December 2020 **State aid evaluation of the UK National Broadband Scheme**

Technical Appendix 3 – Economic and Social Impacts

Ipsos MORI



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This work was produced using statistical data from ONS. The use of the ONS statistical data in this work does not imply the endorsement of the ONS in relation to the interpretation or analysis of the statistical data. This work uses research datasets which may not exactly reproduce National Statistics aggregates.

Key Findings

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 2019. The analysis is based on econometric analysis of a variety of administrative and secondary datasets providing longitudinal data at a small area level. This analysis provides estimates of the local impact of the Superfast Broadband Programme on the areas where the programme has provided subsidised coverage.

However, these local impacts cannot be summed to provide an estimate of the national benefits of the Superfast Broadband Programme. Some of the economic impacts the programme has generated will displace economic activity from other areas in the UK. The national economic benefits (net of this displacement, crowding out and sorting effects) have been estimated and are presented in the benefits to cost ratio.

Key definitions

- **Outcomes:** Outcomes are social or economic measures that could be affected by the programme (e.g. jobs, turnover, life satisfaction). Outcomes are measured at the local level.
- Impacts: Impacts are the effects on the outcome that are attributable to the programme over and above what would have occurred in the absence of the programme. Impacts occur over a longer time period. Impacts are measured at the local level.
- Benefits: A measurable improvement of a positive outcome (as perceived a by one or more stakeholders), which contributes towards one or more organisational objectives. Benefits are measured at a national level, net of displacement.

Impacts on businesses

The results indicated that by 2018, subsidised coverage led to the following estimated impacts on those areas benefitting from the programme:

- Jobs: Subsidised coverage led to the creation or retention of 17,600 jobs in the areas benefitting from the programme by 2018 (compared to 7,400 by 2016¹).
- **Turnover:** Subsidised coverage also increased in the annual turnover of firms located in these areas by £1.9bn by the end of 2018 (compared to £1.8bn by the end of 2016).
- Additional turnover from efficiency gains: The total increase in the annual turnover of firms driven by increases in the productivity of local firms was estimated at £845m by the end of 2018². As time has passed, the programme's effects on local employment have strengthened relative to its effects on turnover growth. This tendency has reduced the increase in annual turnover from efficiency gains from £1.4bn at the end of 2016.
- Relocations and new firm formation: These local economic impacts were partly driven by an increase in the number of firms located in the area. Subsidised coverage increased the number of firms located in areas benefitting from the programme by 0.5 percent. The relocation of firms to areas

¹ 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 at the local level were likely to be significant. ² This is calculated as the turnover per worker in 2012 x % impact of subsidised coverage x number of workers employed in 2012.

benefitting from the programme will have offsetting effects in the areas from which they relocated. Additionally, the growth of firms in the programme area may also have come at expense of loss of market share of firms located elsewhere. As a consequence, these findings capture the local rather than the national economic impacts of the programme.

Productivity gains: At the national level, the economic benefits of the programme can be understood in terms of its effects on the productivity of firms benefitting from subsidised coverage. This was understood by focusing on those firms that did not change their location after the improvements to local broadband infrastructure were completed. The findings indicated that subsidised coverage increased the productivity (approximated by turnover per worker) of this group of firms by 0.7 percent by 2018, suggesting the programme has produced important benefits at the both the local and the national level.

Analysis of the impacts by phase of the programme indicated that Phase 1 had a persistent effect on local economic performance – leading to increases in employment, turnover, and turnover per worker over six years. Phase 2 appears to have increased the size of the local economy (leading to an expansion of both the turnover and employment of local firms), though this appears to be driven to a large degree by the relocation of the firms to the areas benefitting. Subsidised coverage brought forward under Phase 3 did not yet appear to have a significant effect on local economic activity.

Analysis of the impacts of the programme by the speed of connection available suggested that there were diminishing returns to the predicted speed of the connection. The effects of moving to speeds below 24Mbps³ were estimated to be between 2.5 and 3 times larger than the impacts of superfast connectivity (on employment, turnover and turnover per worker). This indicates the absence of basic broadband is potentially a more severe impediment for businesses and releasing businesses from this constraint can have significant economic impacts.

Impacts on workers

The analysis undertaken found a positive impact on the hourly wage of workers in the Output Area 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.

Consumer value and well-being

Impacts on consumer value and well-being have been inferred using a revealed preference approach through an analysis of the impact of the Superfast Broadband Programme on house prices. This analysis indicated that the programme has led to an increase in house prices of 0.6 to 0.7 percent. Applying these to the average price of houses sold in the programme area between 2012 and 2019 (£304,986 in 2019 prices), gives a range for the average impact on house prices of £1,700 to £3,500, which is the estimated value for the well-being impact. This indicates that buyers were willing to pay a premium to obtain homes that had been upgraded.

Impacts on the public sector

An experimental analysis of the impact of the Superfast Broadband Programme on the public sector has been undertaken. The key findings from this analysis were:

³ Note that the analysis included premises upgraded where the predicted speeds were lower than superfast speeds.

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- **Number of patients**: Subsidised coverage increased the number of patients registered with GPs by 3.2 to 5.9 percent on average between 2013 and 2019.
- Staffing: However, the number of staff employed by GP surgeries did not rise to the same degree. While subsidised coverage led to an increase in the number of nursing and non-clinical staff of 5.3 to 5.4 and 5.4 to 7.4 percent respectively, there was no effect identified on the number of GPs in the same period.
- **Overall satisfaction with GP services:** Subsidised coverage appeared to reduce the share of patients that described their experience as fairly or very good by two percentage points.
- Primary School income: Total incomes were estimated to rise by 1.7 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).
- Primary school resources: The programme had an impact on ICT, teaching expenditure and the number of teachers, with these decreasing by 17.7 percent, increasing by 8.2 percent and 2.0 percent respectively. However, these findings were not robust to the addition of further controls and as such the findings are inconclusive.
- Primary school pupil numbers and composition: The programme had a positive effect 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. The programme also led to reductions in the share of pupils eligible for Free School Meals (FSM) or with Special Educational Needs (SEN) (of 2.8 and 4.6 percentage points respectively), and a slight increase in the share of pupils with English as an Additional Language (EAL).

Benefit to cost ratio

The additional total public expenditure required to deliver the Superfast Broadband Programme has been estimated to be \pounds 807 million in nominal terms. This is less than the estimated total cost of the programme of \pounds 1.9 billion, as there has been a large amount of forecasted clawback generated from the beneficiaries delivering the programme.

Taking into account the estimated level of additionality generated through the programme (the displacement of economic activity), the productivity gain between 2011/12 and 2018/19 was estimated at approximately £1.1bn, with a further £125m benefit in terms of GVA estimated from reductions in long-term unemployment. Finally, net land value uplifts (a new outcome) contributed a further estimated £742m to £1.5bn. Total net benefits at a national level were valued at between £1.9bn and £2.7bn.

Summary of estimated local and national impacts

| Benefit type | Estimated local impact ⁴ | Estimated national benefit ⁵ |
|--|--|--|
| Productivity growth | Increase in the annual turnover of firms located in relevant areas of £1.9bn (compared to £1.8bn by the end of 2016). Increase in the annual turnover of firms driven by efficiency gains was estimated at £845m by the end of 2018 (compares to £1.4bn at the end of 2016). | Productivity gain estimated at approximately £1.1bn (compared to £692m in 2016) |
| Labour market | Increase in local jobs of 17,600 due to the subsidised coverage (compared to 7,400 by 2016). | Reductions in long-term unemployment of approx. 2100 fewer estimated at £125m |
| | Reduction in unemployment benefit claimants of 0.6 per Lower Super Output Area (LSOA) upgraded. | (compared to £37.7m in 2016). |
| Housing market impacts (well-being) | Increase in house prices of 0.6 to 0.7 percent with an average impact on house prices estimated between £1,700 to £3,500 | Land value uplifts estimated to be between £742m to £1.5bn. |

Source: Ipsos MORI analysis

Using the estimates of the net benefits of the programme on businesses and households and the cost of the programme, the estimated Benefit to Cost Ratio (BCR) associated with the programme **in the short-term is between £2.7 and £3.8 per £1 of net lifetime public sector costs**. This exceeds the hurdle rate of return normally applied in the appraisal of public sector programmes and suggests that the programme has already delivered a strong rate of return. In **the long-term (allowing for future economic benefits i.e. 2019-2030), the BCR is estimated to rise to between £3.6 and £5.1 per £1 of net public sector spending**.

⁴ Impacts net of local displacement and crowding out

⁵ Estimated net benefits applicable under Green Book guidance and accounting for the proportion of coverage that would have otherwise come forward in the absence of the programme

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 2019. The analysis is based on econometric analysis of a variety of administrative and secondary datasets providing longitudinal data at a small area level and below (including micro data).

This analysis provides estimates of the local impact of the Superfast Broadband Programme on the areas where the programme has provided subsidised coverage.

However, these local impacts cannot be summed to provide an estimate of the national benefits of the Superfast Broadband Programme. Some of the economic impacts the programme has generated will displace economic activity from other areas in the UK. The national economic benefits (net of this displacement, crowding out and sorting effects) have been estimated and are presented in the cost benefit analysis.

1.1 Key definitions

- **Outcomes:** Outcomes are social or economic measures that could be affected by the programme (e.g. jobs, turnover, life satisfaction). Outcomes are measured at the local level.
- Impacts: Impacts are the effects on the outcome that are attributable to the programme over and above what would have occurred in the absence of the programme. Impacts occur over a longer time period. Impacts are measured at the local level.
- Benefits: A measurable improvement of a positive outcome (as perceived a by one or more stakeholders), which contributes towards one or more organisational objectives. Benefits are measured at a national level, net of displacement.

1.2 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 otherwise benefit from commercial deployments. The aim of this Appendix is to provide a quantitative assessment of the economic and social impacts and benefits of the programme between 2012 and 2019. The paper seeks to address the following core questions defined by 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 evaluation⁶ relating to the indirect impacts of the intervention (namely – has the scheme had spill-over effects on other firms or geographical regions?). This Appendix considers the impacts of the programme in four key areas

⁶ 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).

- 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).

| Benefit type | Benefit | Coverage in this report |
|------------------------------------|---|---|
| | Increased business productivity | Section 4 |
| Productivity growth | New businesses established | Section 4 |
| , roudourny growth | Increased ICT skills and wider educational attainment | Section 7 (educational attainment) |
| Employment | Employment (safeguarded or new) | Section 4 |
| | More efficient delivery and increased access to public services | Section 7 |
| Public sector efficiency | 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 and unemployment), Section 6 (well-being and 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.

1.3 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 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 (a pipeline approach) to those benefitting later. This approach will provide robust estimates of the impacts of the programme if there are no systematic differences between areas benefitting at different stages that are correlated with the outcomes of interest. Further details of the rationale for this approach are set out in Section 3.

1.4 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 is monitored at the level of the overall contract). 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 superfast coverage, the estimates should be robust to issues of technological substitution (e.g. using mobile data services in place of fixed lines). They do not account for the possibility that subsidised coverage could have come forward in the absence of the programme (i.e. if network providers would have extended their

networks without public funding). This aspect of additionality also needs to be addressed to provide estimates of the net (rather than gross) benefits of the programme – and 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 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 the benefits of the programme at a national level are presented.

- 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.
- 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. While this could plausibly be explored using the small area data taken from the regular Office for National Statistics (ONS) Census of Population, these take place every ten years. The next Census is due to take place in 2021 and not available at the time of writing. For some outcomes explored, there are some questions as to how far the outcomes of interest are a direct or indirect consequence of superfast connectivity (e.g. expansions in GP patient registers could be explained by the possible effect of enhanced connectivity in opening new channels to the resident population or by its effects in making the area more attractive to new residents causing local populations to grow).
- COVID-19 pandemic: The data deployed in this analysis ran up to mid-2019 and therefore does not allow for an analysis of the impacts of the programme in relation to COVID-19. It is likely that the programme enabled benefits such as remote working, the delivery of public services (e.g. GP consultations) on-line and increased local resilience through supporting social distancing arrangements. These benefits will be considered in a future assessment of the programme, as part of the final round of evaluation.
- Future trading relationship with the EU: There are a number of uncertainties in relation to the UK's future trading relationship with the EU which could impact the long-term benefits of the programme. At this stage, any forecasting of these costs and benefits would be highly speculative and therefore has not been attempted as part of this analysis. Impacts of the programme in relation to EU exit will be explored in a future analysis of the programme.

1.5 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.
- 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 the programme.

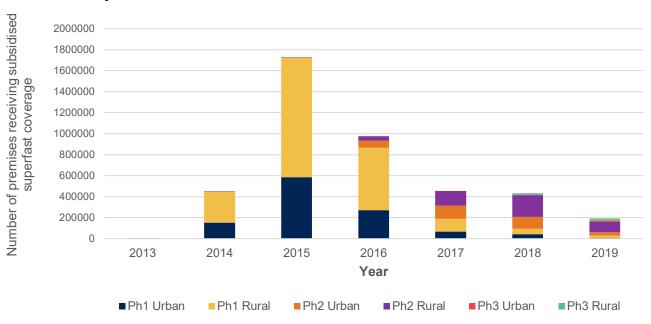
2 Analytical framework

This section provides an overarching analytical framework for the assessment of the economic and social benefits of the Superfast Broadband Programme. This section provides a theoretical outline explaining 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 2019, under Phase 1, 2 and 3 of the programme.

Figure 2.1: Number of premises receiving superfast (30Mbps⁷) coverage subsidised by BDUK, Phase 1, Phase 2, and Phase 3 SCTs are available, 2013 to September 2019⁸



Panel B: Delivery of all contracts

Source: C3 reports, Ipsos MORI 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

⁷ 24MBits for Phase 1 and Phase 2

⁸ Data allocated to Connected Nation years and not calendar or financial years (distinction provided above in data section)

to obtain faster connectivity through leased 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 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 FTTP technology in the latter phase 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 recent review⁹ of the impacts of ultrafast network deployment highlights several potential business applications of faster connectivity:
 - Access to new markets: On-line channels to market are becoming an increasing important source of revenues to businesses in the UK, rising to £688bn in 201810 from £375bn in 2009. A 2010 Government review highlighted that the use of ICT and broadband can enable small businesses to access to new markets¹¹. 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 markets¹².
 - 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. 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 making13. One example is the energy efficiency savings that are possible using smart meters to manage energy and heat consumption in industrial contexts. Again, as these applications are data intensive, higher capacity networks are needed to enable their implementation.

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

⁹ Ofcom (2018) The Benefits of Ultrafast Network Deployment

¹⁰ ONS (2018) E-commerce and ICT activity

¹¹ BSI (2010) Britain's Superfast Broadband Future

¹² Pllymouth Business School (2016) The Impact of Fibre Connectivity on SMEs: Benefits and Business Opportunities.

¹³ OECD (2016) Seizing the Benefits and Addressing the Challenges

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 as noted below, 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.

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 employment and GVA (product market displacement).
- Crowding out: Additionally, expansion of demand may also place upward pressure on local wages and prices, potentially encouraging other firms locally to reduce their output (crowding out)¹⁴. 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 via the spatial reallocation of economic activity. Several studies¹⁵ have illustrated that the availability of broadband makes economic activities 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 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, encouraging lower productivity firms to reduce their output or relocate

¹⁴ 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.

¹⁵ Broadband's contribution to economic growth in rural areas: Moving towards a causal relationship, Whitacre, B., Gallardo, R., and Stover S, Telecommunications Policy, 2014

to lower cost locations. Many of these effects could be expected to play out over the mediumterm.

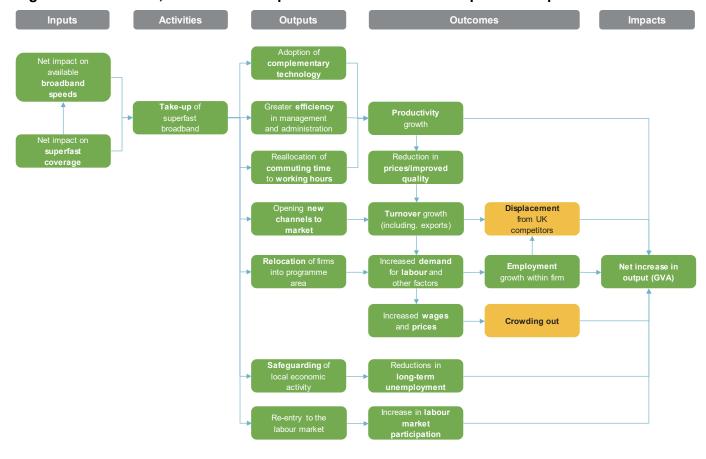


Figure 2.2: Business, local economic performance and worker impacts of superfast broadband

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. 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 organisational commitment on the days they worked entirely from home¹⁶. Similar findings were also obtained in a study of US federal Government workers¹⁷. As the COVID-19 pandemic has resulted in a substantial expansion in teleworking as workers have been asked to work from home where possible, past studies may not be a good guide to the future effects of the programme on worker productivity.
- 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

¹⁶ De Vries et al (2018) The Benefits of Teleworking in the Public Sector: Reality or Rhetoric?

¹⁷ Caillier (2012) The Impact of Teleworking in a US Federal Government Agency

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(through additional profits earned the supply of services¹⁸) 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, to the degree that the programme enables workers to become more productive – either by enabling more productive working practices or by stimulating investments in training – they may benefit from enhanced wages. These wage gains may reflect their increase in productivity¹⁹ and could differ across occupational groups (e.g. if the programme results in reduced demand for unskilled workers).

- Labour market participation impacts: The enablement 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 workers²⁰. Additionally, firms in some sectors appear less able to exploit the availability of broadband to raise productivity, particularly the manufacturing sector²¹²². The economic performance of rural areas has also been shown to be linked to the adoption rates of broadband²³, with areas less able to absorb the technology seeing declines in employment. 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 do they seek to meet these 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

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 Productivity and Broadband: The Human Factor, Mack, E., and Faggian, A. International Regional Science Review, 2013.

²¹ Broadband adoption and firm productivity: Evidence from Irish manufacturing firms, Haller, S.A., and Lyons, S. 2014.

²² The Employment and Wage Impact of Broadband Deployment in Canada, Ivus, O., and Boland, M, Canadian Journal of Economics 2013.

²³ Broadband's contribution to economic growth in rural areas: Moving towards a causal relationship, Whitacre, B., Gallardo, R., and Stover, S. 2014.

problems could produce local issues of long-term unemployment²⁴ 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.

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, such 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 has 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).
- 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

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

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 users²⁵.

- 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 London²⁶ revealed a perception that recent investments in infrastructure have exacerbated disparities in amenities and mainly benefitted those that were already affluent. 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).
- 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.

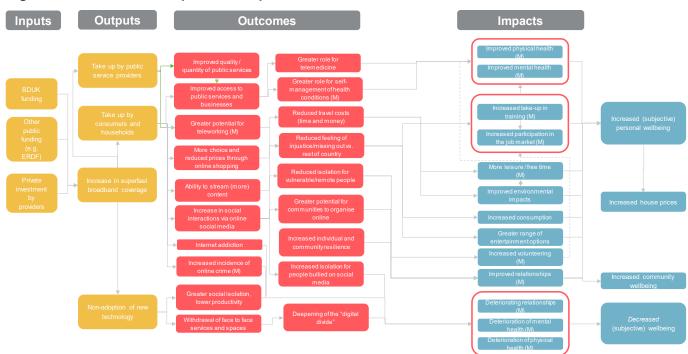


Figure 2.3: Household impacts of superfast broadband

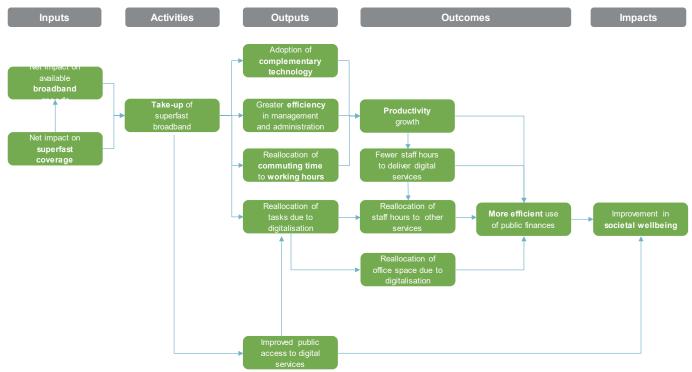
2.5 Impacts on public sector service delivery

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 how far

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).





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 Counterfactual

A credible assessment of the impact of the programme requires a counterfactual group of areas that did not benefit from the intervention (to identify what may have occurred in its absence). Ideally, this group of areas should be equivalent to those areas benefitting from the programme in all relevant respects except for their exposure to subsidised broadband coverage. As the programme was not delivered as a randomised experiment, the selection of these areas involves some challenges:

- 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 those areas receiving the investment would be expected to grow more rapidly anyway. This problem is perhaps less acute in the case of the Superfast Broadband Programme 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. However, several Local Bodies have used the tendering process to align the delivery of the programme with local economic development priorities and reverse causality problems are likely present in at least some areas benefitting from the programme.
- Selection bias: Potentially more problematic, suppliers chose which premises to upgrade based 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). As such, there will also be problems of selection bias 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, in principle, 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. This enables comparisons to be made between those areas that benefitted from the programme first to those that received the intervention later. In this set up, areas receiving subsidised coverage at later stages act as a comparison group for those that receive the intervention earlier. In this design, comparisons are restricted to areas that eventually received the intervention. As such, comparisons should be robust to problems caused by systematic differences between areas that do and do not benefit from subsidised broadband coverage.

The pipeline model was implemented using the following generic econometric model:

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

This model links the outcome of interest for area *i* in period $t(y_{it})$ to whether the area has benefitted from subsidised coverage in period $t(T_{it})$. The coefficient β captures the effect of subsidised coverage on the outcomes. Models also generally included a vector of time varying control variables describing other characteristics of the areas that may also influence the outcome of interest (X_{it}). Econometric models were also developed to allow for unobserved but time invariant characteristics of the areas of interest that could bias results (α^i) as well as unobserved but time specific shocks (α^t) affecting all areas²⁷.

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 responsible for delivering the project. 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. Evidence from Technical Appendix 1 suggests that in Phases 1 and 2, network providers tended to prioritise postcodes with higher demand density. However, in Phase 3, network providers appeared to prioritise lower density areas where competitors were less likely to have a presence nearby. If higher 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

²⁷ All models have been estimated with robust standard errors. Hausman tests were applied to determine the use of Fixed or Random Effects.

benefitting from the programme that have not been controlled for in the analysis. 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

In order 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. Significant differences in the key characteristics of these areas would weaken the pipeline approach and would support a hypothesis that the choice of areas to be delivered to over time was systematic and not random.

The postcodes first receiving subsidised coverage in each year between 2013 and 2018 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 subsection 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 upgraded in 2016 was, however, lower than the average across areas upgraded in other years.

Table 3.1: Comparison of the economic performance of areas receiving coverage in each year between 2013 and 2018

| | Year postcode was first upgraded | | | | |
|--|----------------------------------|---------|----------|---------|----------|
| | 2014 | 2015 | 2016 | 2017 | 2018 |
| Average total employment of OA | 218.3 | 207.3* | 201.8* | 218.7 | 209.0* |
| Average total turnover of OA (£,000) | 31679.7 | 33162.8 | 27389.7* | 33698.7 | 28984.6* |
| Average turnover per worker of OA (\pounds ,000/worker) | 90.1 | 91.0 | 89.0 | 88.6 | 87.4 |
| Share of local units in OA by size: | | | | | |
| Micro | 78.9% | 80.2% | 80.2% | 79.4% | 79.2% |
| Small | 7.9% | 7.8% | 7.5% | 7.7% | 7.4% |
| Medium | 2.7% | 2.5% | 2.5% | 2.6% | 2.6% |
| Large | 10.5% | 9.4% | 9.8% | 10.4% | 10.8% |
| Share of local units in OA by sector: | | | | | |
| C | 13.4% | 14.4% | 15.2% | 14.1% | 12.1% |
| DE | 0.6% | 0.6% | 0.6% | 0.6% | 0.6% |
| F | 13.2% | 13.1% | 13.4% | 12.4% | 13.4% |
| G | 15.4% | 14.0% | 13.8% | 14.1% | 13.6% |
| Н | 4.0% | 4.0% | 4.1% | 4.8% | 4.7% |
| 1 | 6.4% | 5.7% | 5.9% | 6.0% | 6.0% |
| J | 4.9% | 5.1% | 5.3% | 5.5% | 6.2% |
| К | 1.4% | 1.3% | 1.3% | 1.4% | 1.6% |
| LMN | 23.8% | 25.2% | 24.9% | 24.6% | 25.0% |
| 0 | 1.2% | 1.1% | 1.1% | 0.9% | 1.0% |
| Р | 3.1% | 3.1% | 2.9% | 3.1% | 2.9% |
| Q | 6.3% | 6.1% | 6.2% | 6.4% | 6.4% |
| RS | 6.3% | 6.3% | 6.2% | 6.0% | 6.5% |

Source: Business Structure Database; C3 Reports; Ipsos MORI analysis; * indicates value is statistically significant from the equivalent in the first available year

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 subsection 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 between2013 and 2018

| | Year postcode was first upgraded | | | | | |
|---------------------------------------|----------------------------------|---------|----------|---------|----------|----------|
| | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
| Gender | 1.48 | 1.48 | 1.49 | 1.49 | 1.49 | 1.53* |
| Proportion full-time | 0.65 | 0.69 | 0.71* | 0.71* | 0.71* | 0.72* |
| Hourly earnings | 1145.01 | 1208.21 | 1442.62* | 1298.88 | 1321.91* | 1413.16* |
| Total hours worked | 31.90 | 32.99* | 33.73* | 33.69* | 33.95* | 33.85* |
| Occupation: | | | | | | |
| Managers and senior officials | 7.6% | 7.8% | 7.9% | 7.5% | 7.7% | 7.4% |
| Professional | 10.4% | 11.5% | 13.8% | 13.8% | 13.8% | 17.4%* |
| Associate professional and technical | 10.6% | 11.8% | 12.3% | 11.3% | 11.7% | 11.6% |
| Administrative and secretarial | 12.6% | 13.9% | 13.9% | 14.6% | 13.1% | 14.5%* |
| Skilled trades | 8.7% | 8.4% | 7.7% | 7.8% | 7.9% | 6.6% |
| Personal service | 9.4% | 8.9% | 8.6% | 9.2% | 8.5% | 9.0% |
| Sales and customer service | 13.4% | 13.1% | 12.1%* | 12.3% | 12.1% | 12.2% |
| Process, plant and machine operatives | 8.3% | 8.0% | 8.0% | 8.1% | 8.2% | 7.1% |
| Elementary | 18.9% | 16.6% | 15.8% | 15.5% | 16.9% | 14.3%* |
| SIC 2007 (1-digit): | | | | | | |
| 1 | 4.3% | 4.7% | 5.0% | 4.3% | 4.9% | 3.7% |
| 2 | 5.9% | 7.2% | 7.6% | 7.7% | 8.2%* | 6.5% |
| 3 | 3.2% | 3.3% | 3.4% | 3.4% | 4.9% | 3.3% |
| 4 | 26.1% | 27.6% | 26.0% | 25.4% | 25.9% | 24.1%* |
| 5 | 12.8% | 9.7%* | 8.9%* | 9.3%* | 8.9%* | 7.2%* |
| 6 | 8.0% | 8.5% | 7.7% | 7.6% | 6.8% | 8.8% |
| 7 | 10.2% | 8.1% | 7.0% | 6.4% | 6.3% | 6.1% |
| 8 | 25.0% | 27.4% | 30.9%* | 32.5%* | 31.0%* | 37.3%* |
| 9 | 4.4% | 3.5% | 3.6% | 3.4% | 3.1% | 2.9% |

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

Comparisons of GP surgeries in postcodes upgraded at different times identified GPs upgraded in 2017 and 2018. In the year before the upgrade, those upgraded in 2017 were found to be very similar to those upgraded in 2018 with the exception of a slightly lower proportion using online services and more likely to be in rural areas.

| | Year before postcode was upgraded | | |
|---|-----------------------------------|-------------------------|--|
| | 2016 (Upgraded in 2017) | 2017 (Upgraded in 2018) | |
| Registered patients | 8310.01 | 8332.25 | |
| GPs FTE | 4.46 | 3.92 | |
| Nurse FTE | 2.45 | 2.45 | |
| Non-clinical FTE | 9.08 | 9.76 | |
| Proportion of patients booking appointments online | 7.9% | 10.2% | |
| Proportion of patients ordering repeat prescriptions online | 11.5% | 16.7%* | |
| Proportion of patients accessing medical records online | 1.4% | 2.7%* | |
| Proportion Rural | 35.1% | 24.2%* | |

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

In the case of schools, a similar trend is apparent in so far as schools upgraded later (e.g. in 2017) are fewer and therefore differ to those on postcodes upgraded earlier. The differences in other years across the variables below are smaller but do 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 2018

| | Year before postcode was upgraded | | | | | | |
|-------------------------------|-----------------------------------|---------|--------|--------|---------|--|--|
| | 2013 2014 2015 2016 | | | | | | |
| Number of pupils | 196.28 | 172.80* | 181.16 | 185.00 | 267.07* | | |
| Percentage of pupils with EAL | 3.26 | 2.97 | 5.36* | 5.10* | 7.16* | | |
| Percentage of pupils with FSM | 10.61 | 9.07* | 8.89* | 8.68* | 18.72* | | |
| Percentage of SEN pupils | 4.38 | 3.53* | 6.98* | 7.72* | 12.03* | | |

Source: DfE school database; C3 reports; Ipsos MORI 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 is an annual snapshot of the Interdepartmental Business Register (IDBR). The database contains longitudinal observations of employment and turnover at an enterprise and workplace²⁸ level and was accessed through the Office for National Statistics (ONS) Secure Research Service (SRS).

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 Survey²⁹ 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 horizons³⁰. Annual cross sections from 2012 to 2018 were used for the following analyses (at the time of writing, the 2019 BSD was not available).

The BSD incorporates 'live' local units. Between 2012 and 2018, a total of 5,354,635 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.

²⁹See:

https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/employmentandemployeetypes/methodologies/businessregisterandemploy mentsurveybres#bres-quality-and-methods

³⁰ 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 |

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 GDP deflator and expressed in 2019 prices³¹.

The most granular geographical identifier of individual local units was the Output Area³² (the postcodes of local units were withdrawn in 2019). 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 were calculated by dividing through the total turnover of firms located in the Output Area giving measures of turnover per worker were calculated by dividing through the total turnover of firms located in the Output Area with the total employment. The final panel dataset comprised 509,166 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 2018. 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. Of the 5,354,635 unique local units covered by the BSD, 4,605,693 (86 percent) were marked as spatially stable. 1,175,328 (22 percent) were both spatially stable (i.e. did not move location) and present in each cross section between 2012 and 2018 (new start-ups established or business closing since 2012 would not appear in this latter figure).

³¹ 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.

³² Output Areas for England, Wales, Scotland as well as Small Areas for Northern Ireland were present in the data.

- 30
- 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 5,354,635 unique local units covered by the BSD, 4,581,023 (86 percent) were marked as single site.

The use of data at the Output Area has some advantages over an analysis configured at the postcode level. As the observations cover all economic activity in an area, findings implicitly account for any displacement or crowding out effects at the local level. However, as it was not possible to identify whether specific firms had benefitted from subsidised coverage brought forward by the programme, a replication exercise was completed to explore the comparability of results generated in a prior study³³ using postcode level data. These analyses used data from the BSD between 2012 and 2016 but involved equivalent data processing steps. The table below provides a comparison between the estimated impacts on turnover, employment and turnover per worker based on postcode and Output Area data for the equivalent period³⁴.

The comparison between the results highlights some important aspects. The employment impact at the Output Area level is around 75 percent smaller than estimates using postcode level data. This is likely to be partly driven by dilution – i.e. not all postcodes within an Output Area will have benefitted from subsidised upgrades so effects at this level can be expected to be smaller. There may also be displacement effects at a very local level (e.g. firms relocating over very short distances to take advantage of enhanced connectivity). However, the estimated impacts on turnover were broadly similar at 1.2 percent. As such, the estimated impact on turnover per worker at the level of the Output Area rises from 0.3 percent to 0.9 percent. This indicates that subsidised upgrades could produce local productivity spillovers that may arise from increased economic density. The estimated impact on the number of firms does not differ substantially across models configured at the postcode and at the Output Area level, indicating that enhanced connectivity attracts firms to the area from outside the immediate locality.

| | Employment | Turnover | Turnover per worker | Number of firms |
|-------------------|------------|----------|------------------------|-----------------|
| Postcode level | 0.8%*** | 1.2%*** | 0.3%* | 0.3%*** |
| Output Area level | 0.3%*** | 1.2%*** | 0.9%*** | 0.4%*** |

Table 4.2: Replication results – estimated impact of the Superfast Broadband Programme using postcode and output area level results (2012 to 2016)

Source: Ipsos MORI analysis and DCMS (2018) 'Economic Impacts and Public Value Impacts of the Superfast Broadband Programme'

The figure below presents the average download speeds of connections for the group of Output Areas used in the analysis, in the year before and after the first premises was upgraded. This shows average speeds rising from around 17Mbps to 30Mbps from the year before to the year after the first premise in the Output Areas was upgraded. Note that this is likely to be heavily influenced by residential coverage.

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³³ Economic and Public Value of the Superfast Broadband Programme. (2018). DCMS. Available at:

https://www.gov.uk/government/publications/evaluation-of-the-economic-impact-and-public-value-of-the-superfast-broadband-programme ³⁴ These models were implemented using the econometric specification specified in section 4.3.1 (configured at a postcode and Output Area level respectively).

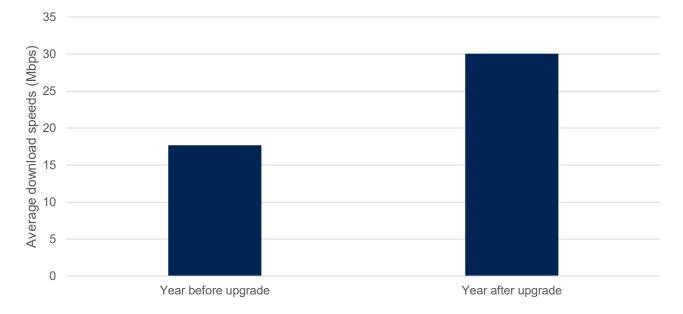


Figure 4.1: Average download speeds of connections in OA the year before and after first premise upgraded for OAs

Source: Ofcom Connected Nations; Ipsos MORI analysis

4.1.2 Valuation Office Agency

The Valuation Office Agency (VOA) periodically compiles and maintains local rating lists for each Billing Authority in England and Wales. These lists contain information on around two million commercial properties at any one time and detail the 'rateable value' of these properties. The rateable value denotes the estimated open rental market value of the property and is combined with local authority multipliers to work out the business rates payable by commercial entities.

Revaluation usually takes place every five years. The most recent revaluation in 2017 took place seven years after the prior one in 2010. Around 80 percent of rateable values are supported by a site and building survey at revaluation with the remaining 20 percent generated using more specialised surveys or based on construction costs or annual accounts. Data from both 2010 and 2017 revaluations were used for this study.

In total, there were 802,579 and 717,478 commercial properties listed on postcodes included in the build plans in areas in the 2010 and 2017 revaluations respectively, covering 40 percent of the total number included for revaluation each year. Data on the total rateable value and commercial floorspace of individual premises were aggregated to the postcode level. These aggregate measures were then calculated for 2010 and 2017. Postcodes were then linked to data on the timing of subsidised coverage derived from the C3 reports described below. A total of 1,384,539 (residential and commercial) premises were upgraded before the 2017 revaluation across 88,463 postcodes.

4.1.3 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 MORI. 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 4 2018/19 were used to support the analyses reported below,

providing details of some 6.1m³⁵ 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 450,059 postcodes in the UK (27.7 percent of the 1,625,197 postcodes in the UK³⁶). These were spread over 72,739 Output Areas.

4.2 Overview

Figures 4.1 and 4.2 provide an overview of trends in economic activity in the programme areas between 2012 and 2018 (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 Phases 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.

Data from the VOA suggested that the average rateable value per square metre was lower on postcodes in build plans of schemes funded than across England and Wales in 2010 (at £876 vs £1,124³⁷). This indicates that the willingness to pay to obtain floorspace in the programme area was lower amongst businesses, suggestive of lower productivity advantages attached to the location (although these simple averages do not account for differences in the mix of retail, warehousing, commercial and industrial floorspace). Postcodes in the build plans of funded schemes saw average rateable values per square metre rise from £876 to £1208 (38 percent) between 2010 and 2017, slightly more rapidly but not dissimilar to the rise observed for England and Wales overall at 32 percent (from £1,124 to £1,489)³⁸.

³⁵ This differs from the 5.2m quoted in Section 8 as it relates to a more extensive period, and includes upgrades claimed by the network provider for which they did not receive subsidies (e.g. if an upgrade to a cabinet led to superfast services being made available to premises that had been descoped).

³⁶ As covered in the 2018 Ofcom Connected Nations data

³⁷ In 2019 prices.

³⁸ Relative change in commercial rental values also were not statistically significant at the 95 percent level of confidence.

Figure 4.2: Average employment and turnover per output area, outputs areas benefitting from subsidised coverage (2019 prices)

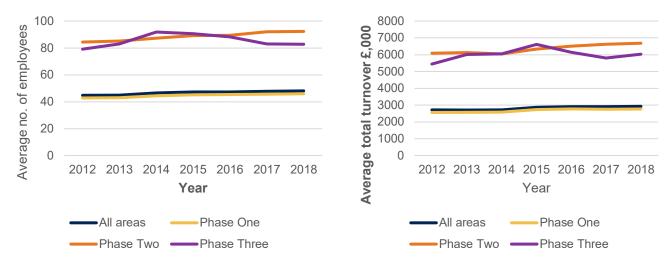
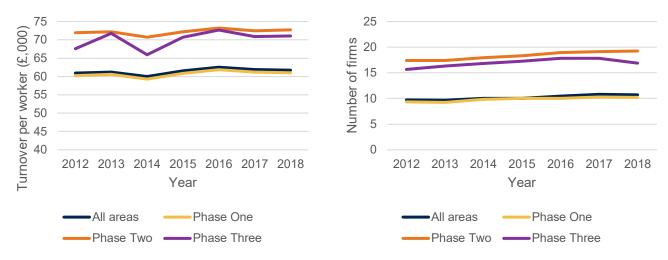


Figure 4.3: Average turnover per worker and average number of firms per output area, output areas benefitting from subsidised coverage (2019 prices)



Source: Ipsos MORI analysis of Business Structure Database (2012 to 2018)

4.3 Results

4.3.1 Business Structure Database

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

$$Y_{it} = \alpha_i + \beta T_{it} + \gamma_t + \delta X_{i,t=2012}t + \alpha_i + \varepsilon_{it}$$

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 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 72,739 Output Areas that received subsidised coverage at some point between 2012 and 2019 (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 2018.

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 (1.0 percent) was larger than the effect on employment (0.6 percent), implying that the productivity of local firms rose in response to subsidised coverage (0.4 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.

March 2018 (%)

No. of observations

level (%)

R-squared

Implied effect at the Output Area

Estimated effect at the Output

| worker, 2012 to 2018, all firms located in Outputs Areas receiving subsidised coverage | | | | | | | |
|--|-------------|-------------|------------------------|-----------------|--|--|--|
| Outcome | Employment | Turnover | Turnover per Worker | Number of firms | | | |
| Estimated effect per premises upgraded, areas upgraded by | 0.000067*** | 0.000120*** | 0.000053*** | 0.000061*** | | | |

0.555***

509,166

0.286

0 000***

0.992***

509,166

0.607

4 4 0 4 * * *

0.436***

509,166

0.620

0 000***

Table 4.3: Estimated impact of subsidised coverage on employment, turnover, and turnover per worker, 2012 to 2018, all firms located in Outputs Areas receiving subsidised coverage

| Area level (12-16, %) | 0.293**** | 1.121*** | 0.920*** | 0.430*** |
|---------------------------------|--|---------------------------|-----------------------------|-----------------------------|
| Source: Ipsos MORI analysis. | The outcome variables were express | ed in the form of natural | logarithms and the coeffici | ients can be interpreted as |
| the marginal percentage effect | t of subsidised coverage on the ou | tcome of interest. All mo | odels were estimated with | fixed effects, allowing for |
| unobserved trends at the nation | onal level, and at the sector and size | e-band (based on the O | utput Areas share of empl | oyment by sector). Effects |
| were aggregated to the level of | of OA by multiplying the estimated e | effect per premises by th | he average number of sub | sidised upgrades in areas |
| benefitting by March 2018 (82. | 7). | | | |

Comparisons between the impact of the programme over the period 2012 to 2016 (as set out in Table 4.2) and the period 2012 to 2018 highlights that its effects may evolve with time. Subsidised coverage appeared to have had a larger effect on employment and a smaller effect on the turnover of local firms in the longer-term. The estimated effect on local productivity (turnover per worker) was also smaller in the longer-term. This could be explained if firms take time to respond to an increase in turnover (i.e. they may be reluctant to recruit additional workers to satisfy additional demand if they lack confidence their growth is permanent). Additionally, as at least a share of these impacts was driven by incoming firms, there could also be lags if they begin recruitment for new or vacant posts following the relocation.

Persistence of impacts over time

The results above suggest that the impact of the programme has varied with time. The estimated effect of the programme on turnover per worker has apparently got smaller with time. This could be explained if the impact of subsidised coverage decays with time (i.e. the effect of enhanced infrastructure on competitiveness is temporary rather than permanent). There may also be diminishing marginal returns as the programme expands - firms located in areas benefitting from the programme at later stages may be less able to exploit enhanced connectivity. These issues were explored by examining the relative impact of subsidised coverage under Phases 1, 2 and 3 of the programme³⁹.

The results suggest some variability in the impacts of the programme by phase. The findings indicated that Phase 1 had a persistent impact on local economic performance – leading to increases in employment, turnover, and turnover per worker over six years. The magnitude of these estimated impacts aligns with the overall estimated effects of the programme (perhaps unsurprisingly as Phase 1 accounted for most of the subsidised coverage delivered by March 2018). Phase 2 appears to have increased the size of the local economy (leading to an expansion of both the turnover and employment of local firms), though this appears to be driven to a large degree by the relocation of the firms to the areas benefitting from the programme. Subsidised coverage brought forward under Phase 3 did not yet appear to have a significant impact on local economic activity.

0.504***

509,166

0.285

A 400***

³⁹ This was achieved by adapting the specification to allow for the cumulative number of premises upgraded in each phase of the programme as separate independent variables.

| Outcome | Employment | Turnover | Turnover per worker | Number of firms |
|-----------------------|-------------|-------------|------------------------|-----------------|
| Phase 1 (2012 – 2016) | 0.000050*** | 0.000114*** | 0.000064*** | 0.000046*** |
| Phase 2 (2015 – 2018) | 0.000237*** | 0.000179*** | -0.000059 | 0.000215*** |
| Phase 3 (2018) | -0.000661 | 0.001220 | 0.001880* | -0.000117 |
| Overall | 0.000067*** | 0.00012*** | 0.0000527*** | 0.0000609*** |
| No. of observations | 509,166 | 509,166 | 509,166 | 509,166 |

Table 4.4: Estimated impact of subsidised coverage on local employment, turnover and turnover per worker per premises upgraded, by Phase (2012 to 2018)

Source: Ipsos MORI 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). The periods covered by each Phase are provided in parentheses in the first column – note that these do account for delivery in 2019 and future years.

As highlighted below, there were no statistically significant differences in the profile of firms (by sector or size-band) benefitting from subsidised coverage in different years that would provide an obvious explanation for these differences. The findings above could be explained if firms take time to realise the benefits of enhanced connectivity. A large share of the premises upgraded under Phase 2 were delivered in 2017 and 2018 (see Figure 2.1). Very little in the way of delivery of Phase 3 contracts was complete by March 2018. This 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 2018. The results are summarised in the following figure (Figure 4.4).

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. 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.

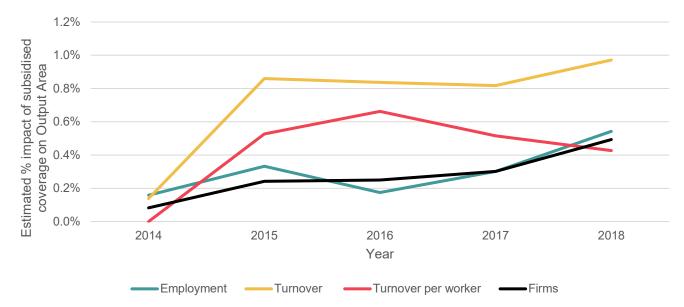


Figure 4.4: Impact of subsidised coverage delivered by March 2016 on employment, turnover, turnover per worker and number of local firms, by year (2014 to 2018)

Source: Ipsos MORI 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 2018.

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

- **Overall impacts:** Across all areas upgraded by March 2018, subsidised coverage increased the average employment of spatially stable firms by 0.45 percent and their turnover by 0.64 percent. There was no statistically significant effect on turnover per worker.
- Impacts on areas receiving subsidised coverage by end of March 2016: The programme did however, lead to productivity impacts on those areas that had benefitted from subsidised coverage by the end of March 2016. By the end of 2018, subsidised coverage increased the employment of spatially stable firms by 0.17 percent and their turnover by 0.88 percent. The impact on turnover per worker was estimated 0.71 percent.
- Persistence of impacts: Equivalent results to the end of March 2016 are provided in the final panel (4 rows) of the following table. Comparisons between the effects of the programme to 2016 and 2018 shows a similar pattern to that suggested above. It appears that subsidised coverage leads to an initial impact on turnover, which is followed by an expansion in employment. This erodes the initial productivity gain, and in this case the estimated rate of decay in the estimated effect on turnover per worker was 12.8 percent per annum.

The findings also suggest that the programme has had smaller (or different) economic impacts on areas receiving subsidised coverage in 2017 and 2018 (or that it was too early to detect these impacts in the data). This aligns with the findings above.

Table 4.5: Estimated impact of subsidised coverage on employment, turnover, and turnover per worker, 2012 to 2018, spatially stable firms located in Outputs Areas receiving subsidised coverage

| Outcome | Employment | Turnover | Turnover per Worker | | | | |
|--|---|------------------------------|---------------------|--|--|--|--|
| Area | Areas upgraded by March 2018 – analysis from 2012 to 2018 | | | | | | |
| Estimated effect per premises upgraded, areas upgraded by March 2018 (%) | 0.0000545*** | 0.0000769*** | 0.0000224 | | | | |
| Implied effect at the output area level (%) | 0.45 | 0.64 | - | | | | |
| No. of observations | 509,166 | 509,166 | 509,166 | | | | |
| R-squared | 0.165 | 0.354 | 0.356 | | | | |
| Area | as upgraded by March 2016 - | - analysis from 2012 to 2018 | | | | | |
| Estimated effect per premises upgraded, areas upgraded by March 2016 (%) | 0.0000207*** | 0.0001060*** | 0.0000851*** | | | | |
| Implied effect at the output area level (%) | 0.17 | 0.88 | 0.71 | | | | |
| No. of observations | 437,262 | 437,262 | 437,262 | | | | |
| R-squared | 0.166 | 0.355 | 0.355 | | | | |
| Area | as upgraded by March 2016 - | - analysis from 2012 to 2016 | | | | | |
| Estimated effect per premises upgraded, areas upgraded by March 2016 (%) | -0.0000095 | 0.0001040*** | 0.0001130*** | | | | |
| Implied effect at the output area level (%) | - | 0.85 | 0.93 | | | | |
| No. of observations | 312,330 | 312,330 | 312,330 | | | | |
| R-squared | 0.150 | 0.327 | 0.327 | | | | |

Source: Ipsos MORI analysis. The outcome variables were expressed in the form of natural logarithms and the coefficients can be interpreted as the marginal percentage effect of subsidised coverage on the outcome of interest. 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). 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.

Single site firms

As highlighted in subsection 4.1, 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 4.6: Estimated impact of subsidised coverage on employment, turnover, and turnover per worker, 2012 to 2018, single site firms located in Outputs Areas receiving subsidised coverage

| Outcome | Employment | Turnover | Turnover per Worker | | | |
|--|-------------|-------------|---------------------|--|--|--|
| Single site firms – estimated effects from 2012 to 2018 | | | | | | |
| Estimated effect per premises upgraded, areas upgraded by March 2018 | 0.000065*** | 0.000113*** | 0.000048*** | | | |
| No. of observations | 509,166 | 509,166 | 509,166 | | | |
| R-squared | 0.235 | 0.539 | 0.567 | | | |
| All firms – estimated effects from 2012 to 2018 | | | | | | |
| Estimated effect per premises upgraded, areas upgraded by March 2018 | 0.000067*** | 0.000120*** | 0.000053*** | | | |

Source: Ipsos MORI 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). The use of both technologies was limited, however, by March 2018 and it is arguably too early to judge the relative effectiveness of these competing solutions.
- Diminishing returns to speed: The findings suggested that there were diminishing returns to the predicted speed of the connection available. The effects of moving to speeds below 24Mbps⁴⁰ were estimated to be between 2.5 and 3 times larger than the impacts of superfast connectivity (on employment, turnover and turnover per worker). 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. The findings did not indicate that ultrafast connectivity (download speeds exceeding 80Mbps) had statistically significant impacts on employment, turnover or turnover per worker. However, this is connected to the findings relating to FTTP. As stated above, it is likely too early to explore the long-term economic impacts of making faster speeds available (and in the context of growing demand for bandwidth, the full impacts of the faster speeds will not be observed in the short-term).
- 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.

⁴⁰ Note that the analysis included premises upgraded where the predicted speeds were lower than superfast speeds.

| Outcome | Employment | Turnover | Turnover per worker | Number of firms |
|-------------------------------|---------------|------------------------|------------------------|-----------------|
| | Effects | by type of technology | | |
| FTTC | 0.000065*** | 0.000118*** | 0.000054*** | 0.000061*** |
| FTTP | 0.000144* | 0.000154 | 0.000010 | 0.000041 |
| Wireless | 0.000540** | 0.000680** | 0.000141 | 0.000429*** |
| | Effects by pr | edicted speed of conne | ection | |
| Basic (<24Mbps) | 0.000182*** | 0.000305*** | 0.000123*** | -0.000020 |
| Superfast (>24Mbit to 80Mbps) | 0.000054*** | 0.000100*** | 0.000047*** | 0.000070*** |
| Ultrafast (>80Mbps) | 0.000143* | 0.000152 | 0.00008 | 0.000041 |

Source: Ipsos MORI 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 separately⁴¹. 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. However, there were no statistically significant differences in terms of the estimated effect on turnover per worker and the number of firms located in the Output Area.

It should be noted that the economic density of rural Output Areas benefitting from the programme was higher than urban areas (i.e. at 48.4 jobs per rural Output Area in comparison to 39.4 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 more workers on average, leading to larger economic impacts in absolute terms than delivery in urban zones.

Table 4.8: Estimated impact of subsidised coverage on local employment, turnover and turnover per worker per premises upgraded, by urban and rural areas (2012 to 2018)

| Outcome | Employment | Turnover | Turnover per worker | Number of firms |
|---------|-------------|-------------|------------------------|-----------------|
| Urban | 0.000157*** | 0.000216*** | 0.000059** | 0.000121*** |
| Rural | 0.000076*** | 0.000159*** | 0.000084*** | 0.000117*** |

Source: Ipsos MORI 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).

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⁴¹ 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%20 of%2010%2C000%20or%20more) and _ in Northern Ireland. All other areas were classified as rural

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 to the average total employment and turnover of firms located in the Output Area in 2012. The results indicated that by 2018, the subsidised coverage led to the following estimated local impacts (these should not be interpreted as the net economic impacts at the national level):

- Jobs: The number of workers employed in Output Areas benefitting from the programme increased by 17,600 jobs due to the subsidised coverage (compared to 7,400 by 2016⁴²). This accounts for any offsetting and 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 £1.9bn (compared to £1.8bn by the end of 2016). Again, this is net of any offsetting and 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 £845m by the end of 2018⁴³. This compares to £1.4bn at the end of 2016.

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.

| Outcome | Average in 2012 (per Output Area) | Estimated % impact | No. of Output Areas receiving subsidised coverage by March 2018 | Estimated total impact (jobs/£m per annum) | Estimated impacts to March 2016 |
|-----------------------------|---|-----------------------|--|---|---------------------------------------|
| Employment | 44.8 | 0.55 | 71,071 | 17,634 | 7,459 |
| Turnover (£m per annum) | 2.7 | 0.99 | 71,071 | 1,916 | 1,868 |
| Turnover per worker (£000s) | 61.0 | 0.44 | 71,071 | 845 | 1,430 |

Table 4.9: Estimated local economic impacts of the Superfast Broadband Programme by 2018

Source: Ipsos MORI analysis

4.3.2 Commercial rental values (Valuation Office Agency)

The findings from the BSD analysis indicated that subsidised coverage increased the turnover per worker of firms located in the programme area. If the mix and/or relative price of inputs used by firms is unaffected by the programme, then this would imply it has led to an improvement in productivity. However, there are scenarios in which changes in turnover per worker would not reflect changes in underlying efficiency. For

⁴² 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.

⁴³ This is calculated as the turnover per worker in 2012 x % impact of subsidised coverage x number of workers employed in 2012.

example, if firms merely increase their level of outsourcing in response to the upgrade then there would be no gain in efficiency.

To probe this issue, the following analysis examines the effects on commercial rents as inferred from changes in rateable value between 2010 and 2017. Productivity effects can be inferred indirectly from changes in the rental value of commercial space, and land values. The amount businesses are willing to pay to move to new premises would be expected to be equal to the benefit they expect to gain from access to facilities offered by the property. If enhanced connectivity leads to higher commercial rents, this should provide an indirect measure of the increased profitability that can be obtained by firms by relocating to the property. In this respect, an increase in rateable value (the VOA's estimate of the rental value of the property) can be viewed as a measure of the productivity gain expected by a new tenant (in line with DCLG's appraisal guidance⁴⁴) – though this will likely factor in the timeline over which the productivity gain is expected to persist.

Econometric model

The data available enabled an assessment of the change in the average rateable value per metre squared between 2010 and 2017. The data available provided information for two years, so a simpler difference-in-difference model was used to assess the impact of the programme:

$$\Delta y_i = \alpha_i + \beta T_i + \delta X_i + \varepsilon_i$$

In this model, the change in rateable value per metre squared in postcode $i (\Delta y_i)$ is determined by whether the area has benefitted from subsidised coverage before the 2017 VOA revaluation (T_i), and the parameter β gives an estimate of the effect of interest. The treatment variable was defined as a dummy variable denoting whether one or more premises had been upgraded in the postcode by the time of the VOA revaluation in 2017. The model is specified in first differences and implicitly accounts for any unobserved (but time invariant) differences between postcodes (which are differenced out of the model).

The models also controlled for unobserved trends across a vector of network and socio-economic characteristics (X_i). Here, X_i represents the extent of NGA coverage in 2012 in the postcode, network characteristics in 2013 (such as line length) and local economic variables such as unemployment, population and premise density and wages. This would limit the degree to which estimates of the impact of the programme are biased by any correlations between trends in these characteristics and the likelihood the postcode benefitted from enhanced coverage in the 2010 to 2017 period.

The primary comparator group for these analyses were postcodes that were included in the build plans of local schemes but had not received subsidised coverage by the 2017 revaluation. This will limit the degree of any bias driven by unobserved differences between postcodes receiving subsidised coverage and those that do not.

Results

The results of the analysis suggested that subsidised coverage increased commercial rents by 1.8 percent once local characteristics are controlled for (though no effect was found in simpler models without these controls). This finding is of similar order of magnitude to the effect found on turnover per worker, increasing confidence that the effect can be interpreted as a productivity gain. The effect was also larger than the

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⁴⁴ The DCLG Appraisal Guide. (2016). DCLG. Available at:

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/576427/161129_Appraisal_Guidance.pdf

estimated effect on turnover per worker (raising questions as to how far the economic gains of the programme are being captured by landlords as a result of temporary supply constraints).

 Table 4.10: Estimated impact of subsidised coverage on commercial rents (between 2010 and 2017 revaluations)

| Outcome | Effect of subsidised coverage on ra | teable value per square metre (£, log) |
|------------------------------|-------------------------------------|--|
| Postcode level controls | No | Yes |
| All areas within build plans | 0.001 | 0.0182** |
| Number of observations | 111,195 | 105,612 |
| Adjusted r-squared | 0.000 | 0.0021 |

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

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 and other secondary data on unemployment 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 workers' wages, records of premises upgraded were linked to the details of the location of the employer of workers 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 workers 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 workers 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 approximate 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 workers 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 27,024 Output Areas benefitting from subsidised coverage between 2012 and 2018 were linked to at least one local unit containing a sampled employee between these years. A total of 89,031 workers were associated with firms located in subsidised areas providing a total of 435,217 annual observations of wages and pay.

5.1.2 Claimant Count

Experimental data on the claimant count was taken from NOMIS⁴⁵. 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 work⁴⁶. 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 2019 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 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. 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 beneficiaries 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 valid 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

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⁴⁵ See <u>https://www.nomisweb.co.uk/sources/cc</u>

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 nonresidential 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. However, it is also possible that the inclusion of residential delivery could dilute the precision of findings if it is more weakly correlated with reductions in unemployment. An approach to addressing this issue was through by 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 fixed effects model was implemented using the aggregated data from the ASHE (implementing the pipeline approach described in the Section 3):

$$Y_{it} = \alpha_i + \beta T_{it} + \gamma_t + \delta X_{i,t=2012}t + \alpha_i + \varepsilon_{it}$$

In this model, the outcomes of interest for individual worker *i* in period *t* (Y_{it}) is determined by whether the area had benefitted from subsidised coverage (T_{it}), and the parameter β gives an estimate of the effect of interest. The treatment variable was defined as *a* dummy variable (taking the value of 1 after the first premises and 0 otherwise - represented by T_{it}).

The models also controlled for general trends at the national level (*t*) and allow 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 fixed in 2012. The model also controls for any time invariant unobserved differences between output areas (αi). 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 2019.

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 workers 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 2018

(though it is important to note that the restrictions placed on this model reduced the sample size substantially to just over 6,020 observations).

| Outcome | Model 9 | Model 11 |
|---------------------------------------|--|-------------|
| 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 impa | ct following the first premises upgraded | d |
| Hourly wage (£, ln) | 0.00738*** | 0.00342 |
| Total hours worked (hrs, In) | 0.000725 | -0.00418* |
| Number of observations | 432,681 – 432,771 | 6,020 |
| Adjusted R-squared | 0.209-0.357 | 0.258-0.274 |
| | | |

Source: Ipsos MORI 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 0.8 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 workers at a 1.1 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 5.2: Impact of subsidised coverage on hourly earnings and total hours worked by occupation group (SOC10), 2013 to 2018

| Outcome | Hourly wage (£, In) | Total hours worked (hrs, In) |
|---------------------------------------|----------------------------|------------------------------|
| 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 |
| Eff | ects per premises upgraded | |
| Managers and senior officials | 9.88e-05 | -0.00430* |
| Professional | 0.00726*** | -0.00862*** |
| Associate professional and technical | -0.00109 | -0.00115 |
| Administrative and secretarial | 0.00414 | -0.000233 |
| Skilled trades | 0.00594* | -0.00604** |
| Personal service | 0.00400 | -0.00276 |
| Sales and customer service | 0.0116*** | -0.000389 |
| Process, plant and machine operatives | -0.00164 | -0.00651** |
| Elementary | 0.00816*** | 0.00333 |
| Number of observations | 34,154 – 63,465 | 35,155 – 63,477 |
| Adjusted R-squared | 0.128-0.238 | 0.127 – 0.309 |

Source: Ipsos MORI 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:

$$Y_{it} = \alpha + \beta T_{it} + \gamma X_i, 2013 + \delta_t + \varepsilon_{it}$$

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 pre-programme characteristics are controlled for to avoid possible issues with endogeneity that could cause estimates of impact to be biased.

Overall effects

The overall effects on the number of people claiming unemployment benefits are presented below:

Models 1 and 2 provide the pooled Ordinary Least Squares (OLS) results using all white areas as a comparison group respectively (with controls for the introduction of Universal Credit added in the second model). In these models we see an increase in the number of claimants equal to between 0.7 and 1.9 claimants per LSOA upgraded between 2013 and 2019.

- Model 3 and 4 expand upon models 1 and 2 by restricting the sample to only those areas that had received subsidised coverage by 2019. Here, there was a reduction of between 0.4 and 1.1 claimants per LSOA upgraded.
- Model 5 uses a 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 7. The most robust model (Model 7) implies a reduction of 0.6 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.

| Outcome | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 | Model 7 |
|----------------------------|-------------|---------------|----------------|-----------------|----------------|--------------|--------------|
| 2013 controls | Yes | Yes | Yes | Yes | No | No | No |
| UC control | No | Yes | No | Yes | Yes | Yes | Yes |
| Time FE | No | No | No | No | No | Yes | Yes |
| Area level trends | No | No | No | No | No | No | Yes |
| Areas included | All white | All white | Treated only | Treated only | Treated only | Treated only | Treated only |
| Model specification | OLS | OLS | OLS | OLS | FE | FE | FE |
| | Dummy treat | ment variable | (equal to 0 be | fore year of up | ograde and 1 a | ifter) | |
| Claimant count (number) | 0.776*** | 1.948*** | -1.118*** | -0.410*** | -6.653*** | -0.723*** | -0.648*** |
| Number of observations | 255,654 | 255,654 | 143,598 | 143,598 | 152,481 | 152,481 | 152,481 |
| Adjusted R-squared | 0.328 | 0.545 | 0.338 | 0.550 | 0.150 | 0.377 | 0.434 |

Table 5.3: Impact of subsidised coverage on the claimant count, 2013 to 2019

Source: Ipsos MORI 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 8) 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 8 below indicated that for every 10,000 premises upgraded, the number of unemployed claimants fell by 32 over subsequent years⁴⁷. 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 0.28 fewer claimants. This

⁴⁷ Applying a very rough approximation of the amount of benefit payments avoided results in around £126m saved for the public sector in fewer benefit payments. This assumes an average claimant amount equal to JSA of £74.35 per week and applies the additional number of premises passed by year as illustrated in table 9.3. Note that benefits payments are considered transfers and are excluded from the CBA analysis.

| Table 5.4: Impact of subsidised coverage on the claimant count, dose-response models, 2013 t | to |
|--|----|
| 2019 | |

| Outcome | Model 8 | Model 9 |
|-------------------------|--|-----------------------------|
| 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 |
| | | |
| Claimant count (number) | -0.2785*** | -0.00321*** |
| Number of observations | 151,858 | 152,481 |
| Adjusted R-squared | 0.437 | 0.434 |

Source: Ipsos MORI 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 9 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 31 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 301 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 5.5: Impact of subsidised coverage on the claimant count, residential vs non-residential effects, 2013 to 2019

| Outcome | Mod | el 10 | | | | | |
|-------------------------|-------------------------|-----------------------------|--|--|--|--|--|
| Areas controls (2013) | Y | Yes | | | | | |
| Areas included | Treate | Treated only | | | | | |
| Unobserved area effects | Y | Yes | | | | | |
| Unobserved area trends | Y | Yes | | | | | |
| Model specification | F | FE | | | | | |
| Treatment variable | Number of prer | nises upgraded | | | | | |
| | Residential coefficient | Non-residential coefficient | | | | | |
| Claimant count (number) | -0.00309*** | -0.00309*** -0.0305*** | | | | | |
| Number of observations | 61, | 61,542 | | | | | |
| Adjusted R-squared | 0.4 | 18 | | | | | |

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

6 Impacts on households

This section provides estimates of the effects of the Superfast Broadband Programme in creating value for consumers. The analysis focuses on two overall metrics of utility or welfare - a hedonic pricing analysis exploring the degree to which the value created by the programme is reflected in house prices, and an assessment of the impact of the programme on subjective well-being. It should be noted that these analyses focus on overall measures of well-being rather than factors driving the effects on the programme.

6.1 Key issues

Understanding the impacts of the programme for households (over and above the economic impacts 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 impacts of making superfast broadband infrastructure available (i.e. the well-being indicator should measure the consumers' surplus⁴⁸).
- 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 impacts 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 result in both positive impacts (reduced congestion) and costs (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 superfast

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⁴⁸ This can be understood in as difference between what consumers would have been willing to pay for superfast broadband services and what they actually paid.

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 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 in the preceding section. As such, alternative approaches are needed to estimate the value of benefits to the consumer. Two strategies are adopted in the following sections. Firstly, a revealed preference approach is adopted 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 second approach based on stated preferences is adopted, 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 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 therefore represent the present value of the future net benefit they expect to gain from access to faster internet services.

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.
- 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 1,186,131 homes sold on postcodes that benefitted from subsidised coverage at some point between 2013 and 2019, and a further 213,963 homes sold on postcodes defined in the build plans for contracts awarded through the programme but which have not been upgraded yet. Around 586,510 (49 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 2019 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.

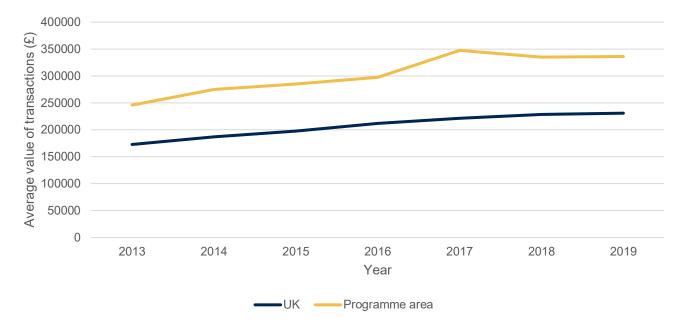


Figure 6.1: Evolution of house prices in the UK and programme areas, 2013 to 2019

Source: Land Registry HPI, SCTs, Ipsos MORI analysis

On average, the prices of houses sold in the programme area were 46 percent higher than those sold nationally (£303,251 versus £207,146). 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 2019, detached house sales in build areas were sold for an average of £356,980 compared to £379,959 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 2019 (percentage of transactions)

| Type of home | Programme area | England and Wales overall ⁴⁹ |
|---------------|----------------|---|
| Detached | 36% | 23% |
| Semi-detached | 23% | 25% |
| Terraced | 24% | 26% |
| Flat | 11% | 19% |

Source: Land Registry, SCTs, Ipsos MORI analysis

The dataset was enriched with a further set of controls derived from the DfT Journey Time Statistics (previously Accessibility Statistics) between 2012 and 2017⁵⁰. 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

⁴⁹ Taken from the March 2020 Price Paid Data update. See: <u>https://www.gov.uk/government/news/march-2020-price-paid-data</u>

⁵⁰ The publication of 2018 journey time statistics (due in August 2020) was cancelled due to the COVID-19 pandemic.

services, town centres, and transport hubs. In the absence of estimates for 2018 and 2019, journey times were assumed to be constant from 2017 onwards.

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 different types (i.e. detached, semidetached, 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 table. Basic fixed effects models pointed to implausibly strong effects on the average prices of houses sold of 14.8 percentage points. However, controlling for national trends in house prices reduced this estimate to 1.2 percentage points. Additionally, allowing for time-specific shocks and local characteristics likely to influence house prices reduced this further to 0.6 to 0.7 percentage points. Applying these to the average price of houses sold in the programme area between 2012 and 2019 (£304,986 in 2019 prices), gives a range for the average impact on house prices of £1,700 to £3,500.

This indicates that buyers were willing to pay a premium to obtain homes that had been upgraded. These estimates also compare to results from 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)⁵¹. 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:

⁵¹ Gabriel Ahlfeldt (2014) Speed 2.0 Evaluating Access to Universal Digital Highways

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- 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. As such, it
 may not be possible to assume that the apparent price premium reflects improvements the welfare
 of all residents of the area concerned (who may place a lower value of superfast broadband).
- Expectations: There are also questions as to how consumers form expectations regarding the likely future availability of superfast broadband and build this into their willingness to pay for houses. In principle, 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 associated with having access to superfast broadband services more rapidly. However, it is also possible that households are short-sighted or have imperfect information in which case the price premium would represent the value attached to gaining access to superfast broadband coverage forever. Such an interpretation would increase the plausibility observed of the result, though this perhaps does not seem realistic given broader Government commitments to extend broadband coverage on a universal basis in the near to medium-term.
- Broadband vs other factors: As illustrated in Section 4, superfast broadband coverage appears to have induced firms to relocate to areas benefitting from the programme. As such, the change in house prices may not just reflect the value of the technology to users, but may also be driven up by the need for employees to relocate to avoid episodes of unemployment or lengthy commutes. These advantages will be permanent and provide a reasonable explanation for the apparent effect on willingness to pay. However, these other features of the property will be of relatively little importance for those that are not employed by the relocating firms. This substantially limits how far such a measure can be extrapolated across the broader population benefitting from subsidised coverage.
- Functioning of housing markets: As a final point, the operation of the housing market may not
 operate perfectly as it relies in part on the role of agents in the transaction process. Agents may seek
 to exploit broadband availability as a marketing feature to drive up prices (in which case, the price
 premium may not reflect improvements in underlying welfare).
- Migration: Finally, to the degree that changes in house prices are driven by migration (rather than by the broadband coverage itself), there may be corresponding falls in house prices in other areas (so these values may not represent net effects).

Table 6.2: Impact of subsidised coverage house prices, 2013 to 2019

| 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 | OLS | OLS | OLS | OLS |
| Effects per prem | ises upgraded (po | stcode level resul | ts) | |
| Average price of houses sold (£, log) | 0.148*** | 0.0116*** | 0.0056*** | 0.0065*** |
| Number of observations | 836,606 | 836,606 | 836,606 | 836,606 |
| Adjusted R-squared ⁵² | 0.06 (0.828) | 0.09 (0.832) | 0.09 (0.879) | 0.07 (0.879) |
| Effects applying from sche | eme announcemen | t date (postcode l | evel results) | |
| Average price of houses sold (£, log) | 0.164*** | 0.0224*** | 0.0160*** | 0.0074*** |
| Number of observations | 836,606 | 836,606 | 836,606 | 836,606 |
| Adjusted R-squared | 0.05 (0.82) | 0.09 (0.83) | 0.09 (0.83) | 0.06 (0.88) |

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

6.3 Subjective well-being

The second strand of this analysis (led by Simetrica-Jacobs) examined the effect of subsidised coverage on the subjective well-being of residents of properties that benefited from the programme. This updated research completed as part of a prior evaluation of the programme⁵³, which combined BDUK and Ofcom Connected Nations data on programme rollout and connection speeds with two nationally representative UK household surveys that include individuals' assessments of their subjective well-being.

6.3.1 Data

The primary outcome measure for this analysis was the ONS Life Satisfaction measure that has been widely adopted as a metric of social well-being. The ONS Life Satisfaction questionnaire requires individuals to self-report their overall life satisfaction on a scale of 1 to 10. This has several advantages over house prices in that they provide a measure of well-being for all residents of an area (rather than the sub-group of individuals that moved to the area). Measures of life satisfaction were obtained from the Annual Population Survey (APS) between 2011 and 2019. This is a cross-sectional survey of the population of Great Britain used by ONS to develop key labour market statistics (e.g. measures of unemployment).

The APS data provided the postcode of individual respondents which were linked to records of premises upgraded. This gave a total sample of 477,469 observations of the subjective well-being from residents living on postcodes that received subsidised coverage (246,416 after the upgrade and 231,053 after the upgrade). On average, reported life satisfaction was 7.6 before the upgrade and 7.8 after the upgrade. It should be noted that the data was not longitudinal in nature – the data did not track the same individuals over time. As such, the evidence will conflate well-being outcomes associated with the consumption of the technology by existing residents with changes in well-being driven by changes in the composition of the

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⁵² 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.

⁵³ <u>https://www.gov.uk/government/publications/evaluation-of-the-economic-impact-and-public-value-of-the-superfast-broadband-programme</u>

resident population. However, as the APS is sampled using random probability methods, results should not be biased by systematic differences in those responding to the survey before and after the upgrade.

A second set of analysis was completed using the Understanding Society dataset⁵⁴ spanning the years 2009 to 2019. It tracks households and individuals over time, and provided 182,172 longitudinal observations (129,035 before the upgrade and 53,137 after the upgrade). Geographical identification of households is less precise, with only the Lower Layer Super Output Area (LSOA) available. Life satisfaction is measured on a 1-7 scale in Understanding Society as opposed to a 0-10 scale in the APS. This variable was transformed linearly to map them to the 0-10 APS scale, for ease of comparison.

6.3.2 Econometric model

The following econometric model was adopted to investigate the impacts of subsidised coverage on subjective well-being:

$$y_t = \alpha + \beta T_t + \delta X_t + \rho t + \varepsilon_{it}$$

This model linked the self-reported well-being of individuals in period $t(y_{it})$ 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}). A vector of individual controls (X_t) was included to control for a set of individual characteristics known to influence well-being. These controls included factors such as age, gender, marital status, ethnicity, level of education, home ownership, number of children, urbanisation, smoking behaviour, and region. Critically, the models also controlled for incomes, employment status and receipt of benefits to ensure that the results focused on impacts on well-being over and above those driven by the employment effects of the programme (as the preceding chapter illustrated, workers benefitted from the programme through higher wages and shorter working hours for some groups).

The modelling adopted the same pipeline approach as adopted elsewhere in this report. In this model, residents that are yet to benefit from subsidised coverage act as the comparison group. As longitudinal data at the level of individuals was not available, it was not possible to control for unobserved individual characteristics that do not change with time. However, the models did control for unobserved time trends affecting all individuals in the sample.

Further analysis was completed by exploring the relationship between well-being and other measures of secondary interest (which explore the effect of other connectivity measures on well-being, but do not provide a direct measure of the impact of the subsidised coverage brought forward through the programme):

- Median download speed median download speed in Mbps of all premises in the respondent's full
 postcode area in the year of the respondent's interview.
- Next Generation Access (NGA) a variable equal to 1 if there was at least one premise in the respondent's full postcode area that attained the speed of a NGA connection (>24 Mbps download speed) in the year of the interview, and 0 otherwise.

6.3.3 Overall results

The overall findings of the analysis were broadly in line with results obtained in prior research at a population level. The findings using the Annual Population Survey indicated that subsidised coverage did

⁵⁴ The Understanding Society data is provided by the UK Data Service under Special Licence access under dataset usage number 116026.

not lead to an overall improvement in subjective well-being at the level of the overall population (and suggested more broadly, that NGA coverage led to reductions in well-being). The results using an equivalent methodology applied to the Understanding Society dataset, however, suggested that there was a positive effect on subjective well-being at the level of the overall population (with subsidised coverage increasing self-reported well-being by 0.066 against the 10-point Life Satisfaction scale).

The results from the APS in particular do not align with the findings on the effects of the programme on house prices (which suggested that at least those buying properties in the programme placed a premium on the value of the coverage brought forward). There are a range of possible factors that might explain this:

- Population sorting: As highlighted above, almost 0.6m residential properties in the programme area were sold after the subsidised coverage was brought forward. This equates to almost 14 percent of the total number of residential premises upgraded by 2019 (estimated at 4.3m). This implies there has been a degree of churn in the resident population, and the findings on well-being may be driven by changes in the composition of residents induced by the programme that may offset any positive well-being effects associated with consumption of superfast broadband. For example, residents of urban areas tend to rate their well-being less highly than rural populations and if there is migration from urban to rural areas, this could reduce the well-being of the overall resident population if these tendencies do not change rapidly following migration.
- Effects of population growth: As the following chapter shows, population growth in the programme area appears to have placed pressure on public services, reducing overall satisfaction (at least in relation to primary care services). This type of pressure may have adversely affected the well-being of existing residents. As flagged elsewhere, changes in population may also have adverse consequences for social and community cohesion.
- COVID-19: The findings predate the COVID-19 pandemic and it is likely that the effects of the programme on well-being will differ substantially from those presented below, given the role connectivity has played in supporting resilience to the social distancing measures introduced to contain the outbreak.

Table 6.3: Estimated impact of subsidised coverage and other measures of connectivity on subjective well-being, 2012 to 2019

| | Results fro | om the APS | Results using Und | erstanding Society |
|----------------------|-----------------|-----------------|-------------------|--------------------|
| Measure of treatment | Effects to 2016 | Effects to 2019 | Effects to 2016 | Effects to 2019 |
| Upgraded | -0.005 | -0.008 | 0.111*** | 0.066*** |
| Median speed | -0.0013** | -0.00017 | 0.0032* | 0.0019** |
| NGA | -0.02* | -0.02** | 0.031 | 0.047* |

Source: Simetrica-Jacobs analysis. '**', '**', and '*' indicate whether the estimated coefficient was significant at the 99, 95 and 90 percent level of confidence. excluding Northern Ireland as this does not have postcodes available within the APS; Standard well-being controls used; OLS regression conducted with heteroscedasticity-robust standard errors as is best practice in subjective well-being analysis; a *** indicates statistical significance at the 1% level, a ** indicates significance at the 5% level, a * indicates significance at the 10% level; Life satisfaction on a 0-10 scale. Data source: ONS.

6.3.4 Well-being impacts by age group

Table 6.4 provides disaggregated results across the GB-wide sample exploring differential impacts by age group (35 and below, 36-64 and 65+)⁵⁵. Again, the findings broadly confirm the findings of prior research that shows that there are differential effects by age group. Both sets of findings suggest that the oldest (those aged 65 and over) age groups experience improvements in well-being because of subsidised coverage. However, evidence of the impact of subsidised coverage on other groups is more mixed – the results using the APS suggest that there are negative effects on well-being amongst those aged 36 to 64 and positive effects amongst those aged 18 to 35, while the findings using Understanding Society indicated there were no effects on the well-being of those of working age.

These findings could support the hypothesis that the results are linked to population changes rather than negative effects arising directly from consumption of broadband. Migration statistics suggest that net internal migration from urban to rural areas has been positive in recent years, with net flows largest amongst those aged 30 to 64. If the Superfast Broadband Programme has accelerated this process, then this would likely reduce reported well-being. However, there are other possible explanations (such as the possible role of superfast connectivity in reducing the quality of interpersonal relationships within the family).

Table 6.4: Estimated impact of subsidised coverage and other measures of connectivity on subjective well-being by age group, 2012 to 2019

| Measure of treatment | Aged 18 to 35 | | Aged 3 | 6 to 64 | Aged 65+ | |
|----------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| | Effects to 2019 | Effects to 2016 | Effects to 2019 | Effects to 2016 | Effects to 2019 | Effects to 2016 |
| | | | | | | |
| Upgraded | 0.05*** | 0.08*** | -0.05*** | -0.03** | 0.04** | 0.001 |
| Median speed | 0.002*** | 0.003** | -0.002*** | -0.006*** | 0.002*** | 0.002*** |
| NGA | 0.05*** | 0.05** | -0.07*** | -0.06*** | 0.02* | -0.004 |
| | | | | | | |
| Upgraded | 0.095* | 0.017 | 0.109** | 0.044 | 0.133** | 0.158*** |
| Median speed | 0.0072*** | 0.0025* | 0.0020 | 0.00097 | 0.0017 | 0.003** |
| NGA | 0.075* | 0.056 | 0.003 | 0.005 | 0.044 | 0.116*** |

Source: Simetrica-Jacobs analysis. '***', '**', and '*' indicate whether the estimated coefficient was significant at the 99, 95 and 90 percent level of confidence. excluding Northern Ireland as this does not have postcodes available within the APS; Standard well-being controls used; OLS regression conducted with heteroscedasticity-robust standard errors as is best practice in subjective well-being analysis; a *** indicates statistical significance at the 1% level, a ** indicates significance at the 5% level, a * indicates significance at the 10% level; Life satisfaction on a 0-10 scale. Data source: ONS.

⁵⁵ These splits enable the distribution of a suitable proportion of observations across young (35 and below), middle-aged (36-64) and older (65+) age groups.

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, and the findings set out in this section should be considered preliminary (i.e. identifying issues for further exploration through primary research).

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.

Data available at the time of writing suggested use of video consultations was low⁵⁶. The GP Patient Survey (GPPS) has included a question on video consultations since 2018. Less than one percent of appointments in that year were via video call. No increase was visible in the 2019 data with video consultations still accounting for less than one percent of all appointments offered to respondents on the last appointment. The available data is, however, dated in that it predates the COVID-19 pandemic and use of remote consultations has expanded substantially since March 2020⁵⁷.

Commitments have though 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 350Kbps per consultation⁵⁸, 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 2019⁵⁹, and has proven an inhibiting factor in pilot programmes rolling out video consultations⁶⁰. 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.

⁵⁶ Prior to information regarding usage throughout the covid-19 pandemic.

⁵⁷ See for example <u>https://www.health.org.uk/news-and-comment/charts-and-infographics/how-might-covid-19-have-affected-peoples-ability-to-see-GP</u>

⁵⁸ iplato (2020) Video consultation technical requirements.

⁵⁹ DHSC (2019), NHS hospitals and GP practices to get fibre optic internet, Press release.

⁶⁰ Donaghy et al (2019) Acceptability, benefits, and challenges of video consulting. British Journal of General Practice

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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 study⁶¹ 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)⁶². There is also evidence that greater convenience can induce greater demand. For example, an evaluation of the Babylon GP at Hand service⁶³ 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. A recent review of the potential impacts of online consultation services also highlighted evidence that GPs 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)⁶⁴.

Research has also suggested that users have positive experiences of online video consultations compared to telephone consultations⁶⁵ 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). 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 Digital⁶⁶. The data available included details of the number of 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 2,907 GP surgeries that had benefitted from subsidised broadband coverage between 2013 and 2019. 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 14.7Mbps to 43.2Mbps and from 1.2Mbps to 8.6Mbps respectively.

Additional longitudinal data on patients' experience of GP services was obtained by data-linking. Unique reference numbers contained within the GP practice data was matched to GP Patient Survey (GPPS) data⁶⁷. 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. The focus was on the period 2016 to 2019 to ensure that the variables used in the analysis were consistent over the period of analysis.

⁶¹ 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.

⁶² The face-to-face appointment costs stated are assumed to exclude any travel costs incurred by patients which, if included, could increase this figure.

⁶³ Ipsos MORI (2019) Evaluation of Babylon GP at Hand

⁶⁴ Marshall et al (2018) Online consultation in general practice, submission to BMJ Analysis (draft).

⁶⁵ Donaghy et al (2019) Acceptability, benefits, and challenges of video consulting. British Journal of General Practice

⁶⁶ https://digital.nhs.uk/data-and-information/data-tools-and-services/data-services/general-practice-data-hub

⁶⁷ https://www.gp-patient.co.uk/

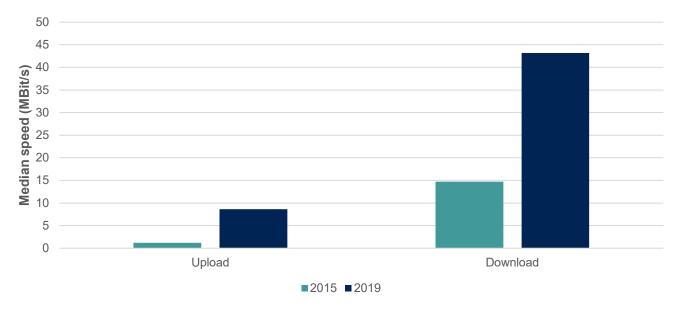
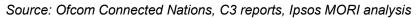


Figure 7.1: Increase in median upload and download speeds for postcodes with GP practices⁶⁸



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.

| Outcome | Metric (2016-2019) | 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 ⁶⁹ |
| 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 |

Table 7.1: Outcomes for General Practice

Source: NHS Digital, GP Patient Survey

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⁶⁸ Note that 2015 is the first year for which median upload and download speeds were presented in Connected Nations data.

⁶⁹ File name epraccur.csv - available from: <u>https://digital.nhs.uk/services/organisation-data-service/data-downloads/gp-and-gp-practice-related-data</u>

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 j 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^i) 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 7, 5 and 6 percentage points respectively in response to the provision of subsidised coverage.
- Usage: Usage of these services increased between 2 and 4 percent. Implied take-up of opportunities
 to order repeat prescriptions was highest (at around 66 percent of those newly aware of the
 availability of these services).

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 su | ubsidised | coverage | on | awareness | and | usage | of | on-line | primary | care |
|-------------------|--------|------------|-------------|-------|-----------|-----|-------|----|---------|---------|------|
| services, 2016 to | 2019 (| % of regis | tered patie | ents) |) | | _ | | | - | |

| C | Dutcome | Model 1 | Model 2 | Model 3 |
|----------------------------------|---------------------------|------------------------------|------------------------------|-----------|
| Fixed effects | | Yes | Yes | Yes |
| Time specific shocks | | No | Yes | No |
| Model specification | | OLS | OLS | Tobit |
| Booking appointments | Awareness (% of patients) | 0.0718*** | 0.0730*** | 0.0718*** |
| online | Usage (% of patients) | 0.0380*** | 0.0398*** | 0.0380*** |
| Order repeat | Awareness (% of patients) | 0.0567*** | 0.0537*** | 0.0540*** |
| prescriptions on-line | Usage (% of patients) | 0.0347*** | 0.0356*** | 0.0347*** |
| Access medical records | Awareness (% of patients) | 0.0602*** | 0.0602*** | 0.0567*** |
| on-line | Usage (% of patients) | 0.0175*** | 0.0195*** | 0.0175*** |
| Number of GPs | | 1,406 | 1,406 | 1,406 |
| Number of observations | | 5,603 | 5,603 | 5,603 |
| Adjusted R-squared ⁷⁰ | | 0.02 - 0.03 (0.52 - 0.80) | 0.02 - 0.03 (0.66 - 0.86) | N/A |

Source: Ipsos MORI 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.

7.1.5 Patient satisfaction

There are four measures of patient experience that have been consistently tracked by the GP Patient Survey⁷¹ 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 share that were regularly able to see their preferred GP, and their overall satisfaction⁷². 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 to two percentage points.

⁷⁰ 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.

⁷¹ <u>https://www.gp-patient.co.uk/surveysandreports</u>

⁷² 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 three to four percentage points) and the share of
 patients able to see their preferred GP most or all of the time (by eight 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 2019 (% of registered patients)

| Outcome | Model 4 | Model 5 | Model 6 |
|--|------------------------------|-----------------------------|---------------|
| Fixed effects | Yes | Yes | Yes |
| Time specific shocks | No | Yes | No |
| Model specification | OLS | OLS | Tobit |
| % of patients satisfied with amount of time for their last appointment | 0.0107*** | 0.0107*** | 0.0159*** |
| % of patients able to see their preferred GP most or all of the time (%) | -0.0901*** | -0.0790*** | -0.0790*** |
| % of patients satisfied with the availability of appointments | -0.0417*** | -0.0417*** | -0.0333*** |
| % of patients satisfied describing their experience as fairly or very good | -0.0199*** | -0.0199*** | -0.0141*** |
| Number of GPs | 1,406 | 1,406 | 1,406 |
| Number of observations | 5,599 – 5,827 | 5,599 – 5,827 | 5,599 – 8,237 |
| Adjusted R-squared ⁷³ | 0.01 – 0.03 (0.70 – 0.84) | 0.01 – 0.03 (0.72- 0.86) | N/A |

Source: Ipsos MORI 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.

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 2019). 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 3.2 to 5.9 percent on average.
- **Staffing:** However, the number of staff employed by GP surgeries did not rise to the same degree. While subsidised coverage led to an increase in the number of nursing and non-clinical staff of 5.3 to 5.4 and 5.4 to 7.4 percent respectively, there was no effect on the number of GPs.

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. This is

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.

consistent with the findings above on access to GP appointments and continuity of care. These types of issue have also highlighted as explanatory factors for the general declines in public satisfaction with primary care services observed since 2009⁷⁴, though it should be noted that access and continuity of care were not highlighted as major drivers of patient satisfaction in past studies⁷⁵.

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.

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

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.

| Outcome | Model 6 | Model 7 | Model 8 (effects on other GP surgeries within 20km) |
|---|------------------------------|------------------------------|---|
| Fixed effects | Yes | Yes | Yes |
| Time specific shocks | No | Yes | Yes |
| Model specification | OLS | OLS | OLS |
| Number of patients registered with the GP (log) | 0.0593*** | 0.0323*** | 0.0700*** |
| Number of GPs (FTEs, log) | 0.0101 | 0.0091 | |
| Number of nursing staff (FTEs, log) | 0.0529** | 0.0541*** | |
| Number of non-clinical staff (FTEs, log) | 0.0744*** | 0.0544*** | |
| 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 ⁷⁶ | 0.02 – 0.03 (0.91 – 0.95) | 0.02 - 0.04 (0.91 – 0.95) | 0.05 (0.97) |

Table 7.4: Impact of subsidised coverage on the number of patients registered with GPs, and clinical and non-clinical staffing levels, 2016 to 2019

Source: Ipsos MORI 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

⁷⁴ King's Fund (2018) Public satisfaction with GP services drops to lowest level in 35 years

⁷⁵ Madison et al (2009) Drivers of overall satisfaction with primary care: Evidence from the English General Practice Patient Survey

⁷⁶ 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.

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)⁷⁷.

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 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 attainment⁷⁸. 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 outcomes⁷⁹. 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.

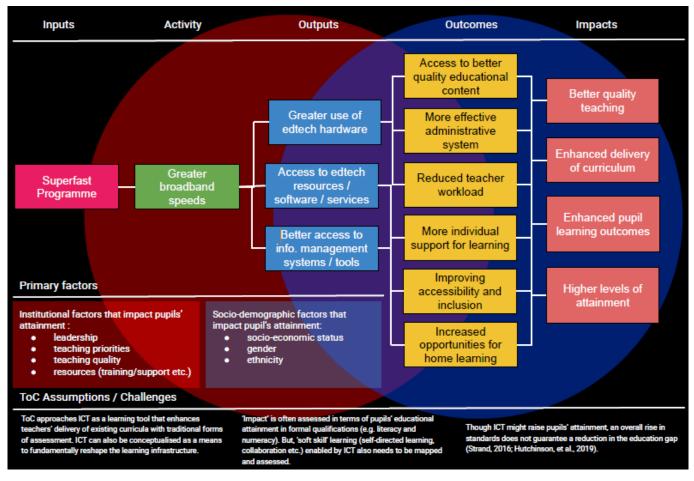
The figure below outlines a theory of change for ICT use and primary and secondary attainment.

⁷⁷ US Chamber of Commerce (2010) The Impact of Broadband on Education

⁷⁸ Sanchis-Guarner et al (2016) Faster broadband: are there any educational benefits?

⁷⁹ 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

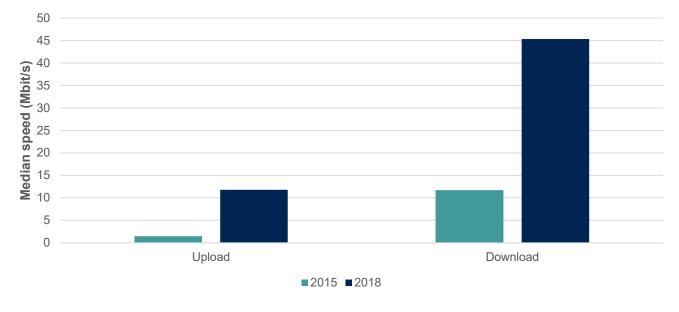
7.2.2 Data

Data on schools is publicly available from the Department for Education's (DfE) 'find and compare schools' webpage⁸⁰. 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 3,735 primary schools, 184 secondary schools and 1,815 academies that benefitted from subsidised broadband coverage between 2013 and 2018. 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 11.7Mbps to 45.3Mbps and from 1.5Mbps to 11.8Mbps respectively.

⁸⁰ This can be accessed here: <u>https://www.compare-school-performance.service.gov.uk/schools-by-type?step=phase&geographic=all®ion=0&phase=primary</u>

^{18-101398-01 |} Final Version | This work was carried out in accordance with the requirements of the international quality standard for Market Research, ISO 20252, and with the Ipsos MORI Terms and Conditions which can be found at http://www.ipsos-mori.com/terms. © DCMS 2020





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 set out in Section 2 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). Whilst data was available for pupil attainment and absence, the experimental approaches to this analysis only explored intermediate outcomes initially, meaning that these outcomes were not assessed. Longerterm impacts on attainment are planned to be explored through later research into the public sector impacts of the Superfast programme.

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:

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

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 17.7 percent and increasing by 8.2 percent and 2.0 percent respectively. However, these findings were not robust the addition of further controls and as such the findings are inconclusive.

| 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) | -0.177*** | 0.00526 | 0.00751 | -0.00115 | -0.0267 |
| Expenditure on teaching (£s, log) | 0.0819*** | 0.000360 | -0.00420 | -0.00624* | -0.00323 |
| Number of teachers (FTE, log) | 0.0200*** | -0.00123 | -0.00638 | -0.00540 | -0.000305 |
| Number of observations | | | 16,485 to 18,08 | 1 | |
| Adjusted R-squared | | | 0.006 to 0.209 | | |

Table 7.5: Impact of subsidised coverage on school expenditure and teaching staff, 2014 to 2019

Source: Ipsos MORI 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 1.7 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).

| 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) | 0.112*** | 0.0168*** | 0.000343 | -0.00134 |
| Self-generated (£s, log) | 0.106*** | 0.0174*** | -0.000401 | -0.00232 |
| Grant funding (£s, log) | 0.267*** | 0.00873 | 0.0216 | 0.0270* |
| Number of observations | 20,274 to 21,870 | | | |
| Adjusted R-squared | 0.049 to 0.439 | | | |

Source: Ipsos MORI 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 2.8 and 4.6 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.

Table 7.7: Impact of subsidised coverage on pupil headcount and percentage of pupils eligible for FSM, with EAL and SEN, 2014 to 2019

| | 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) | | 0.0320*** | 0.00219 | -0.00392 |
| % of pupils eligible for FSM | | 0.775*** | -2.885*** | -0.0863 |
| % of pupils with EAL | | 0.548*** | 0.100** | -0.0426 |
| % of pupils with SEN | | -1.272*** | -4.591*** | -0.376 |
| Number of observations | | | 24,162 to 25,616 | |
| Adjusted R-squared | | | 0.003 to 0.383 | |

Source: Ipsos MORI 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.

8 Cost Benefit Analysis

This final section brings the findings of the evaluation together in the form of a cost-benefit analysis of the programme. The analysis has been undertaken in line with the principles 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 of upgraded that would not have been in the absence of the programme) are derived from parallel analysis set out in Technical Appendix 1.

The analysis considers costs and benefits over two time horizons – benefits to date (2019) and a projection of costs and benefits covering the 2020 to 2030 period. However, the analysis only considers the impacts of premises upgraded by the end of March 2019. The modelling does not seek to provide projections of the potential impacts of premises upgraded beyond this point.

8.1 Costs

BDUK monitoring data gave details of 144 contracts that had been signed as part of the Superfast Broadband Programme across Phase 1, 2 and 3 of the programme. The gross value of the public funding associated with these contracts was £1.9bn at the point of award (in nominal terms), providing funding for the capital costs associated with upgrading network infrastructure in the programme area. However, the clawback mechanisms integrated in the contracts required beneficiaries 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).

The value of clawback will not be known until the contracts have been fully wound down seven years post completion, so a total of 79 of these contracts were subject to a modelling exercise in which projections were developed to estimate lifetime net public costs (i.e. net of implementation and take-up clawback) based on (a) current expectations of the build costs based on the performance of the contract to date, and (b) projections of future take-up (to predict levels of future take-up clawback). Details of this analysis is set out in Technical Appendix 2 but a summary is provided in the following table. This illustrates:

- Gross public spending: The value of expected public spending of the lifetime of these contracts associated with these contracts was estimated at £743m in 2019 prices (£634m in present value terms) based on data available in June 2020.
- Net public spending: However, after accounting for implementation and take-up clawback, it was estimated that the net cost of the contracts to the public sector was £334m (in 2019 prices). A large share of the difference was accounted for by the level of take-up clawback associated with Phase 1 contracts, which were projected to be delivered at a net cost to the public sector of £60m against forecast public spending of £304m (in 2019 prices, £86.9m in present value terms).
- Time costs: The clawback mechanisms employed in the delivery are expected to be highly effective in returning resources to the public sector for example, of the 28 contracts modelled under Phase 1, 12 were expected to be delivered at no nominal cost to the public sector. However, a significant share of the costs is driven by the opportunity cost of temporarily tying up public sector resources in the programme. For example, while the nominal net expected cost of the 28 Phase 1 contracts modelled was £38.1m, the present value of these expected costs (in real terms) was £86.9m. This implies that around 60 percent of the costs of these projects will be in the form of inflation (i.e. future payments will be received in nominal terms and will be worth less in real terms in future years) and

social preference for consumption today versus consumption in the future. These time costs will partly be offset by interest payments made to BDUK that could only be taken into account in the modelling of projects that had been completed.

For 28 of the 34 unmodelled contracts **[redacted]** under Phases 1 and 2, BDUK had prepared forecasts of future implementation and take-up clawback which were used as the basis for estimating the expected costs to the public sector. These forecasts are based on lower long-run take-up than assumed in the modelling described above, and may understate the levels of take-up clawback that may ultimately be returned to the public sector. For Phase 3 contracts (where delivery was at very early stages), and contracts awarded to **[redacted]**, no adjustment was made for possible future implementation and take-up clawback. As such, the overall estimated net cost of the programme (£832m in present value terms, in 2019 prices), is likely to be overstated.

There is a substantial difference between the gross value of public spending associated with the contracts awarded (£1.9bn) and forecast public spending before clawback (£1.7bn in 2019 prices and £1.5bn in nominal terms). This is largely driven by underspending on Phase 1 contracts. The gross value of the public spending associated with contracts at the point they were awarded was £1.2bn. However, final claims were only made for £689m of public funding.

| Phase | Number of contracts | Forecast public funding (£m) | | Forecast implementation clawback (£m) | | Forecast take- up clawback (£m) | | Net cost to the public sector (£m) | |
|---------|---------------------|------------------------------|------------|---|--------|---------------------------------------|--------|--|-------|
| | | Nom. | PV | Nom. | PV | Nom. | PV | Nom. | PV |
| | | | Modelled | contracts | | | | | |
| Phase 1 | 28 | 303.9 | 277.0 | -34.1 | -30.0 | -210.0 | -160.1 | 59.9 | 86.9 |
| Phase 2 | 31 | 340.2 | 279.7 | -11.1 | -8.4 | -126.7 | -89.2 | 202.4 | 182.1 |
| Phase 3 | 20 | 98.9 | 77.4 | -21.8 | -17.2 | -5.0 | -3.2 | 72.1 | 57.0 |
| Total | 79 | 743.1 | 634.1 | -66.9 | -55.6 | -341.7 | -252.5 | 334.4 | 326.0 |
| | | U | nmodelle | d contracts | 5 | | | | |
| Phase 1 | 17 | 700.7 | 654.7 | -80.0 | -63.3 | -338.1 | -248.5 | 282.6 | 342.9 |
| Phase 2 | 17 | 135.9 | 116.1 | 0.0 | 0.0 | -34.0 | -23.9 | 102.0 | 92.2 |
| Phase 3 | 31 | 88.4 | 71.1 | 0.0 | 0.0 | 0.0 | 0.0 | 88.4 | 71.1 |
| Total | 65 | 925.0 | 842.0 | -80.0 | -63.3 | -372.1 | -272.4 | 472.9 | 506.2 |
| | | | Overall pr | ogramme | | | | | |
| Phase 1 | 45 | 1004.7 | 931.7 | -114.1 | -93.3 | -548.2 | -408.6 | 342.4 | 429.8 |
| Phase 2 | 48 | 476.1 | 395.8 | -11.1 | -8.4 | -160.7 | -113.1 | 304.3 | 274.3 |
| Phase 3 | 51 | 187.3 | 148.5 | -21.8 | -17.2 | -5.0 | -3.2 | 160.5 | 128.1 |
| Overall | 144 | 1668.1 | 1476.1 | -147.0 | -119.0 | -713.9 | -524.9 | 807.2 | 832.2 |

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

Source: BDUK, Ipsos MORI analysis

This analysis focuses on delivery of the programme to March 2019. While Phase 1 and 2 of the programme were largely complete at this stage, Phase 3 contracts were at relatively early stages of delivery (around 56,900 premises had been upgraded under Phase 3 contracts (around 17 percent of the 322,242 contracted). This was factored into the analysis by adjusting down the net costs of Phase 3 in proportion to the share of contracted delivery completed by this stage. This gave a total cost for the programme of

£727m. This does not include administrative costs incurred by BDUK and the Local Bodies in their management of the programme.

| Phase | Net cost to the public sector, net of clawback (£m present value) | % of contracted premises delivered | Costs included in the analysis |
|---------|---|------------------------------------|--------------------------------|
| Phase 1 | 429.8 | ~100 | 429.8 |
| Phase 2 | 274.3 | ~100 | 274.3 |
| Phase 3 | 128.1 | 17 | 22.6 |
| Total | 838.6 | | 726.7 |

| Table 9.2. Expected | nat nublia agatar | agata (Cm 2010 | prices) of deliver | v to March 2010 |
|---------------------|-------------------|-------------------|--------------------|-----------------|
| Table 8.2: Expected | net public sector | COSIS (2111, 2013 | prices) or deliver | y to march 2019 |

Source: BDUK, Ipsos MORI analysis

8.2 Additionality

As highlighted in Section 3, the results set out in the preceding section explore the impacts of subsidised coverage. However, the results do not factor in the likelihood that much of this coverage may well have been brought forward through commercial deployments in the absence of the programme. As noted, estimates of the additionality of the coverage funded through the programme are taken from Technical Appendix 1, which examined the 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:

- Evolution over time: The level of additionality is estimated to peak in the year after the premises was upgraded at 61 percent. Additionality decayed between the second and fourth year following the upgrade at a rate of 14 percent per annum (to 38 percent in the fourth year). These patterns were broadly stable over Phase 1, 2 and 3 of the programme. This is consistent with a view that the programme substantially accelerated the deployment of superfast connectivity. However, in the absence of the programme, rising demand and take-up as well as regulatory innovation would have led to greater commercial viability over time. This would have induced commercial deployments in many areas in the longer-term in the absence of the programme.
- Projected additionality: A high to low range for the future additionality of the programme was developed on the following basis:
 - Extrapolation of trends: A lower bound scenario was developed by extrapolating the trends implied by the results over the duration of the appraisal period. This implied a higher rate of decay (14 percent per annum) and the rate of additionality fell to 4 percent over 14 years. This would capture scenarios in which unforeseen technological innovations enable the hardest to reach premises to be served profitably.
 - Future telecoms infrastructure review: A projection of past trends may produce an overly pessimistic view of future additionality. The Future Telecoms Infrastructure Review was prepared on the basis that the final 10 percent of premises (3m of 30.5m in the UK) would never receive commercial investment in full fibre connectivity. This assumption was used to explore the sensitivity of results to a more optimistic view of additionality in the long-run as follows. In 2019, Ofcom's Connected Nations report suggests that 95 percent of premises received superfast coverage. This is equivalent to 29m premises and implies that around 1.5m of the 'last 10 percent' received superfast coverage by 2019. By 2019, 5.3m premises had received subsidised coverage implying that just under 30 percent would never receive commercial

deployments. In this scenario, this share is treated as a notional limit for additionality and the rate of additionality is assumed to decay from 38 percent to 30 percent over 14 years (a rate of decay of 2.0 percent per annum). As this assumption is based on the viability of FTTP rather than FTTC infrastructure, this scenario will likely overstate the long-run additionality associated with the investments (and has been developed primarily to probe the stability of the core findings to alternative assumptions).

Delaying effect: The evidence also suggested that nine 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 the qualitative research with network providers 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.

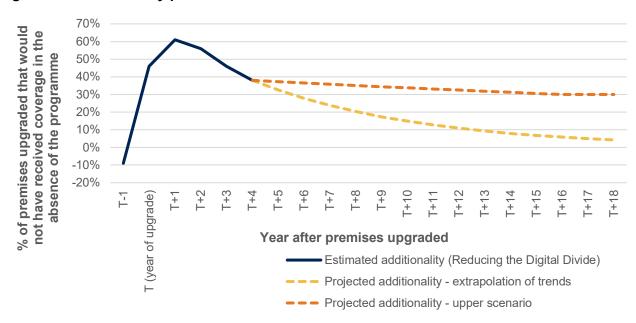


Figure 8.1: Additionality profile over time

Source: Ipsos MORI analysis

The table below provides the estimated number of additional premises passed based on this additionality profile. The gross number of premises passed is based on BDUK's Broadband Performance Indicator for the period 2012/13 to 2017/18. Delivery for 2018/19 is taken from BDUK's Table of Local Broadband Projects. Under the two additionality scenarios, the number of additional premises upgraded are largely equivalent by 2018/19 but diverge by 2029/30 (giving a long-term range for the number of additional premises upgraded of between 500,000 and 1.7m).

Table 8.3: Estimated number of additional premises passed, 2012/13 to 2029/30

| Year of | No. of | | | Estimated | number of a | dditional pre | mises passe | d by year | | | |
|-------------------------|---------------------|---------|---------|-----------|-------------|---------------|-------------|-----------|-----------|---------|-----------|
| upgrade | premises passed | 2011/12 | 2012/13 | 2013/14 | 2014/15 | 2015/16 | 2016/17 | 2017/18 | 2018/19 | 2029 | 9/30 |
| | | | | | | | | | | Low | High |
| 2012/13 | 16,638 | -1,497 | 7,653 | 10,149 | 9,317 | 7,653 | 6,322 | 5,407 | 4,624 | 967 | 4,991 |
| 2013/14 | 492,163 | 0 | -44,295 | 226,395 | 300,219 | 275,611 | 226,395 | 187,022 | 159,938 | 33,461 | 150,586 |
| 2014/15 | 1,902,594 | 0 | 0 | -171,233 | 875,193 | 1,160,582 | 1,065,453 | 875,193 | 722,986 | 151,258 | 593,715 |
| 2015/16 | 1,429,248 | 0 | 0 | 0 | -128,632 | 657454 | 871,841 | 800,379 | 657,454 | 132,868 | 454,877 |
| 2016/17 | 585,850 | 0 | 0 | 0 | 0 | -52727 | 269,491 | 357,369 | 328,076 | 63,686 | 190,164 |
| 2017/18 | 345,714 | 0 | 0 | 0 | 0 | 0 | -31,114 | 159,028 | 210,886 | 43,945 | 114,450 |
| 2018/19 | 496,191 | 0 | 0 | 0 | 0 | 0 | 0 | -44,657 | 228,248 | 73,754 | 167,533 |
| Additiona passed (to | l premises otal) | -1,497 | -36,641 | 65,311 | 1,056,098 | 2,048,575 | 2,408,388 | 2,339,741 | 2,312,211 | 499,940 | 1,676,317 |

Source: BDUK, Ipsos MORI analysis

8.3 Economic and social benefits

8.3.1 Productivity gains

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 and 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 based 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. The effect of the programme was also visible in commercial rental values – which rose by 1.8 percent in response to the upgrade.

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 at the local level may rise 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:

Short-term impact on turnover per premises upgraded: The short-term impact of the programme on the turnover per worker of spatially stable firms was estimated at 0.01 percent per premises upgraded in the Output Area (based on results covering the 2016 to 2018 period). The average turnover per worker of spatially stable firms benefitting from the programme was approximately £106,000. This implies that turnover per worker rose by just under £12 for each premise upgraded across spatially stable units. The average level of employment amongst spatially stable firms in Output Areas supported by the programme was almost 37 employees per output area. This gives a total effect on turnover driven by apparent efficiency gains of £450 per premises upgraded (per annum).

- Short-term impact on GVA per premises upgraded. It was 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 2008 to 2018 period (31 percent)⁸¹, this gives an effect on GVA per premises upgraded of £140 (per annum).
- Persistence: The results of the evaluation suggested that the estimated effect on turnover per worker per premises upgraded fell from 0.011 percent at the end of 2016 to 0.009 percent at the end of 2018 (a rate of decay of 13.2 percent per annum). The average age of these upgrades was 1.8 years at the end of March 2016 and 3.8 years at the end of March 2018. It is assumed that the short-term effect of the programme persists for the first two years following the upgrade, and thereafter decays at a rate of 13 percent per annum.

These results were applied to the profile of additional premises upgraded set out in the subsection 8.2. Summary results covering the 2011/12 to 2018/19 period (benefits to date) and the 2011/12 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 £1.1bn by 2018/19 and between £1.6bn and £1.8bn 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 spill-overs 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.

Table 8.4: Additional GVA resulting from productivity gains (£m, 2019 prices)

| Period | Undiscounted (£m) | Discounted (£m) |
|--|-------------------|-------------------|
| Productivity gains 2011/12 to 2018/19 (£m) | 1243.1 – 1245.1 | 1,078.8 - 1,080.4 |
| Productivity gains 2011/12 to 2029/30 (£m) | 1972.9 – 2275.0 | 1,609.9 – 1,810.8 |

Source: 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 32.1 claimants. The extent to which these effects might be understood as net economic benefits will be linked to how far the

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⁸¹ Source: Annual Business Survey, ONS. Ten year average of GVA as a percentage of turnover used to avoid bias from annual fluctuations in GVA to turnover ratio.

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 unemployment⁸²).

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 series⁸³) 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, it is estimated that for every 10,000 premises upgraded, the number of long-term claimants fell by 9.2.

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 annum⁸⁴, it is estimated that these effects could have led to an additional £125m in national economic output (GVA) by 2019 (in present value terms). This effect is estimated to rise to between £237m to £306m 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 8.5: Additional GVA resulting from reduction in long-term unemployment (£m, 2019 prices)

| Undiscounted (£m) | Discounted (£m) |
|-------------------|-----------------|
| 144.5 – 144.9 | 124.9 – 125.2 |
| 303.5 – 409.9 | 237.1 – 305.9 |
| | 144.5 – 144.9 |

Source: BDUK, Ipsos MORI analysis

8.3.3 Social benefits

The findings of the study suggested that the programme led to an increase in house prices suggesting that buyers valued the technology. However, the findings provided mixed evidence as to how far there was an overall impact on the subjective well-being of residents. This creates some challenges in interpreting the impact of the programme on house prices:

Scope of welfare gains: As noted, there was mixed evidence as to how far the subjective wellbeing of residents did not increase in response to the programme. However, there was substantial uncertainty as to how far this reflected migration of population induced by the programme. Amongst older populations least likely to migrate, the well-being effect was positive. As the effect of the programme on house prices reflects the valuation of the marginal buyer (rather than the broader population of residents), it was assumed that effect on house prices reflected the welfare benefits accruing to the population of households that moved to the programme area rather than all residential premises receiving subsidised coverage. This is a conservative approach that implicitly assumes that other residents either derive no benefit from the availability of superfast broadband or that the benefits they derive are offset by other factors (such as increased congestion or reductions in social cohesion). As such, the findings below should be considered a 'lower bound' to the value of social benefits arising from the programme.

⁸² Though some of these episodes will have otherwise evolved into long-term unemployment.

⁸³ DCMS (2018) Economic and Public Value Impacts of the Superfast Broadband Programme.

⁸⁴ 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).

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- Valuation: To reach an estimate of the welfare gains, the implied house price premium of £1,700 to £3,500 was applied to the number of houses sold in the programme area after the premises was upgraded (813,500). This gave a gross value of the price uplift of £1.4bn to £2.9bn.
- Expectations: An assumption was applied that consumers had reasonably formed expectations regarding the likelihood that homes would receive superfast coverage in the future. As such, the impact of the programme on house prices is interpreted as the present value of the total welfare gains associated with having access to superfast coverage immediately (and possibly other relevant features of the home, such as proximity to newly relocated employers) as opposed to coverage at some uncertain point in time in the future.
- Additionality: Flowing from this, the gross value of the price uplift was adjusted in light of the short-term additionality (an average of 54 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. As such, the present value of welfare benefits to 2019 and to 2030 are equivalent (and estimated at £741m to £1.5bn).
- Net effects: As highlighted in Section 6, 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 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).

The following table provides a summary of the results.

Table 8.6: Land value uplift arising from impacts on house prices (£m, 2019 prices)

| | Low house price premium (0. 56%) | High price premium (1.16%) |
|---------------------------------------|--|----------------------------|
| Welfare impact | s confined to households purchasing home | ès |
| Land value uplift (£m, present value) | 741.9 | 1,536.8 |
| Ostrano DDUIK, Jacob MODU stratusia | | |

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 subsection 8.1. This gives a range for the BCR as follows:

- Benefits from 2012 to 2019: The short-term BCR (based on benefits to date) is estimated at between £2.7 and £3.8 per £1 of net lifetime public sector costs. This exceeds the hurdle rate of return normally applied in the appraisal of public sector programmes and suggests that the programme has already delivered a strong rate of return.
- Benefits from 2012 to 2030: In the long-run (allowing for future economic benefits), the BCR is estimated to rise to £3.6 to £5.1 per £1 of net public sector spending.
- Sensitivity: It should also be noted that investment in the programme can also be justified on the long-term economic benefits alone. Excluding the welfare effects inferred from house prices (which

are less certain), the BCR is estimated to range from £2.5 (low future additionality) to £2.8 (high future additionality). The narrow nature of this range indicates that the benefit to cost ratio is not heavily dependent on the assumptions made regarding future additionality. It should also be noted that the economic benefits are likely to be understated, given the conservative approach adopted to assess the supply side impacts.

It is important to note that the modelling of the future benefits do not attempt to incorporate the possible effects of COVID-19 or the departure of the UK from the European Union (as the magnitude and direction of these effects are largely unknown at this stage). As these events are likely to have a transformative effect on the UK economy, projections of the future benefits of the programme should be treated as indicative.

Table 8.7: Benefit to Cost Ratios, 2012 to 2019 and 2012 to 2030

| | 2012 to | o 2019 | 2012 to 2030 | | |
|--|--|---|--|---|--|
| Period | Low additionality / house price effects | High additionality / house price effects | Low additionality / house price effects | High additionality / house price effects | |
| | Benefits | | | | |
| Productivity gains (£m) | 1,079 | 1,080 | 1,610 | 1,811 | |
| Long-term unemployment (£m) | 125 | 125 | 237 | 306 | |
| House prices (£m) | 742 | 1,537 | 742 | 1,537 | |
| Total | 1,946 | 2,742 | 2,589 | 3,697 | |
| | Costs | | | | |
| Lifetime cost (£m) | 727 | 727 | 727 | 727 | |
| Benefit to cost ratio Source: BDUK, Ipsos MORI analysis | 2.7 | 3.8 | 3.6 | 5.1 | |

8.5 Margin of error

The results set out above are based on the central estimates of the impact of 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 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.

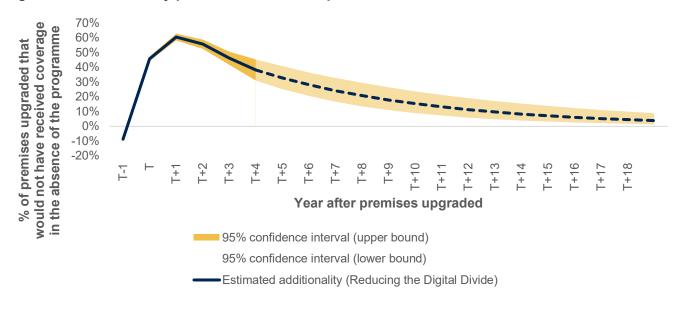


Figure 8.2: Additionality profile over time – 95 percent confidence interval

Source: Ipsos MORI analysis

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 standard errors associated with some estimates (e.g. turnover per worker and higher bound estimates of impacts on house prices) were not meaningfully different from zero (and were reported as zero in the software used to implement these models).

Table 8.8: 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 (to 2016) | 0.00011 | 0.00011 | 0.00011 |
| Turnover per worker (to 2018) | 0.00009 | 0.00009 | 0.00009 |
| Unemployment | -0.00321 | -0.00359 | -0.00283 |
| House prices (low premium) | 0.00560 | 0.00246 | 0.00874 |
| House prices (high premium) | 0.01160 | 0.01160 | 0.01160 |
| Source: BDUK, Ipsos MORI analysis | | | |

8.5.3 Benefit to Cost Ratios

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 and low house price premium effects). The findings indicate that at the lower bound, the costs of the programme remain justified by the benefits and the social rates of return continue to exceed the hurdle rate of return typically applied in the appraisal of public sector programmes.

Table 8.9: Benefit to Cost Ratios, 95 percent confidence interval (low additionality scenario with low house price premium)

| | 2012 to 2020 | | 2012 to | 2030 |
|--|--|--|--|---|
| Period | Lower bound (low house price effect) | Upper bound (low house price effect) | Lower bound (low house price effect) | Upper bound (high house price effect) |
| | Benefits | | | |
| Productivity gains (£m) | 1,004 | 1152 | 1415 | 1,837 |
| Long-term unemployment (£m) | 102 | 150 | 174 | 322 |
| House prices (£m) | 326 | 1157 | 326 | 1,157 |
| Total | 1,432 | 2,459 | 1915 | 3,316 |
| | Costs | | | |
| Lifetime cost (£m) | 727 | 727 | 727 | 727 |
| Benefit to cost ratio | 2.0 | 3.4 | 2.7 | 4.6 |
| Benefit to cost ratio (central estimate) | 2.7 | 2.7 | 3.6 | 3.6 |

Source: BDUK, Ipsos MORI analysis

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