.

Commitments have been made in the NHS England Long Term Plan to a ‘digital first’ primary care system by 2023/24 and giving patients a right to video consultations by April 2021. Higher capacity networks will typically be needed to implement these plans. Online video consultations are estimated to require up 350Kbit/s per consultation, [55] placing considerable additional pressure on local Wi-Fi networks that will be simultaneously used to access and update medical records or action scanned documents. This presents a possible constraint with 40 percent of NHS organisations estimated to be using lower capacity copper lines in April 2019,[56] and has proven an inhibiting factor in pilot programmes rolling out video consultations.[57] The Government announced in 2019 that it would support all NHS organisations in obtaining full fibre connectivity to help realise these goals, though clearly the improved broadband infrastructure brought forward under the Superfast Broadband Programme has the potential to address some of the constraints faced.

The claimed benefits of video consultations have tended to focus on enhanced time efficiency for GPs and greater convenience for patients. The available evidence on this is mixed. A 2017 study exploring the use of online consultations in 36 GP surgeries found that online video consultations took longer than face-to-face appointments and cost slightly more to deliver (£36 per appointment versus £33). [58][59] There is also evidence that greater convenience can induce greater demand. For example, an evaluation of the Babylon GP at Hand service found that patients registering increased their demand for primary care appointments, raising questions about the size of the potential cost savings attached to ‘digital first’ working practices. [60] A recent review of the potential impacts of online consultation services also highlighted evidence that GPs

---

[55] iplato (2020) Video consultation technical requirements.
[56] DHSC (2019), NHS hospitals and GP practices to get fibre optic internet, Press release.
[57] Donaghy et al (2019) Acceptability, benefits, and challenges of video consulting. British Journal of General Practice
[58] Edwards et al (2017) Use of a primary care online consultation system, by whom, when and why: evaluation of a pilot observational study in 36 general practices in South West England.
[59] The face-to-face appointment costs stated are assumed to exclude any travel costs incurred by patients which, if included, could increase this figure.
[60] Ipsos (2019) Evaluation of Babylon GP at Hand

often regarded these services as adding to, rather than reducing, their workloads (with a reasonable share, 38 percent, of online consultations leading to a face-to-face consultation). [61]

Research has also suggested that users have positive experiences of online video consultations compared to telephone consultations, although there are questions as to the degree to which they are preferred to face-to-face consultations and whether they are suitable for discussing all types of patient concerns (e.g. issues of sexual health). [62] Video consultations were particularly helpful for working people and people with mobility or mental health problems and considered superior to telephone consultations in providing visual cues and reassurance, building rapport, and improving communication.

7.1.2 Data

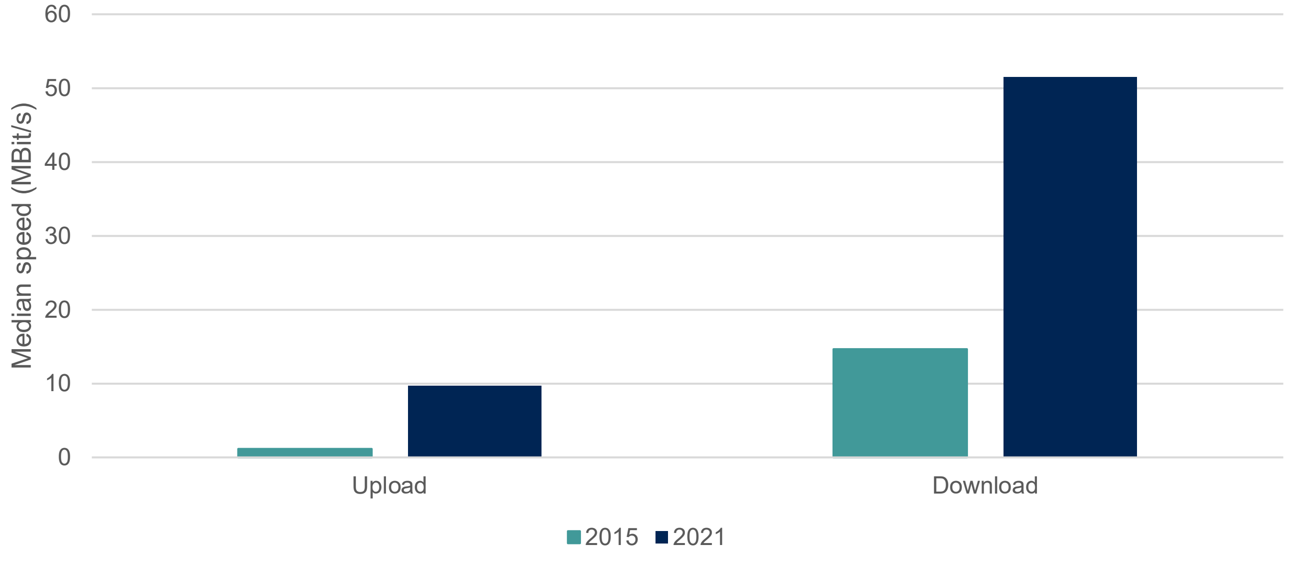
A complete list of general practices was acquired using GP practice data made available through NHS Digital[63]. The data available included details of the patients registered at GPs as well as the scale and composition of the local workforce at GP surgeries. Details of the premises upgraded through the Superfast Broadband Programme (via the C3 reports) were linked to this database to identify how many GP surgeries had benefitted from enhanced coverage.

This process identified a total of 2,985 GP surgeries that had benefitted from subsidised broadband coverage between 2013 and 2021. Figure 7.1 provides an illustration of the improvement in available speeds associated with these upgrades, with median available download and upload speeds rising from 14.7Mbit/s to 51.5Mbit/s and from 1.2Mbit/s to 9.7Mbit/s respectively.

Additional longitudinal data on patients' experience of GP services was obtained by linking. Unique reference numbers contained within this data was then matched to GP Patient Survey (GPPS) data. [64] The GPPS is an annual postal survey of people registered with a GP and collects patients' views of their experiences of primary care. The survey began in 2007, however the questionnaire has changed on several occasions since then. The most recent set of questions were developed for the 2018 survey and many variables are not directly comparable with previous years.

[61] Marshall et al (2018) Online consultation in general practice, submission to BMJ Analysis (draft).
[62] Donaghy et al (2019) Acceptability, benefits, and challenges of video consulting. British Journal of General Practice
[63] https://digital.nhs.uk/data-and-information/data-tools-and-services/data-services/general-practice-data-hub
[64] https://www.gp-patient.co.uk/

Figure 7.1: Increase in median upload and download speeds for postcodes with GP practices[65]



Source: Ofcom Connected Nations, C3 reports, Ipsos analysis

The final dataset provided longitudinal data on the following outcomes of interest. Log transformations of the continuous variables were used as they displayed a distribution that was closer to the normal distribution. No additional controls were included in the regressions.

Table 7.1: Outcomes for General Practice

Outcome	Metric (2016-2021)	Source
Number of GPs	In FTE	NHS Digital Workforce data
Number of nursing staff	In FTE	NHS Digital Workforce data
Number of non-clinical staff	In FTE	NHS Digital Workforce data
Register size	Number of registered patients	NHS Digital Practice data[66]
Awareness/Use of ability to book appointment online	Proportion of patients aware of/using online appointment booking services (%)	GPPS
Awareness/Use of ability to order repeat prescription online	Proportion of patients aware of/using online repeat prescription ordering (%)	GPPS
Awareness/Use of ability to view medical records online	Proportion of patients aware of/accessing online medical records (%)	GPPS
Satisfaction with the amount of time afforded them by GP	Proportion of patients satisfied with amount of time for their last appointment (%)	GPPS
Ability to see preferred GP	Proportion of patients able to see preferred GP most or all of the time (%)	GPPS
Satisfaction with available appointments	Proportion of patients satisfied with availability of appointments last time they enquired (%)	GPPS
Overall satisfaction	Proportion of patients describing their overall experience as fairly or very good (%)	GPPS

Source: NHS Digital, GP Patient Survey

[65] Note that 2015 is the first year for which median upload and download speeds were presented in Connected Nations data.

[66] File name epraccur.csv - available from: https://digital.nhs.uk/services/organisation-data-service/data-downloads/gp-and-gp-practice-related-data

7.1.3 Econometric model

To estimate the effects of the Superfast Broadband Programme on the economic outcomes of interest, fixed effects modelling was applied to the data assembled. The model below was fitted to the data:

$$y_{it} = \alpha_i + \beta T_{it} + \alpha^i + \alpha^t + \varepsilon$$

Here, the outcome for GP practice i in period t (y_{it}), is determined by its exposure to BDUK subsidies (T_{it}). The treatment variable is a binary variable taking the value of 0 before the postcode of the practice receives enhanced coverage and 1 thereafter. The parameter β provides an estimate of the impact of subsidised coverage on the outcome of interest. The analysis was limited to only those GP practices located on postcodes which received upgraded coverage at some point in time, to limit the potential biases driven by systematic differences between GP practices located on postcodes benefitting from BDUK subsidies and those which were not.

As noted, there were limited control variables available for the analysis. The model does allow for unobserved differences between areas that do not change over time (α^i). Models were also estimated to accommodate unobserved but time specific shocks (α^t) that affect all areas. However, there may be time varying but unobserved changes in area characteristics that could bias results. This could include the size and composition of the local patient population. However, as these variables are potentially endogenous (i.e. the Superfast Broadband Programme may have produced impacts on the size or nature of the local population, for example, by making the areas concerned more attractive to higher income groups) the inclusion of changes in population characteristics could produce biased estimates of impact. It should be noted, however, that the resultant estimates will capture both the effect of the programme in providing enhanced connectivity to GP surgeries and its effects on the resident population.

The findings could also be influenced by unobserved changes in the managerial characteristics of the GP surgery. If those benefitting from the programme at later stages were more likely to see an improvement or deterioration in management practices, then findings could be biased downwards or upwards respectively. There is no upfront reason to suggest that this may be the case, but the issue may merit further exploration in future research.

7.1.4 Impacts on awareness and usage of digital services

The results of the econometric analysis indicated that the programme had an impact in both raising awareness and usage of online services amongst patients registered with GP surgeries:

- **Awareness:** Awareness of the availability of on-line services to book appointments, order repeat prescriptions and review medical records online rose by 9, 7 and 7 percentage points respectively in response to the provision of subsidised coverage.

- **Usage:** Usage of these services increased between 2 and 7 percent.

The findings suggest that patients have found new ways to access primary care services as a result of the Superfast Broadband Programme. However, the underlying mechanism is not clear and there are several possible explanations of the underlying result. Enhanced connectivity may have encouraged or enabled GP surgeries to offer more services on-line. However, these results would also be explained if increased take-up of superfast connectivity in the surrounding area made residents more aware of online services already being provided by GPs (or if it attracted new residents to the areas concerned that were more familiar with the on-line delivery of primary care services). Qualitative research will be completed to explore these hypotheses as part of BDUK's broader evaluation programme.

It should be noted that the models explained a low share of the variance in the dependent variables (possibly due to the absence of additional control variables in the model). This suggests the presence of omitted explanatory variables - though as the evidence is based on surveys rather than a census of GP patient register, it is likely that measurement error arising from small samples at the local level is a contributory factor. As noted above, omitted variables will only bias the findings to the degree that they have a joint causal relationship with patient experience and the order in which subsidised coverage was rolled out. Additionally, the findings may be influenced by demographic change – for example, if the programme encouraged individuals with a tendency to report lower satisfaction with primary care services to migrate to the area, then this would be captured in these findings.

Table 7.2: Impact of subsidised coverage on awareness and usage of on-line primary care services, 2016 to 2021 (% of registered patients)

Outcome		Model 1	Model 2
	Fixed effects	Yes	Yes
	Time specific shocks	No	Yes
	Model specification	FE	FE
Booking appointments online	Awareness (% of patients)	0.0953***	0.0940***
	Usage (% of patients)	0.0682***	0.0685***
Order repeat prescriptions on-line	Awareness (% of patients)	0.0792***	0.0743***
	Usage (% of patients)	0.0383***	0.0379***
Access medical records on-line	Awareness (% of patients)	0.0702***	0.0692***
	Usage (% of patients)	0.0238***	0.0221***
Number of GPs		1,482	1,482
Number of observations		6,183	6,183
Adjusted R-squared[67]		0.02 – 0.04 (0.55 – 0.84)	0.02 – 0.05 (0.68 – 0.89)

*Source: Ipsos analysis. '***', '**', and '*' indicate whether the estimated coefficient was significant at the 99, 95 and 90 percent level of confidence. The outcome variables were bounded at 0 and 1, and Tobit models were used to explore whether OLS models produced biased results.*[68]

7.1.5 Patient satisfaction

There are four measures of patient experience that have been consistently tracked by the GP Patient Survey over the period of interest - satisfaction with the process of booking an appointment, the share of patients that felt that GPs gave them enough time, the shares that were regularly able to see their preferred GP, and their overall satisfaction.[69] [70] The findings gave mixed results in terms of the impact of enhanced broadband connectivity on these measures:

- **Time with GP:** Subsidised coverage appeared to increase the proportion of patients that were satisfied with the amount of time given to them for their last appointment by one percentage point.

[67] Figures in brackets are generated using areg in Stata and therefore include the share of the overall variance absorbed by group effects. This method is analytically identical to xtreg.
[68] There is a potential technical issue with the linear modelling approach as described above. The fractional outcomes used are bound at 0 and 1 and do not follow a linear distribution. This means that a linear models can provide biased or infeasible estimates (e.g. predicted values below 0 or above 1) - although they do provide a reasonable approximation where observations are clustered on the linear section of the logistic distribution. The reasonableness of using a linear modelling in this case was tested using a Tobit model with censoring at zero and one, a procedure recommended by some researchers. However, as the Tobit model also implies a linear distribution, other researchers have proposed alternative methods for examining fractional outcomes, including Generalised Linear Models with e logistic link function.
[69] https://www.gp-patient.co.uk/surveysandreports
[70] Satisfaction was measured as the proportion of respondents fairly or very satisfied with their overall experience of their last appointment.

- **Access and continuity of care:** However, subsidised coverage had a negative impact on measures of access and continuity of care. Subsidised coverage led to a reduction in the share of patients satisfied with the availability of appointments (by four percentage points) and the share of patients able to see their preferred GP most or all of the time (by five percentage points). These are indicative of capacity pressures on GP surgeries benefitting from subsidised coverage.

- **Overall satisfaction:** Overall, subsidised coverage appeared to reduce the share of patients that described their experience as fairly or very good by two percentage points.

Table 7.3: Impact of subsidised coverage on access, continuity of care and satisfaction with GP services, 2016 to 2021 (% of registered patients)

Outcome	Model 3	Model 4
Fixed effects	Yes	Yes
Time specific shocks	No	Yes
Model specification	FE	FE
% of patients satisfied with amount of time for their last appointment	0.0094***	0.0090***
% of patients able to see their preferred GP most or all of the time (%)	-0.0548***	-0.0531***
% of patients satisfied with the availability of appointments	-0.0395***	-0.0374***
% of patients satisfied describing their experience as fairly or very good	-0.0164***	-0.0155***
Number of GPs	1,482	1,482
Number of observations	5,893 - 6,083	5,893 - 6,083
Adjusted R-squared[71]	0.01 – 0.04 (0.72 – 0.83)	0.01 – 0.04 (0.70-0.87)

*Source: Ipsos analysis. '***', '**', and '*' indicate whether the estimated coefficient was significant at the 99, 95 and 90 percent level of confidence. The outcome variables were bounded at 0 and 1, and Tobit models were used to explore whether OLS models produced biased results.*[72]

7.1.6 GP resources

The data also supported an investigation of the impacts of the Superfast Broadband Programme on the supply and demand for primary care services (over a more extensive period, from 2012 to 2021). This included the number of patients registered with the GPs concerned (giving a measure of demand), and clinical and non-clinical staff employed by the GP surgery (giving a measure of supply). The findings indicated:

- Number of patients: Subsidised coverage increased the number of patients registered with GPs by 3.4 to 8.1 percent on average.

- Staffing: However, the number of staff employed by GP surgeries did not rise to the same degree. Subsidised coverage led to an increase in the number of nursing and non-clinical staff of 5.6 to 5.7 and 5.6 to 7.6 percent respectively. The number of GPs also increased by between 3.1 and 4.5 percent unlike in previous analysis.

The findings indicate that subsidised coverage has led to an increase in demand for primary care services (as visible in the positive effects on the number of patients registered with the GP). However, the increase in demand has not been met by an equivalent increase in the supply of primary care services.

[71] Figures in brackets are generated using areg in Stata and therefore include the share of the overall variance absorbed by group effects. This method is analytically identical to xtreg.
[72] See footnote 68.

These patterns could be explained if subsidised coverage GPs opened new channels to patients or otherwise attract them from competing GP surgeries locally. A complementary set of analyses were completed to explore whether the subsidised coverage had a negative impact on nearby GPs (within 20km) that did not receive subsidised coverage. This model (Model 8 in table 7.4) was defined as follows.

$$y_{jt} = \alpha_i + \beta T_{jt} + \alpha^i + \alpha^t + \varepsilon$$

Here, the number of patients registered with GP surgeries that did not benefit from subsidised coverage (y_{jt}) is determined by the number of GP surgeries within 20km that benefitted from subsidised coverage (T_{jt}). If there was displacement of patients between GP surgeries at the local level, this would be visible in a negative effect on patient numbers. However, the model suggested that the subsidised coverage also had a positive effect on the number of patients registered with GP surgeries that did not benefit from enhanced connectivity. As such, a more plausible explanation would be that the programme stimulated population growth in the areas benefitting from the programme - increasing demand for primary care services regardless of whether the GP surgery benefitted from enhanced connectivity.

Table 7.4: Impact of subsidised coverage on the number of patients registered with GPs, and clinical and non-clinical staffing levels, 2016 to 2021

Outcome	Model 5	Model 6	Model 7 (effects on other GP surgeries within 20km)
Fixed effects	Yes	Yes	Yes
Time specific shocks	No	Yes	Yes
Model specification	FE	FE	FE
Number of patients registered with the GP (log)	0.0806***	0.0308***	0.0403***
Number of GPs (FTEs, log)	0.0446*	0.0307*	.
Number of nursing staff (FTEs, log)	0.0573**	0.0558***	.
Number of non-clinical staff (FTEs, log)	0.0758***	0.0561***	.
Number of GPs	1,406 – 1,527	1,486 – 1,504	6,050
Number of observations	5,603 – 5,827	5,603 – 5,827	23,018
Adjusted R-squared[73]	0.02 – 0.03 (0.91 – 0.95)	0.02 - 0.04 (0.91 – 0.95)	0.05 (0.97)

*Source: Ipsos analysis. '***', '**', and '*' indicate whether the estimated coefficient was significant at the 99, 95 and 90 percent level of confidence.*

7.2 Primary and secondary education

Substantial attention has been given in recent decades to the potential of information and communication technologies (ICTs) to transform education by enriching educational content. A US study commissioned in 2010 highlighted the potential for broadband enabled technologies to improve learning outcomes by enriching educational content, enabling more interactive and innovative modes of learning, providing more individualised education targeted at refining specific skills, and supporting the delivery of administrative efficiencies (e.g. by enabling cloud computing). [74]

Empirical studies investigating the impact of broadband on educational outcomes have, however, produced mixed findings. While early studies tended to show a positive impact of broadband availability and access to other ICTs on attainment, later studies adopting more rigorous designs have not always

[73] Figures in brackets are generated using areg in Stata and therefore include the share of the overall variance absorbed by group effects. This method is analytically identical to xtreg.

[74] US Chamber of Commerce (2010) The Impact of Broadband on Education

reproduced these results. For example, a UK study exploring the impact of the availability of enhanced broadband coverage in the home found no effect on attainment. [75] While no UK study appears to have explored the impacts of broadband in the school, a 2011 study of Portuguese schools receiving connection subsidies found that enhanced connectivity had a negative impact on learning outcomes. [76] This contrasts substantially with results of an evaluation of a 2008 Brazilian initiative to bring broadband to urban elementary and middle schools, which suggested that participation in the programme had positive impacts on Portuguese and maths exam scores.

One reason put forward for contrasting results across studies is that while broadband has the potential to enable more productive modes of learning it also offers students opportunities for distraction. For example, the aforementioned study examining Portuguese subsidies for school broadband connections also found that those schools that blocked YouTube and other similar websites fared comparatively better. Again, the research is mixed on these points: the previously cited UK study of superfast broadband connectivity in the home also found no effects of faster internet access on days per week using the internet, weekly hours spent using email and online social media, weekly hours doing homework, or propensity to use online resources for homework.

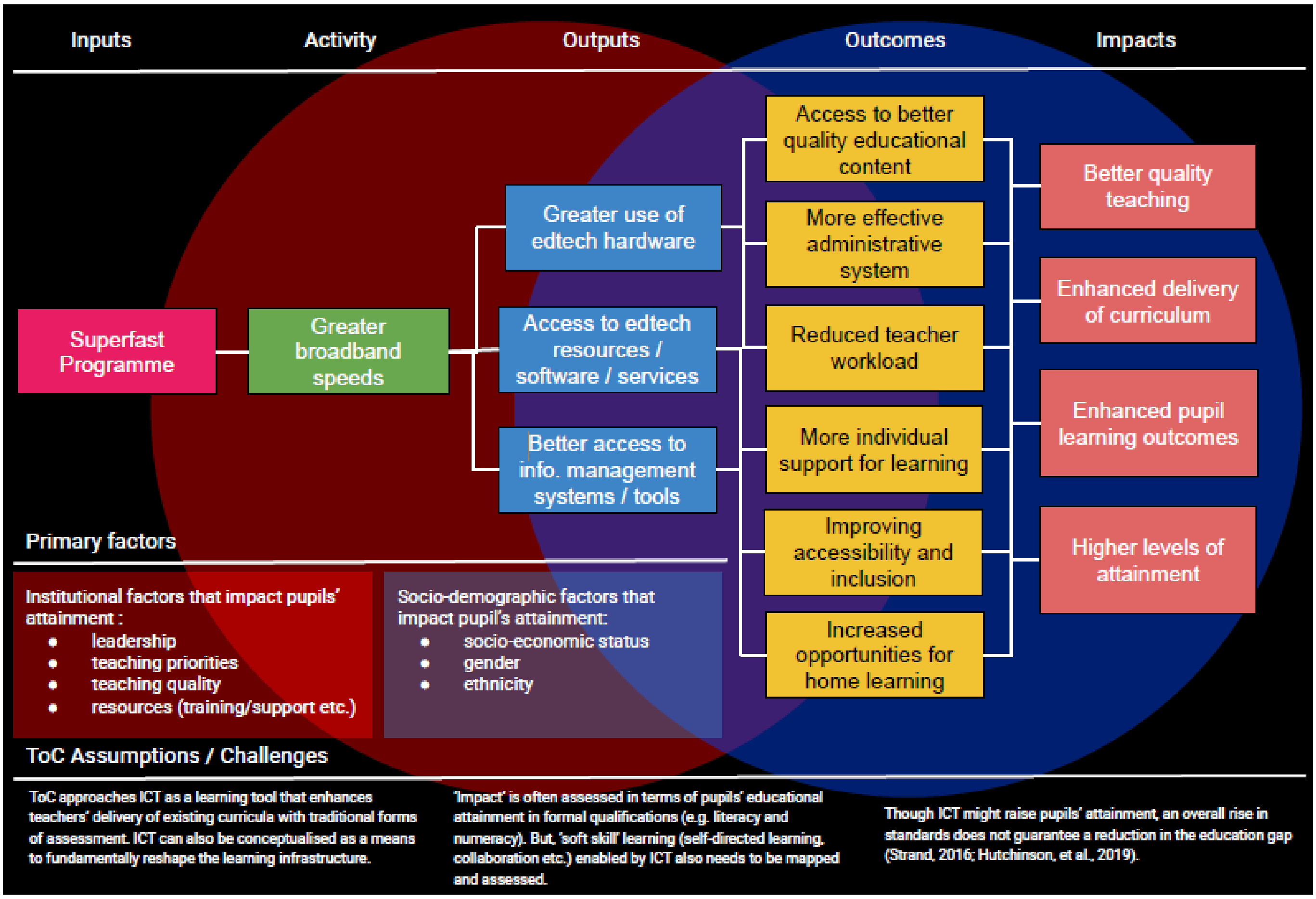
In addition, it is difficult to draw firm conclusions on the impact of ICT from existing literature, and detailed explanations as to the mechanisms through which ICT in schools can improve learning remain somewhat unclear. Amongst the challenges in identifying impact are the fact that the term 'ICT' encompasses a wide range of software applications and operating systems including, for example, desktops, laptops, mobile phones, projection technology, digital recording equipment, software applications, multimedia resources, information systems, intranet, internet, tablets, e-readers etc. These applications or systems differ in terms of form (e.g. complexity, interactivity, authorship etc.) and function (e.g. feedback, mobility, publishing, collaboration, communication etc.) with the impact of ICT on learning dependent upon how ICT is integrated in schools. The adoption and use of technology also depend on the technology's perceived advantages, its compatibility with teachers'/institutions' objectives, its complexity and the observability of its utility with the process of how teachers use ICT strongly influenced by the attitude of teachers to technology. A lack of confidence, lack of technical skills, lack of time, and/or resistance to change are significant barriers to successful integration. Other possible organisational barriers include a lack of resources and/or lack of effective training and support for teachers. There are also other non-ICT factors that influence attainment that are difficult to control for.

The figure below outlines a theory of change for ICT use and primary and secondary attainment.

[75] Sanchis-Guarner et al (2016) Faster broadband: are there any educational benefits?

[76] Belo et al (2011) The effect of broadband in schools: evidence from Portugal

Figure 7.2: Theory of change for ICT use and primary and secondary attainment



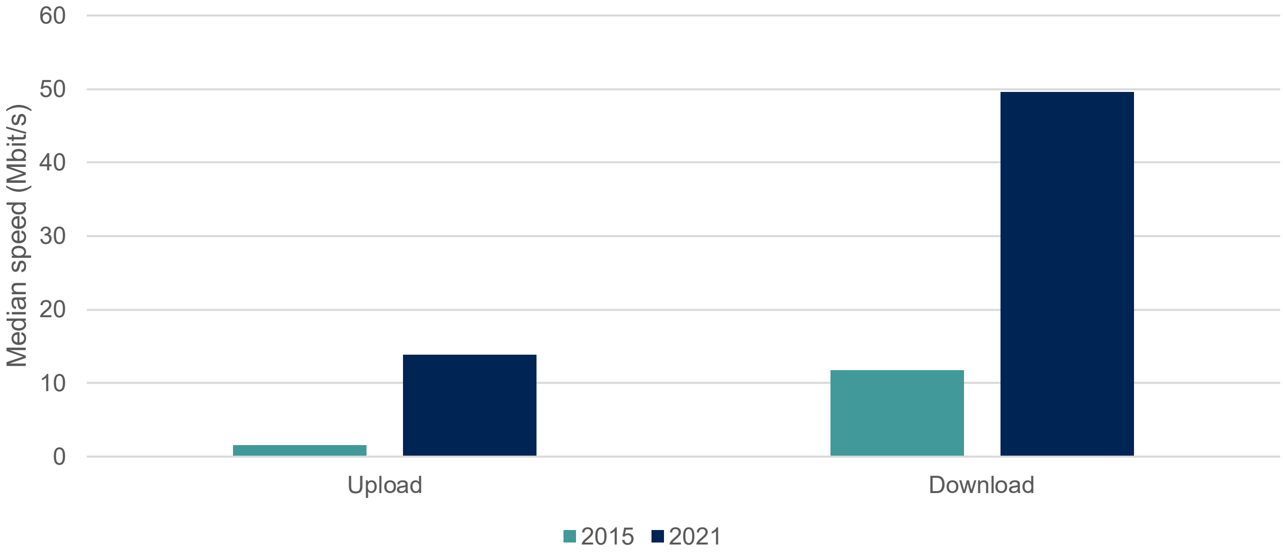
Source: BDUK, Benefits Realisation and Evaluation Team 2020

7.2.2 Data

Data on schools is publicly available from the Department for Education's (DfE) 'find and compare schools' webpage. [77] Details of the premises upgraded through the Superfast Broadband Programme were also linked to DfE databases of primary and secondary schools and academies to identify the educational institutions that benefitted from enhanced coverage. This process identified a total of 3,843 primary schools, 187 secondary schools and 1,855 academies that benefitted from subsidised broadband coverage between 2013 and 2021. The figure below provides an illustration of the improvement in available speeds associated with these with these upgrades, with median maximum available download and upload speeds rising from 11.7Mbit/s to 49.6Mbit/s and from 1.5Mbit/s to 13.8Mbit/s respectively.

[77] This can be accessed here: https://www.compare-school-performance.service.gov.uk/schools-by-type?step=phase&geographic=all&region=0&phase=primary

Figure 7.3: Increase in median upload and download speeds, primary and secondary schools and academies located on postcodes benefitting from subsidised coverage, 2015 to 2021



Source: Connected Nations (Ofcom), C3 reports, DfE school database

The published data provides information on the following outcomes of interest:

- **Expenditures incurred by schools** – including expenditure on ICT, to explore the hypothesis that enhanced connectivity would enable public services to realise administrative efficiencies through adoption of cloud computing.
- **Resources available to school** – including income (from DfE grants and self-generated sources) and the scale of the workforce (teachers and teaching assistants).
- **Demand** – as inferred from pupil headcount, which would capture any indirect effects of superfast connectivity via population growth (or possibly changes in the composition of local populations – e.g. older residents being replaced by younger residents with children).
- **Attainment and absence** – data was available to explore the impact of subsidised coverage on school performance measures. It should be noted that analysis of these measures would conflate several effects. While this may capture the impact of broadband enabled improvements in teaching, it is important to note that these outcomes will also be influenced by any changes in the composition of the pupil population induced by subsidised coverage in the local area (as well as any behavioural changes induced by take-up of superfast services by the resident population).

In terms of control variables, the following data was available to control for the characteristics of the pupil population that could also influence the outcomes above:

- **Free School Meals (FSM)**: The proportion of pupils eligible for free school meals. This reflects the prosperity of the area in which the school is located (although not all pupils eligible for free school meals will take this up). Eligibility for free school meals is also linked to attainment and absence rates and will also influence school income through the DfE grant funding formula.
- **English as a second language (EAL):** The proportion of children for whom English is not a first language reflects the ethnic population of the local areas which may again be correlated with

attainment outcomes. Schools are also awarded additional funding for the number of pupils with English as a second language.

- **Special educational needs (SEN):** Finally, the proportion of pupils with special educational needs provides an indication of the resources the school might require and could be reflected in attainment and the incomes of schools.

It should be noted that these controls are potentially endogenous if subsidised coverage leads to changes in the composition of local populations. The inclusion of these control variables could therefore potentially produce biased estimates of the impact of subsidised coverage and the models below are presented with and without the inclusion of these controls. It was also not possible to control for the institutional factors identified in the ToC above.

In addition, data was only available at the school level for these analyses and therefore the individual circumstances and characteristics of pupils attending these schools can only be controlled for in a broad way. Future research will seek to identify an approach for more robust assessment potentially using individual pupil level data.

Finally, secondary data sources providing information on the outputs and outcomes of the theory of change identified in the figure above are not widely available. An assessment of the impact of attainment outcomes should start with these and be implemented when appropriate data sources are available.

7.2.3 Econometric models

To estimate the effects of the Superfast Broadband Programme on the economic outcomes of interest, fixed effect modelling was applied to the data assembled. The model below was fitted to the data:

$$y_{jt} = \alpha_i + \beta T_{jt} + \gamma X_{jt} + \alpha^i + \alpha^t + \varepsilon_{it}$$

Here, the outcome for school j in period t (y_{jt}), is determined by its exposure to subsidised coverage (T_{jt}). The treatment variable is a binary variable taking the value of 0 before the postcode of the school receives enhanced coverage and the 1 thereafter. The parameter β provides an estimate of the impact of subsidised coverage on the outcome of interest. The models were also estimated using time varying controls accounting for the number of pupils in the school, and the share eligible for FSM, with English as an additional language and with SEN (X_{jt}). However, as there were concerns that these factors were potentially endogenous (as a result of the indirect impact of subsidised coverage on the characteristics of the local population), the models were estimated with and without these controls.

The model also allowed for unobserved differences between schools that do not change over time (α^i). The analysis was limited to only those schools located on postcodes which received upgraded coverage at some point in time, to limit the potential biases driven by systematic differences between schools located on postcodes benefitting from BDUK subsidies and those which were not. As with other models, the findings could potentially be biased if there were systematic differences between those schools benefitting from subsidised coverage at earlier and later stages. The extent of observable differences between groups are considered below.

7.2.4 Impacts on ICT spending and other school resources

The table below sets out the estimated effect of subsidised coverage on ICT spending and other school resources. Simple fixed effects models (without controls) found significant effects on all outcomes including ICT spend, teaching spend and the number of teachers, with these decreasing by 11 percent and increasing by 6.4 percent and 2.2 percent respectively. However, these findings were not robust to the addition of further controls and as such the findings are inconclusive.

Table 7.5: Impact of subsidised coverage on school expenditure and teaching staff, 2014 to 2021

Outcome	Model 1	Model 2	Model 3	Model 4	Model 5
Fixed effects	Yes	Yes	Yes	Yes	Yes
LAD trends	No	Yes	No	Yes	Yes
Time FE	No	No	Yes	Yes	Yes
Controls for FSM, EAL and SEN	No	No	No	Yes	Yes
Controls for number of pupils	No	No	No	No	Yes
Model specification	FE	FE	FE	FE	FE
ICT expenditure (£s, log)	-0.110**	0.00424	0.00472	-0.00104	-0.0314
Expenditure on teaching (£s, log)	0.0641***	0.000264	-0.00374	-0.00532	-0.00373
Number of teachers (FTE, log)	0.0218***	-0.00172	-0.00673	-0.00462	-0.000273
Number of observations	17,054 to 18,832				
Adjusted R-squared	0.004 to 0.284 (0.342 to 0.637)				

*Source: Ipsos analysis. '***', '**', and '*' indicate whether the estimated coefficient was significant at the 99, 95 and 90 percent level of confidence.*

In terms of income, basic fixed effects models find significant increases in total income as well as income from grants and self-generated income. The findings are broadly stable to the addition of controls for unobserved trends at the local authority level – with findings suggesting the total incomes rose by 1.3 percent largely due to increases in self-generating income (this could be explained if superfast connectivity has enabled schools to make more efficient use of leisure facilities and/or has attracted higher income residents to the area). However, the findings were again not robust to the inclusion of time fixed effects and are inconclusive.

Table 7.6: Impact of subsidised coverage on school income, 2014 to 2021

Outcome	Model 1	Model 2	Model 3	Model 4
Fixed effects	Yes	Yes	Yes	Yes
LAD trends	No	Yes	No	Yes
Time FE	No	No	Yes	Yes
Controls for FSM, EAL and SEN	No	No	No	Yes
Model specification	FE	FE	FE	FE
Total income (£s, log)	0.163***	0.0127***	0.000194	-0.00047
Self-generated (£s, log)	0.143***	0.0133***	-0.000274	-0.00193
Grant funding (£s, log)	0.194***	0.00836	0.0184	0.0180*
Number of observations	21,473 to 22,394			
Adjusted R-squared	0.056 to 0.482 (0.365 to 0.647)			

*Source: Ipsos analysis. '***', '**', and '*' indicate whether the estimated coefficient was significant at the 99, 95 and 90 percent level of confidence.*

7.2.5 Impacts on number of pupils and pupil composition

The findings below provide estimates of the effects of the programme on pupil headcount and the composition of pupils. Basic fixed effects models point to positive effects on overall pupil numbers (which would be consistent with the findings set out above for GP surgeries), though these results are not robust to unobserved local authority trends or time specific shocks affecting all schools.

In terms of the composition of pupils, more robust models controlling for local authority trends indicated that the programme led to reductions in the share of pupils eligible for FSM or SEN (of 2.5 and 4.8 percentage points respectively), and a slight increase in the share of pupils with English as an additional language (EAL). Again, this would support hypotheses set out elsewhere that the programme has worked to alter the composition of rural populations, though these results are not confirmed by models that allow for time specific shocks affecting all schools (so again, the findings are inconclusive).

Table 7.7: Impact of subsidised coverage on pupil headcount and percentage of pupils eligible for FSM, with EAL and SEN, 2014 to 2021

Outcome	Model 10	Model 11	Model 12
Fixed effects	Yes	Yes	Yes
LAD trends	No	Yes	No
Time FE	No	No	Yes
Model specification	FE	FE	FE
Number of pupils (log)	0.0414***	0.00753	-0.00637
% of pupils eligible for FSM	0.683***	-2.463***	-0.0573
% of pupils with EAL	0.473***	0.0843**	-0.0293
% of pupils with SEN	-1.743***	-4.849***	-0.416
Number of observations		25,204 to 25,927	
Adjusted R-squared		0.004 to 0.413 (0.284 to 0.526)	

*Source: Ipsos analysis. '***', '**', and '*' indicate whether the estimated coefficient was significant at the 99, 95 and 90 percent level of confidence. The outcome variables were bounded at 0 and 1, and Tobit models were used to explore whether OLS models produced biased results.*[78]

7.2.6 Absences

The impact of subsidised coverage on pupil absence rates was explored by linked details of schools benefitting from broadband upgrades to DfE pupil absence data[79]. The analysis suggested that provision of enhanced broadband connectivity increased the rate of pupil absence. The overall rate of absences[80] rose by 0.12 percentage points in response to the subsidised coverage, while the rate of persistent absences (share of pupils absent for 10[81] percent or more of possible sessions throughout the academic year) rose by 4.4 percentage points.

To account for the change in definition for persistent absence, models were also run restricting the data to post 2016 (the first year for which the change in the categorisation of persistent absence was made), the effects on absence are not statistically significant in these models and therefore these figures should be viewed with caution.

[78] See footnote 68.

[79] https://www.gov.uk/government/collections/statistics-pupil-absence

[80] Defined as the percentage of possible sessions recorded as an absence from school for whatever reason, whether authorised or unauthorised.

[81] Note that before 2014, this was 15 percent. To account for this, these regressions include a dummy variable that is equal to 0 before 2014 and 1 thereafter.

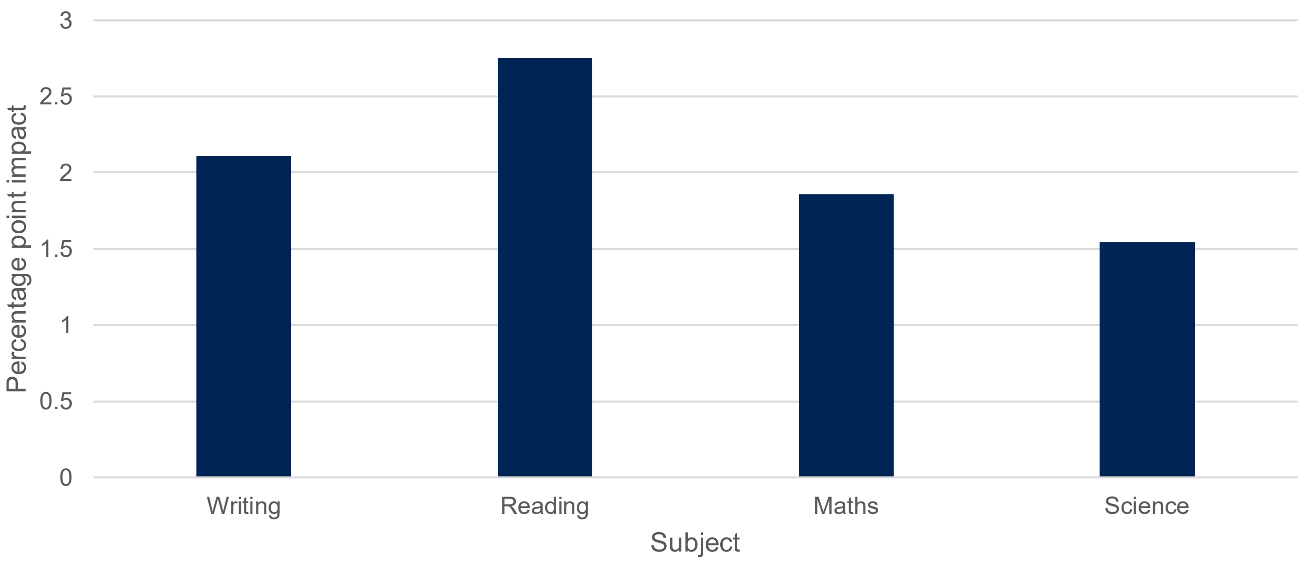
7.2.7 Attainment

Impacts on primary school attainment, in the form of effects on pupil progress[82] in reading, writing and maths at Key Stage 2 were also explored in the evaluation, as were the proportion of pupils attaining the expected standard in maths, reading and the teacher assessments for science and writing. The literature suggests that ICT in general presents opportunities to improve educational attainment by expanding access to quality education, providing student-centred learning and enhancing learning outcomes. However, a key determinant of pupil attainment is pupil socio-demographic status. The analysis controls for deprivation and socio-economics to some degree through the incorporation of the proportion of pupils eligible for free school meals, proportion of pupils with special educational needs and the proportion with English not as their first language, however it is not possible in this context to control for pupils past performance or prior education and therefore the below should be viewed with caution.

This analysis found small negative impacts on both reading and maths progress however only the effect on reading progress scores were found to be significant at the 95% confidence level. This suggests progress scores were 0.17 points lower schools in areas receiving enhanced coverage.

However, in terms of pupil attainment, more positive effects were identified with the proportion of pupils attaining the expected levels in reading, writing, maths, and science increasing. Reading attainment was shown to have increased most, with a 2.75 percentage point increase compared to 2.11 for writing, 1.86 for maths and 1.54 for science.

Figure 7.4: Estimated impact of subsidised coverage on primary school pupil attainment



Source: DfE KS2 attainment data, C3 reports, Ipsos analysis

[82] Progress scores relate to pupil progress t the Key Stage 2 level. See https://www.gov.uk/government/collections/statistics-key-stage-2 for more detail.

8 Cost Benefit Analysis

This final section brings the findings of the evaluation together in the form of a cost-benefit analysis of Phase 3 of the Superfast Broadband Programme. The analysis was undertaken in line with the guidelines set out in the HM Treasury Green Book and relates the net costs of the programme to the public sector to estimates of the net economic and social benefits derived from the results set out in the preceding sections. Estimates of additionality (i.e. the share of premises that would not have been upgraded in the absence of the programme) are derived from parallel analysis set out in Technical Appendix 1 (Reducing the Digital Divide).

The analysis considers costs and benefits over the following time horizons:

- Benefits to date (from April 2016/17 to the end of March 2021/22); and,
- A projection of costs and benefits covering the period April 2016/17 to March 2029/30.

However, the analysis only considers the impacts of premises upgraded by the end of March 2021/22. The modelling does not seek to provide projections of the potential impacts of premises that will be upgraded beyond this point (based on BDUK monitoring information, around 50 percent of contracted premises had been delivered at the end of March 2021/22).

8.1 Costs

BDUK monitoring data gave details of 67 contracts that had been signed as part of the Superfast Broadband programme under Phase 3 of the programme. The gross contract value of the public funding associated with these contracts was more than £1bn at the point of award (in nominal terms), providing funding for the capital costs associated with upgrading network infrastructure in the programme area. [83]

This total includes expected costs associated with the future delivery of contracts and does not reflect the actual costs of delivery. Additionally, this does not allow for possible reductions in costs to the public sector arising from the clawback mechanisms integrated in the contracts. These require suppliers to return resources to the public sector in the event the delivery cost of the project was lower than expected (implementation clawback) or if the project was more profitable than expected (take-up clawback). Estimates of the net costs associated with delivery of contracts by the end of March 2021/22 were estimated on the following basis:

- **Actual costs:** Observations of the actual costs to the public sector by the end of March 2021/22 were taken from BDUK monitoring information (Finance Trackers) for the 35 of the 67 Phase 3 contracts for which this information was available. In 27 cases where this information was not available, an estimate of actual costs to the public sector was derived by adjusting expected delivery costs (as derived from the Project Financial Model) by the ratio of actual to contracted premises upgraded by the end of March 2021/22. This implies an assumption that the unit cost of delivery will align with expectations at the time the contract was signed. As illustrated in Technical Appendix 2 (financial analysis), costs of delivery have generally exceeded expectations and this approach may lead to an understatement of the net costs to the public sector. In five cases, no Project Financial Model was available, and the costs of these contracts are not included in the estimates below.

[83] This comprises all sources of public funding, not just funding provided by BDUK.

- **Clawback:** In addition, there was sufficient information available in relation to 27 contracts to enable a modelling exercise in which projections were developed to estimate levels of take-up clawback based on projections of future take-up. As described in Technical Appendix 2, implementation clawback was also included to account for reductions in the scale of contracts. Details of these analyses are set out in Technical Appendix 2. As the focus on this analysis is on premises upgraded by the end of 2021/22, estimates of future take-up clawback were scaled in line with the share of contracted premises that had been delivered by the end of March 2022.

  No adjustments were made for clawback for the remaining 33 projects included in the analysis. As take-up levels are generally projected to exceed expectations set out in the Project Financial Model, this is likely to overstate net costs to the public sector.

The resultant estimates of costs to the end of March 2022 are set out in Table 8.1. The present value[84] of actual public spending associated with Phase 3 contracts by the end of March 2022 were estimated at £239.2m (with a baseline of 2016/17). These contracts were expected to return £21.6m to £28.9m to the public sector via clawback (in present value terms, depending on whether take up stabilises at 60 or 85 percent in the long run). This gives an estimated net cost to the public sector of £210.2m to 217.5m (in present value terms). In addition to the caveats outlined above, it should be noted that these estimates do not include administrative costs to BDUK, Local Bodies, or network providers.

Table 8.1: Expected net public sector costs (£m, 2019 prices)

Data available	Number of contracts	Forecast public funding (£m)		Forecast take-up clawback (£m)		Net cost to the public sector (£m)	
		Nom.	PV	Nom.	PV	Nom.	PV
Full information (subject to IRR modelling)	29	111.4	98.0	-27.5 to -37.8	-21.6 to -28.9	74.1 to 83.9	69.1 to 76.3
Actual costs of delivery (Finance Tracker)	6	6.6	5.6	0	0	6.6	5.6
Expected costs only (PFM)	27	155.3	135.6	0	0	155.3	135.6
No cost information	5	0	0	0	0	0	0
Total	**67**	**273.3**	**239.2**	**-27.5**	**-21.6**	**236.0 to 245.8**	**210.2 to 217.5**

Source: BDUK, Ipsos MORI analysis

8.2 Additionality

As highlighted in Section 3, the results set out in the preceding sections explore the impacts of subsidised coverage. However, the results do not factor in the possibility that some coverage may have been brought forward through commercial deployments in the absence of the programme. Estimates of the additionality of the coverage funded through the programme are taken from Technical Appendix 1, which examined the

84 The present value is the current value of a cashflow discounted for the rate of social time preference (i.e. reflecting that households prefer cash today over the same sum in the future). All future values were discounted by the rate recommended in the HM Treasury Green Book (3.5 percent).

share of the premises involved that would not have been upgraded in the absence of the programme (and how this evolved with time). These findings suggested that:

- **Superfast vs gigabit availability:** The results indicated that the level of additionality associated with gigabit coverage was higher than for superfast availability. This implies that while many households would not have benefitted from gigabit infrastructure in the absence of the programme, some may have benefitted from upgrades that enabled superfast broadband services. The purpose of this analysis is to estimate the additional economic and social benefits of the infrastructure. As the marginal benefit associated with moving from superfast to gigabit capable services is unknown, average levels of additionality across the two technological standards was used in the following analysis (reflecting an assumption of diminishing returns to speeds, though this may be conservative as the marginal benefits of FTTP connectivity are likely to rise with time).

- **Evolution over time:** Based on the findings set out in Technical Appendix 1, the average level of additionality was estimated to peak in the year after the premises was upgraded (at 81 percent). Additionality was estimated to decay to 49 percent in the fourth year post-installation (an average rate of decay of 16 percent per annum).

  This pattern aligns with results obtained for prior Phases of the programme, though the estimated level of additionality associated with Phase 3 was notably higher than for prior Phases. [85] This indicates that the areas concerned were substantially less likely to benefit from commercial deployments of gigabit capable technologies without public sector support (and a significant share would also not have had access to superfast services). However, while the programme was targeted at some of the harder areas to reach, eligible areas were identified through Open Market Review processes completed in 2015/16. [86] This predated the growth in private investment in the deployment of FTTP networks observed since 2019. As such, trends towards lower rates of additionality might be expected, with an implication that the programme largely helped accelerate deployment of gigabit capable networks.

  However, the finding set out in Technical Appendix 2 indicate that the rates of return associated with Phase 3 contracts are likely to fall below network providers' cost of capital in many cases (raising questions regarding the strengths of commercial incentives to deploy networks without public assistance). Additionally, estimates of the rate at which the programme accelerated commercial deployments are based on delivery in the first years of the programme (which may not be representative, given the large increases in delivery observed post 2019). As such, it is also plausible that additionality decays at a slower rate moving forward.

- **Projected additionality:** Projections of additionality to 2029/30 were developed on the following basis:

  - **Lower bound estimate:** A lower bound estimate was developed by extrapolating the findings over the duration of the appraisal period (i.e. assuming additionality continues to decay at a rate of 16 percent per annum). This assumption implies that additionality would fall to 12 percent twelve years post-installation, capturing a scenario in which 88 percent of premises upgraded eventually benefit from enhanced broadband coverage.

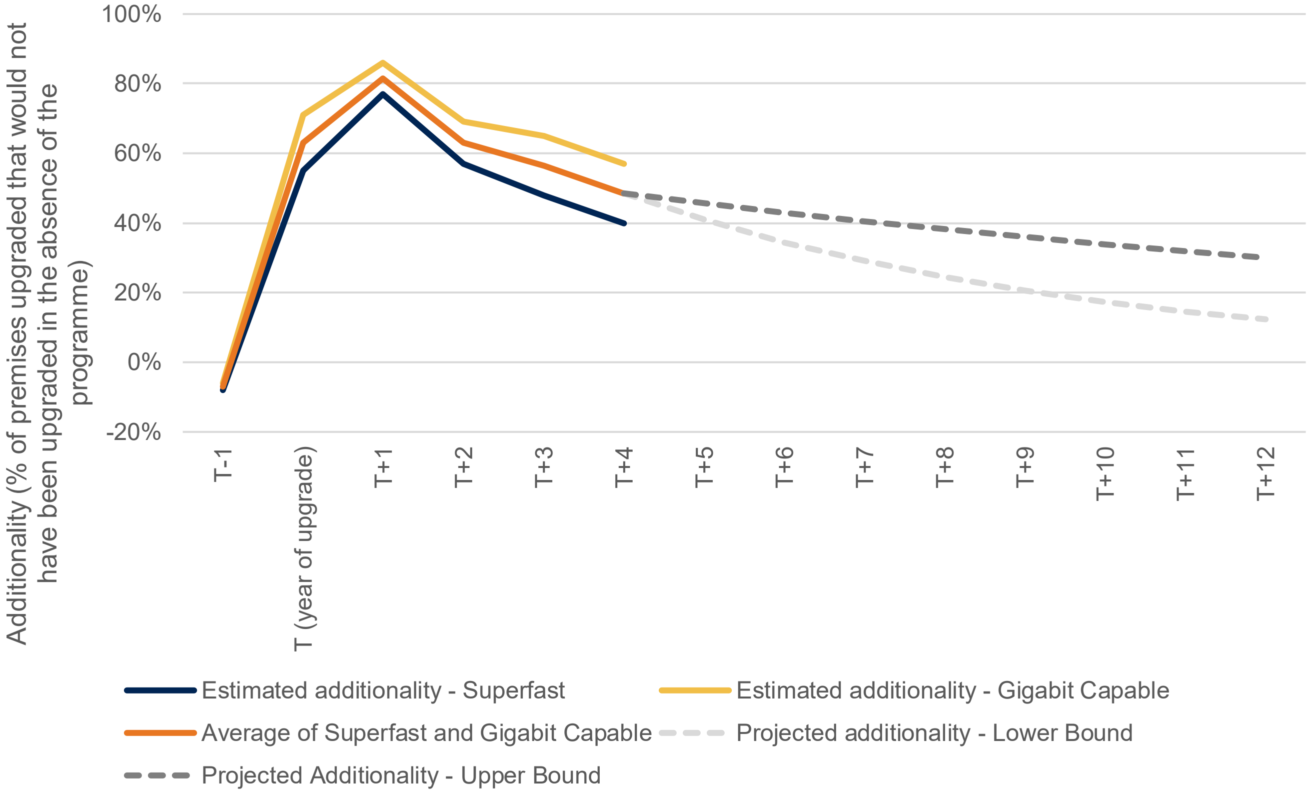
[85] DCMS (2021) State aid evaluation of the Superfast Broadband Programme: Technical Appendix One
[86] And as such, the findings of this analysis cannot necessarily be transferred to current programmes.

- **Upper bound estimate:** This projection appears potentially pessimistic given parallel findings in relation to the commercial viability of investments in FTTP in areas covered by Phase 3 contracts. While commercial deployments of FTTP have expanded rapidly since 2019, it might be expected that some areas will never be covered by commercial deployments without substantial technical innovations to reduce deployment costs (or if network providers are able to subsidise such deployments with profits earned from investments in commercially viable areas). An upper bound scenario, in which additionality decays at a slower rate to 30 percent in 2029/30 was adopted to capture this possibility.

- **Delaying effect:** The evidence also suggested that seven percent of premises upgraded would have otherwise received superfast coverage one year earlier in the absence of the programme. This is consistent with evidence from qualitative research with network providers as part of the 2020 State aid evaluation that suggested that the OMR process could lead to some postcodes being marked as eligible for investment where commercial deployment plans were insufficiently developed or certain. The likelihood that a subsidised competitor would emerge would discourage investment in these areas. This delaying effect will have negative economic and social costs in the short-term and this is modelled using a negative value for additionality in the year prior to the upgrade.

The figure below displays the assumed additionality profile over time under the two scenarios.

Figure 8.1: Additionality profile over time



Source: Ipsos MORI analysis

The table below provides the estimated number of premises upgraded by March 2020 that would not have had enhanced broadband connectivity in the absence of the programme (in 2021/22 and 2028/29) under the two scenarios for future additionality. The gross number of premises passed is based on C3 reports provided by BDUK. The number of additional premises passed in 2021/22 is estimated at 192,700. This is estimated to fall to between 58,300 and 102,600 by 2029/30 based on the scenarios described above.

Table 8.2: Estimated number of additional premises passed, 2012/13 to 2029/30

Year of upgrade	Gross number of premises passed	Estimated number of additional premises passed		
		2021/22	2029/30	
			Low	High
2017/18	4,868	2,400	600	1,500
2018/19	38,624	21,800	5,700	12,300
2019/20	72,559	45,700	12,600	24,500
2020/21	74,608	60,800	15,400	26,800
2021/22	98,404	62,000	24,100	37,500
Total	**289,063**	**192,700**	**58,300**	**102,600**

Source: BDUK, Ipsos MORI analysis. Estimates have been rounded to the nearest 100.

8.3 Economic and social benefits

8.3.1 Productivity gains

The evaluation produced a variety of evidence to show that the programme has led to important economic impacts at the local level. This was visible in estimates of the impact of the programme on employment, unemployment, and wages. However, in line with the HM Treasury Green Book, it is assumed that the local economic impact of the programme will largely be neutralised by offsetting effects elsewhere in the economy (displacement). While businesses located in areas receiving subsidised coverage have expanded their sales, this will have come at the expense of loss of market share for competing firms (who may be located locally or elsewhere in the UK).

The findings also suggested that relocation of economic activity was an important driver of the effects observed. Assuming these activities would have otherwise been relocated elsewhere in the UK it is likely that much of the job creation impacts described above would have been realised in other locations. Even if firms expanded without directly displacing the activities of domestic competitors, increased demand for workers and other inputs can be expected to have placed additional pressure on prices, resulting in reductions in output and employment elsewhere.

As such – and in line with the principles of the HM Treasury Green Book - only the effects of the programme in terms of raising productivity are considered to qualify as economic benefits at the national level. The evaluation provided a range of results to indicate that the programme has supported improvements in productivity – including raising the turnover of per worker and wages of employees of firms located in areas benefiting from subsidised coverage under Phase 3 (which rose by 0.6 and 0.8 percent respectively in response to the upgrades). It should be noted that the revised Green Book now allows 'place based' BCRs to be presented alongside BCRs at the national level, which would include local benefits driven by the creation or attraction of new jobs to the areas benefitting from the programme.

GVA based measure of economic benefits

An increase in productivity will increase overall economic output (GVA) as resources are used more efficiently. However, it is important to note that turnover per worker may rise at the local level both because firms become more efficient, and because more productive firms relocate to the area (a displacement effect that would not lead to improvements in productivity at the national level). To address this issue, the economic benefits of the programme have been estimated based on its effects on firms that did not relocate (i.e. spatially stable firms) over the period of interest, as follows:

- **Impact on turnover per premises upgraded:** The estimated impact of the programme on the turnover per worker of spatially stable firms was estimated at 0.002 percent per premises upgraded in Output Areas benefitting from Phase 3 contracts. The average turnover per worker of spatially stable firms benefitting from Phase 3 contracts was approximately £95,372. This result implies that turnover per worker in spatially stable firms rose by around £2 per premises upgraded under Phase 3. The average level of employment amongst spatially stable firms in these areas was 32 employees per output area. This gives a total effect on turnover driven by apparent efficiency gains of £63 per premises upgraded.

  The overall effect on turnover per worker per premises upgraded was lower than estimated for prior Phases of the programme (as explored in the 2020 State aid evaluation report). This is likely driven by an increasing share of residential upgrades under Phase 3 of the programme (which has focused on addressing gaps in network deployment in largely residential areas, meaning that relatively smaller numbers of commercial enterprises have benefitted from subsidised coverage). Additionally, businesses located in areas benefitting from Phase 3 of the programme tended to be less productive and employed fewer workers than those benefitting from prior Phases. These features will also have limited the net economic impacts of subsidised coverage. However, as it is not possible to identify individual enterprises that have benefitted from subsidised coverage in the available data, it is also not possible to rule out the possibility that the relevant businesses have been less able to exploit enhanced connectivity to realise efficiency gains.

- **Short term impact on GVA per premises upgraded.** It is assumed that firms did not change the shares of labour and other inputs used in production in response to the subsidised coverage, and the effect on turnover per worker can be interpreted as an improvement in productivity. Applying the average GVA as a percentage of turnover across the UK as whole over the 2016 to 2021 period (32 percent)[87], this gives an effect on GVA per premises upgraded of £20 (per annum).

The assumptions were applied to the profile of additional premises upgraded set out in the preceding section. Summary results covering the 2016/17 to 2021/22 period (benefits to date) and the 2016/17 to 2029/30 period (including projected benefits) are set out in the table below. The present value of GVA benefits (with a baseline of 2012/13) are estimated at £7.2m by 2018/19 and between £20.8m and £23.1m by 2029/30.

This approach may understate the economic benefits of the programme. If spatially stable firms displace sales from less productive firms, then there will also be benefits associated with the transfer of output from less to more productive producers which are not captured in this analysis. The programme is also assumed not to lead to productivity gains for relocating firms (as the quality of their broadband access prior to the relocation is unknown). Additionally, the relocation of firms to the programme area may also produce agglomeration economies (e.g. resulting from knowledge spillovers arising from greater opportunities for face-to-face interaction and collaboration) that could only be partly captured in the econometric analysis. However, it should be noted that these relocations will be accompanied by disagglomeration elsewhere and these effects may neutralise each other at the national level.

[87] Source: Annual Business Survey, ONS

Table 8.3: Additional GVA resulting from productivity gains (£m, 2019 prices, low – high range)

Period	Undiscounted (£m)	Discounted (£m)
Productivity gains 2016/17 to 2021/22 (£m)	8.4	7.2
Productivity gains 2016/17 to 2029/30 (£m)	26.5 – 29.9	20.8 – 23.1

Source: BDUK, Ipsos MORI analysis

8.3.2 Unemployment impacts

The results of the evaluation suggested that for every 10,000 premises upgraded there was a corresponding on-going reduction in the number of unemployed claimants of 34.3 claimants. The extent to which these effects might be understood as net economic benefits will be linked to how far the programme drew individuals out of (or helped them avoid) extended periods of involuntary worklessness in which they were not productively deployed (rather than short-term episodes of unemployment[88]).

The data available did not permit an analysis of the effects of the programme on long-term unemployment directly as claimant counts at the local level do not provide information on the duration of claims. However, a prior evaluation (using different data series[89]) suggested that for every individual taken out of unemployment by the programme, 0.29 individuals were taken out of long-term employment. Assuming this applies to the results obtained in this study, [90] it is estimated that for every 10,000 premises upgraded, the number of long-term claimants fell by 9.8.

Assuming the effects on long-term unemployment represent the effect of the programme on the overall productive capacity of the economy, and valuing the output produced by those individuals at £15,480 per annum[91], it is estimated that these effects could have led to an additional £5.5m in national economic output (GVA) by 2019 (in present value terms). This effect is estimated to rise to between £15.7m to £317.4m in the longer term (though to the extent this is driven by relocation of economic activity, there may have been corresponding increases in long-term unemployment elsewhere).

Table 8.4: Additional GVA resulting from reductions in long-term unemployment t(£m, 2019 prices, low – high range)

Period	Undiscounted (£m)	Discounted (£m)
GVA from the reduction in long-term unemployment 2016/17 to 2021/22 (£m)	6.3	5.5
GVA from the reduction in long-term unemployment 2016/17 to 2029/30 (£m)	20.0 – 22.6	15.7 – 17.4

Source: BDUK, Ipsos MORI analysis

8.3.3 Social benefits

The findings of the study suggested that the programme led to an average increase in house prices of between £1,900 and £4,900 suggesting that buyers were willing to pay a premium to obtain houses benefitting from subsidised upgrades. Based on hedonic pricing approaches, this can potentially be interpreted as a measure of the average gain in social welfare associated with access to superfast and gigabit capable broadband networks (i.e. on the basis that the maximum households are willing to pay

---

88 Though some of these episodes will have otherwise evolved into long-term unemployment.

89 DCMS (2018) Economic and Public Value Impacts of the Superfast Broadband programme.

90 Note that the results are not highly sensitive to this assumption. If it is assumed that all reductions in unemployment were from the long-term unemployed, then the resultant productivity gains would increase to £19.2m by 2022 and between £55.0m and £61.0m by 2030.

91 It is assumed that the productivity of the average worker avoiding long-term unemployment due to the programme is lower than the national average, and here we have assumed that workers would gross annual pay at the 25th percentile of all workers (based on the 2017 Annual Survey of Hours and Earnings). This is consistent with DfT Transport Appraisal Guidance treatment of labour supply impacts.

should reflect the marginal gain in wellbeing derived from access to the technology). However, there are several issues of interpretation that create some complexities in this approach:

- **Expectations:** There are questions as to how consumers form expectations regarding the likely future availability of superfast broadband and build this into their willingness to pay. If households have perfect information on the deployment plans of network providers, the estimated effects of the programme show what households are willing to pay for a housing with superfast broadband coverage over and above housing that will be upgraded in later years. If this is the case, then the results can be understood as the short-term gain in welfare associated with having access to superfast broadband services as opposed to coverage at some uncertain point in time in the future. As users will continue to derive benefits from the availability of superfast broadband beyond the point where it is available on a close to universal basis, the house price premium is also likely to understate the long-term social benefits of access to superfast networks.

- **Additionality:** Flowing from the above, the gross value of the price uplift was adjusted in light of estimates of short-term additionality (an average of 72 percent up to two years following the upgrade) to reflect the possibility that the premises would have otherwise received subsidised coverage in the absence of the programme at the time of purchase. However, the value of the price uplift was not adjusted further in the long term as it was assumed that the possibility that the property would have received superfast coverage in the future was factored into willingness to pay.

- **Estimated total land value uplift:** BDUK monitoring information indicated that 93 percent of the 289,000 premises upgraded were residential premises (269,000). Assuming the house price premium provides a reasonable measure of the average gain in welfare across the programme, this gives an estimate of the present value of welfare benefits of £370m to £947m.

- **Representativeness of buyers:** The price of homes sold will reflect the value of the property to the marginal buyer. Buyers are likely to have different preferences to the average resident of the programme area and may place a particularly high value on the features of the property such as broadband capability. Existing residents would have moved into the area before superfast connectivity arrived. As such, it may not be possible to assume that the apparent price premium reflects improvements of the welfare of other residents of the areas concerned (who may place a lower value on superfast broadband).

- **Lower bound estimate:** A lower bound estimate was derived by assuming the house price premium only provided a reasonable approximation of the welfare gains associated with the programme in cases where houses were sold after the premises was upgraded (114,162). This gives a lower estimate of the total welfare gains of between £157m to £402m, although this is a highly conservative approach as it assumes that existing residents derive no value from enhanced broadband connectivity.

- **Uncertainty:** To the extent that house prices were driven by migration induced by the programme, these may not represent net benefits as there may be offsetting effects elsewhere. Additionally, there is a possibility that the house price uplift may be linked to the programme's effects in attracting additional economic activity to the area (in which case, there may be an element of double counting with the economic benefits). Further analysis will be completed as part of the final evaluation using alternative methods (e.g. wellbeing valuation) to provide further evidence on the social benefits of the programme.

The following table provides a summary of the results.

Table 8.5: Land value uplift arising from impacts on house prices (£m, 2019 prices)

	Low house price premium (0.78%)	High price premium (1.43%)
Land value uplift (£m, present value)	370.3	946.9
Land value uplift (£m, only sold properties)	157.2	402.1

Source: BDUK, Ipsos MORI analysis

8.4 Benefit to Cost Ratios

Drawing on the results above, low, and high estimates of the Benefit to Cost Ratio (BCR) associated with the programme are developed using the estimates of the net cost of the programme set out in the Section 8.1. This gives a range for the BCR as follows:

- **Benefits from 2016 to 2022:** The short term BCR (based on benefits to date) is estimated at between £1.76 and £4.57 per £1 of net lifetime public sector costs. This assumes that the house price premium is a reasonable approximation of the average welfare gain associated with the programme (and the width of the range is driven largely by modelling uncertainty regarding the size of the house price premium associated with subsidised coverage).

- **Benefits from 2016 to 2030:** In the long run (allowing for future economic benefits), the BCR is estimated to rise to £1.87 to £4.70 per £1 of net public sector spending.

- **Lower bound estimates:** As noted above, it is possible that the house premium overstates the average welfare gain associated with enhanced broadband connectivity. Using the lower bound estimates of the social benefits of the programme outlined above, the long-term BCR would fall to between £0.89 and £2.04. This will clearly understate the net benefits of the programme, as it assumes that existing residents derive no value from superfast broadband availability.

- **Comparisons with prior findings:** Previous analysis set out in the 2020 State aid evaluation report found that the Benefit Cost Ratio associated with the overall programme was substantially higher (£3.6 to £5.1 between 2012 and 2030).[92] The average benefit per premises upgraded for Phase 3 was in line with (if not higher than) estimates for prior Phases. However, unit cost of upgrades to the public sector was markedly higher for Phase 3 than for prior phases of the programme. The net cost per additional premises passed was by 2022/23 was estimated at £1,270 for Phase 3, versus £217 for all Phases of the programme. This increase in cost was driven by a change in technical focus to gigabit capable technologies (which are more costly to deploy) and a change in spatial focus to areas that are harder to reach. Contracts awarded under Phase 3 are also expected to generate substantially lower levels of implementation and take-up clawback than contracts awarded under Phase 1 (which were often commercially viable without subsidy).

- **Omitted benefits:** It should be noted that these results also do not factor in the value of some important potential benefits of the programme, particularly in terms of its impact in improving equity in access to broadband infrastructure. These types of benefit are likely to become more significant in the longer term, as new applications dependant on faster broadband speeds are brought to market (leading to greater risks of digital exclusion).

[92] Note that these should be compared with the lower bound estimates for consistency in approach.

Table 8.6: Benefit to Cost Ratios, 2016 to 2022 and 2016 to 2030

Period	**2016 to 2022**		**2016 to 2030**	
	Low additionality / house price effects	High additionality / house price effects	Low additionality / house price effects	High additionality / house price effects
Benefits				
Productivity gains (£m)	7.3	7.3	20.8	23.1
Long term unemployment (£m)	5.5	5.5	15.7	17.4
House prices (£m)	370.3	946.9	370.3	946.9
Total	**383.1**	**959.8**	**407.0**	**987.7**
Costs				
Lifetime cost (£m)	210.2 to 217.5	210.2 to 217.5	210.2 to 217.5	210.2 to 217.5
Benefit to cost ratio (£)	**1.76 to 1.82**	**4.41 to 4.57**	**1.87 to 1.94**	**4.54 to 4.70**
Lower bound estimate of total benefits and costs				
Total benefits (£m, house premium applies to sold houses only)	170.1	415.0	194.0	442.9
Lifetime cost (£m)	210.2 to 217.5	210.2 to 217.5	210.2 to 217.5	210.2 to 217.5
Lower bound BCR (£)	**0.78 to 0.81**	**1.91 to 1.97**	**0.89 to 0.92**	**2.04 to 2.11**

Source: BDUK, Ipsos MORI analysis

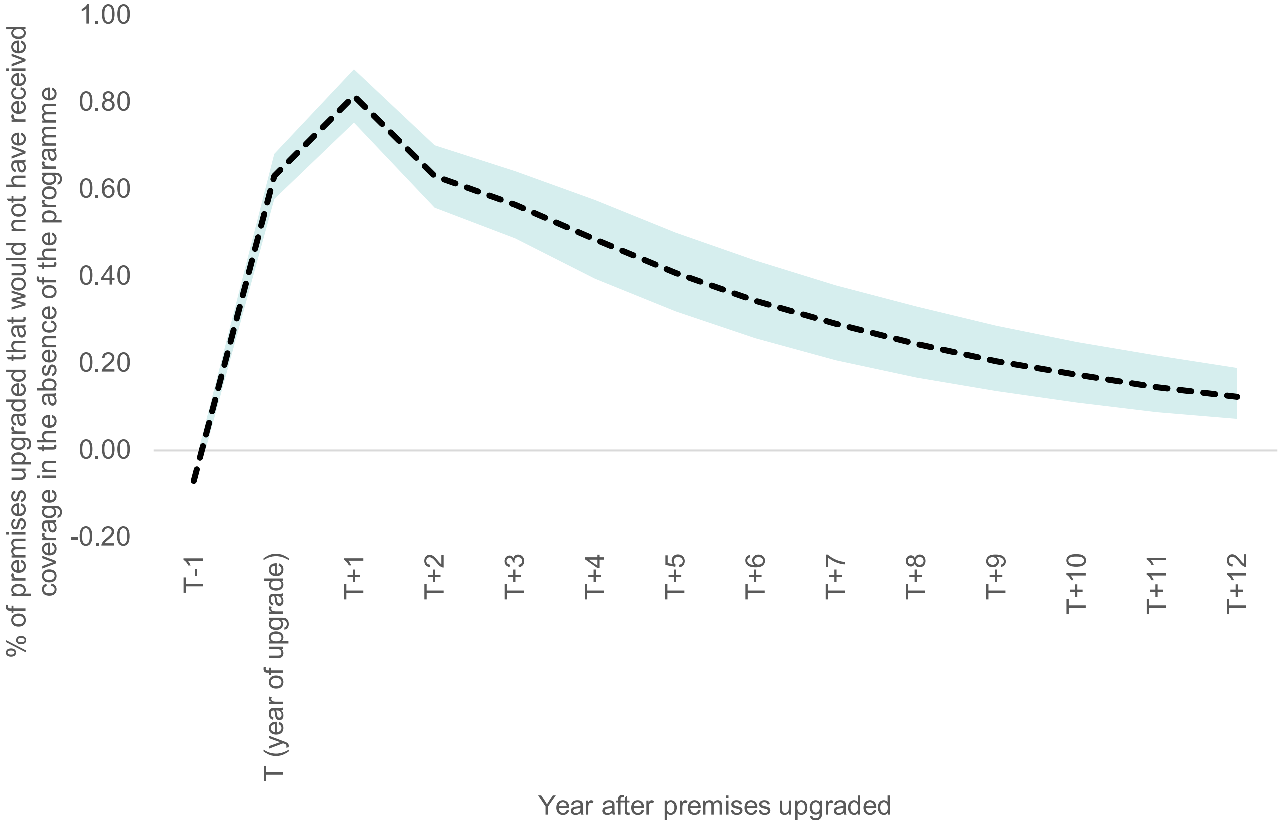
8.5 Margin of error

The results set out above are based on the central estimates of the impacts the programme. However, the key results upon which it was based are subject to statistical uncertainty. This section provides further sensitivity analysis exploring the margin of error associated with these results.

8.5.1 Additionality

The following figure shows the 95 percent confidence interval for the lower bound additionality estimates used to drive the analysis (with the lower and upper bounds projected forwards using the same approach). The 95 percent confidence interval after 4 years gives a margin of error around the estimated additionality of 38 percent, of 31 to 45 percent.

Figure 8.2: Additionality profile over time – 95 percent confidence interval



Source: Ipsos MORI analysis. Shaded area shows the 95% confidence interval.

8.5.2 Productivity, unemployment and house prices

The table below provides the 95 percent confidence interval for key parameters driving the estimates of benefits (i.e. the estimated impacts on turnover per worker, unemployment, and house prices). The estimated effect of the programme on turnover per worker was only significant at the 90 percent level of confidence, and the lower bound estimate is negative (although this only has a marginal effect on the BCR, given the share of total benefits derived from productivity gains).

Table 8.7: 95 percent confidence interval – effects on turnover per worker, unemployment and house prices

	Central estimate	95 percent confidence interval (lower bound)	95 percent confidence interval (upper bound)
Turnover per worker	0.00002	-0.000003	0.00004
Unemployment	-0.00343	-0.00152	-0.00495
House prices (low premium)	0.0061	0.0014	0.0108
House prices (high premium)	0.0156	0.0101	0.0218

Source: BDUK, Ipsos MORI analysis

8.5.3 BCRs

The table below illustrates the margin of error around the most conservative estimates set out in Table 8.6 (i.e. those associated with lower additionality). The findings indicate that there is substantial statistical uncertainty in relation to the BCRs associated with subsidised coverage, driven principally by uncertainty (modelling, statistical, and interpretation uncertainty) regarding the size of the effect of the programme on house prices. After allowing for statistical uncertainty, the BCR associated with the programme could range from £0.17 to £7.11 per £1 of public sector spending (by 2030).

Table 8.8: Benefit to Cost Ratios, 95 percent confidence interval (low additionality scenario with low house price premium)

Period	2016 to 2022		2016 to 2030	
	Lower bound (low house price effect)	Upper bound (high house price effect)	Lower bound (low house price effect)	Upper bound (high house price effect)
Benefits				
Productivity gains (£m)	-1.1	17.6	-3.0	53.2
Long term unemployment (£m)	2.2	8.8	5.8	26.6
House prices (£m)	33.3	1,426.9	33.3	1426.9
Total	**34.3**	**1,453.3**	**36.0**	**1,506.6**
Costs				
Lifetime cost (£m)	210.2 to 217.5	210.2 to 217.5	210.2 to 217.5	210.2 to 217.5
Benefit to cost ratio	**0.16 to 0.16**	**6.68 to 6.91**	**0.17 to 0.17**	**6.93 to 7.17**

Source: BDUK, Ipsos MORI analysis

For more information

3 Thomas More Square
London
E1W 1YW

t: +44 (0)20 3059 5000

www.ipsos.com
http://twitter.com/IpsosUK

About Ipsos Public Affairs

Ipsos Public Affairs works closely with national governments, local public services and the not-for-profit sector. Its c.200 research staff focus on public service and policy issues. Each has expertise in a particular part of the public sector, ensuring we have a detailed understanding of specific sectors and policy challenges. Combined with our methods and communications expertise, this helps ensure that our research makes a difference for decision makers and communities.

Ipsos MORI