Ipsos MORI
Social Research Institute

July 2018

Superfast Broadband Programme Evaluation

Annex B: Economic Impacts

Technical Paper

Contents

List of Figures

List of Tables

1 Economic Impacts

This paper explores the economic impacts of the Superfast Broadband Programme between 2012 and 2016. The key focus of this paper is on how far subsidised coverage raised employment, turnover, output and the productivity of firms for which enhanced connectivity was made available. It is important to note that the paper focuses on assessing the impact of improved connectivity but does not offer an assessment of the net economic impact of BDUK subsidies. Such an assessment also requires an assessment of how far connectivity would have been brought forward in relevant postcodes in the absence of BDUK subsidies, as explored in the Reducing the Digital Divide paper.

1.1 Theory of Change

The effect of the Superfast Broadband programme in bringing forward superfast coverage may result in second order effects through raising the performance of the economy. A range of economic impacts might be anticipated at the local and national levels:

- Productivity gains: Numerous studies have shown that faster broadband stimulates productivity growth. Adoption of superfast broadband could raise the productivity of local firms in several different ways. These improvements may take time to arise and complementary business investments may be required take advantage of higher speeds:
  - Adoption of complementary technology: 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 or the application of cloud computing. This would enable businesses to produce higher levels of output (GVA) with the same resources. The extent to which these effects are realised will be in part dependent on the ability of firms in subsidised areas to absorb the technology. For example, evidence from the US has suggested that broadband tends to raise productivity only in areas where there is strong supply of highly skilled workers[1]. Additionally, firms in some sectors appear less able to exploit the availability of broadband to raise productivity, particularly the manufacturing sector[2][3]. The economic performance of rural areas has also been shown to be linked to the *adoption* rates of broadband[4], with areas less able to absorb the technology seeing declines in employment.
  - Product or process innovation: Firms may also be able to use the technology to drive forward product or process innovations that increase the value of their output or reduce their use of factor inputs. The availability of broadband has been shown, in the short term, to stimulate R&D activity and the introduction of new processes and products in both the UK and Germany. The efficiency gains resulting from these types of investment may take time to arise.
  - Raising teleworker productivity: Firms may also benefit from any effects through which the availability of superfast broadband enables workers to work from home more effectively. Such effects could arise from the reallocation of commuting time to productive activities. or raise the efficiency of their working hours. These benefits may accrue to firms located outside of the programme area, it should be noted.

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

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

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

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

- **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.

- **Displacement and crowding out:** 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). 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)[5].

- **Sorting effects:** The programme may also result in local economic benefits via the spatial reallocation of economic activity. Several studies[6] have illustrated that the availability of broadband makes 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. 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). 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. 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 to lower cost locations. Many of these effects could be expected to play out over the medium term (3 to 5 years) and may not yet be visible given the time that has elapsed since the start of the programme.

- **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. While many workers may be able to adjust to such local economic shocks by relocating, retraining or commuting to more buoyant local economies, some may be unable to do so. This might occur, for example, if workers are unable to bear the costs of relocating. These types of problem could produce local issues of long-term unemployment[7] and permanent losses of output (i.e. hysteresis effects) because these workers would not be redeployed elsewhere in the economy.

- **Labour market participation impacts:** The enablement of superfast broadband in low connectivity areas could also have further economic benefits though increasing labour supply. Prior evidence suggests that these effects could arise through enabling carers or those with disabilities to enter the labour market through teleworking. 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

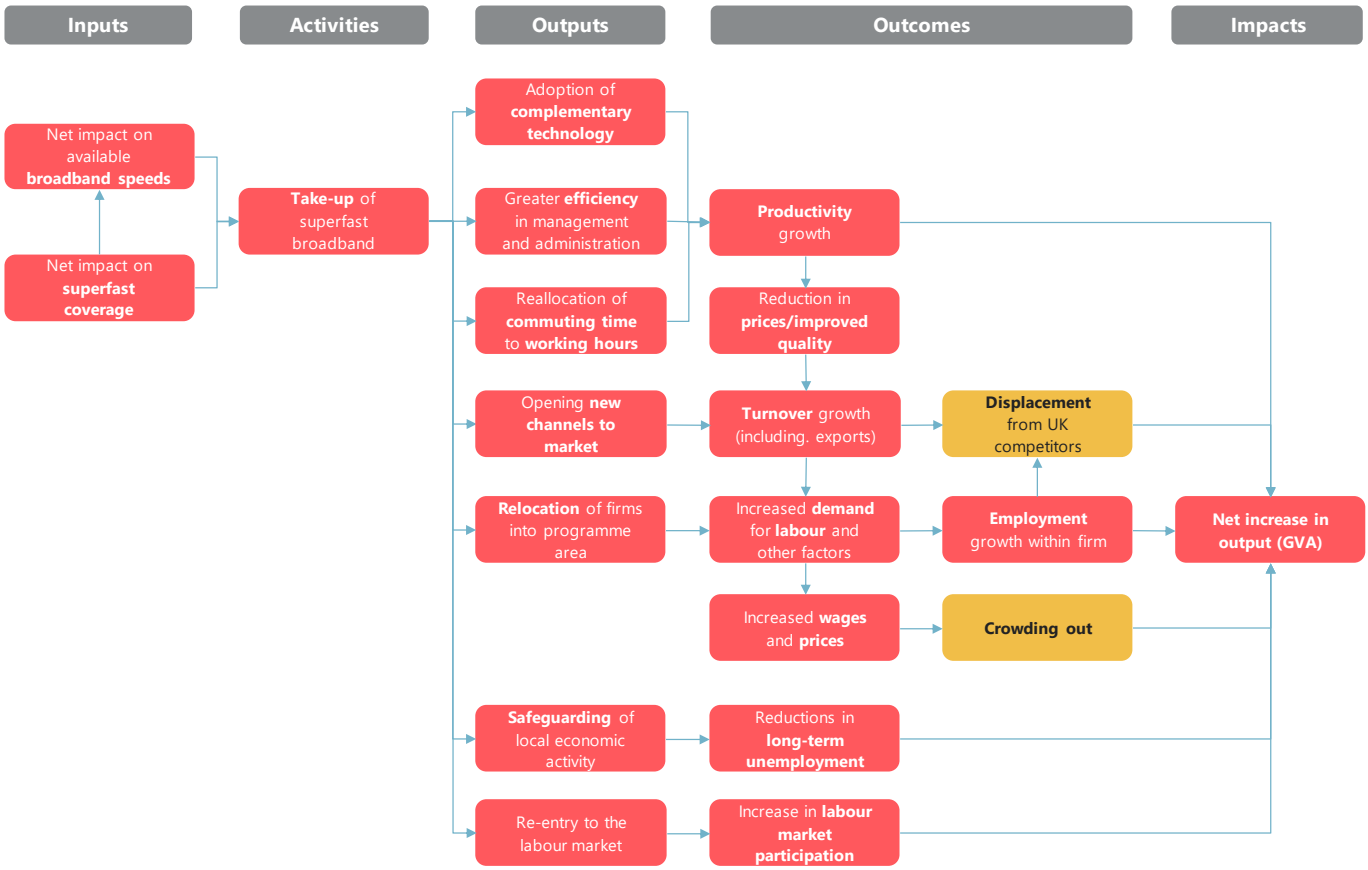
[5] In light of these issues, the HM Treasury Green Book recommends that the focus of economic appraisal should be on increases in the productive capacity of the economy, rather than on short term demand side effects.

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

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

areas, then the jobs created may have features (higher wages, greater flexibility, better working conditions) that are attractive to residents that are economically inactive.

Figure 1.1: Logic Model - Economic Impact of the Superfast Broadband Programme



1.2 Context

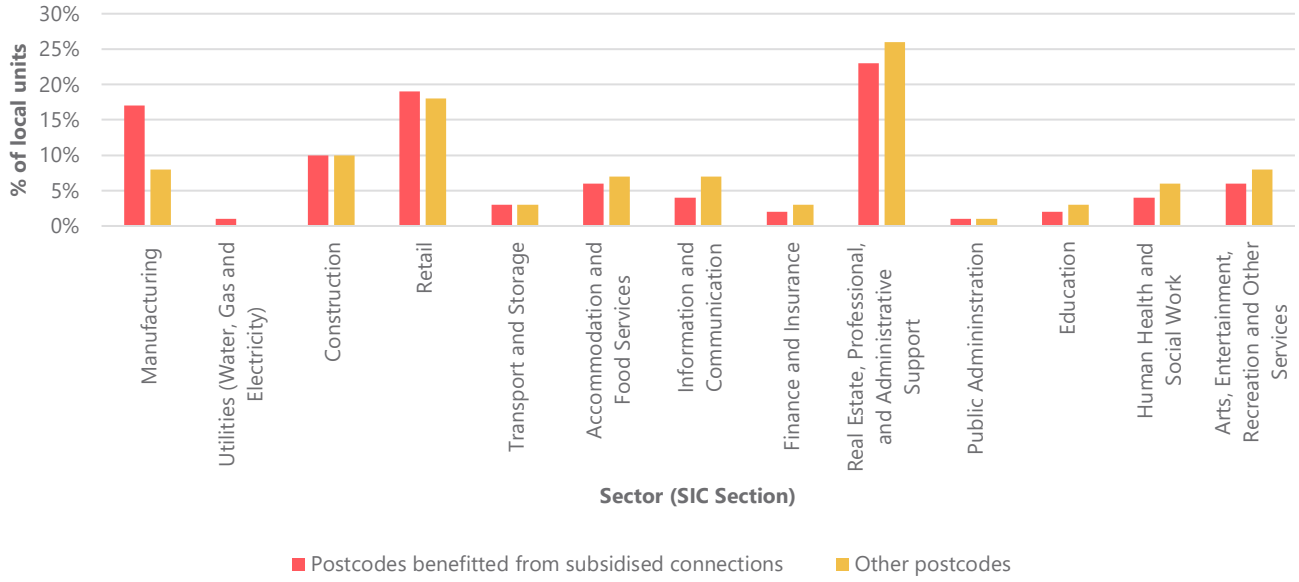
1.2.1 Firms Benefitting from Subsidised Coverage

Analysis of the Business Structure Database (BSD)[8] suggested that the number of workplaces located on postcodes benefitting from the Superfast Broadband programme rose from 686,841 to 733,601 between 2012 and 2016 (7 percent growth). The growth in the number of workplaces was less rapid than seen elsewhere, which grew by 14 percent from 1.8m to 2.1m.

Figure 1.2 below provides an overview of the sector distribution of the local units benefitting from the superfast coverage subsidised by the programme. Firms located on postcodes within the scope of local schemes were more likely to be operating in the manufacturing sector than elsewhere in the UK, while a range of high and low productivity service sectors were less well represented, including businesses in the financial services, professional and scientific services, education, health and social work, and arts and recreation sectors. Additionally, the accommodation and food services sectors were less prevalent within the areas covered by the programme, suggesting a lower dependency on the visitor economy.

[8] The BSD is a snapshot of the Inter-Departmental Business Register (IDBR). The IDBR is a live register of data collected by HM Revenue and Customs and is based mainly on the submitted VAT and Pay As You Earn (PAYE) records of UK registered privately held limited companies, partnerships and publicly listed companies (PLCs). See also section 2.1.1.

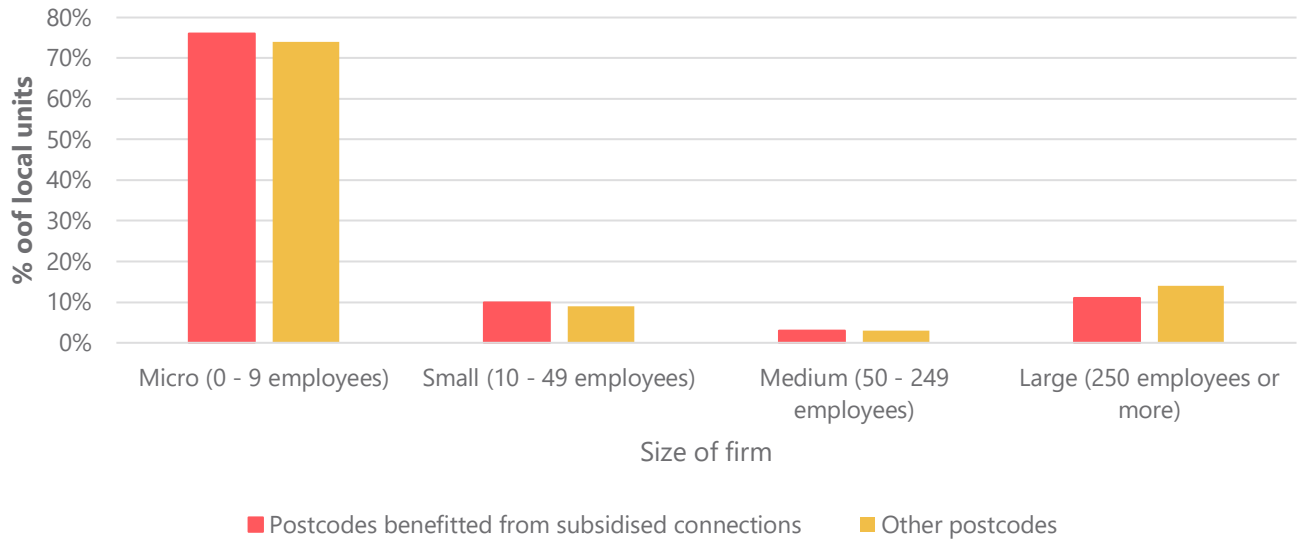
Figure 1.2: Sector Distribution of Local Units Benefitting from Subsidised Superfast Coverage, 2012



Source: Business Structure Database, Office for National Statistics, Ipsos MORI analysis

Firms located within areas covered by the programme tended to be smaller than firms elsewhere. The average number of workers employed within local units located in the programme area was 7.8 in 2012, in comparison to 11.1 elsewhere. This is reflected in the size distribution of firms, shown in figure 1.3. Large firms were less prevalent and there was a greater prevalence of micro-businesses, i.e. those with 0 to 9 employees. The average annual turnover of firms in the programme area was also lower in 2012 at £900,000 in comparison to £2.0m amongst firms elsewhere.

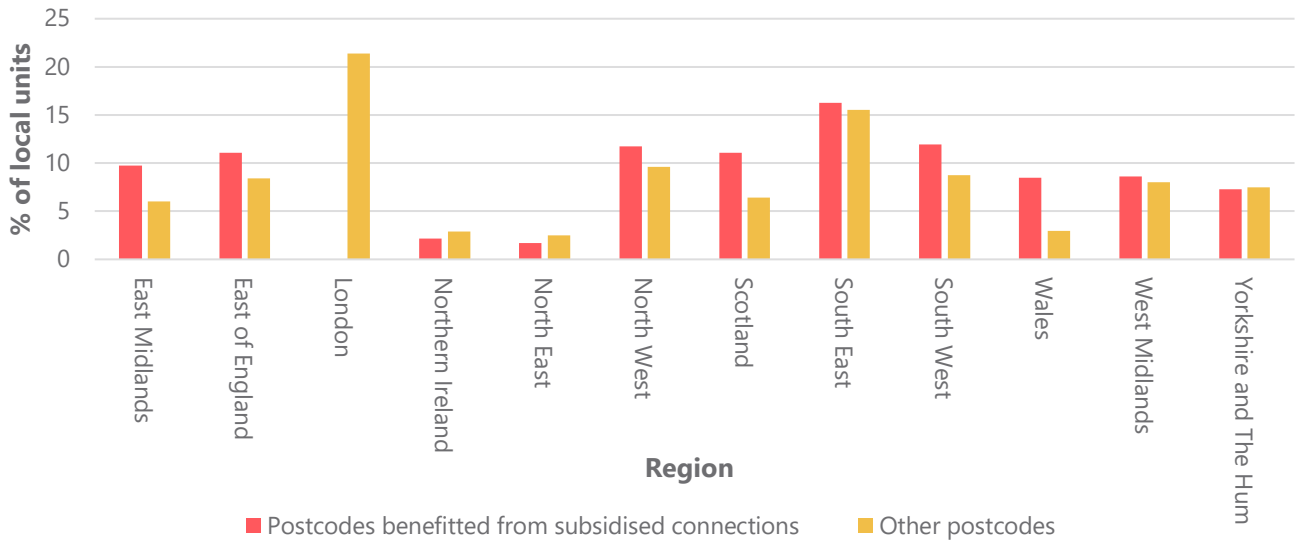
Figure 1.3: Size Distribution of Firms Benefitting from Subsidised Coverage, 2012



Source: Business Structure Database, Office for National Statistics

Finally, the regional distribution of firms benefitting from access to subsidised coverage is set out in figure 1.4.

Figure 1.4: Regional Distribution of Firms Distributed

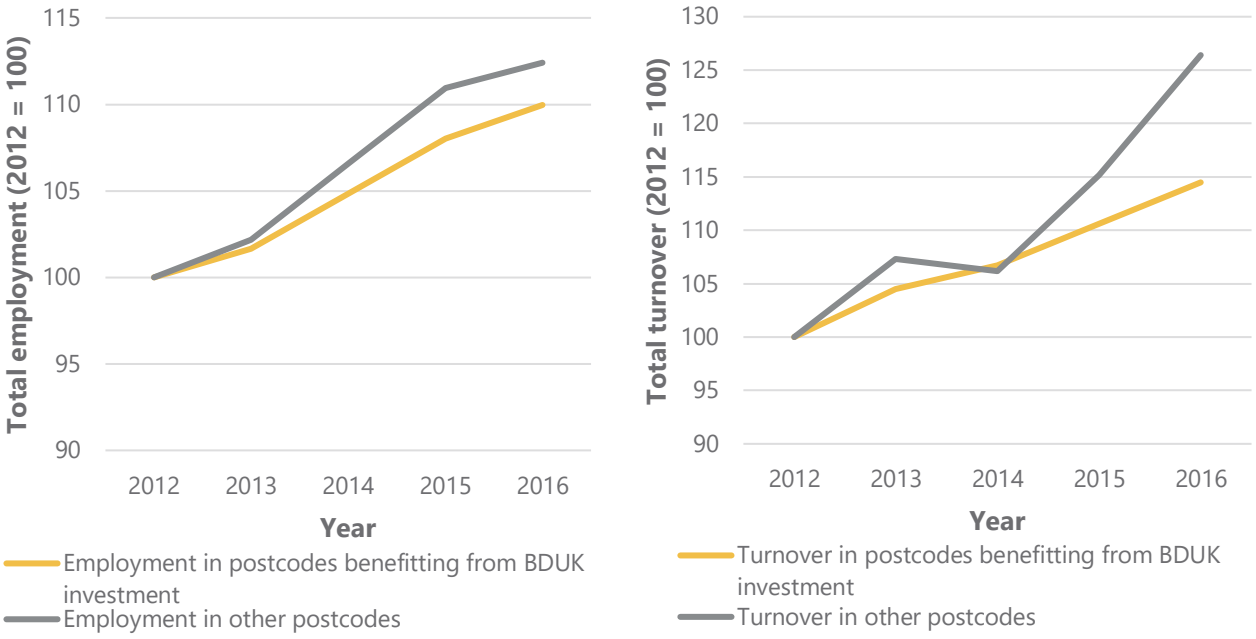


1.2.2 Employment, Turnover, and Productivity

Between 2012 and 2016, employment across all areas grew as the economy recovered from the 2008 financial crisis. Overall employment in postcodes covered by the analysis rose from 19.1m in 2012 to 21.3m in 2016 (growth of almost 11.7 percent), though employment growth was less rapid amongst firms located within the programme area (10.0 percent) than outside (12.4 percent).

The average number of workers in local units within the programme area fell by 2 percent over the period, suggesting that overall employment growth has primarily been driven either by new enterprises or firms relocating to the programme area. This was trend was more pronounced in other postcodes where the average number of workers of firms fell by 5 percent. The average turnover of local units benefitting from subsidised coverage also rose over the same period (though less rapidly than elsewhere).

Figure 1.5: Employment and Turnover of Local Units Benefitting from Subsidised Coverage, 2012 to 2016



Source: Business Structure Database, Office for National Statistics

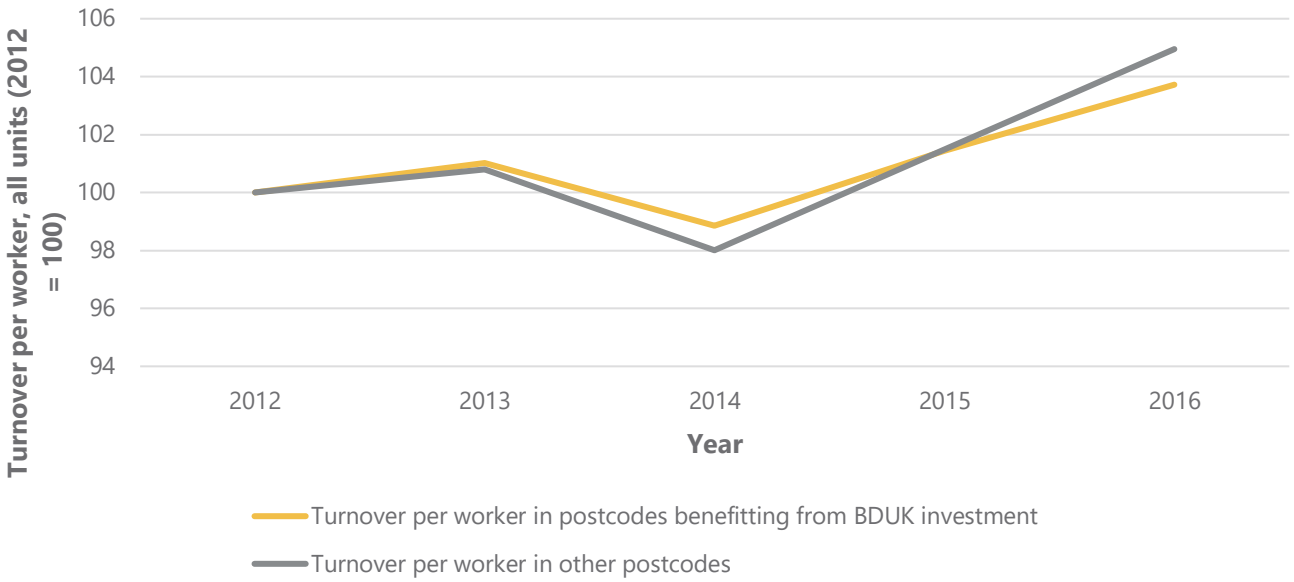
Analysis of the Business Structure Database and the Annual Business Survey both suggested that the local units based on postcodes within the scope of local schemes were less productive than average. Turnover per worker (taken as a proxy for productivity) was an average of £106,400 between 2012 and 2016 for local units receiving access to subsidised coverage, around 24 percent lower than for those located outside of the programme area (£140,000). GVA per worker was estimated at £36,000 to £37,000 for reporting units located within the scope of local schemes[9], which compared to an average of £43,000 nationally, excluding crop and animal production and financial services[10]. Turnover per worker also grew less rapidly amongst local units within the build plans of local schemes between 2012 and 2016, as illustrated in Figure 1.6[11].

[9] Note that the sample of businesses available from the ABS was not representative of the firms located within the scope of local schemes.

[10] Annual Business Survey 2016, Office for National Statistics.

[11] Note that the drop in turnover of businesses in 2014 corresponds with figures published by ONS.

Figure 1.6: Turnover per worker, 2012 to 2016

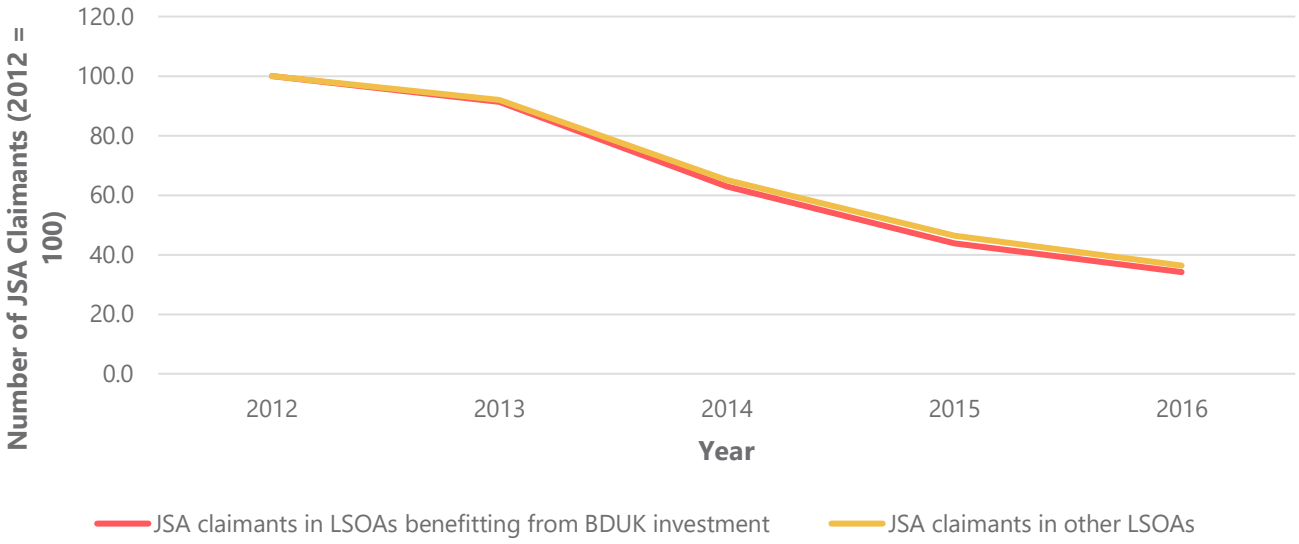


Source: Business Structure Database, Office for National Statistics

1.2.3 Unemployment, Long-term Unemployment and Out of Work Benefits

The Superfast Broadband programme was delivered during a period in which unemployment was falling rapidly across all areas of the country as the economy emerged from the 2008 financial crisis. The overall number of JSA claimants in the areas included in the analysis fell from 1.3m to 0.5m between 2012 and 2016 (a reduction of almost 65 percent). As illustrated in the Figure 1.7, areas benefitting from BDUK subsidies saw similar trends to other areas, with claimant numbers falling slightly more rapidly than in areas that did not benefit from subsidised coverage.

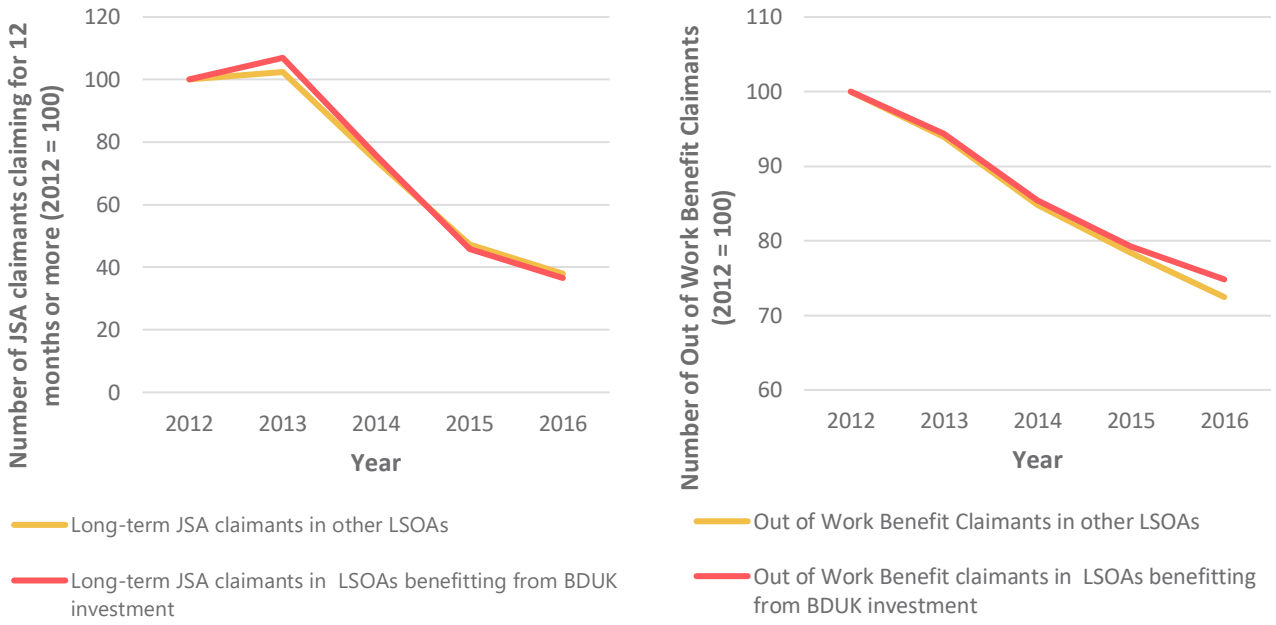
Figure 1.7: Unemployment (Claimant Count), 2012 to 2016



Source: DWP Benefits Database, 34,533 LSOAs and Data Zones in England, Wales and Scotland

Long-term unemployment[12] also fell broadly in line with overall claimant numbers, from 344,000 in 2012 to 129,000 in 2016, with the decline slightly more rapid in areas benefitting from coverage subsidised by BDUK. The number of individuals claiming out of work benefits fell less rapidly, declining by 25 percent from 4.1m to 3.1m over the period. Overall numbers claiming out of work benefits fell slightly less rapidly in areas that received subsidised coverage.

Figure 1.8: Long-term JSA (12 months or more) and Out of Work Benefit Claimants, 2012 to 2016



Source: DWP Benefits Database, 34,533 LSOAs and Data Zones in England, Wales and Scotland

[12] Defined here as JSA claimants claiming for 12 months or more

2 Firm Level Impacts

This section provides an assessment of the causal effects of subsidised coverage on the economic performance of firms located within the scope of local schemes funded through the programme.

2.1 Data

This section provides an overview of the data employed in this analysis and highlights any associated issues that need to be accounted for in the analysis.

2.1.1 Business Structure Database (BSD)

Longitudinal observations of employment and turnover at an enterprise and workplace[13] level were taken from the Business Structure Database (BSD) and accessed through the Office for National Statistics (ONS) Virtual Microdata Laboratory (VML).[14] The data provides longitudinal observations of employment and turnover for all firms in the register between 1998 and 2016, and is used as the main sampling frame for ONS business surveys. The data also provides industry sector and the postcode associated with each workplace, enabling tracking of relocations and the opening of new locations. Business births and deaths can also be identified.

The underlying data on employment and turnover are assembled from PAYE and VAT returns or from Annual Business Survey or Business Register of Employment Survey 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 that some records are thought to be up to two years out of date, and some caution is urged by ONS in using the BSD in evaluating policy interventions over short time horizons, as is the case in this instance. The lagged nature of the data could lead to an understatement of the programme's effects.

2.1.2 Annual Business Survey (ABS)

Further information on Gross Value Added (GVA) was sourced from the ABS. This is a large-scale business survey completed annually by the Office for National Statistics covering 62,000 firms in its most recent year with its data used for a variety of purposes including providing key national accounting measures and calibrating other surveys, such as investigations into changes in the capital stock. ABS data is made available at the reporting unit level and there are several issues to consider:

- Large firms: The ABS is a mandatory census survey of all firms with 250 or more employees. As such, longitudinal measures were available on a consistent basis between 1998 to 2015 for all large firms.
- SMEs: The ABS is a random probability sample survey of small and medium sized enterprises (SMEs). Completion of the survey is mandatory. SMEs are typically surveyed in two consecutive years and then drop out of the sample for the ABS. Following this, they will not be resampled for at least two years. This limited the volume of longitudinal data available to feed into the analysis for SMEs, which is particularly problematic in this case, as SMEs are more likely than large firms to use the types of asymmetric digital subscriber lines that were subsidised through the programme, as opposed to using leased lines.

[13] Formally described as local units.

[14] No known as the Secure Research Service (SRS)

- Micro-businesses: 'Osmotherly' rules apply for businesses with 1 to 9 employees: any micro-business sampled for the ABS will not be resampled for at least three years and limited longitudinal data was available for the smallest firms.
- Northern Ireland: It should be noted that the ABS does not cover Northern Ireland.
- Timing of programme delivery: Most postcodes receiving subsidised coverage through the programme did so in 2015. This is potentially problematic for any analysis using Annual Business Survey as results for 2016 were not available at the time of writing, and the extent to which any impacts may visible in the analysis of this data is dependent on how far firms can exploit the benefits of enhanced connectivity sufficiently rapidly. A more general word of caution is that the results set out in this paper focus only on very short term effects, and insufficient time has passed since the delivery of subsidised coverage to enable an assessment of the programme's long-term impacts or their durability. BDUK plans to assess longer-term effects by repeating the analysis.

2.1.3 C3 Reports

Claimed delivery of superfast coverage are reported to BDUK by contractors in a 'C3 report.' 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 1 2017/18 were used to support the analyses reported below and elsewhere in this evaluation, providing details of some 5.2m 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, i.e. delivery of sub-superfast coverage and coverage delivered in grey, black, and ineligible areas were included. The C3 reports covered a total of 375,428 postcodes in the UK (24 percent of the 1,549,195 postcodes in the UK[15]).

2.1.4 Data Processing: Business Structure Database

Several steps were taken to process the available data before linking it to the C3 reports to identify the population of firms benefitting from subsidised superfast coverage. The BSD research data consists of annual cross-sections at the enterprise and local unit level. The latter provides the postcodes and employment associated with local units, while turnover is recorded at the enterprise level. Turnover was apportioned to local units on the basis of employment. A panel dataset was constructed by linking each of the local unit cross sections using the unique identifiers held within the BSD. Different types of local units were then identified from the variables contained within the panel, including:

- Spatially stable: Local units which remain situated in the same postcode between 2012 and 2016.[16] The firms were identified by comparing the postcodes for each local unit across each cross section. Where these postcodes remained the same across the period, the local unit was marked as 'spatially stable'. These firms were identified to provide a clearer understanding of the economic impacts of the programme by seeking to remove those driven by the relocation of firms.
- 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 to provide a check against the process of apportioning turnover across local units did not result in misleading results (i.e. that turnover growth on sites not benefitting from subsidised broadband coverage was not mistakenly attributed to the programme).

[15] As covered in the Ofcom Connected Nations data

[16] These units also remain live between 2012 and 2016

As is the standard process for ONS published figures, only live local units have been used for this analysis, which requires the identification and removal of local units where a date of death is present. Table 2.1 outlines the number of affected observations in the BSD by year. The number of local units in the sample increased with time, with our processing of the data producing a sample of 3.1m local units in 2016. The sample of 2,974,482 compares with published figures of 2,891,830 workplaces in the UK in 2015[17]. This difference is caused by the exclusion of local units with zero recorded employees in the published information. These local units have been retained for the purpose of this analysis on the basis that the owner could be considered an employee even if not compensated through PAYE[18].

Turnover information is only available at the enterprise level and the enterprise level datasets were linked to the local unit data using the enterprise reference number present in all datasets. These figures were then deflated in line with the GDP deflators produced by the ONS for the quarterly national accounts (putting turnover in constant 2016 prices) [19].

Table 2.1: Number of 'live'/'dead' local units by year

Year	Total number of local units	Live local units	Dead local units
2012	3,570,326	2,759,459	810,867
2013	3,563,183	2,773,332	789,851
2014	3,642,049	2,883,622	758,427
2015	3,718,352	2,974,482	743,870
2016	3,823,996	3,077,227	746,769

Source: Business Structure Database,

The resulting dataset was linked to the C3 reports to identify all local units that benefitted from access to subsidised coverage by BDUK and create the following derivative datasets:

- Postcode level dataset: The local unit level data was aggregated to the postcode level for each year between 2012 and 2016 and then linked to the sample of postcodes covered by the Connected Nations report (just 1.5m postcodes). A total of 1,048,421 postcodes were successfully matched to a local unit. A further 500,744 postcodes were present in the Connected Nations report but did not contain any local units over the period (i.e. the postcodes were purely residential) and were dropped from the sample (note that the BSD will include some firms that are registered at a residential rather than a commercial property address). This data was then linked to the C3 reports to identify the number of postcodes with local units that have benefitted from subsidised coverage (235,321 in total).

- Local unit level dataset: This dataset was created by matching the postcode associated with each local unit in each year directly to the C3 reports. For the purposes of this analysis, a local unit is considered to have benefitted from subsidised coverage for the time it was located at a postcode that had previously received subsidised coverage. Spatially stable

[17] See Number of Workplaces and Employees by Enterprise Size in the UK: 2001 and 2015, Office for National Statistics, May 2016. Available at: https://www.ons.gov.uk/businessindustryandtrade/business/activitysizeandlocation/adhocs/005696numberofworkplacesandemployeesbyenterprisesizeintheuk2001to2015

[18] One employee was added to the employment of all local units to mitigate issues whereby turnover per worker cannot be computed where there is zero employment. This can be rationalised as included the owner of the firm as an employee (who may not be registered for PAYE).

[19] The June figures were the latest available at the time analysis began and 2016 was used as the base year. Deflators available at: https://www.gov.uk/government/statistics/gdp-deflators-at-market-prices-and-money-gdp-june-2017-quarterly-national-accounts-june-2017

local units (see point above) are considered to have benefitted from the year in which the postcode was upgraded. Local units relocating to a postcode that has previously received BDUK investment is considered to have benefitted from subsidised coverage from that point forward, while a local unit moving from a such a postcode to one not in receipt of investment is no longer considered to benefit from the subsidised coverage from that point forwards.

Annual Business Survey (ABS) data linking

A similar process was required with the ABS to create a dataset for analysis. However, the ABS cross sections are completed on a reporting unit basis. This adds an additional complication in that a reporting unit can cover one or more local units and does not necessarily cover all local units for an enterprise. As a result, the respondent files and 'universe' files needed to be used in conjunction[20] to allow the identification of the local units covered by the reporting units responding to the ABS.

Again, a dataset was created containing details of GVA, location (postcode) and employment at the local/reporting unit level. GVA measures also required apportioning in the ABS and GVA was deflated in a similar manner to turnover in the BSD[21]. This was achieved using the share of each local unit's employment of the total employment under the reporting unit. The completed panel was then matched to the C3 reports in the same way the BSD panel was linked, based on postcode. It was not necessary to drop units as 'dead' in this analysis as the ABS indicates active units by way of their return submission. In total, there were 41,823 eligible local units in this dataset.

2.1.5 Control variables

There are three key variables that can have been controlled for in the analysis of the BSD and ABS:

- Industry type: The BSD and ABS provide details of the SIC code most applicable for each local unit contained in the data. These can be used to control for industry effects in the regression analysis,
- Firm size: Similarly, employment can be used to generate variables describing the size of the enterprise each local unit belongs to. Different size categories of firms by employment could be expected to behave differently.
- Region: Lastly, the postcode can be used to control for regional differences when looking at all firms.[22] NUTS1 geographical regions have been used.

2.2 Methodological Issues

A credible quantitative assessment of the impact of the Superfast Broadband programme requires the selection of an appropriate set of areas that did not benefit from subsidised coverage, the purpose being to establish what may have occurred in the programme's absence. There are several complexities involved in establishing a suitable counterfactual for these analyses. Issues of reverse causality are particularly problematic. Areas that receive investment in infrastructure tend to do so because they are expected to grow rapidly in the future. As such, comparisons between high and low connectivity

[20] Respondent files contain the responses to the ABS for reporting units that compete them in each cross section. The universe files contain the sample and non-sample details of units as per the IDBR. As these units were not sampled/did not respond to the ABS, no ABS question responses are available in this data.

[21] The deflator was reconfigured to use 2015 as the base year.

[22] By definition, spatially stable firms do not move region and as such, region falls out of this analysis.

areas would tend to yield misleading results because those areas benefitting from subsidised coverage would generally be expected to outperform areas that do not, regardless of the investments made.

The primary solution to these problems was the adoption of a design that exploits the staggered roll-out of the programme, both within and across phases of the contracts. The basis of this approach (a pipeline design) is that areas that have received BDUK investment first are also likely to experience the impacts of those investments first. Under this approach, those areas receiving BDUK investment at later stages, become a counterfactual for areas receiving investment earlier. The approach has the following advantages:

- Feasibility: This approach is only feasible with longitudinal panel data, i.e. annual observations of the same individuals, firms, or areas, to exploit staggering in the roll out of the programme. This ultimately proved problematic using the data from the Annual Business Survey and an adaptation of the general framework was required.

- Selection bias: The approach avoids the problems normally associated with selection bias because no areas that did not receive BDUK investment are included in the analysis. As such, all areas can be assumed to share unobserved features that influenced their selection into the programme. Thus, the approach can in principle attain levels of robustness equivalent to Level IV on the Maryland Scale of Scientific Methods. However, the strength of the results depends on the assumption that there are no systematic differences between areas receiving investment earlier and later that are also correlated with the outcomes of interest. For example, if subsidised coverage is rolled out to areas experiencing higher productivity growth first, then this will overstate the impact of the programme[23].

- Differences between Phase One and Phase Two: As noted elsewhere, analysis suggests there were differences between postcodes receiving investment in Phases One and Two in terms of density of premises, which is thought to be correlated with commercial attractiveness to suppliers, and may also be correlated with other observable or unobserved variables determining the economic performance of areas. Phase Two was more focused on urban areas than Phase One, and the validity of the pipeline approach considering the implied differences between the two Phases is given more detailed consideration below.

2.3 Analysis Using the Business Structure Database

This section focuses on the results of analysis using the Business Structure Database.

2.3.1 Econometric Model

To estimate the effects of the Superfast Broadband Programme on the economic outcomes of interest, a simple pooled regression model was first estimated using data aggregated at the postcode level to establish a benchmark set of results. This was then augmented to include fixed effects at the postcode level and random effects at the postcode level with a Hausman test used to ascertain the preferred model. Finally, time trends were incorporated into the regression model before application to each outcome in turn. The following fixed effects model was settled on as the preferred model using the postcode level aggregated data:

$$Y_{it} = \alpha_i + \beta T_{it} + \gamma t + \delta X_{i,t=2012} t + \alpha^i + \mathrm{D}_i + \varepsilon_{it}$$

[23] This was the most robust approach that could be feasibly implemented. More robust approaches, including an Instrumental Variables design, and a Regression Discontinuity Design, were trialled but proved infeasible.

In this model, each of employment, turnover and turnover per worker in postcode *i* in period *t* (Y_{it}) is determined by its exposure to BDUK subsidies (T_{it}), and the parameter β gives an estimate of the effect of interest. The model controls for general trends at the national level (t)[24] 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. The model also controls for any time invariant unobserved differences between postcodes (α^i) and a dummy variable ($\mathbf{D}_i$) was also included to capture the influence of any unobserved differences between postcodes benefitting from Phase One and Phase Two of the programme. The variable α_i represents the estimated intercept for each postcode.

This approach mitigates the risk that systematic and observable differences between areas that received enhanced connectivity at different times are also connected to the economic performance and may bias results. There are still risks that estimates of the impact of the programme are biased by time varying unobserved differences between areas.

As defined in section 2.1.4, postcode characteristics and outcomes were also calculated for spatially stable firms and single site firms. Following regressions using all firms, regressions focusing only on those that remain situated in the same postcode before and after upgrade allows us to better gauge the effect of the upgrade on the outcomes. This is because using all firms does not take into the potential for firms to move between postcodes, therefore making it difficult to separate any effect moving may have on the outcomes from the effect of the upgrade itself. For variables constructed using only single site firms, the advantage lies in the fact that the turnover variable relates directly to the site, meaning that turnover per worker figures are likely to be more robust for this group.

An additional set of analyses were implemented using data at the firm level with a similar panel model fitted:

$$Y_{jt} = \alpha_j + \beta T_{jt} + \gamma X_{j,t}\mathrm{t} + \delta t + \alpha^i + \varepsilon_{jt}$$

Here, the local unit employment/turnover/turnover per worker for local unit j in period t (Y_{jt}), is determined by the its exposure to BDUK subsidies (T_{jt}). Again, the parameter β provides an estimate of the impact of subsidised coverage on the outcome of interest. The model also controls for national trends (t)[25], and trends at the sector level and at the level of the employment size-band of the firm ($X_{j,t}\mathrm{t}$). The model also allowed for unobserved differences between firms that do not change over time (α^i). The analysis was limited to only those firms located on postcodes which received an upgraded coverage at some point in time, to limit the potential biases driven by systematic differences between firms located on postcodes benefitting from BDUK subsidies and those that are not.

As in the postcode level analysis, the regressions were also run using spatially stable and single site only firms. For the firm level analysis, this did not require any further processing with the sample simply limited to the relevant group of firms.

In all models, the equations were first estimated using random effects and compared to a fixed effects model. In every case, the Hausman test rejected the random effects specification in favour of fixed effects. This implies that the unobserved components of the model (i.e. postcode level effects) were correlated with the other independent variables in the model.

It is important to note that the focus here is on the effect of making superfast broadband speeds available, rather the effects of businesses taking up these speeds. While the latter could potentially be achieved by comparing the relative performance

[24] Which is equal to the calendar year (i.e. 2012, 2013, 2014 etc).

[25] Defined in the same way as above.

of businesses that take-up the technology[26] and those that do not, other studies[27] have shown the major challenges involved in establishing causality with such a design. Higher productivity businesses are more likely to take-up higher broadband speeds, and once self-selection has been accounted for, past research has found it challenging to demonstrate that faster speeds contribute to productivity growth. Focusing on availability rather than use helps avoid these types of complexities, giving results that can be more clearly interpreted as the causal effect of the subsidised coverage.

2.3.2 Validity of the Pipeline Design

In order for the pipeline design to produce unbiased estimates of the programme impact, there must be no 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. In general, this assumption holds. However, postcodes/local units receiving investment in 2016 as part of Phase Two do appear to differ to those in Phase One and across all other years. More specifically, average employment appeared to be higher, possibly reflecting the greater focus on urban areas in Phase Two. The tables in Appendix A outline the differences between postcodes (as of 2012) receiving investment in phase 1, phase 2 and in each year from 2013 to 2016. The issue raised was accommodated by allowing for unobserved differences between postcodes treated in Phase 1 and Phase 2 using postcode level fixed effects.

2.3.3 Postcode Level Results

Table 2.2 below sets out the estimated results of a variety of models exploring the overall effects of the subsidised coverage on the main outcomes of interest. For each of these models, the 'treatment' variable takes the value of 1 in both the year that the postcode first receives subsidised coverage and in subsequent years, and the value of zero in preceding years. By doing so, the models aim to capture the long-term effect of the programme on the outcomes of interest. The models include controls for region, sector and firm size in addition to time trends, overall and for each control. The dependent variables in the below models were all specified in log form.[28]

- Model 1 compares the outcomes of interest using all postcodes identified as white following the open market review process. No statistically significant effect was found on employment in this model, however statistically significant impacts on turnover per annum and turnover per worker were found of 0.4 percent and 0.5 percent respectively. This model includes a control group of firms based on white postcodes that did not benefit from subsidised coverage, and could produce biased results if there are unobserved but features of the firms located on those postcodes or features of the local economy that influence their ability to accommodate economic growth.

- Model 2 addresses these issues by restricting the analysis only to those postcodes that benefitted from BDUK subsidies. A statistically significant effect is found on the three main outcomes of interest. These suggest that subsidised coverage led to an increase of 0.8 percent in employment, a 1.2 percent increase in turnover and a 0.3 percent increase in turnover per worker. The number of local units within a postcode is also estimated to have increased by approximately 0.25 percent following BDUK investment.

- Model 3 applies the same framework but limits the local units included to just those that remain on the same postcode for the full 5 years from 2012 to 2016. These models also demonstrate employment impacts, turnover and turnover per

[26] This was not feasible due to the scope of the data available - no information was available on which firms took up broadband.

[27] See Broadband adoption and firm productivity: Evidence from Irish manufacturing firms, Haller, S.A., and Lyons, S. 2014, for a discussion.

[28] Distributions of dependent variables all better resemble a normal distribution in log form.

worker impacts and suggest that the effects observed in the Model 1 are not solely the result of the relocation, creation and closure of firms. The magnitude of the estimated productivity effects (0.38 percent) are broadly in line with other recent research into the economic impact of broadband in the UK[29].

- Model 4, the final model in table 2.2 limits the analysis to just enterprises that operate from one site only. These models suggest a negative impact on employment of around 0.5 percent but a positive effect on turnover of 1 percent. Turnover per worker is estimated to have increased by 1.4 percent for this group of firms. One key purpose of these analyses was to establish the reliability of the approach of apportioning firm turnover to local units, though it should be noted that there are substantial differences in the composition of single site firms relative to all local units benefitting from the programme. This group of firms were substantially more likely to be in the manufacturing sector (27 percent relative to 19 percent) or in the construction sector (20 percent relative to 10 percent) and tended to be smaller businesses (80 percent with 0 to 9 employees, in comparison to 73 percent).

Table 2.2: Estimated Effect of Subsidised Coverage on Employment, Turnover and Turnover per Worker

	Model 1		Model 2		Model 3		Model 4	
Postcodes included	All White		Treated		Treated		Treated	
Local units included	All		All		Spatially stable		Single site	
Model	Fixed effects		Fixed effects		Fixed effects		Fixed effects	
Dependent variable	Log number		Log number		Log number		Log number	
Outcome	Coeff.	R^2	Coeff.	R^2	Coeff.	R^2	Coeff.	R^2
Employment	-0.001	0.100	0.008***	0.100	0.002*	0.044	-0.005**	0.043
Turnover	0.004**	0.041	0.012***	0.039	0.006***	0.007	0.010***	0.014
Turnover per worker	0.005***	0.030	0.003**	0.032	0.004**	0.007	0.014***	0.008
Number of local units	-	-	0.003***	0.035	-	-	-	-

Source: Ipsos MORI analysis.

*Table note. *** indicates the coefficient was significant at the 99 percent level and ** indicates the coefficient was significant at the 95 percent level. * indicates the coefficient was significant at the 90 percent level. Since the model is a log-linear model, the interpretation of coefficients is that the upgrade is associated with a change in the magnitude of the outcome variable of the coefficient expressed as a percentage, all other things being equal. This applies to all tables in which the dependent variable is specified as 'log number'.*

In addition to the models implemented above, further robustness checks were made by replacing the time trend variable with unobserved time fixed effects. This more stringent specification allows for unobserved but time specific shocks affecting all postcodes. Findings from these showed qualitatively similar results to models 2 and 3 in the table above. The models found effects of 0.5 percent on employment, 0.8 percent on turnover and 0.4 percent on turnover per worker.

2.3.4 Urban and Rural Postcodes

A further set of models explored the relative effects of the programme in urban and rural areas (see table 2.3). This analysis was completed using ONS urban and rural classification at an Output Area level[30], which is available for England, Wales and Scotland. The analysis found differential effects in urban and rural areas:

[29] The Economic Impact of Broadband: Evidence from OECD Countries, Dr. Pantelis Koutroumpis, Ofcom, 2018

[30] A zone for reporting small area statistics representing around 10 postcodes.

- The estimated effects of subsidised coverage on employment and turnover are larger on urban postcodes in comparison to rural ones. However, there was no evidence that enhanced connectivity subsidised by the programme raised the productivity of firms located in urban areas, while rural postcodes saw turnover per worker rise by 0.43 percent. The results also indicated that subsidised coverage had a larger effect on the number of enterprises located in urban areas than in rural areas.

Table 2.3: Estimated Effect of Subsidised Coverage on Employment, Turnover and Turnover per Worker by Urban/Rural Postcodes

	Model 11		
Areas included	Treated Only		
Model	Fixed effects		
Dependent variable	Log number		
Treatment variable	Binary (0 before and 1 after investment)		
Unobserved area effects	Yes		
Unobserved area trends	Yes		
Outcome	Urban Coeff.	Rural Coeff.	R^2
All firms			
Employment	0.013***	0.006***	0.107
Turnover	0.014***	0.012***	0.043
Turnover per worker	0.000	0.004**	0.032
Number of firms	0.004*	0.002*	0.038
Spatially stable			
Employment	0.006**	0.000	0.032
Turnover	0.012**	0.004**	0.007
Turnover per worker	0.005*	0.003*	0.008

Source: Ipsos MORI analysis.

*Table note. *** indicates the coefficient was significant at the 99 percent level and ** indicates the coefficient was significant at the 95 percent level. * indicates the coefficient was significant at the 90 percent level.*

2.3.5 Firm Level Effects

Table 2.4 below shows the results from the analysis of the firm level BSD dataset. For each of these models, the 'treatment' variable takes the value of 1 in both the year that the postcode first receives a subsidised coverage and in subsequent years, and the value of zero in preceding years. Like the model in section 2.3.3 the model aims to capture the long-term effect of the programme on the three outcomes. The models include controls for region, sector and firm size in addition to time trends, overall and for each control. The dependent variables in the below models were all specified in logarithmic form[31] so the estimated coefficients represent the estimated percentage effect on the outcome.

- Model 1 fits the specification to all local units included in the sample and produces similar results to the postcode level analysis. It suggests subsidised coverage led to an average increase of employment of 0.6 percent, turnover of 1.6 percent

[31] Distributions of dependent variables all better resemble a normal distribution in log form.

and turnover per worker of 0.9 percent. These effects broadly correspond to the pattern of results seen in the postcode level models, though is suggestive of larger effects at the firm level.

There are also some important differences of interpretation to highlight with respect to the postcode level models. The postcode level models provide an estimate of the causal effect of subsidised coverage on the total level of economic activity on the postcode. However, these firm level results include the effects of relocating to a postcode that was enabled. The findings will therefore include all effects of the relocation on the business—and while access to improved connectivity may help raise efficiency or support growth, other aspects of the relocation decision may also contribute to these results. For example, the relocation may have been primarily motivated by expansion requirements, and access to larger premises may have been the central driver of employment impacts in these cases.

- Model 2 restricts the sample to just spatially stable units and produces very similar results to those obtained when looking at the postcode level data.

- Model 3 looks exclusively at single site enterprises and finds effects only on turnover and turnover per worker of 1.5 and 1.6 percent respectively. The negative effect on employment disappears in these analyses.

Overall, results from the firm level analysis support the conclusions from the postcode level analysis and are consistent with the above models.

Table 2.4: Estimated Effect of Subsidised Coverage on Employment, Turnover and Turnover per Worker—Firm Level Results

	Model 1		Model 2		Model 3	
Postcodes included	Treated		Treated		Treated	
Local units included	All		Spatially stable		Single site	
Model	Fixed effects		Fixed effects		Fixed effects	
Dependent variable	Log number		Log number		Log number	
Outcome	Coeff.	R^2	Coeff.	R^2	Coeff.	R^2
Employment	0.006**	0.127	0.002**	0.104	-0.001	0.163
Turnover	0.016**	0.011	0.005**	0.009	0.015**	0.010
Turnover per worker	0.010**	0.016	0.003**	0.014	0.016**	0.231

Source: Ipsos MORI analysis.

*Table note. ** indicates the coefficient was significant at the 99 percent level and * indicates the coefficient was significant at the 95 percent level.*

2.3.6 Effects by Home Nation

The firm level analysis was also repeated to explore effects by home nation. Table 2.5 presents these results, illustrating the consistency across the administrations. In all cases, the results suggested that subsidised coverage had a positive effect on turnover and turnover per worker, while positive effects on employment were also found in Wales and England. These findings are similar to the overall findings presented above and would suggest that the benefits of superfast broadband have been evenly spread. The coefficients for Northern Ireland are of similar magnitude to those for England, though are not statistically significant. Models for spatially stable firms in Northern Ireland and Wales suffer from a relative lack of observations that are likely the cause of the lack of any significant effects here.

Table 2.5: Estimated Effect of Subsidised Coverage on Employment, Turnover and Turnover per Worker—Results by Home Nation

	Model 1		Model 2	
Postcodes included	Treated		Treated	
Local units included	All		Spatially stable	
Model	Fixed effects		Fixed effects	
Dependent variable	Log number		Log number	
Outcome	Coeff.	R^2	Coeff.	R^2
Scotland:				
Employment	0.000	0.127	-0.007***	0.108
Turnover	0.021***	0.014	0.005	0.011
Turnover per worker	0.020***	0.018	0.012***	0.016
Wales:				
Employment	0.007***	0.118	-0.000	0.102
Turnover	0.016***	0.010	0.005	0.010
Turnover per worker	0.009***	0.021	0.005	0.020
Northern Ireland:				
Employment	0.004	0.102	0.003	0.102
Turnover	0.029***	0.009	0.004	0.011
Turnover per worker	0.024***	0.009	0.001	0.013
England:				
Employment	0.007***	0.129	0.003***	0.105
Turnover	0.015***	0.011	0.005***	0.009
Turnover per worker	0.008***	0.016	0.002	0.014

Source: Ipsos MORI analysis.

*Table note. *** indicates the coefficient was significant at the 99 percent level and ** indicates the coefficient was significant at the 95 percent level and * indicates the coefficient was significant at the 90 percent level.*

2.3.7 Effects by Size-band

Using the firm level data, it has been possible to explore the impact of the Superfast Broadband Programme on firms of differing sizes and within different sectors[32]. A further set of analyses look at these differing effects. The first set are presented in table 2.6 and look at enterprise size, i.e. the size of the enterprise and not the local unit.

- Model 1 looks at all firms in the sample and implies significant effects on turnover per worker for each size band. Employment appears to increase further in micro and large firms and decreases in small firms. Turnover increases by between 1.6 and 2.5 percent for micro and large firms respectively.

- Model 2 limits the sample to spatially stable firms and finds fewer significant effects. One potential explanation for this may be the reduced sample size for these regressions. However, there appears to still be a significant impact on turnover

[32] As defined in the BDUK Benefits Model

for micro, medium and large firms which is largest for large firms. There are also significant impacts on turnover per worker for medium and large firms of 1.5 and 0.8 percent respectively. Employment increases only in micro firms by approximately 0.2 percent.

- Model 3 explores single site firms only and produces significant effects on turnover per worker for micro, small and medium firms. The effect is largest for medium sized firms and smallest for small. No significant effects are found for large firms which is unsurprising given the small sample of large, single site firms.

Together these results suggest that employment gains are experienced predominantly in micro firms whilst turnover gains are captured more widely between micro, medium and large firms. There did not appear to be significant effects for small firms.

Table 2.6: Estimated Effect of Subsidised Coverage on Employment, Turnover and Turnover per Worker—by Size of Firm

	Model 1		Model 2		Model 3	
Postcodes included	Treated		Treated		Treated	
Local units included	All		Spatially stable		Single site	
Model	Fixed effects		Fixed effects		Fixed effects	
Dependent variable	Log number		Log number		Log number	
Outcome	Coeff.	R^2	Coeff.	R^2	Coeff.	R^2
Micro:						
Employment	0.008**	0.127	0.002*	0.104	-0.000	0.163
Turnover	0.016**	0.011	0.004*	0.009	0.017**	0.010
Turnover per worker	0.008**	0.016	0.002	0.014	0.017**	0.023
Small:						
Employment	-0.009**	0.127	-0.001	0.104	-0.007**	0.163
Turnover	0.005	0.011	0.005	0.009	0.005	0.010
Turnover per worker	0.014**	0.016	0.005	0.014	0.012**	0.023
Medium:						
Employment	0.004	0.127	0.004	0.104	0.011*	0.163
Turnover	0.019**	0.011	0.019**	0.009	0.036**	0.010
Turnover per worker	0.015**	0.016	0.015*	0.014	0.025**	0.023
Large:						
Employment	0.006**	0.127	0.003	0.104	0.023	0.163
Turnover	0.025**	0.011	0.011**	0.009	0.037	0.010
Turnover per worker	0.019**	0.016	0.008*	0.014	0.014	0.023

*Source: Ipsos MORI analysis. *** indicates the coefficient was significant at the 99 percent level and ** indicates the coefficient was significant at the 95 percent level and * indicates the coefficient was significant at the 90 percent level.*

2.3.8 Results by Sector

In addition to analysing the impact of BDUK investment on the main outcomes of interest by the enterprise size band of local units in our sample, analysis has also explored at differential impacts by sector[33]. Table 2.7 of provides estimates of the impact of subsidised coverage by sector:

- Model 1 shows the estimated effect of subsidised coverage on all local units included in the sample. Statistically significant impacts are identified on employment for 8 out of the 13 groupings with the highest for Utilities (2.1 percent). Eleven sector groups saw turnover growth as a result of having received BDUK investment, typically in the region of 1 percent (though a number of sectors saw higher turnover growth). Effects on turnover per worker ranged from 0.8 percent to 4.7 percent (across 7 sectors).

- Model 2 isolates only the spatially stable local units for analysis and finds fewer significant effects, partly explained by a reduced sample size. These models find an impact on employment for only 4 sectors including Health, Education, Other Community Services and Manufacturing. The estimated impact on Manufacturing is negative (minus 0.1 percent). Impacts on turnover and turnover per worker are also evident on a fewer number sectors in these models but for the education (P) and health and social work (Q) sectors.

- Model 3 presents the results from the analysis of single site firms only. Findings from these models are similar to those from model 1 albeit with fewer statistically significant effects resulting from the reduction in sample size. However, impacts on turnover and turnover per worker for these firms are typically more prominent. For example, the effect on turnover for the post and telecommunications sector was not present in the full sample model but rises to 4.4 percent in the single site model. The single site measures of turnover are more accurate as described earlier in section 2.4.1] and lend further support to the findings from model 1.

The main messages at a sector level are as follows[34]:

- Education and Health and Social Work: The chief beneficiaries of subsidised coverage were the education and health sectors[35]. These sectors saw gains in turnover per worker of 4.7 and 3.7 percent respectively. The gains seen in these two sectors far exceeded those in other sectors, suggesting that access to superfast connectivity removed a substantial constraint on the operation of those businesses. Further qualitative research into the factors driving these gains could be beneficial, though it might be possible to speculate that increasing digitalisation of the NHS may have been important factors in the health sector.

- Manufacturing: The findings suggested that the subsidised coverage raised the efficiency of the manufacturing sector by around 0.8%. While this conflicts with the results of the past studies which found no causal effect of improved broadband speeds on the efficiency of the manufacturing sector,[36] the focus of prior studies was on total factor productivity growth rather than the proxy measure for average labour productivity adopted here. Manufacturers appear to have been able to raise their turnover as a result of the technology without expanding their employment. This could possibly be a signal that manufacturers were carrying spare capacity during the downturn.

[33] Grouping as defined in the BDUK Benefits Model

[3434] NB. The data did not cover the agricultural sector.

[35] This will exclude public sector activity, but would include the activities of General Practitioners and Dentists that operate as private enterprises.

[36] Broadband adoption and firm productivity: Evidence from Irish Manufacturing Firms, Haller and Lyons, Economic and Social Research Institute, Dublin, 2012.

- Professional services: High value added professional services sectors saw growth in employment (0.7%), turnover (1.5%) and turnover per worker (0.7%) following the upgrade. This result is potentially unsurprising given the sector's generally high consumption of information and communication technology over the past 30 years.

- Construction and Accommodation and Food: The construction and hospitality industries have benefitted from greater turnover as a result of access to faster connectivity—but appeared to also expand their employment in response to the greater demand and did not realise efficiency gains as a consequence. This could be expected—increased connectivity through fixed broadband may enable these industries to access wider markets, but may not help firms deliver efficiency gains, e.g. construction activity is delivered off-site, so fixed broadband coverage may not enhance the efficiency of the production process, while the hospitality sector is highly labour intensive and difficult to digitise. It should be noted that there may be some doubt about the construction industry results, as figures on turnover are based on VAT returns and there may be some degree of under-recording.

- Financial intermediation and transport and storage: Subsidised coverage appeared to have no effect on the performance of the finance and transport and storage sectors.

Table 2.7: Sector level results

	Model 1		Model 2		Model 3	
Postcodes included	Treated		Treated		Treated	
Local units included	All		Spatially stable		Single site	
Model	Fixed effects		Fixed effects		Fixed effects	
Dependent variable	Log number		Log number		Log number	
Outcome	Coeff.	R^2	Coeff.	R^2	Coeff.	R^2
C—Manufacturing						
Employment	0.002	0.127	-0.001*	0.104	-0.003	0.163
Turnover	0.011**	0.011	-0.005	0.009	0.017**	0.010
Turnover per worker	0.009**	0.016	-0.005	0.015	0.019**	0.023
DE—Electricity, Gas and Water Supply						
Employment	0.021**	0.127	0.010	0.104	0.020	0.163
Turnover	0.031*	0.011	-0.008	0.009	0.056*	0.010
Turnover per worker	0.009	0.016	-0.018	0.015	0.037	0.023
F—Construction						
Employment	0.008**	0.127	0.002	0.104	-0.002	0.163
Turnover	0.010**	0.011	0.003	0.009	0.007	0.010
Turnover per worker	0.002	0.016	0.001	0.015	0.009*	0.023
G—Wholesale and Retail Trade						
Employment	0.004**	0.127	0.001	0.104	-0.003	0.163
Turnover	0.013**	0.011	0.006*	0.009	0.013**	0.010
Turnover per worker	0.009**	0.016	0.005**	0.015	0.016**	0.023
H—Transport and Storage						
Employment	0.005	0.127	-0.002	0.104	-0.002	0.163
Turnover	0.012	0.011	0.000	0.009	0.012	0.010
Turnover per worker	0.006	0.016	0.001	0.015	0.013	0.023
I—Hotels and Restaurants						
Employment	0.013**	0.127	0.007**	0.104	0.000	0.163
Turnover	0.016**	0.011	0.008	0.009	0.002	0.010
Turnover per worker	0.002	0.016	0.000	0.015	0.002	0.023
J—Post and Telecommunications						
Employment	0.006*	0.127	0.000	0.104	-0.002	0.163
Turnover	0.012*	0.011	-0.001	0.009	0.042**	0.010
Turnover per worker	0.006	0.016	-0.001	0.015	0.045**	0.023
K—Financial Intermediation						
Employment	0.005	0.127	0.006	0.104	0.005	0.163
Turnover	0.012	0.011	0.014	0.009	-0.002	0.010
Turnover per worker	0.006	0.016	0.008	0.015	-0.009	0.023
LMN—Real Estate, Professional Services and Business Activities						
Employment	0.008**	0.127	0.004**	0.104	0.004	0.163
Turnover	0.015**	0.011	0.004	0.009	0.019**	0.010
Turnover per worker	0.008**	0.016	-0.001	0.015	0.014**	0.023
O—Public Admin and Defence; Compulsory Social Security						
Employment	0.008	0.127	-0.003	0.104	-0.006	0.163
Turnover	0.055**	0.011	-0.022	0.009	-0.069*	0.010
Turnover per worker	0.047**	0.016	-0.018	0.015	-0.064	0.023
P – Education						
Employment	0.014**	0.127	0.009*	0.104	0.000	0.163
Turnover	0.051**	0.011	0.051**	0.009	0.033	0.010
Turnover per worker	0.037**	0.016	0.042**	0.015	0.033	0.023
Q—Health and Social Work						
Employment	0.003	0.127	-0.001	0.104	0.001	0.163
Turnover	0.045**	0.011	0.042**	0.009	0.032**	0.010
Turnover per worker	0.042**	0.016	0.043**	0.015	0.031**	0.023
RS—Other Community, Social and Personal Services						
Employment	0.007**	0.127	0.002	0.104	0.001	0.163
Turnover	0.021**	0.011	0.012*	0.009	0.019*	0.010
Turnover per worker	0.014**	0.016	0.011*	0.015	0.019*	0.023

Source: Ipsos MORI analysis.

*Table note. *** indicates the coefficient was significant at the 99 percent level and ** indicates the coefficient was significant at the 95 percent level and * indicates the coefficient was significant at the 90 percent level.*

A similar exercise was undertaken focussing solely on sectors defined as creative industries by DCMS as reported in table 2.8. Overall, the results for the creative industries are in line with those above with the most significant effects evidenced in model one when all postcodes are used in the analysis. Once again, the results for turnover and turnover per worker are most significant across the models estimated.

Table 2.8: Creative Industry results

	Model 1		Model 2		Model 3	
Postcodes included	Treated		Treated		Treated	
Local units included	All		Spatially stable		Single site	
Model	Fixed effects		Fixed effects		Fixed effects	
Dependent variable	Log number		Log number		Log number	
Outcome	Coeff.	R^2	Coeff.	R^2	Coeff.	R^2
Creative Industries						
Employment	0.009***	0.124	0.001	0.146	0.003	0.103
Turnover	0.019***	0.057	0.013**	0.037	0.040***	0.068
Turnover per worker	0.010**	0.024	0.012**	0.026	0.037***	0.034

Source: Ipsos MORI analysis.

*Table note. *** indicates the coefficient was significant at the 99 percent level and ** indicates the coefficient was significant at the 95 percent level and * indicates the coefficient was significant at the 90 percent level.*

2.4 Analysis of the Annual Business Survey

Unlike the BSD, the ABS involves a census of large firms and a sample survey of SMEs. Constructing a longitudinal panel dataset from each ABS between 2012 and 2016 creates a sample that is dominated by large firms only. An alternative approach was also taken to the econometric analysis of this data. A difference-in-difference model was fitted to compare changes in the outcomes between firms treated using a subset of local units for whom data was available in 2012 and 2015, with the basis of this analysis being local units. The model was specified as:

$$\Delta Y_{jt} = \alpha + \beta T_{jt} + \gamma X_{j,t} + \delta t + \varepsilon_{jt}$$

This approach accounts for any unobserved—but time invariant—differences between local units that determine both the timing of superfast coverage subsidised through the programme and its economic performance. As with the above, there are still risks that estimates of the impact of the programme are biased by time varying unobserved differences between firms. It should also be noted that the results relate to the estimated impact of subsidised coverage but do not account for the possibility that some postcodes would have otherwise been upgraded in the absence of the programme.

2.4.1 Comparison of Treatment and Comparison Sample

Comparison of the local units in our sample in a postcode receiving investment before in 2015 and those receiving investment later is necessary to ensure that the two samples are balanced and different compositions do not bias findings. Comparing the sample of firms that are included in the ABS for both 2012 and 2015 and that were in a postcode receiving BDUK investment in 2015, 2016 or 2017, we can see that those units that are in a postcode receiving investment in 2015 are similar to the others in terms of GVA per worker, however they do show slightly lower average employment and overall GVA apportioned to the local unit.

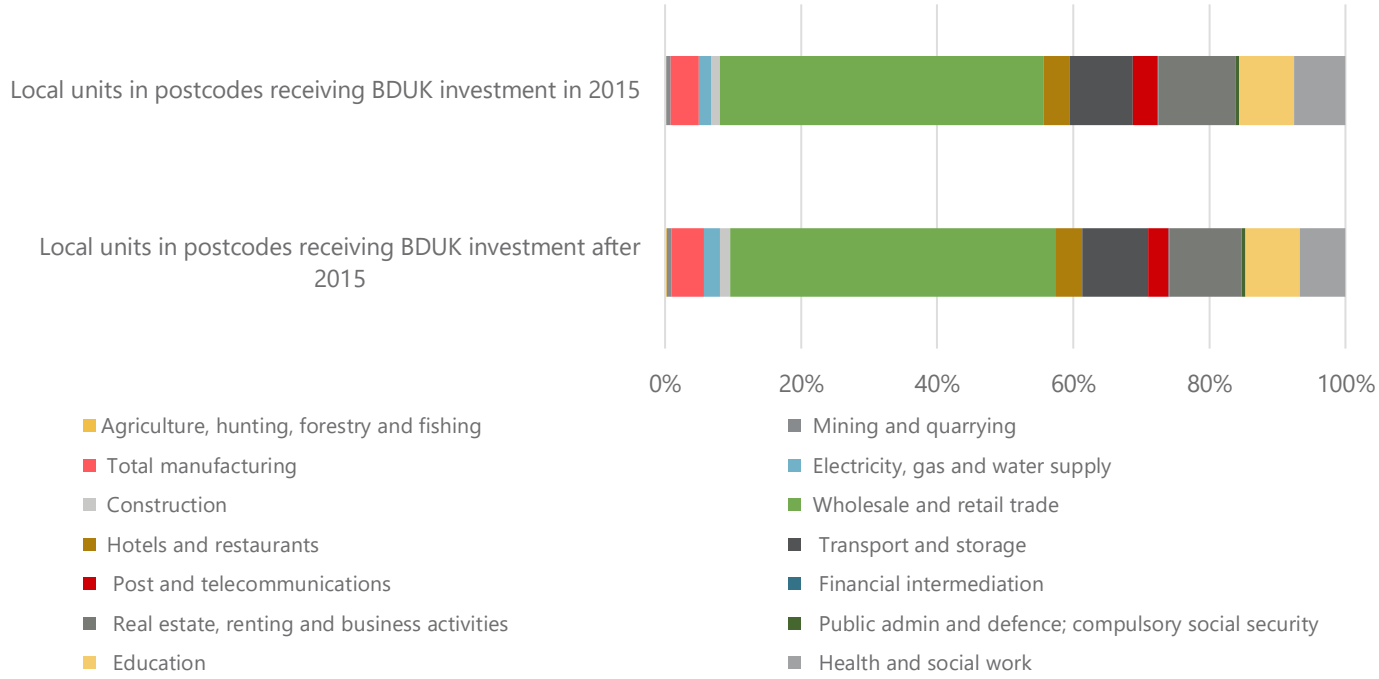
Table 2.9: ABS sample characteristics

Characteristics	Local units in postcodes receiving BDUK investment after 2015	Local units in postcodes receiving BDUK investment in 2015
Mean employment in 2012	34.5	31.4
Mean employment in 2015	35.0	31.5
Mean GVA (,000) in 2012	1622.1	1482.5
Mean GVA (,000) in 2015	1749.5	1574.0
Mean GVA per worker (,000) in 2012	37.3	36.3
Mean GVA per worker (,000) in 2015	49.0	49.7

Source: Ipsos MORI analysis of ABS data

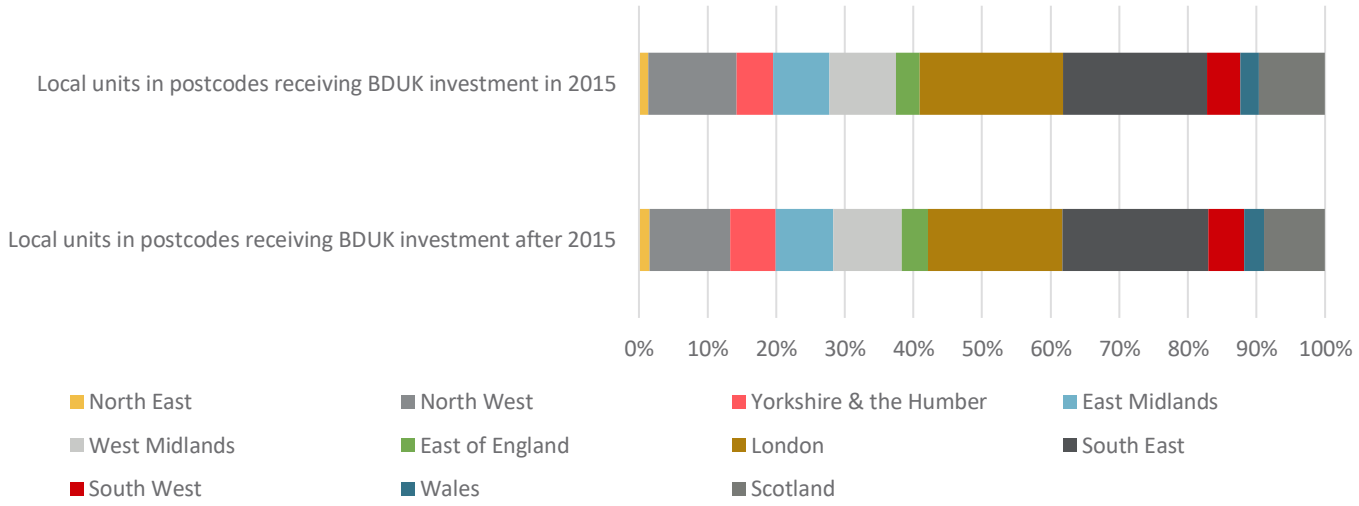
In terms of sector and regional breakdowns of these two groups, there are once again very few differences between them as evidenced in the charts in figure 2.1 and figure 2.2 below.

Figure 2.1: Sector breakdown of ABS sample



Source: Ipsos MORI analysis of ABS data

Figure 2.2: Regional breakdown of ABS sample

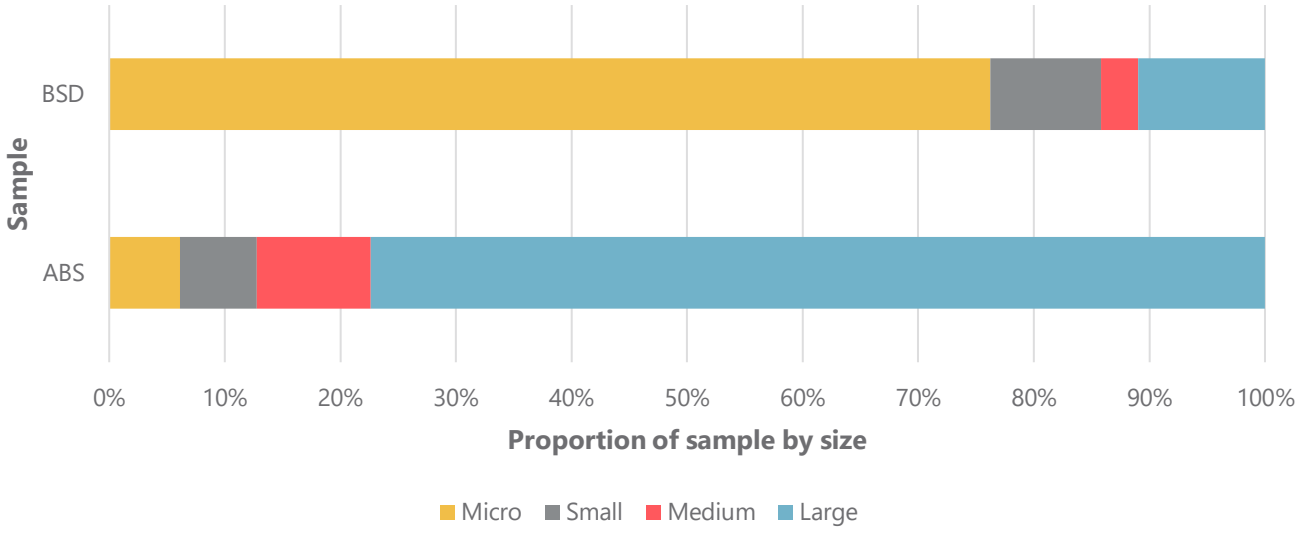


Source: Ipsos-MORI analysis of ABS data

2.4.2 Comparisons between ABS and BSD samples

There were some key differences in the makeup of the two samples used for the analysis. In particular, the ABS sample had a much larger proportion of large firms when compared to the BSD data, with over three quarters of the ABS sample made up of local units belonging to large enterprises in 2012 whereas only 11 percent of the total BSD local units belonged to large enterprises. Average employment within the local unit for the ABS sample was approximately 33.1 compared to 7.8 in the BSD.

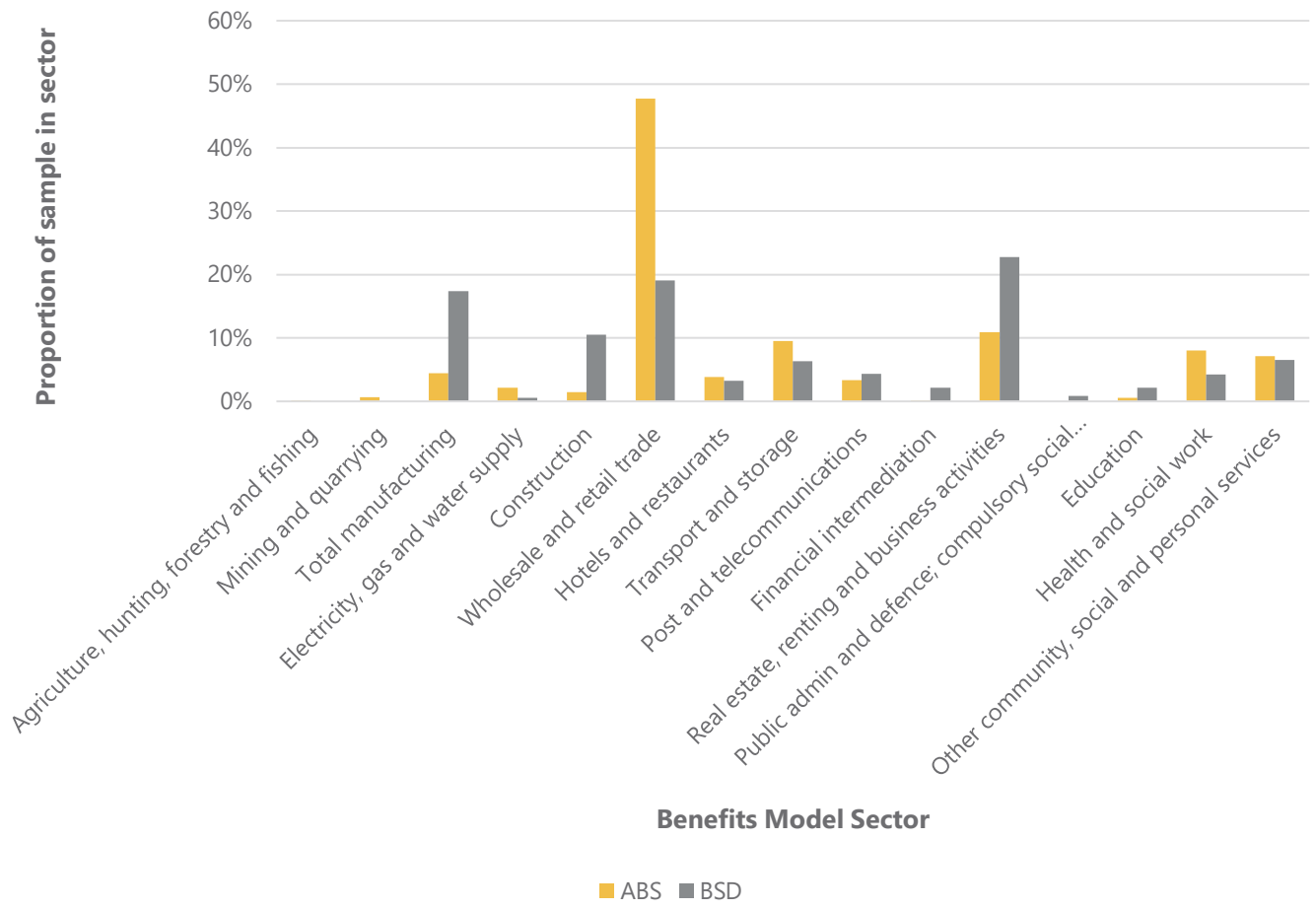
Figure 2.3: Comparison of enterprise size in 2012, ABS vs BSD



Source: Ipsos-MORI analysis of ABS and BSD data

In addition to this obvious bias towards large firms in the ABS, the ABS sample exhibited a very different sectoral composition to the BSD. Most notably, local units operating in wholesale and retail trade are the most common here whilst the BSD has a much more balanced sector distribution between manufacturing, wholesale and retail trade and real estate, renting and business activities.

Figure 2.4: Comparison of local unit sector in 2012, ABS vs BSD



Source: Ipsos-MORI analysis of ABS and BSD data

2.4.3 Results

Table 2.10 contains the results from the analysis of the ABS difference-in-difference approach (described in the introduction to Section 2.4). These regressions control for region, size and sector.

- Model 4 specifies the outcome variable in log form and makes use of two time periods, 2012 and 2015. This analysis shows significant negative impacts on each of the outcomes contained within the ABS, GVA, GVA per worker and employment.

- Model 5 instead specifies the dependent variable in first difference form[37]. In these regressions, the coefficients for GVA and GVA per worker become positive but are not statistically significant. The estimated impact on employment remains insignificant.

There are several potential explanations for these results. Firstly, it is important to bear in mind that the firms included in the ABS analysis exhibit very different characteristics to those in the BSD with a greater density of large firms. These firm are more likely to use a leased line and will not derive benefits from the programme if so. There is also a higher share of firms in retail and less in manufacturing. However, when comparing this to the results by sector in the BSD, the retail and trade sector shows significant effects on all three outcomes. It seems likely that the main issue is that most coverage was only delivered in 2015 and this may not have left enough time for an effect on GVA to appear in the data. Analysis of further data will be required to assess this and is being pursued by BDUK.

Table 2.10: Estimated Effect of Subsidised Coverage on GVA, GVA per Worker and Employment

	Model 4		Model 5	
Postcodes included	Treated		Treated	
Local units included	All		All	
Model	Difference-in-difference		Difference-in-difference	
Dependent variable	Log number		Log number (first differenced)	
Outcome	Coeff.	R^2	Coeff.	R^2
GVA	-0.086**	0.127	0.002	0.417
GVA per worker	-0.027**	0.298	0.002	0.031
Employment	-0.065**	0.068	-0.005	0.006

Source: Ipsos MORI analysis.

*Table note. ** indicates the coefficient was significant at the 99 percent level and * indicates the coefficient was significant at the 95 percent level.*

2.5 Economic Impacts

2.5.1 Local Economic Impacts

The postcode level results provide an estimate of the overall local economic impacts of the Superfast Broadband programme:

- Employment: On average, it is estimated that the programme led to employment growth of 0.8 percent on the relevant postcodes, i.e. the 232,000 postcodes receiving subsidised superfast coverage that were not purely residential. There was an average of 26.1 jobs located on these postcodes between 2012 and 2016, giving an overall estimate of 49,400 jobs created on those postcodes. This amounted to around 9 percent of the total number of jobs created on these postcodes over the period.

- Turnover: The turnover of businesses located on postcodes receiving subsidised coverage was estimated to have risen by 1.2 percent due to enhanced availability of superfast broadband. The average total turnover of businesses on relevant

[37] Subtracting the previous time period's data from the current time period's data, for each year—the first year of data is thereby dropped due to no earlier years being available.

postcodes was £3.2m per annum, giving an estimate of the total impact on turnover of businesses on these postcodes of just under £9.0bn. Again, this accounted for around nine percent of total turnover growth over the period.

- Productivity: The estimated impact of the programme on turnover per worker on relevant postcodes was 0.32 percent. Applying this to the average turnover per worker on these postcodes (£106,400) it is estimated that the share of the increase in turnover driven by higher turnover per worker was almost £350 per worker per postcode per annum. This equates to £2.1bn when aggregated across the 232,069 postcodes of interest, or around 23 percent of the total effect. It can be interpreted as a local productivity effect to the degree that changes in turnover per worker mirror changes in the underlying efficiency of the business. This proxy measure may overstate productivity gains if firms increase their outsourcing in response to access to faster broadband, or understate those gains if firms are able to access lower input prices. Our results imply the remaining £6.8bn were driven by the expansion of firms and entry and exit effects, i.e. firms relocating, opening on and leaving postcodes receiving subsidised coverage. This also implies the jobs created by expansion, entry and exit effects were more productive than average, with an estimated turnover per worker of £139,000, in line with the national average over the period.

The findings implicitly account for any very localised displacement or offsetting effects driven by wage or other price impacts that may have occurred through redistribution of economic activity within a postcode, e.g. a new business taking sales away from neighbouring firms. However, the findings do not account for these wider effects at longer distances. Nevertheless, parallel results that find that the programme reduced unemployment at the LSOA provides some evidence that the effects observed do not merely represent displacement effects at the neighbourhood level, as explored in the following section.

Table 2.11: Overall Economic Impacts—Postcodes Receiving Subsidised Coverage

Effect	Estimated Effect (%)	Average per Postcode 2012-2016	Per Postcode Effect	Postcodes	Total Effect
Employment	0.81	26.19	0.21	232,069	49,361
Turnover (£ms)	1.21	£3.2m	£38,600	232,069	£8,951m
Turnover per Worker	0.32	£106,400	£9,000*	232,069	£2,089m

Source: Ipsos MORI analysis.

Table note. Asterisked value (*) calculated as 26.19 x £106,400 x 0.32

The extent to which these economic impacts are driven by entry and exit effects, i.e. firms moving in and out of postcodes can be explored by comparing the overall effects of the programme at a postcode level to those firms that did not change location between 2012 and 2016. The table below provides a similar estimate of the impact of the programme focusing only on 'spatially stable' local units, and suggests that around 86 percent of the job creation and 65 percent of the impacts on turnover were driven by incoming or new firms. However, most of the apparent gain in efficiency (almost 80 percent) was driven by spatially stable units.

Table 2.12: Overall Economic Impacts—Spatially Stable Units only

Effect	Estimated Effect (%)	Average per local unit 2012-2016	Per Local Unit Effect	Number of Local Units	Total Effect
Employment	0.17	9.6	0.017	407,909	6,800
Turnover	0.63	£1.2m	£7,700	407,909	£3.1m
Turnover per Worker	0.39	£106,400	£4,007	407,909	£1,634

Source: Ipsos MORI analysis.

Table note. Asterisked value (*) calculated as 26.19 x £106,400 x 0.32

2.5.2 National Economic Impacts

At the national level, it is likely that the local economic impacts described above will be largely neutral. While businesses located on postcodes receiving subsidised coverage have expanded their sales, this will have come at the expense of loss of market share for competing firms who could be located locally, elsewhere in the U.K. or overseas. The findings also suggest 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 where firms were able to expand without displacing the activities of domestic based competitors, increased demand for factor inputs can be expected to have placed additional upward pressure on prices, resulting in reductions in output and employment in other locations.

As such, only the effects of the programme in terms of raising efficiency, i.e. turnover per worker, are considered to be economic benefits at the national level, in line with the HM Treasury Green Book. However, while the results above suggest that around 23 percent of the overall growth effect was driven improvements in turnover per worker, it is likely that this will also overstate the net economic benefits involved if productivity was raised by more productive firms relocating to postcodes receiving to subsidised coverage and less productive firms moved out or closed. The impacts could also be overstated if firms could expand at the expense of firms based elsewhere.

These types of effect cannot be measured directly, and the following approach has been adopted to assess the national economic benefits associated with the programme. Firstly, the focus is restricted to firms that did not change location between 2012 and 2016, i.e. spatially stable firms, giving greater assurance that the overall effect was driven by improvements in efficiency rather than displacement or crowding out effects. Secondly, the efficiency gain is assumed to apply only to workers in place before the postcode was upgraded—with any further output created by the recruitment of additional workers assumed to be represent a displacement effects. This gives the following results:

- Efficiency effects on spatially stable firms: The results of the analysis suggested that the programme led to an improvement in the efficiency (turnover per workers) of local units that did not change location between 2012 and 2016 of 0.38 percent. Average GVA per worker for this group of firms was £38,120 in 2012 (in 2016 prices), giving an estimated impact on GVA per worker of £145 (assuming the effect on turnover per worker also applies to GVA per worker). Average employment for this group of firms was 9.6 between 2012 and 2016, giving an estimate of the overall uplift in GVA per annum per firm of £1,391 due to improvements in efficiency resulting from subsidised coverage.

- Gross GVA impact: A total of 408,000 local units that did not move location are thought to have benefitted from subsidised coverage, with the time distribution set out in the table below. It is assumed that the productivity effect estimated above apply from the point installation and do not increase or decay with time. Based on these assumptions,

it is estimated that the programme led to an overall increase in national output of £1.3bn between 2012 and 2016 (in 2015 prices).

It is important to highlight that this is a conservative approach—and will not include any productivity effects driven by the displacement of output from lower to higher productivity producers. Additionally, the results assume that turnover per worker is a reasonable measure of the efficiency gains associated with the programme—while this measure is widely used as a proxy for productivity in studies using the BSD[38], it accounts for workers employed in the production process but not other factor inputs such as capital, raw materials, or outsourcing. On the other hand—there may have been productivity gains that were captured by providers of superfast broadband services, e.g. stemming from local monopoly power for example, which would not be visible in measures of GVA.

Table 2.13: Estimated National Economic Impact (2016 prices)

Local units receiving subsidised coverage in ...	2012	2013	2014	2015	2016	Total
2013	0	22748	22748	22748	22748	
2014	0	0	138148	138148	138148	
2015	0	0	0	173468	173468	
2016	0	0	0	0	73348	
Total	0	22748	160896	334364	407712	
Total GVA impact	0.0	31.6	223.7	465.0	567.0	1287.3

Source: Ipsos MORI analysis
Table note.Number of firms benefitting calculated as £1387 x the number of firms benefitting.

[38] For example, Decomposing UK aggregate labour productivity and growth: 1998-2013, Enterprise Research Centre, 2016

3 Labour Market Impacts

This section explores the labour market impacts of the Superfast Broadband Programme between 2012 and 2016. The central focus of the analysis is on how far the programme helped reduce unemployment, long-term unemployment, and out of work benefit claimants. This section also provides an estimate of the value of these effects.

3.1 Introduction

The results of the evaluation suggest that the local employment effects of Superfast Broadband programme have so far been relatively significant. The estimated impact of subsidised broadband coverage on employment on relevant postcodes was in the order of 0.8 percent by 2016—equivalent to the creation or safeguarding a total of 49,400 additional jobs (see section 2.5.1). In general, these job creation effects would generally be considered, under the principles of HM Treasury Green Book, to be neutral at the national level. Much of the impact is thought to be driven by the retention or attraction of businesses to subsidised postcodes or through displacement or crowding out of activity at the local level or elsewhere (as explained in Section 1.1).

However, there may be economic benefits at the national level if the programme has helped protect previously low connectivity areas from the loss of economic activity: The consequences of losing businesses to an area can also be difficult to reverse, as it reduces the extent to which incoming firms can expect to capture the benefits of being in proximity to incumbents, e.g. through exchange of knowledge/ideas. Many workers may be able to adapt to changing circumstances by obtaining jobs or relocating to economically buoyant areas. Nevertheless, some may be tied in some way to their housing contracts, have insufficient capital to relocate, or may not offer the skillsets required to obtain alternative employment. Residents of low connectivity areas will be particularly disadvantaged if technological change increases the importance of online job search mechanisms or enables the creation of jobs roles that do not require the presence of the worker at the employer's premises. In these situations, there is a risk that workers that are less able to adjust lapse into long-term unemployment, resulting in permanent or long-term losses in the productive capacity of the economy overall.

In addition, access to superfast broadband may produce other labour market effects through enabling jobseekers and the economically inactive to widen their job search strategies or access employment opportunities that do not depend on their presence at a particular location (teleworking). These effects may help increase labour supply, resulting in further increases in the productive capacity of the economy.

This paper explores some of the above issues, providing estimates of the impact of the premises covered through the Superfast Broadband programme on unemployment, long-term unemployment, and out of work benefit claimants by June 2016. The paper also provides an estimate of the potential economic value of these impacts.

3.2 Data

3.2.1 Unemployment and Economic Activity Rates

Evidence on unemployment, long-term unemployment and the number of out of work benefits claimants at a small area level[39] for Great Britain[40] was taken from the DWP Benefits Database[41]. The DWP Benefits Database gives a snapshot of the number of residents claiming out-of-work benefits in each month. Unemployment was defined as the number of residents claiming Jobseekers Allowance (JSA), and long-term unemployment was defined as those claiming for 12 months or more. Given the timeframe for analysis, finding significant effects on the numbers claiming for longer periods were considered unlikely. Annual panel data[42] was assembled by taking the June snapshot of each year to coincide with observations available through Ofcom's Connected Nations report, which takes a snapshot of broadband connectivity every June.

The small area data from the DWP Benefits database is not spatially consistent over time. Observations of JSA claimants are reported against 2001 Census geographies up to mid-2014, and against 2011 Census geographies thereafter. In many cases, these areas did not share the same boundaries. The following approach was adopted to address this issue:

- England and Wales: Of 34,378 LSOAs defined in England and Wales for the 2001 Census, 33,519 (97 percent) were unchanged under the 2011 census geographies. The observations gathered for areas that did not have the same boundaries between 2001 and 2011 were excluded from the analysis, giving a final sample of 33,519 LSOAs.

- Scotland: Of 6,505 Data Zones defined for the 2001 Census, 333 (just 5 percent) corresponded exactly to Data Zones defined for the 2011 Census. However, the published correspondence tables give details of the share of the area of each 2001 Scottish Data Zone that is shared with each 2011 Data Zone. This measure was used to weight observations of unemployment from 2014 to 2016 to give approximate figures for 2001 Scottish Data Zones over the period.

It is also 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. Finally, these figures will also include any effects on unemployment driven by the installation of new technology, i.e. construction jobs. It is assumed that any such effects will 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.

3.2.2 Delivery of subsidised superfast broadband coverage

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 at 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

[39] Lower super output areas (LSOAs) in England and Wales, and Scottish Data Zones in Scotland.

[40] Data is not available for Northern Ireland.

[41] Available through the National Online Manpower Information System

[42] The panel dataset here comprises a series of values recorded for variables across observational units (LSOAs) over multiple years.

- 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.

As with other analyses exploring the economic impacts of the Superfast Broadband programme, all premises reported in the C3 reports were included in these measures. This includes premises claimed by providers but which did not receive a 24Mbit/s 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. 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 sensitivity of results was also checked in some analyses that only include those premises upgraded that BDUK ultimately paid for.

The expectation was that the programme would reduce unemployment through its effects in terms of the retention or attraction of businesses to those locations benefitting from enhanced broadband coverage. To understand the effects of the programme with precision, it would have ideally been possible to refine the focus solely to non-residential premises that have received subsidised coverage. However, this is not captured in the available data, and residential and non-residential premises upgraded are combined in core measures of the treatment variable. This may not be problematic—upgrading residential premises may also support reductions in unemployment—for example, through enabling teleworking or through widening job search strategies. 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 found 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.

3.2.3 Control Variables

Control variables describing the characteristics of LSOAs in 2013 were included in the model as set out in table 3.1. These variables were drawn from Ofcom's Connected Nations Report, evidence on the characteristics of local networks compiled by BDUK, the 2011 Census, the Annual Population Survey and the Annual Survey of Hours and Earnings.

Table 3.1: Control Variables

Network Characteristics	Population Characteristics
Percentage of households with NGA access Average maximum download speeds available (Mbit/s) Average download speeds (Mbit/s) Average length of line between Exchange and Cabinet Modelled average speed in 2013 Average delivery points at serving Exchange Average delivery points at serving Cabinet Percentage of postcodes in Virgin Media footprint Average estimated cost to upgrade the serving cabinet	Working age population Population aged 65 and over Population density Premises density Average gross weekly earnings Employment rate Unemployment rate

3.3 Econometric Model

To examine the effects of the programme on unemployment and labour market outcomes, it was necessary to aggregate the available data at an LSOA level. This enabled the following econometric model to be estimated:

$$Y_{it} = \alpha + \beta T_{it} + \gamma X_{i,2013} + \delta t + \varepsilon_{it}$$

In this model, 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, we only control for pre-programme characteristics to avoid possible issues with endogeneity that could cause our estimates of impact to be biased.

There are also a set of further challenges in identifying the causal effects of the programme at this level of spatial aggregation—LSOAs receiving subsidised coverage may do so due to unobserved factors that determine their long-run economic performance. As such, comparisons between LSOAs that did and did not receive the subsidies could overstate (or understate) the effects of the programme. To mitigate this issue, any LSOAs that did not receive subsidised coverage were excluded from the analysis. Estimates of the impact of the programme were driven by comparisons between those areas that received enhanced connectivity in earlier and later years. As this includes only those LSOAs that ultimately received subsidies, this will limit the risk that observed and unobserved differences between LSOAs will bias results. This approach does not fully eliminate the issues involved:

- Quantity of premises upgraded: The models developed assume a 'dose-response' relationship in which reductions in the number of claimants will be linked to the number of premises upgraded in the LSOA (or share of postcodes receiving subsidised coverage, as modelled in some analyses). However, it is possible that the volume of premises upgraded may be linked to unobserved features of areas that also determine economic performance. For example, if residents of areas with higher numbers of premises receiving superfast coverage are more likely to offer the skills needed to fill any jobs created than those in less dense areas, then this could overstate the impact of the Superfast Broadband Programme.

- Differences over time: The results of the model could also be biased if there are systematic and observable differences between areas that received enhanced connectivity at different times that are also connected to the economic performance. For example, if those areas with residents that were least able to fill jobs created by the economy received investment at later stages, then comparisons between areas receiving subsidised coverage earlier and later will overstate the impact of the programme.

Steps were taken to mitigate against these possibilities by exploiting the availability of panel data to accommodate the possible influence of unobserved differences between areas. Firstly, the core models were estimated using a difference-in-differences specification, which will account for any unobserved—but time invariant—differences between LSOAs that determine either the timing or quantity of premises upgraded through the programme and its economic performance. The models also allowed for unobserved but time-invariant effects at the level of the Travel-to-Work Area (θ^{TTWA}) as well as unobserved time trends (again, at the Travel to Work Area, $\theta^{TTWA,t}$), using the following specification:

$$\Delta Y_{it} = \alpha + \beta T_{it} + \gamma X_{i,2013} + \delta t + \theta^{TTWA} + \theta^{TTWA,t} + \varepsilon_{it}$$

There are still risks that estimates of the impact of the programme are biased by time varying unobserved differences between areas. It should also be noted that the results relate to the estimated impact of subsidised coverage but do not account for the possibility that some premises would have otherwise been upgraded in the absence of the programme.

3.4 Results

3.4.1 Overall effects

Table 3.2 below sets out the estimated results of a variety of models exploring the overall effects of the subsidised coverage on the three outcomes of core interest. In these models, the 'treatment' variable takes the value of 1 in both the year that the LSOA first receives a subsidised coverage and in subsequent years, and the value of zero in preceding years (and capture the long-term effect of the programme on the outcomes of interest). The models include the list of observable controls set out in table 3.1 and allow for unobservable trend effects at the national level, but do not allow for unobserved effects and trends at the Travel to Work Area (TTWA) level:

- A comparison of Models 1 and 2 shows the effect of adopting the pipeline design described above. When all LSOAs are included in the analysis, the results suggest that the effect of the programme is to raise the number of claimants. This apparently adverse effect disappears (except with respect to Out of Work Benefits claimants) once LSOAs were not included in the build plans of local schemes are excluded from the analysis (note that this step excludes Wales owing to the absence of a Speed and Coverage Template). These models were estimated with OLS and could be biased by unobserved differences between LSOAs that do not change with time.

- Model 3 adopts a difference-in-differences specification and is in principle robust to time invariant differences between LSOAs. This model suggested that the effect of subsidised coverage was to reduce the average number of unemployed, long-term unemployed and out of work benefits claimants by 0.85, 0.48 and 0.38 respectively (on a per LSOA basis).

- Model 4 implements the Model 3 using the natural logarithm of claimant counts[43]. These models also found that the programme reduced unemployment and long-term unemployment, though the quality of the model fit (as measured by the R^2 statistic) was very low, meaning that the variability in the right-hand side of the model explains only 1 percent or less of the variability in claimant numbers. Further inspection suggested that differences in the absolute number of claimants more closely approximated a normal distribution, and Model 3 was favoured for further refinement.

[43] The coefficients can be interpreted as the percentage effect on the number of claimants

Table 3.2: Estimated Effect of Subsidised Coverage on the Number of Unemployed, Long Term Unemployed and Out of Work Benefit Claimants

	Model 1		Model 2		Model 3		Model 4	
Areas included	All		Treated Only		Treated Only		Treated Only	
Model	OLS		OLS		First Differences		First Differences	
Dependent variable	Number of Claimants		Number of Claimants		Number of Claimants		Log No. Claimants	
Outcome	Coeff.	R^2	Coeff.	R^2	Coeff.	R^2	Coeff.	R^2
Unemployment	3.07**	0.43	0.54	0.43	-0.85**	0.13	-0.09**	0.01
LT Unemployment	0.91**	0.35	-0.19	0.34	-0.48**	0.06	-0.33**	0.00
Out of Work Benefits	12.30**	0.39	6.58**	0.42	-0.38**	0.10	0.00	0.00

Source: Ipsos MORI analysis.

Table note. *** indicates the coefficient was significant at the 99 percent level and * indicates the coefficient was significant at the 95 percent level.*

The models above are not sensitive to the overall quantity of premises upgraded within an LSOA. An LSOA with a single upgraded premise is treated equivalently to an LSOA with a large number of premises upgraded. The results of refinements to this approach are set out in table 3.3. These involved redefining the treatment variable as the cumulative proportion of postcodes in an LSOA (Model 5) and as the overall number of premises upgraded within the LSOA (Model 6). Allowances were also made for the possibility of lagged effects.

These models offered a superior fit to the data, with the results from Model 6 preferred as they are thought to be less sensitive to differences in the sizes of LSOAs and Data Zones. The results of this latter model indicated that for every 10,000 premises upgraded, the number of unemployed claimants fell by 39 over the following three years, and the number of long-term claimants fell by 5 over the same period. These effects appeared to have persistence, i.e. there are no indications that unemployment rises again at a later stage, though reductions in the number of out of work benefits claimants were only seen two years post installation.

Table 3.3: Estimated Effect of Subsidised Coverage on the Number of Unemployed, Long Term Unemployed and Out of Work Benefit Claimants, Dose-Response Models

	Model 5		Model 6	
Areas included	All		Treated Only	
Model	First Differences		First Differences	
Dependent variable	Number of Claimants		Number of Claimants	
Treatment variable	Cumulative % of postcodes receiving subsidised coverage		Number of premises upgraded	
Outcome	Coeff.	R^2	Coeff.	R^2
Unemployment	0.320	0.1986	-0.0007 **	0.2589
- *Lagged 1 year*	-0.645 **		-0.0018 **	
- *Lagged 2 years*	-0.500		-0.0014 **	
LT Unemployment	0.166	0.1586	-0.0005 **	0.1465
- *Lagged 1 year*	-0.215**		-0.0003	
- *Lagged 2 years*	-0.192		0.0002	
Out of Work Benefits	0.328	0.1215	-0.0004	0.1277
- *Lagged 1 year*	-0.474		-0.0008	
- *Lagged 2 years*	0.454		-0.0001	

*Source: Ipsos MORI analysis. ** indicates the coefficient was significant at the 99 percent level and * indicates the coefficient was significant at the 95 percent level*

Finally, the robustness of the favoured model to the inclusion of unobserved area effects and area trends at the TTWA level was tested in table 3.4. The inclusion of unobserved area effects (Model 8, the preferred model) only had a limited effect on the estimated impact on the number of claimants, e.g. from 39 to 42 JSA claimants per 10,000 premises upgraded. Qualitatively similar findings were also found using a general Fixed Effects model with unobserved area level trends (not reported in table 3.4). In terms of the central conclusions from these results:

- Delivery of subsidised coverage was found to have reduced unemployment and long-term unemployment. Every 10,000 premises upgraded are estimated to have reduced the number of JSA claimants by between 34 and 40 over a three-year period, and the number of long-term JSA claimants by between 5 and 7. These effects appear to be persistent in the short term.

- The analysis suggests that the programme did not have an effect on the number of out of work benefit claimants.

- A final model was implemented to test the robustness of the results to the roll out of Universal Credit (model 9). The introduction of Universal Credit has begun to replace of Jobseekers Allowance and other out of work benefits, leading to reduction in the numbers of claimants of these benefits. If areas benefitting from the programme first were also more likely to be included in earlier stages of the roll-out, then the results of the other models will overstate the effects of the programme. This possibility was tested by including a dummy variable taking the value of 1 from the point at which Universal Credit was rolled out to the LSOA and 0 otherwise. The results of the models did not change when controls were added for the Universal Credit roll-out.

Table 3.4: Estimated Effect of Subsidised Coverage on the Number of Unemployed, Long Term Unemployed and Out of Work Benefit Claimants, Robustness to Unobservables

	Model 6		Model 7		Model 8		Model 9	
Areas included	Treated Only		Treated Only		Treated Only		Treated Only	
Model	First Differences		First Differences		First Differences		First Differences	
Dependent variable	Number of Claimants		Number of Claimants		Number of Claimants		Number of Claimants	
Treatment variable	Number of premises upgraded		Number of premises upgraded		Number of premises upgraded		Number of premises upgraded	
Unobserved area effects	No		Yes		Yes		Yes	
Unobserved area trends	No		No		Yes		Yes	
Controls for areas in Universal Credit roll out	No		No		No		Yes	
Outcome	Coeff.	R^2	Coeff.	R^2	Coeff.	R^2	Coeff.	R^2
Unemployment	-0.0007 **		-0.0008 **		-0.0006 *		-0.0008**	
- *Lagged 1 year*	-0.0018 **	0.2589	-0.0018 **	0.2779	-0.0014 **	0.3006	-0.0015 **	0.3008
- *Lagged 2 years*	-0.0014 **		-0.0016 **		-0.0014 **		-0.0014 **	
LT Unemployment	-0.0005 **		-0.0007 **		-0.0006 **		-0.0006 **	
- *Lagged 1 year*	-0.0003	0.1465	-0.0003 **	0.1682	-0.0002	0.1789	-0.0002	0.1729
- *Lagged 2 years*	0.0002		-0.0000		0.0000		0.0003	
Out of Work Benefits	-0.0004		-0.0006		-0.0007		0.0005	
- *Lagged 1 year*	-0.0008	0.1277	-0.0005	0.1622	-0.0006	0.1767	-0.0006	0.1807
- *Lagged 2 years*	-0.0001		-0.0000		-0.0005		-0.0004	

Source: Ipsos MORI analysis.

*Table note. ** indicates the coefficient was significant at the 99 percent level and * indicates the coefficient was significant at the 95 percent level*

3.4.2 Residential and Non-Residential Premises Upgraded

The table below provides results from a variant of Model 8 that estimates the effect of upgrading residential and non-residential premises separately. These results suggest that:

- Upgrading non-residential premises has had a substantially larger effect on unemployment than upgrading residential premises (15 to 20 times as large). However, the effect of upgrading non-residential premises occurs relatively rapidly (within one year of installation) and its effects on unemployment (though not long-term unemployment) appear to be persistent. Upgrading residential premises has a weaker effect on unemployment—effects are not realised immediately but become more important after two years.

- The results appeared to suggest that upgrading residential premises has had no effect over two years in terms of reducing the number of out of work benefit claimants (with positive and negative effects cancelling each other out). However, upgrading non-residential premises appears to reduce the number of out of work benefit claimants—with the overall effect similar in magnitude to the effect on the claimant count. As such, it does not appear that subsided superfast broadband coverage has had an effect in terms of reducing economic inactivity rates amongst lower income residents (though effects amongst higher income residents cannot be ruled out).

Table 3.5: Estimated Effect of Subsidised Coverage on the Number of Unemployed, Long Term Unemployed and Out of Work Benefit Claimants, Residential and Non-Residential Premises Upgraded

	Model 10		
Areas included	Treated Only		
Model	First Differences		
Dependent variable	Number of Claimants		
Treatment variable	Number of premises upgraded		
Unobserved area effects	Yes		
Unobserved area trends	Yes		
Outcome	Residential Coeff.	Non-Residential Coeff.	R^2
Unemployment	0.0003	-0.0189 **	0.3014
- *Lagged 1 year*	-0.0015 **	-0.0000	
- *Lagged 2 years*	-0.0018 **	0.0082	
LT Unemployment	-0.0003 **	-0.0066 **	0.1795
- *Lagged 1 year*	-0.0004 **	0.0047 **	
- *Lagged 2 years*	-0.0001	0.0080 **	
Out of Work Benefits	0.0016 **	-0.0147 **	0.1771
- *Lagged 1 year*	0.0003	-0.0032 *	
- *Lagged 2 years*	-0.0002	-0.0046	

Source: Ipsos MORI analysis.

*Table note. ** indicates the coefficient was significant at the 99 percent level and * indicates the coefficient was significant at the 95 percent level*

3.4.3 Urban and Rural

A final set of models were developed to explore the relative effects of the programme in urban and rural areas. This analysis was completed using the ONS urban and rural classification at an LSOA level (which is available for England and Wales only). The analysis found strong evidence of differential effects in urban and rural areas:

- Premises upgraded to superfast had an impact on the numbers claiming JSA in rural areas but not in urban areas.
- The findings also do not point to any effects on the number of out of work benefit claimants.

Table 3.6: Estimated Effect of Subsidised Coverage on the Number of Unemployed, Long Term Unemployed and Out of Work Benefit Claimants, Urban and Rural Premises Upgraded

	Model 11		
Areas included	Treated Only		
Model	First Differences		
Dependent variable	Number of Claimants		
Treatment variable	Number of premises upgraded		
Unobserved area effects	Yes		
Unobserved area trends	Yes		
Outcome	Urban Coeff.	Rural Coeff.	R^2
Unemployment	-0.0001	-0.0016 **	0.3432
- *Lagged 1 year*	0.0006	-0.0034 **	
- *Lagged 2 years*	0.0004	-0.0005 **	
LT Unemployment	-0.0001	-0.0008 **	0.2045
- *Lagged 1 year*	0.0010 **	-0.0008 **	
- *Lagged 2 years*	0.0014 **	-0.0012	
Out of Work Benefits	-0.0006	-0.0003	0.1787
- *Lagged 1 year*	0.0004	-0.0008	
- *Lagged 2 years*	0.0008	-0.0035	

Source: Ipsos MORI analysis.

*Table note. ** indicates the coefficient was significant at the 99 percent level and * indicates the coefficient was significant at the 95 percent level*

3.4.4 Effects by home nation

The following table sets out results by home nation (England and Scotland). Results broadly align with the findings set out above, though there were some indications that subsidised coverage had a stronger effect in reducing unemployment in Scotland than in England. Results are not available for Northern Ireland owing to an absence of detailed data on claimant numbers (as explained above), while results are not available for Wales owing to the absence of a Speed and Coverage Template which hindered the identification of those LSOAs included in the build plans of local schemes.

Table 3.7: Estimated Effect of Subsidised Coverage on the Number of Unemployed, Long Term Unemployed and Out of Work Benefit Claimants, by Home Nation

	Model 12	
Areas included	Treated Only	
Model	First Differences	
Dependent variable	Number of Claimants	
Treatment variable	Number of premises upgraded	
Unobserved area effects	Yes	
Unobserved area trends	Yes	
Outcome	England	Scotland
Unemployment	-0.0004	-0.0002
- *Lagged 1 year*	-0.0011 ***	-0.0020 **
- *Lagged 2 years*	-0.0012 **	0.0004
LT Unemployment	-0.0004 **	-0.0009 ***
- *Lagged 1 year*	-0.0002	0.0006
- *Lagged 2 years*	0.0003	0.0004
Out of Work Benefits	0.0009 *	0.0005
- *Lagged 1 year*	0.0000	-0.0037 ***
- *Lagged 2 years*	-0.0003	0.0039

Source: Ipsos MORI analysis.

*Table note. *** indicates the coefficient was significant at the 99 percent level and ** indicates the coefficient was significant at the 95 percent level*

3.5 GVA Impacts

- The Superfast Broadband Programme was delivered over a period in which unemployment was falling rapidly across all areas of the country as the economy recovered from the 2008 financial crisis. However, the findings of this analysis suggest that the Superfast Broadband Programme made a substantial contribution to reducing unemployment in those areas benefitting from BDUK subsidies.

- Applying the results to the preferred model developed above (Model 8 – see table 3.4) to the overall number of premises upgraded delivered through the programme between 2012 and 2016, it is estimated that the programme reduced the number of individuals claiming JSA by 8,755 and the number claiming JSA for more than 12 months by 2,500 by the end of 2016. Assuming the effects on long-term unemployed represent the effect of the programme on the overall productive capacity of the economy, and valuing the output produced by those individuals at £14,458 per annum[44], it is estimated that these effects could have led to an additional £70.5m in national economic output (GVA) by 2016.

[44] 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).

Table 3.8: Estimated Impacts of Subsidised Coverage on Unemployment and Long-Term Unemployment

	2013	2014	2015	2016	Total
Number of Premises Covered[45]	38343	849770	2017651	1115283	4021047
Cumulative reduction in unemployment	29	728	3,601	8,755	
Cumulative reduction in long term unemployment	24	552	1,805	2,498	-
GVA impact of reductions in long term unemployment (£m)	0.3	8.0	26.1	36.1	70.5

Source: Ipsos MORI analysis.

[45] This is based on the Broadband Performance Indicator. Available at https://www.gov.uk/government/collections/broadband-performance-indicators (accessed May 2018).

4 Conclusions

Firm Level Impacts

- Although the programme was primarily focused on providing access to superfast broadband speeds for residential premises, a significant number of businesses have also benefitted. These businesses tend to be smaller, less productive, and more concentrated in the manufacturing sector than those firms located on postcodes outside of the programme area. By and large, this is to be expected given the targeting of the scheme outside of more productive urban agglomerations where commercial deployments were expected to be extensive and proved to be so.

- The findings of this evaluation show that the programme has had a positive effect on economic development outcomes in those postcodes benefitting from subsidised coverage. It is estimated that faster available download speeds increased employment by 0.8%, turnover by 1.2% and productivity (approximated by turnover per worker) by 0.3% on postcodes benefitting from the programme. This is equivalent to the creation of just over 49,000 jobs at the local level and an increase in turnover of £8.9bn.

- A significant share of this growth was driven by sorting effects, i.e. the creation of new businesses, the relocation of larger and more productive firms to postcodes benefitting from subsidised postcodes, and the exit of smaller or less productive firms, from their closure or moving elsewhere. Overall, subsidised coverage is estimated to have increased the number of firms located on postcodes benefitting from the programme by 0.5%, equivalent to almost 1,800 businesses or workplaces. This suggests that higher levels of connectivity are attractive to firms and does influence location decisions, and this was an important contributor to the outcomes observed. Around 86 percent of the increase in employment and 65 percent of the increase in turnover were attributable to higher connectivity, based on comparisons to the impacts of the programme on local units that did not change location between 2012 and 2016.

- There was evidence that subsidised coverage delivered improvements in economic efficiency alongside attracting economic activity to areas benefitting from enhanced connectivity. Improved connectivity is estimated to have raised the efficiency (turnover per worker) of those businesses that were located on postcodes receiving subsidised coverage by an average of 0.4%. Taking the conservative assumption that this is best available measure of the national economic benefit of the programme (with other effects likely to represent crowding out or displacement), it is estimated that subsidised coverage led to an increase in national economic output (GVA) of around £1,400 per annum per firm receiving access to subsidised coverage. The cumulative economic value of these improvements in productivity are estimated at £1.325bn between 2012 and 2016.

- The results highlight the potential role of well targeted infrastructure investment in raising productivity and improving economic development outcomes in lagging areas. While the programme has likely done little to accelerate the growth of the firms operating at the technology frontier, it has improved the competitiveness of the least productive firms in the UK, that were by and large located in the least productive regions and areas of the country. As such, the programme has delivered important redistributive effects—and critically, by raising economic efficiency rather than merely displacing economic activity from more productive areas of the economy.

- The findings reinforce the importance of the Open Market Review process in ensuring public investment reached lagging areas. Without encouraging firms to reveal their existing commercial plans, it is reasonable to expect that providers

would have sought subsidies to deliver coverage in denser and higher productivity areas where the commercial returns were more assured. While the findings suggest that firms located in these areas may be better able to exploit the technology that was made available, it is important to note the results set out in Annex A that these were also the areas in which commercial deployments were most likely to have come forward without a subsidy.

Labour Market Effects

- The Superfast Broadband Programme was delivered over a period in which unemployment was falling rapidly across all areas of the country as the economy recovered from the 2008 financial crisis. However, the findings of this analysis suggest that the Superfast Broadband Programme made a substantial contribution to reducing unemployment in those areas benefitting from BDUK subsidies.

- It is estimated that the programme reduced the number of individuals claiming JSA by 8,800 and the number claiming JSA for more than 12 months by 2,500 by the end of 2016. Assuming the effects on the long-term unemployed represent the effect of the programme on the overall productive capacity of the economy, and valuing the output produced by those individuals at £14,458 per annum, it is estimated that these effects could have led to an additional £70.5m in national economic output (GVA) by 2016.

- Effects on unemployment appear to be driven by two separate processes. In the short term, upgrades to non-residential premises appear to have much larger effects on claimant numbers. These effects are realised relatively rapidly, and indicate that the effects of the programme in attracting or retaining economic activity within areas benefitting from subsidised coverage (as well as raising the performance of incumbent businesses) are the most significant. There was evidence that providing superfast coverage to residential premises had a small but growing effect on unemployment, which could suggest a role for the programme in widening search patterns or enabling teleworking though similar patterns could also be the consequence of sorting effects, e.g. if subsidised coverage attracts high skill residents, then this may force lower skill residents to move elsewhere.

- The findings also suggested that the impacts of the programme have been more significant in rural than in urban areas. This contrasts with findings on the impact of the programme on businesses that suggested that the effect of the programme on firms in urban areas was more significant than in rural areas. This might be explained if those residing in urban areas can search for employment in 'thicker' labour markets, making it more straightforward for them to find alternative employment. Unemployed residents of rural areas are likely to face a smaller number of employment options, resulting in jobs creation in rural areas leading to more significant reductions in claimant numbers.

- The results of analyses provide mixed results regarding the effect of the programme in reducing the number claiming out of work benefits. Where effects have been identified, these effects are no larger than the effect of the programme in reducing in the number of JSA claimants. This suggests that faster download speeds are less effective in reducing economic inactivity rates amongst lower income groups. This could be explained either if anticipated job roles based primarily on teleworking have not emerged at scale anticipated, if those on lower incomes are less able or willing to pay for the faster internet speeds required to access these opportunities, or if they do not offer the skillsets needed. It has not been feasible to assess the labour supply effects of the programme amongst higher income groups.

- The timeframe for the analysis is relatively short (a period of 1 or 2 years following the installation of the new infrastructure) and it is too early to judge how the apparent effects of the programme may prove persistent in the long

term. The findings above also do not allow for the impact of any future premises receiving upgraded coverage through the programme.

The results of this evaluation are short term in nature, and it is uncertain how long the apparently positive effect on productivity will persist into the future. If disparities in connectivity grow in the future it is possible that improvement in competitiveness gained by those firms gaining access to superfast broadband speeds could be lost. As such, the longevity of these gains will be partly dependent on how far future connectivity growth can be delivered through central innovations (such as changes in the way the signal is transmitted across the network) as opposed to investments in local infrastructure—which would carry a greater risk of increasing disparities in connectivity. As such, further public investment may be needed in the future to remedy future disparities in connectivity growth, as the underlying market failures (including imperfect competition) that produced these disparities are unlikely to have been permanently addressed by the programme.

Appendix A: Comparison of Postcodes Receiving Subsidised Coverage by Year

Table 4.1: Comparison of Characteristics of Postcodes Receiving Subsidised Coverage over Time

	All postcodes in receipt of investment	Postcodes not in receipt of investment	Phase One	Phase Two	Investment in 2013	Investment in 2014	Investment in 2015	Investment in 2016
Firm Characteristics								
Employment	25.4	22.0	24.4	41.8	23.9	25.0	24.2	30.1
Turnover (£,000)	3025.6	2860.7	2905.1	5096.8	2593.8	3025.0	2856.7	3633.3
Turnover per worker (£,000)	86.5	88.6	86.0	95.2	87.7	87.6	85.3	87.0
Size share:								
Micro	82.7%	82.7%	83.0%	79.9%	81.6%	82.6%	83.2%	82.1%
Small	7.0%	6.2%	6.9%	8.4%	6.8%	7.1%	6.9%	7.2%
Medium	2.2%	2.1%	2.1%	2.9%	2.5%	2.2%	2.1%	2.3%
Large	8.0%	9.0%	8.0%	8.9%	9.1%	8.1%	7.7%	8.4%
Sector share:								
C - Manufacturing	19.8%	8.7%	19.7%	21.8%	15.4%	17.6%	20.4%	24.5%
DE – Electricity, Gas and Water Supply	0.5%	0.4%	0.5%	0.6%	0.5%	0.5%	0.5%	0.6%
F - Construction	12.6%	14.1%	12.6%	11.2%	13.4%	13.2%	12.4%	11.0%
G – Wholesale and Retail Trade	14.5%	15.0%	14.4%	16.6%	15.5%	14.8%	14.2%	11.3%
H – Transport and Storage	3.4%	3.7%	3.4%	3.5%	3.7%	3.6%	3.4%	3.2%
I – Hotels and Restaurants	6.0%	5.6%	6.0%	5.6%	6.3%	5.9%	6.1%	6.0%
J – Post and Telecommunications	4.7%	7.9%	4.7%	4.3%	4.7%	4.7%	4.8%	4.1%
K – Financial Intermediation	1.3%	1.3%	1.2%	1.5%	1.4%	1.3%	1.3%	1.2%
LMN - Real Estate, Professional Services and Business Activities	22.5%	25.4%	22.6%	21.4%	22.9%	23.3%	22.4%	21.1%
O - Public Admin and Defence; Compulsory Social Security	0.9%	0.6%	0.9%	0.7%	1.0%	0.9%	0.9%	0.8%
P - Education	2.6%	3.0%	2.6%	2.2%	2.8%	2.6%	2.5%	2.4%
Q – Health and Social Work	4.8%	6.9%	4.8%	4.7%	5.8%	5.0%	4.7%	4.3%

RS – Other Community, Social and Personal Services	6.5%	7.4%	6.5%	6.0%	6.6%	6.6%	6.5%	6.1%

Table 4.2: Characteristics of Local Units Receiving Subsidised Coverage Over Time

	All postcodes in receipt of investment	Postcodes not in receipt of investment	Phase One	Phase Two	Investment in 2013	Investment in 2014	Investment in 2015	Investment in 2016
Firm Characteristics								
Employment	7.8	11.1	7.7	9.9	-	-	-	-
Turnover (£,000)	941.7	2037.9	919.7	1214.3	-	-	-	-
Turnover per worker (£,000)	105.6	139.7	104.8	115.8	-	-	-	-
Size share:								
Micro	11.0%	13.6%	10.9%	11.6%	12.5%	11.3%	11.3%	12.3%
Small	3.2%	3.5%	3.2%	4.0%	3.7%	3.5%	3.4%	3.9%
Medium	76.3%	74.2%	76.5%	73.7%	73.7%	74.6%	75.3%	73.6%
Large	9.5%	8.7%	9.4%	10.8%	10.1%	10.6%	10.0%	10.3%
Sector share:								
C - Manufacturing	17.4%	8.1%	17.4%	17.9%	14.5%	17.2%	20.3%	23.6%
DE – Electricity, Gas and Water Supply	0.6%	0.4%	0.6%	0.7%	0.6%	0.6%	0.5%	0.6%
F - Construction	10.5%	10.4%	10.6%	9.6%	10.2%	10.6%	10.0%	9.3%
G – Wholesale and Retail Trade	19.1%	18.0%	19.0%	20.2%	21.4%	20.0%	19.2%	19.1%
H – Transport and Storage	3.2%	3.1%	3.2%	3.1%	3.0%	3.2%	3.0%	3.0%
I – Hotels and Restaurants	6.4%	6.6%	6.5%	5.0%	6.8%	5.8%	5.6%	5.0%
J – Post and Telecommunications	4.3%	6.9%	4.4%	3.7%	4.2%	4.3%	4.3%	3.5%
K – Financial Intermediation	2.1%	3.0%	2.1%	2.3%	2.2%	1.6%	1.5%	1.5%
LMN - Real Estate, Professional Services and Business Activities	22.7%	26.0%	22.4%	26.2%	22.2%	22.4%	21.5%	21.9%
O - Public Admin and Defence; Compulsory Social Security	0.9%	1.0%	0.9%	0.6%	1.0%	0.9%	0.9%	0.7%
P - Education	2.2%	2.7%	2.2%	1.7%	2.2%	2.3%	2.3%	2.2%
Q – Health and Social Work	4.2%	6.1%	4.3%	3.7%	4.9%	4.4%	4.2%	3.8%

RS – Other Community, Social and Personal Services	6.5%	7.6%	6.6%	5.5%	6.9%	6.7%	6.6%	5.9%

Table 4.3: Characteristics of Local Units Receiving Subsidised Coverage Over Time

	All postcodes in receipt of investment	Postcodes not in receipt of investment	Phase One	Phase Two	Investment in 2013	Investment in 2014	Investment in 2015	Investment in 2016
Firm Characteristics								
Employment	9.3	14.7	9.0	11.8	-	-	-	-
Turnover (£,000)	1153.5	2760.3	1122.7	1545.5	-	-	-	-
Turnover per worker (£,000)	106.9	141.6	105.9	118.5	-	-	-	-
Size share:								
Micro	12.8%	16.6%	12.8%	13.4%	14.6%	12.7%	12.5%	13.2%
Small	3.8%	4.3%	3.7%	4.5%	4.1%	3.9%	3.5%	4.0%
Medium	72.7%	68.9%	72.9%	70.1%	70.4%	72.1%	73.6%	72.3%
Large	10.8%	10.3%	10.6%	12.1%	10.9%	11.3%	10.4%	10.6%
Sector share:								
C - Manufacturing	21.4%	10.1%	21.5%	21.7%	16.6%	19.4%	22.2%	24.8%
DE – Electricity, Gas and Water Supply	0.6%	0.4%	0.5%	0.7%	0.6%	0.6%	0.5%	0.6%
F - Construction	9.7%	9.8%	9.8%	8.8%	9.6%	10.1%	9.7%	8.9%
G – Wholesale and Retail Trade	20.2%	19.9%	20.1%	21.4%	22.6%	20.8%	19.7%	19.5%
H – Transport and Storage	3.1%	3.0%	3.1%	3.0%	3.0%	3.2%	3.0%	3.0%
I – Hotels and Restaurants	5.6%	6.2%	5.7%	4.3%	6.3%	5.6%	5.6%	5.2%
J – Post and Telecommunications	3.6%	5.6%	3.6%	3.0%	3.7%	3.7%	3.7%	3.1%
K – Financial Intermediation	1.5%	2.3%	1.5%	1.7%	1.6%	1.5%	1.5%	1.4%
LMN - Real Estate, Professional Services and Business Activities	20.4%	23.7%	20.0%	23.8%	20.4%	20.5%	20.0%	21.0%
O - Public Admin and Defence; Compulsory Social Security	0.9%	1.0%	0.9%	0.5%	1.1%	0.9%	0.9%	0.7%
P - Education	2.4%	3.2%	2.4%	1.9%	2.5%	2.4%	2.4%	2.2%

Q – Health and Social Work	4.3%	6.7%	4.4%	3.7%	5.0%	4.6%	4.3%	3.8%
RS – Other Community, Social and Personal Services	6.5%	8.2%	6.5%	5.5%	7.0%	6.6%	6.5%	5.8%

Table 4.4: Pipeline validity tests—single site units comparison

	All postcodes in receipt of investment	Postcodes not in receipt of investment	Phase One	Phase Two	Investment in 2013	Investment in 2014	Investment in 2015	Investment in 2016
Firm Characteristics								
Employment	8.8	11.8	8.7	10.9	-	-	-	-
Turnover (,000)	1073.0	2901.7	1043.0	1421.3	-	-	-	-
Turnover per worker (,000)	129.2	220.0	127.7	145.9	-	-	-	-
Size share:								
Micro	79.7%	77.4%	80.1%	74.9%	78.6%	77.5%	79.4%	76.7%
Small	17.5%	18.5%	17.2%	21.1%	18.6%	19.3%	17.8%	19.7%
Medium	2.5%	3.3%	2.4%	3.6%	2.6%	2.7%	2.6%	3.2%
Large	0.3%	0.7%	0.3%	0.4%	0.2%	0.4%	0.3%	0.4%
Sector share:								
C - Manufacturing	26.8%	12.5%	26.4%	32.1%	25.1%	26.5%	30.0%	33.7%
DE – Electricity, Gas and Water Supply	0.4%	0.3%	0.4%	0.5%	0.4%	0.4%	0.3%	0.5%
F - Construction	19.5%	20.1%	19.8%	16.1%	19.3%	19.5%	18.3%	16.7%
G – Wholesale and Retail Trade	17.2%	17.5%	17.1%	18.3%	17.8%	17.7%	16.9%	16.4%
H – Transport and Storage	3.1%	2.6%	3.1%	3.0%	3.0%	3.1%	3.0%	2.9%
I – Hotels and Restaurants	5.3%	5.6%	5.4%	3.9%	5.7%	4.9%	5.0%	4.7%
J – Post and Telecommunications	2.4%	4.0%	2.4%	2.0%	2.4%	2.4%	2.3%	1.9%
K – Financial Intermediation	1.8%	3.4%	1.7%	2.1%	1.9%	1.6%	1.5%	1.4%
LMN - Real Estate, Professional Services and Business Activities	12.9%	18.1%	12.9%	12.9%	12.6%	12.7%	12.1%	11.8%

O - Public Admin and Defence; Compulsory Social Security	0.3%	0.2%	0.3%	0.1%	0.4%	0.3%	0.3%	0.2%
P - Education	1.2%	2.2%	1.2%	1.0%	1.3%	1.2%	1.2%	1.0%
Q – Health and Social Work	3.9%	6.3%	3.9%	3.5%	4.4%	4.1%	3.9%	3.6%
RS – Other Community, Social and Personal Services	5.3%	7.2%	5.4%	4.5%	5.8%	5.5%	5.2%	5.0%

Appendix B: Elasticities

This technical note provides estimates of the elasticity of speeds to the outcomes of interest (the percentage change in the outcome associated with a doubling of download speeds). These estimates were developed specifically to update the BDUK Benefits Model.

Estimated Gross Effect on Average Download Speeds

The table below provides a simple comparison between average downloads on postcodes receiving enhanced coverage subsidised by BDUK before and after the connection was installed. The table suggests that average download speeds increased by 11.9 Mbit/s following the upgrade. The change in average download speeds following connection was larger both in absolute and percentage terms on rural postcodes. We are unable to assess the relative effect of the programme on commercial and residential take-up of available speeds.

Table 4.5: Change in Download Speeds Before and After Premises Upgraded

	All	Urban Postcodes	Rural Postcodes
Average Download Speeds Before	9.5	13.8	7.6
Average Download Speeds After	21.4	22.8	20.8
Overall change (Mbit/s)	11.9	9.0	13.2
Percentage change	126	65	173

To provide an estimate of the impact of the subsidised coverage on download speeds, i.e. while controlling for other factors that may have influence take-up of available speeds, OLS and Fixed Effects models were applied using the general pipeline design approach used elsewhere in the study to estimate the impact of the programme. The results of these models are set out in the table below and suggested both observable and unobservable differences between postcodes have biased simple before and after comparisons of average download speeds. The fixed effects estimates are considered most robust as they allow for time invariant but unobserved differences between postcodes.

Table 4.6: Estimated Effect of Subsidised Coverage on Average Download Speeds (Mbit/s)

	All	Urban Postcodes	Rural Postcodes
Simple Mean Comparison	11.9 (126%)	9.0 (65%)	13.2 (173%)
OLS	8.3 (87%)	4.9 (35%)	9.7 (127%)
Fixed Effects	7.4 (78%)	4.7 (34%)	8.6 (113%)

Note: Percentage effects are provided in brackets

Elasticity of Productivity to Average Download Speeds

The estimated (gross) effect of the programme on productivity to date is estimated at 0.38 percent over the same period (i.e. between 2012 and 2016). This allows us to estimate the elasticity of productivity to average download speeds (which has not been possible to generate from the data owing to data constraints). This is achieved by dividing the average change in

productivity by the average change in download speeds (with the resultant figure giving an estimate of impact on productivity associated with a doubling of speeds).

These results give an estimate of the overall change in productivity associated with a doubling of speeds of between 0.30 to 0.49 percent. This compares to 0.31% applied in the BDUK Benefits Model. We find that the elasticity of productivity to speed is higher in urban areas than in rural areas (suggesting that firms in urban areas have been better placed to exploit the technology).

Table 4.7: Estimated Increase in Productivity Associated with a Doubling of Speeds

	All	Urban Postcodes	Rural Postcodes
Estimated Productivity Effect	0.0038	0.0049	0.0034
Elasticities based on:			
Simple Mean Comparison	0.0030	0.0076	0.0020
OLS	0.0044	0.0139	0.0027
Fixed Effects	0.0049	0.0145	0.0030

Elasticity of Long Term Unemployment to Average Download Speeds

Analysis of the labour market effects of the programme suggested the programme reduced long-term unemployment by 1,716 claimants to 2016 (in the LSOAs covered by the analysis only, rather than the results reported in Section 3 which involves an extrapolation of the findings to Wales and Northern Ireland). There were 153,713 long term claimants in the areas covered by the analysis, suggesting that the effect of the subsidised coverage was to reduce the number of long-term unemployed claimants by 3.3 percent. Based on the estimated speed effects, we obtain an elasticity of the number of claimants to average download speeds of between 0.008 and 0.015 (implying a doubling of broadband speeds will lead to a reduction in the number of long-term unemployed claimants of between 0.8 and 1.5 percent).

Table 4.8: Estimated Reduction in Long Term Unemployment Associated with a Doubling of Speeds

	Estimated Elasticities
Estimated Effect on LTU	-0.0330
Elasticities based on:	
Simple Mean Comparison	-0.0089
OLS	-0.0135
Fixed Effects	-0.0151

Appendix C: Supplementary Research on Large Increases in Available Download Speeds

This appendix provides a set of analyses that were explored as a natural extension to the superfast analysis in this annex. While there is a broad evidence base describing the spatial and economic impacts of broadband in general terms, there is little in the way of evidence describing the relative effect of the types of large increases in connectivity. Some such increases have been brought forward as part of the superfast broadband programme, and shall be brought forward further by aspects of the BDUK local full fibre network (LFFN) programme[46].

The research contained in this appendix begins to fill the evidence gap by exploring the short term local effects of large changes in available download speeds, i.e. those of more than 100Mbit/s. The research also compares the economic characteristics of those areas that have benefitted from these improvements in connectivity to those that are currently within the scope of the BDUK LFFN programme, more specifically, the Gigabit Voucher, Schools, West Sussex and Tameside schemes—with a view to assessing the likelihood that similar local economic effects could be anticipated from the LFFN programme.

Postcodes Seeing Large Changes in Available Broadband Speeds

This study focuses on postcodes that have seen particularly large changes in available broadband speeds in a single year. Following a review of the distribution of changes in connectivity across the UK, postcodes were categorised into three groups—those seeing changes available broadband speeds increase by:

- 100 to 200Mbit/s;
- 200 to 500Mbit/s; and
- 500Mbit/s or more.

Changes in connectivity at a postcode level were identified using Ofcom's annual Connected Nations report which captures maximum available download speeds based on records provided by suppliers of broadband services. It should be noted that these records do not capture the speeds available to businesses that choose to pay for a dedicated lease line. Recent research for Ofcom suggests that only 5 percent of small and medium sized businesses, i.e. those with less than 250 employees, choose to purchase dedicated internet access[47]. However, use of Connected Nations will misrepresent speeds typically used in locations where there are significant clusters of large firms able to pay the costs of leased lines. For example, while many firms in the City of London will lease high capacity lines from multiple networks to obtain resilience to technical failures, in the Ofcom data, the maximum available download speeds in the local authority are low by national standards, and few postcodes fall into the categories above.

[46] The LFFN programme aims to stimulate commercial investment in full fibre networks capable of 1Gbit/sec broadband services. The findings contained in this appendix support the BDUK LFFN business case.

[47] The SME Experience of Communications Services: Research Report, Ofcom, January 2017

Ultrafast and Hyperfast Connectivity over Time

Table 4.9 below provides an overview of the number of postcodes that saw maximum available download speeds increase by 100-200, 200-500 and more than 500Mbit/s in single year between 2014 and 2017[48]. As suggested in the table, maximum available download speeds of the levels enabled by full fibre networks were not widely available in 2017. Only 3.8 percent of postcodes in the UK saw maximum available download speeds increase by more than 100Mbit/s between 2014 and 2017, and just 0.2 percent saw these speeds increase by 500Mbit/s or more[49]. The fastest download speeds only began to become available from 2016 onwards, though there is little evidence that the pace of roll out grew substantially over the period.

Table 4.9: Number of Postcodes Experiencing Large Changes in Maximum Available Download Speeds, 2014 to 2017

Annual Change in Maximum Available Download Speeds (Mbit/s)	Year—June to June			Total Postcodes	% of Postcodes in UK
	2014 to 2015	2015 to 2016	2016 to 2017		
100 to 200 Mbit/s	16,031	22,574	21,997	60,602	3.4
200 to 500 Mbit/s	317	1,049	2,277	3,643	0.2
500 Mbit/s or more	7	1,590	1,448	3,045	0.2

Source: Connected Nations, Ofcom

Spatial Distribution of Ultrafast and Hyperfast Connectivity

The figure overleaf shows the spatial distribution of postcodes receiving the enhancements in connectivity described above.

100MB to 200MB: Postcodes benefitting from increases in maximum download speeds of 100 to 200 Mbit/s were concentrated in the urban areas of England, Wales and Scotland—the core cities as well as secondary cities, such as Bradford and Bolton). However, only seven local authorities saw 10 percent or more postcodes being upgraded to these speeds— across a diverse mix of urban and rural areas[50]. A review of press releases suggests that the upgrades were being delivered by a mixture of smaller suppliers, e.g. Telcom in Leeds, CityFibre in Nottingham, Hyperoptic in Newcastle, and Virgin Media under the banner of 'Project Lightning'. Early market deployment of BT's ultrafast service—G.Fast—was announced in May 2017, and early rollout of this service will not have appeared in the figures above.

- 200MB to 500MB: Postcodes receiving increases in maximum download speeds of 200 to 500 Mbit/s were heavily concentrated in Kingston Upon Hull and delivered by K-Com. Around two thirds of all postcodes seeing available downloads speeds increase by this amount were located in the East Riding of Yorkshire or Kingston upon Hull, with penetration reaching 12 and 16 percent of postcodes respectively. While most core cities had some delivery of 200 to 500 Mbit/s improvements in available download speeds, penetration rates were very low in comparison, e.g. penetration was third highest in Cambridge at 0.7 percent of postcodes.

[48] Data before 2014 is not reliable as postcodes with a maximum download speeds larger than 30Mbit/s were grouped under a single category.

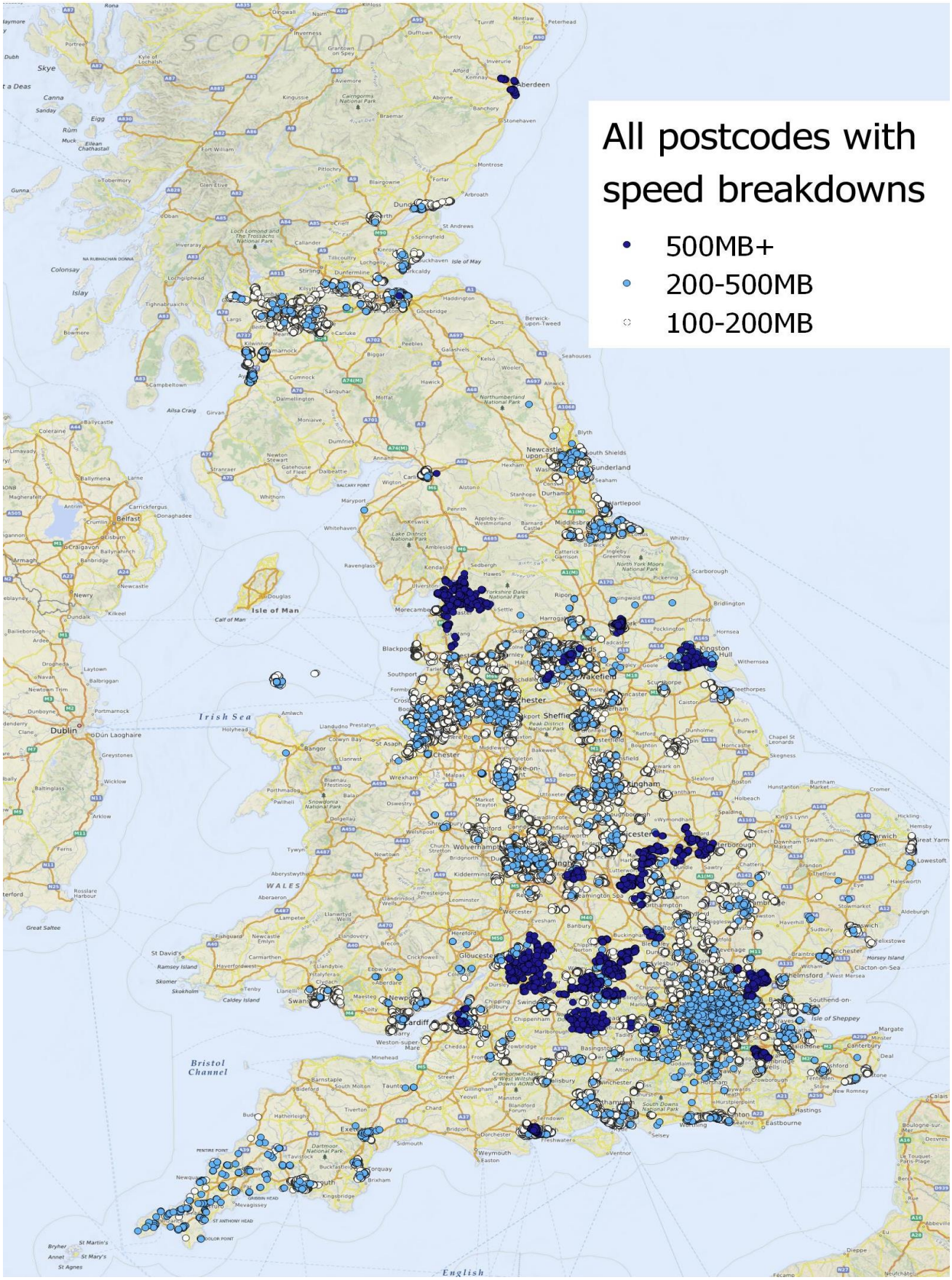
[49] These speeds are comparable to those being delivered to premises as a result of BDUK's LFFN programme.

[50] Blaby in rural Leicestershire (20.8 percent), South Ayrshire (17.3 percent and East Ayrshire (15.1 percent) in the West of Scotland, Newham in East London (13.0 percent), Kingston upon Hull (12.4 percent), and Erewash (10.0 percent) covering the rural area between Derby and Nottingham.

- 500MB or more: The postcodes receiving the largest increases in available download speeds tended to be clustered in different areas to those seeing speed increases of 100-200 Mbit/s. Only 47 (of 390) local authorities had any level of penetration of 'hyperfast' broadband availability. Of these, York, Bournemouth and Peterborough were the only urban areas with any significant penetration, with press reports suggesting these networks were being delivered by UFO[51] in York and by C4L and CityFibre in Bournemouth. The remainder were largely in rural areas—with the most significant clusters in Gloucestershire (Cotswolds with roll out led by Gigaclear), Oxfordshire (Vale of White Horse and South Oxfordshire), and Lancashire (driven forward by Broadband for the Rural North—B4RN).

[51] A Virgin and Talk Talk joint venture.

Figure 4.1: Spatial Distribution of Postcodes Experiencing Large Changes in Connectivity

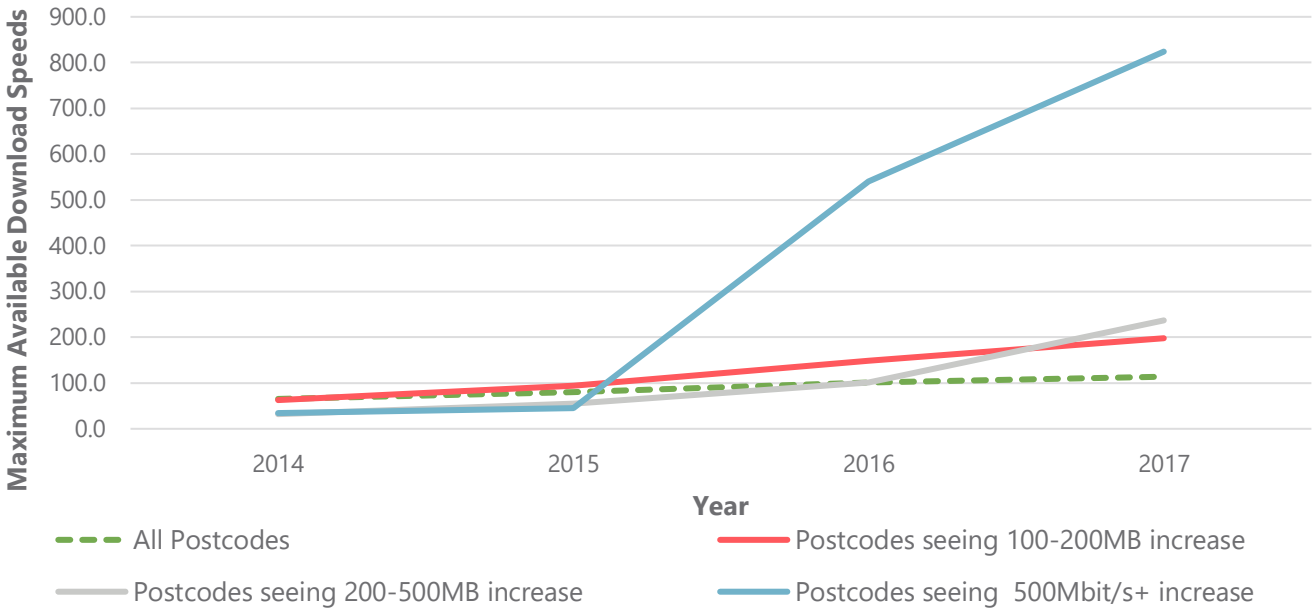


Changes in Available Speeds

Figure 4.2 below shows changes in average maximum download speeds across the three groups of postcodes experiencing large increases in connectivity, relative to the national average:

- Postcodes experiencing 100-200Mbit/s were broadly comparable to the national average in 2014 (circa 65Mbit/s) but saw available speeds rise to almost 200Mbit/s by 2017 compared to 113.9Mbit/s nationally.
- Postcodes seeing larger changes in download speeds were disadvantaged in connectivity terms in 2014, with average maximum download speeds approximately half the speed of those available nationally (32-34 Mbit/s). However, the installation of new technology has seen these areas outperform the national average by 2017. Those postcodes seeing available download speeds increase by more the 500 Mbit/s experience average maximum download speeds rise to 824 Mbit/s in 2017 (more than 700 percent of the national average).

Figure 4.2: Changes in Maximum Available Download Speeds, 2014 to 2017



Role of BDUK

The Connected Nations dataset was linked to records of the delivery of the Superfast Broadband programme to explore how far changes in available download speeds could be attributed to the programme. While the programme largely involved subsidies for Fibre to the Cabinet (FTTC) technology, approximately 15,000 postcodes received Fibre to the Premises (FTTP). This analysis suggested that:

- Only a small share of those postcodes seeing improvements in available download speeds of 100-200 and 200-500 Mbit/s were included in the build plans of schemes funded through the Superfast Broadband programme (6.4 and 5.9 percent respectively).
- However, the role of the programme was substantially more prominent amongst those receiving improvements in available download speeds of 500Mbit/s with 31 percent of these postcodes included in the build plans associated with schemes funded through the Superfast Broadband programme. This will understate the role of the programme, as a

Speed and Coverage Template was not available for Gloucestershire and Herefordshire, meaning it is unknown which postcodes were included in the build plan.

Additionally, a review of press reports suggests that BDUK may have had other roles in bringing forward enhanced connectivity in these postcodes. For example, some press releases suggest that some enhancements in local connectivity were partly funded through the Better Broadband scheme, though data to validate these claims or assess the relative importance of this or any other relevant schemes was not available.

Economic Impacts of Large Changes in Connectivity

This section considers the economic impacts of the large changes in available download speeds described above. The results are based on a similar methodology to that employed to assess the economic impacts of the Superfast Broadband programme. We do not repeat the methodological arguments made in support of the approach here, but the strategy broadly involves comparing economic activity on postcodes benefitting from enhanced connectivity first to those that received it later (which serve as a counterfactual). Issues of reverse causality, i.e. areas that receive enhanced connectivity might be do so because they are expected to grow, are mitigated by the exclusion of any postcode that does not receive enhanced connectivity.

Economic impacts were assessed using firm level data available from the Business Structure Database[52]. This database provides annual measures of turnover and employment, sector and the postcodes associated with local trading addresses for all firms registered for PAYE or VAT, covering 99 percent of economic activity in the UK, though omitting some of the smallest businesses. In all cases, the estimated effects of enhanced connectivity are short term in nature (one to two years), and may misrepresent the medium and long-term effects of making very high broadband speeds available.

For the purposes of this analysis, turnover per worker is taken as a proxy measure of productivity, i.e. output per worker. This measure is only an approximation, as it accounts for the firm's usage of workers but not its spending on other inputs. Productivity effects will be understated if enhanced connectivity enables firms to access lower input prices, and overstated if it facilitates greater outsourcing of activities. Additionally, given the scarcity of the download speeds being explored, it is possible that enhanced connectivity has a direct impact on input costs by raising rents, in which case there may be productivity gains that are captured by landowners rather than the firms covered in the following analyses.

Overall Impacts

The table below provides an overview of the short-term effect of large improvements in available download speeds on overall economic activity on the postcodes benefitting from those enhancements:

- Employment: The results of the analysis did not suggest that the effect of large changes in available download speeds had any effect on overall employment on the postcodes benefitting from enhanced connectivity.
- Turnover: However, the results did suggest that enhanced connectivity led to an increase in turnover amongst firms located on those postcodes. These effects appeared to rise with the size of the change in speed—from 1.2 percent per annum amongst firms located on postcodes seeing available download speeds rise by 100 to 200 Mbit/s to 5.8 percent amongst those seeing available download speeds rise by over 500 Mbit/s. No significant effects were found on postcodes seeing available download speeds rise by 200 to 500 Mbit/s though the estimated effect size lay between these values.

[52] Available at the time of writing between 2012 and 2017

- Turnover per worker: The results also suggested enhancements in connectivity led to more productive economic activity—with turnover per worker rising by 1.2 percent amongst firms located on postcodes seeing available download speeds rise by 100 to 200 Mbit/s and 3.8 percent for firms located postcodes seeing larger changes.

These effects were an order magnitude higher than for those estimated for the Superfast Broadband programme, which saw average maximum available download speeds rise by around 65 Mbit/s. The results are also suggestive of a relationship between the size of the speed change and productivity, though these differences may also be a product of differences between areas and their ability to absorb the technology.

Table 4.10: Effects of Large Changes in Maximum Available Download Speeds on Overall Economic Activity

Annual Change in Maximum Available Download Speeds (Mbit/s)	Percentage Effect on Outcomes		
	Employment	Turnover	Turnover per Worker
100 to 200 Mbit/s	-0.000	0.012***	0.012***
200 to 500 Mbit/s	-0.013	0.029	0.039**
500 Mbit/s or more	0.016	0.058**	0.039**

Source: Ipsos MORI analysis

*Table Note. ***, ** and * indicate significance at the 99, 95 and 90 percent levels*

Firm Entry and Exit

Past research[53] has demonstrated that broadband availability has a significant effect on firm location choice, and given the relative scarcity of download speeds of the nature being explored in this paper, it may be expected that enhancements of this magnitude could have particularly large effects. A further set of analyses were completed to explore the influence of enhanced connectivity on the number of firms located on a postcode, the number of firms establishing a new location on the postcode (start-ups or relocations) and the number of firms leaving the postcode (including business failures).

- Number of firms: Enhanced connectivity appeared increased the number of firms located on the postcode—at least for those seeing increases in maximum download speeds of 100 to 200 Mbit/s (where the number of firms located on the postcode rose by 0.4 percent in response to the installation of new broadband infrastructure). It was not possible to identify an effect on postcodes receiving larger connectivity changes, though it is suspected that this was primarily a function of the substantially smaller sample sizes available for analysis and the small size of the effects of interest. For example, the estimated increase in the number of firms of 1.6 percent on postcodes seeing increases in available download speeds of 500 Mbit/s or more was significant at the 85 percent level of confidence but not the 90 percent level of confidence.

- Firm entry and exit: The results also suggested that enhanced connectivity triggered greater local economic dynamism—with both the number of incoming and outgoing firms rising in response enhanced connectivity, with the effect on the former greater than the latter. Again, these results were only significant for those postcodes seeing maximum available

[53] See for example, Impact of Broadband and other Infrastructure on the Location of New Business Establishments, McCoy, Lyons, Morgenroth, Palcic, and Allen, Journal of Regional Science, January 2018. This study found that broadband availability had significant effect on the location choice of new business establishments, though the effect was partly mediated by the availability

download speeds rise by 100 to 200 Mbit/s, though it is suspected that sample sizes were too small to detect these effects for postcodes benefitting from larger changes in connectivity.

The findings suggest that higher download speeds are attractive for businesses—creating greater demand for premises on postcodes with the highest available download speeds. If this process places upward pressure on rents, some incumbent firms may be 'crowded out' and forced to relocate to a lower connectivity location elsewhere. This is consistent with the results of the analysis—which suggested enhanced connectivity increased the number of out-going firms.

Table 4.11: Effects of Large Changes in Maximum Available Download Speeds on Firm Entry and Exit

Annual Change in Maximum Available Download Speeds (Mbit/s)	Percentage Effect on Outcomes		
	No. of Firms	Firm Entry	Firm Exit
100 to 200 Mbit/s	0.005**	0.007**	0.003*
200 to 500 Mbit/s	0.008	0.009	0.001
500 Mbit/s or more	0.016	0.021	0.004

Source: Ipsos MORI analysis

*Table note. ***, ** and * indicate significance at the 99, 95 and 90 percent levels*

Effects on Spatially Stable and Incoming Firms

The findings on firm location decisions raise questions as to how far the apparent effects of high download speeds on local productivity are driven by the relocation of more productive firms to high connectivity postcodes (implying no net benefit at the national level) or by genuine improvements in efficiency driven by exploitation of the technology made available. This issue is explored in this section by:

- Restricting the analysis to firms that did not change location between 2012 and 2017—whose response to the availability of very high download speeds might be more confidently attributed to the technology.
- For postcodes receiving the greatest improvements in productivity, the analysis is restricted to incoming firms to explore the effect of moving to the high connectivity postcode.

The following table sets out the results of comparable analyses for firms that did not change their location between 2012 and 2017. The findings diverge for postcodes benefitting from changes in connectivity of 100 to 500 Mbit/s and those seeing the greatest improvement in connectivity:

- 100-500Mbit/s: Firms that did not change location reduced their employment levels by just over 2 percent but saw no change in their overall turnover, resulting in an overall improvement in turnover per worker of 2-3 percent. This could suggest that access to the highest levels of connectivity enables firms to improve their productive efficiency, e.g. by enabling data intensive processes to be completed more rapidly but has no marginal benefit in terms of facilitating access to new markets[54]. However, the increased number of firms located on the postcodes could also have the effect

[54] This can be contrasted with the findings from the Superfast Broadband programme evaluation findings—which suggested 24Mbit/s to 80Mbit/s connectivity facilitated access to new markets and enabled firms to expand their revenues. This could be explained if these lower connection speeds are sufficient to enable firms to adopt e-commerce arrangements, with further improvements in connectivity primarily feeding through into enhanced process efficiency.

of increasing competition either in factor markets, placing upward pressure on wages and encouraging incumbent firms to reduce their employment or in product markets, reducing the prices incumbents can earn on products and services sold. It should, however, be noted that any negative effects on employment are offset by the jobs created by incoming firms.

- 500Mbit/s or more: While firms that do not change their location also reduced their employment in response to enhanced connectivity, they also saw their turnover fall by a similar proportion, with no effect on the productivity of this group of firms. This suggests that enhanced connectivity can have a deleterious effect on incumbents, who may be relatively unable to exploit the potential created by very high download speeds—and get crowded out by the more productive firms seeking to relocate to these postcodes. This scenario does not seem implausible given the high share of rural postcodes benefitting from the highest broadband speeds.

- Effects on incoming firms: The finding above raises substantial questions regarding the extent of the economic benefits associated with download speeds of 500 Mbit/s or higher. Given the absence of an effect on the productivity of firms that have remained located at these postcodes, there will only be a net economic benefit from enhanced connectivity if those firms relocating to the postcodes do so to improve the efficiency of their operations, as opposed to moving for other factors, such as lifestyle reasons. This was tested by repeating the analysis and focusing solely on the performance of firms that have relocated to postcodes benefitting from these enhancements in connectivity. These results suggest that the effect of moving to higher connectivity postcodes is substantial—incoming firms saw employment fall by 2 percent while turnover rose by 4 percent, with an overall effect on turnover per worker of 6—7 percent —an effect some 20 times larger than estimated for firms benefitting enhanced connectivity supported by the Superfast Broadband programme itself on average[55]. The results also indicated that many of the incoming firms were relatively young — around 1 to 3 years old —suggesting that it may be a very specific group of firms that can exploit these speeds to their advantage, at least at present.

Table 4.12: Effects of Large Changes in Maximum Available Download Speeds on Overall Economic Activity—Firms that Did Not Change Location

Annual Change in Maximum Available Download Speeds (Mbit/s)	Percentage Effect on Outcomes		
	Employment	Turnover	Turnover per Worker
100 to 200 Mbit/s	-0.021***	0.001	0.023***
200 to 500 Mbit/s	-0.022***	0.007	0.030***
500 Mbit/s or more	-0.018***	-0.017*	0.001

Source: Ipsos MORI analysis

*Table Note. ***, ** and * indicate significance at the 99, 95 and 90 percent levels*

Comparative Analysis

This section provides an analysis of the prevailing socio-economic characteristics of those areas benefitting from particularly large changes in connectivity. BDUK also supplied the details of 987 postcodes within the current scope of the LFFN

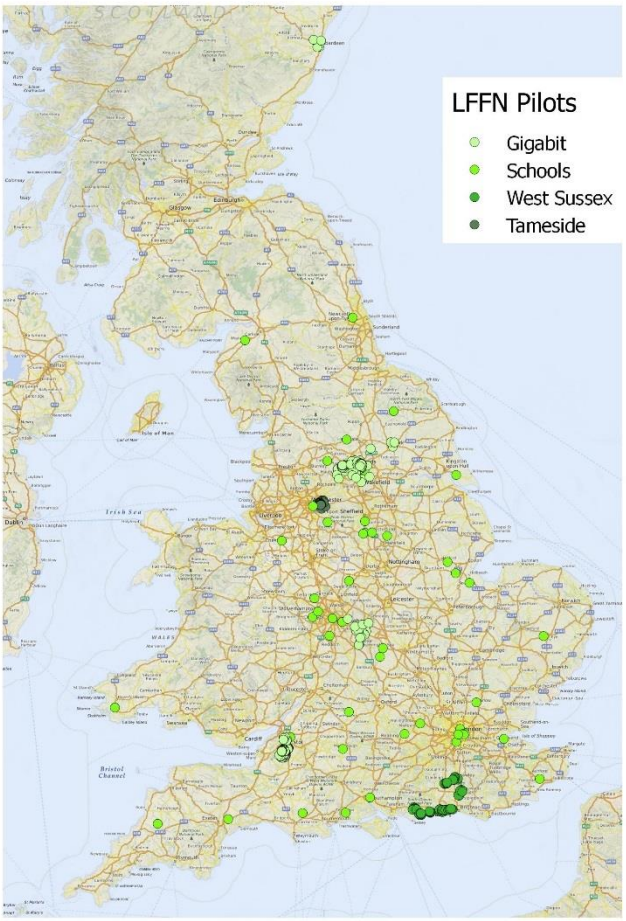
[55] Note that these results are not cleared with the VML at present.

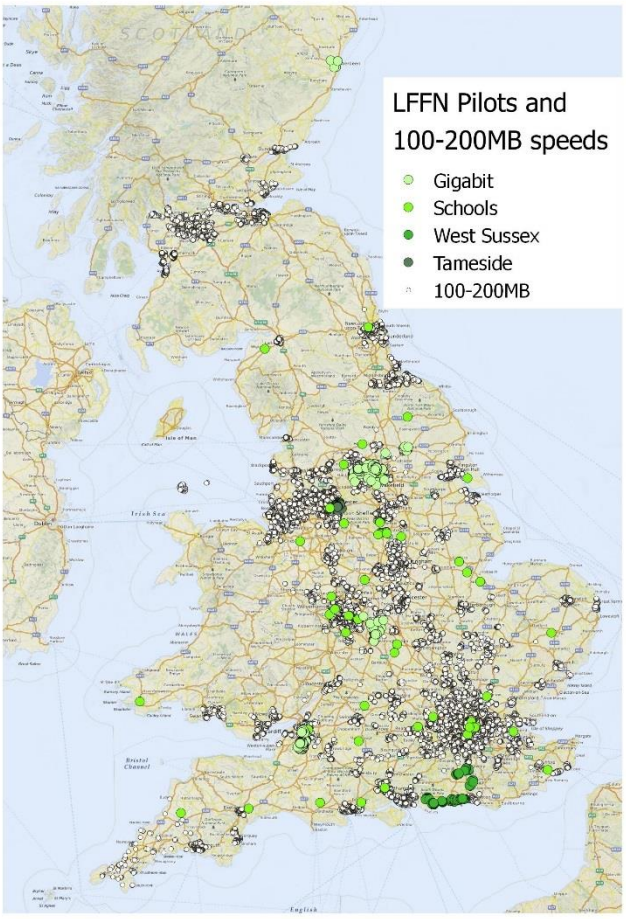
programme, covering the Gigabit Voucher scheme[56], the Schools Programme[57], and public sector anchor tenancy schemes in Tameside and West Sussex. This section considers the characteristics of these areas with a view to anticipating how far it may be reasonable to expect similar effects from the LFFN programme.

Overview of LFFN postcodes

The following figure overlays the distribution of the postcodes associated with the LFFN programme with those benefitting from the improvements in connectivity described above. As the figures illustrate, there was little commonality in the spatial distribution of these postcodes, beyond clusters of Gigabit Connection Voucher Scheme postcodes in Bristol, around Leeds (and surrounding towns) and Aberdeen—areas where there were also clusters of 100 to 200 Mbit/s improvements in connectivity.

Figure 4.3: LFFN Postcodes and Postcodes Benefitting from Large Connectivity Changes (Panel 1)

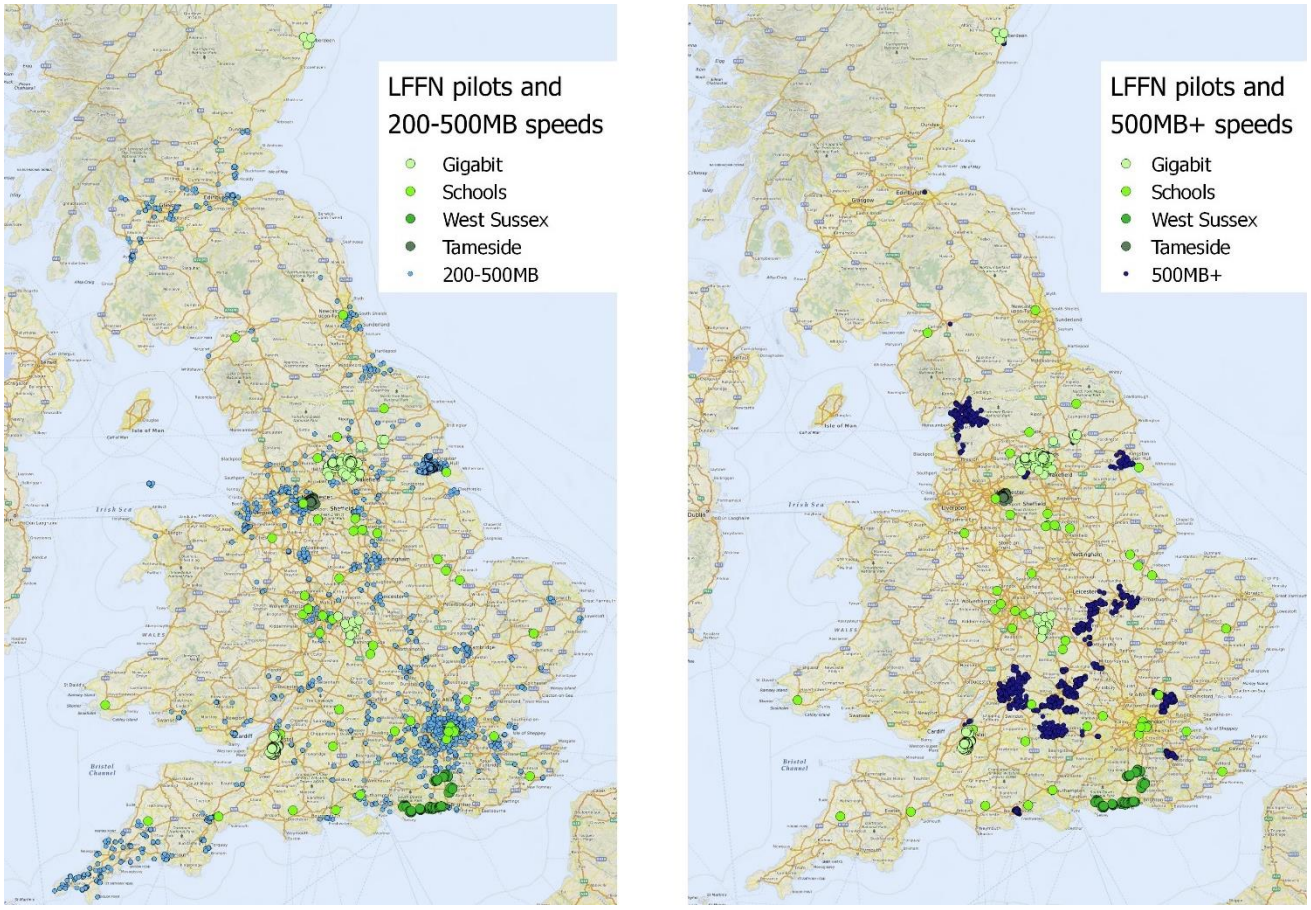




[56] Including both live and not live postcodes.

[57] Details of schools that did not signal an interest in the programme have been removed.

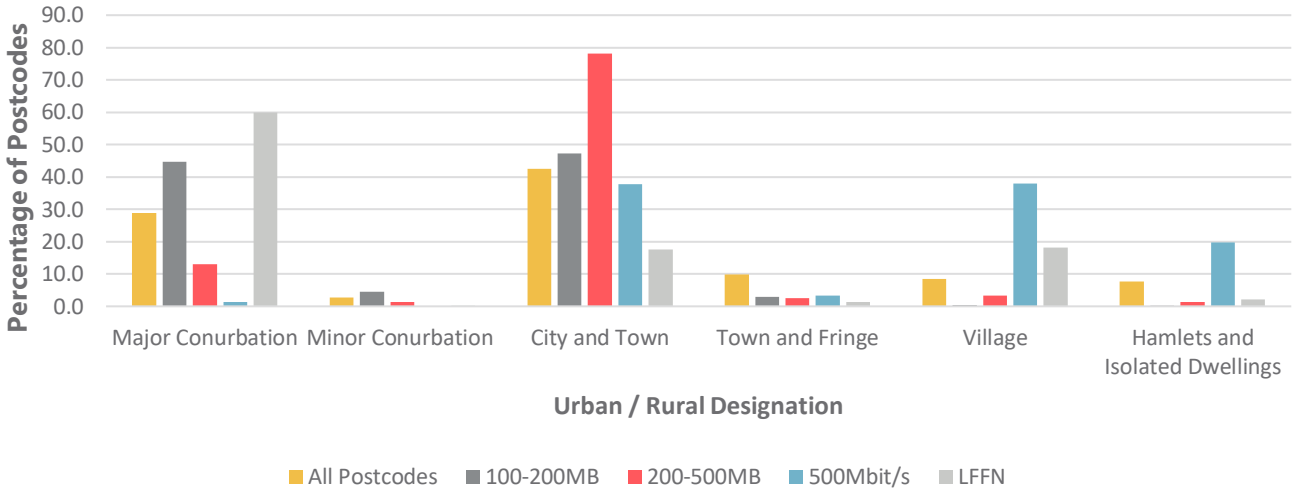
Figure 4.4: LFFN Postcodes and Postcodes Benefitting from Large Connectivity Changes (Panel 2)



Urban and Rural

Figure 4.5 gives an overview of the urban and rural distribution of postcodes identified as having benefitted from large changes in connectivity. These results align with the broad findings set out in Section 1.1.2 above, suggesting that postcodes benefitting from connectivity improvements of 100-200 and 200-500 Mbit/s have been clustered in major and minor urban areas. Larger connectivity gains have been much more heavily concentrated in rural areas typified by villages and hamlets. Postcodes set to benefit from LFFN were most heavily concentrated in urban areas, with 60 percent of relevant postcodes being designated as located in 'major conurbations.'

Figure 4.5: Distribution of Postcodes Benefitting from Large Changes in Connectivity across Urban and Rural Areas (2011 Rural Urban Classification)



Source: ONS Postcode Directory, August 2017

Agglomeration

Table 4.13 below provides a variety of measures of economic density for the postcodes benefitting from enhanced connectivity and its wider local economy (the local authority). The findings broadly align with the results above—the economic density of the wider areas benefitting from increases in maximum available download speeds of 100-200 Mbit/s and 200-500 Mbit/s (as well as LFFN postcodes) are higher than the national average, and lower in those benefitting from increases in maximum available download speeds of 500 Mbit/s or more.

However, the economic density of the *postcodes* benefitting from these improvements tends to be lower than average, suggesting penetration of enhanced connectivity has been more significant in suburban and residential areas than in central business districts where density of employment (and use of leased lines) is higher. In this respect, the LFFN programme appears to have be targeted at more economically dense postcodes and has the potential to raise the productivity of more workers than possible in the areas that have already seen large changes in connectivity.

Table 4.13: Measures of Economic Density, Areas Benefitting from Large Changes in Connectivity

	All	100-200 Mbit/s	200-500 Mbit/s	500 Mbit/s or more	LFFN
Population					
Population per Sq./Km in OA (2011)	7,844	11,666	7,073	1,501	2,863
Population of LA (2017)	167,858	197,511	248,747	143,120	214,560
Employment					
Jobs per postcode, 2017	-	4.8	6.7	7.1	16.7
Jobs in LA, 2015	74621	86940	104,845	65,474	81,528
Firms					
Local units on postcode, 2017	-	3.3	5.9	5.8	6.7
Local units in LA, 2016	8010.0	8708.0	10,802	7,310	8,677

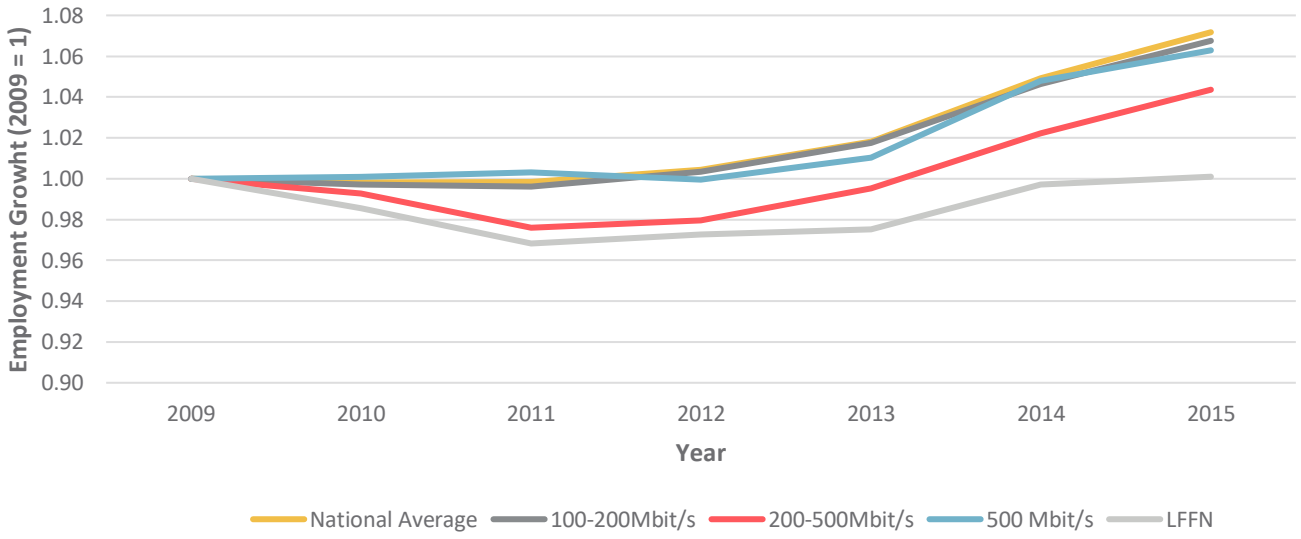
Source: 2011 Census, Mid-Year Population Estimates, Business Register of Employment Survey, UK Business Counts, Business Structure Database, Office for National Statistics.

Table Note. Figures at the LA level have been weighted by the share of postcodes benefitting from enhanced connectivity.

Employment Growth

Figure 4.6 shows employment growth within the local economy (the local authority level) between 2009 and 2015. Areas benefitting from 100-200 Mbit/s and more than 500 Mbit/s improvements in connectivity saw employment recover following the financial crisis at similar rates (rising to 6-7 percent above 2009 levels by 2015). Areas benefitting from 200-500 Mbit/s improvements in connectivity recover at slower rate, perhaps reflecting slower recovery in the more peripheral post-industrial region of Kingston-Upon-Hull. However, employment growth in areas benefitting from LFFN was markedly lower than the national average, with employment continuing to decline to 2011 and only reaching 2009 levels in 2015.

Figure 4.6: Employment Growth in the Local Authority Area, 2009 to 2015



Source: Business Register of Employment Survey, Office for National Statistics.

Table note. LA level figures have been weighted by the share of postcodes benefitting from enhanced connectivity.

Sector Distribution of Employment

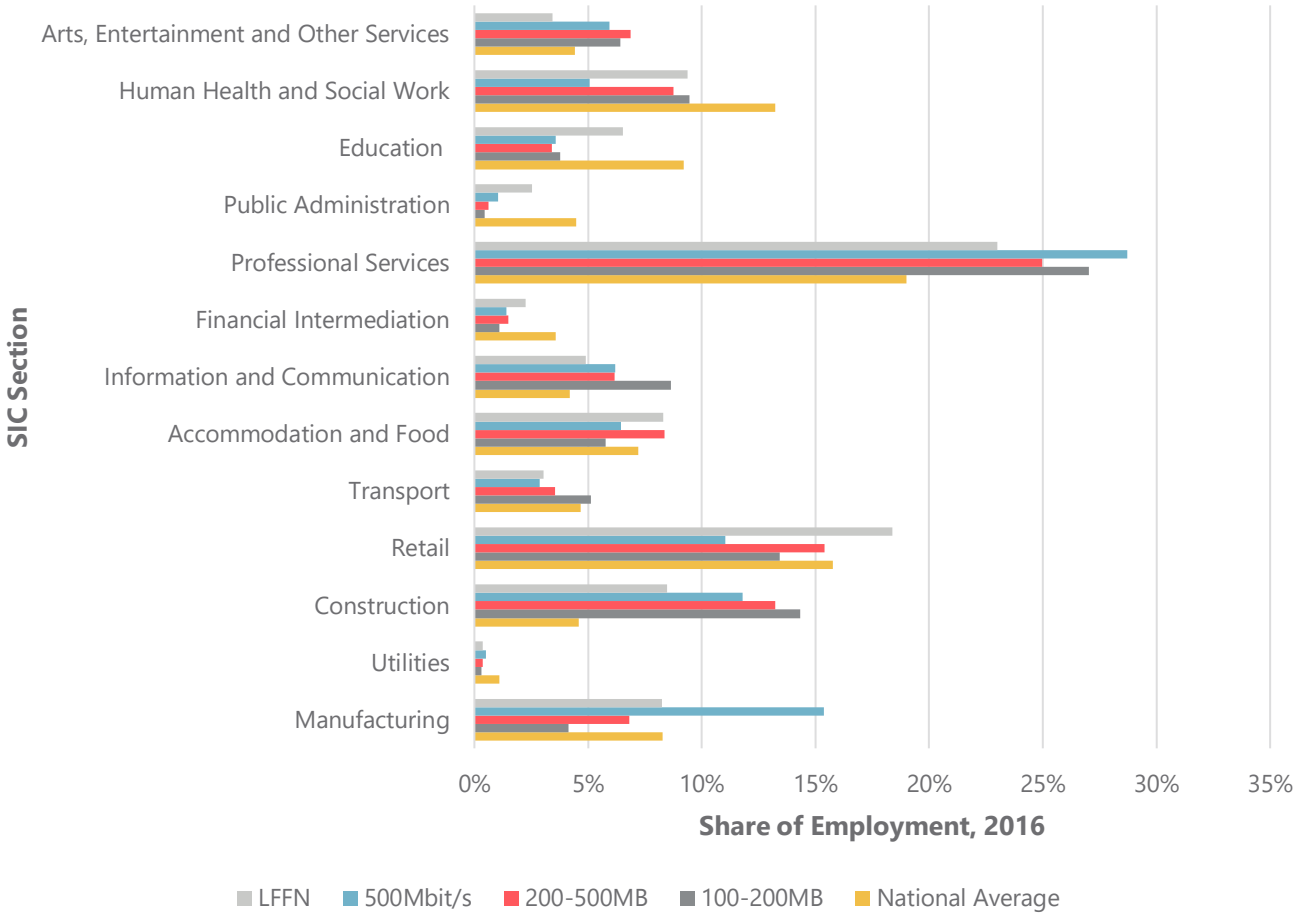
The following figure gives an overview of the sector distribution of employment on postcodes benefitting from enhanced connectivity (and benchmarked against the national average). Areas benefitting from higher connectivity share some common characteristics, including higher concentrations of employment in:

- Higher value professional services industries
- Construction
- Information and Communication
- Arts, entertainment and other services

At the same time, these postcodes showed lower dependency on the public sector and financial intermediation (and to some extent, manufacturing—though this did not hold true for those postcodes benefitting from the largest increases in connectivity).

The sector distribution of employment amongst postcodes likely to benefit from LFFN was broadly similar to those areas benefitting from 100 to 200 Mbit/s and 200 to 500 Mbit/s improvements in connectivity. However, there were some differences—the prevalence of higher value added professional services and construction was lower than in these areas (though higher than the national average), while lower productivity services were more prevalent (such as retail, human health, and education).

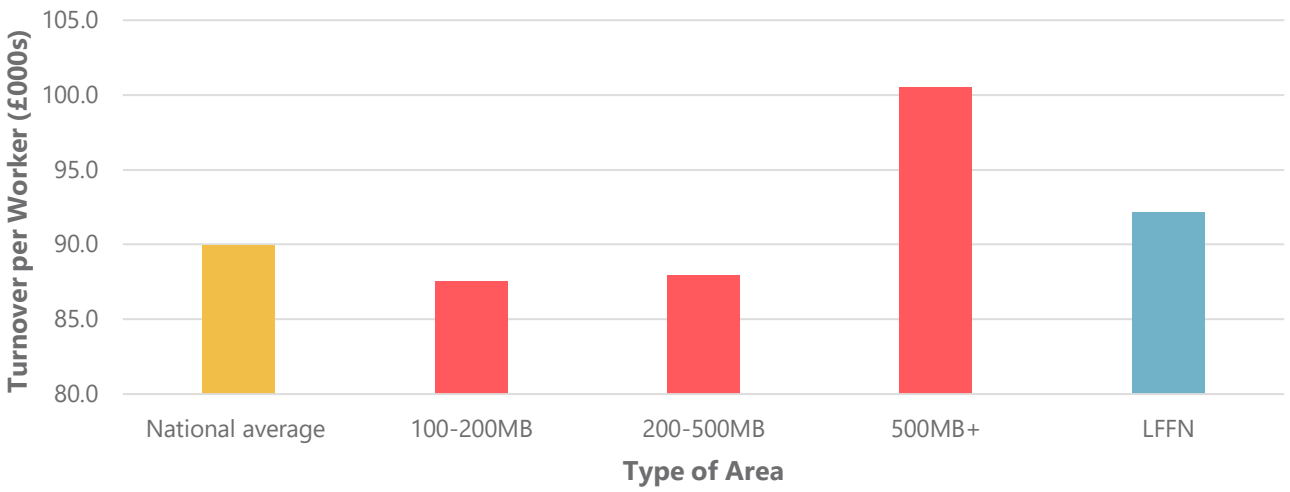
Figure 4.7: Sector Distribution of Employment



Productivity

The figure below provides estimates of turnover per worker (used as a proxy measure for productivity) for the firms located on postcodes benefitting from large enhancements in available download speeds (in 2016). The most productive firms were located on those postcodes benefitting from the largest improvements in connectivity, while firms in other postcodes tended to be associated with turnover per worker comparable to the national average. Firms located on postcodes set to benefit from LFFN appeared to be more productive than the national average (with turnover per worker around 3 percent higher than the national average), though less so than those located on postcodes benefitting from the largest enhancements in connectivity (turnover per worker was around 9 percent lower).

Figure 4.8: Turnover Per Worker, Firms Located on Postcodes Benefitting from Large Connectivity Improvements, 2016

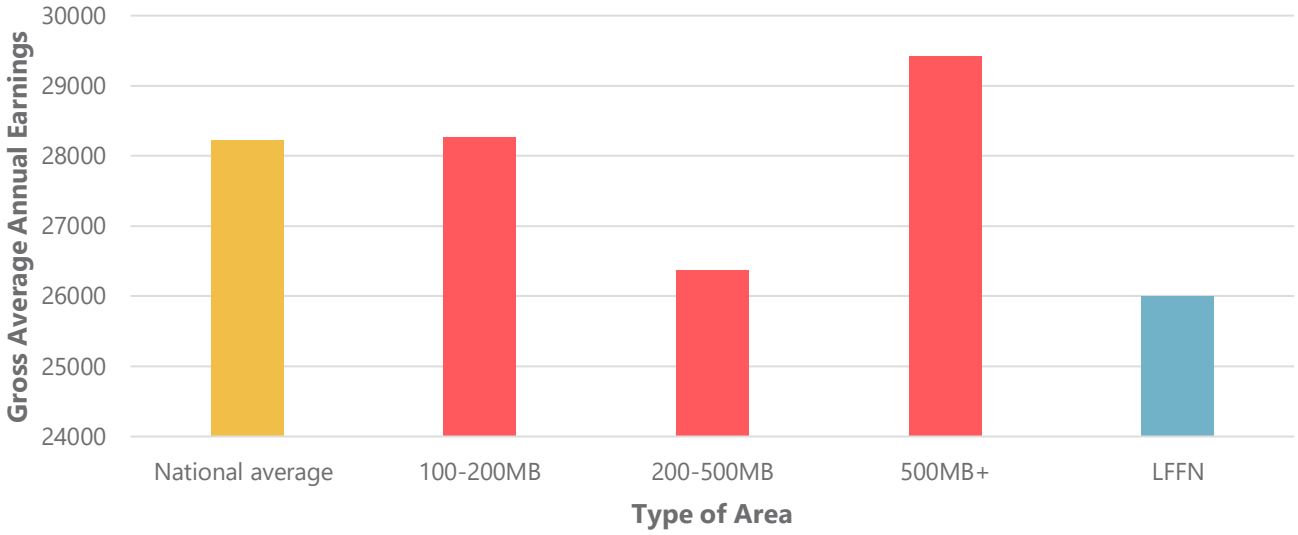


Source: Business Structure Database, Office for National Statistics

Wages

These general patterns were also visible in the earnings of the working population in the local authority, with wages expected to be correlated with the productivity of the local workforce. Workers located in areas benefitting from the largest improvements in connection speeds received annual earnings that were 4 percent higher than the national average. Areas set to benefit from LFFN proved an exception to this, with the local workforce in relevant local authorities receiving annual earnings around 8 percent lower than the national average. This could reflect some selectivity—it may be that firms self-selecting into the Gigabit Voucher Connection scheme are amongst the more productive within low productivity areas.

Figure 4.9: Gross Average Annual Earnings, 2017

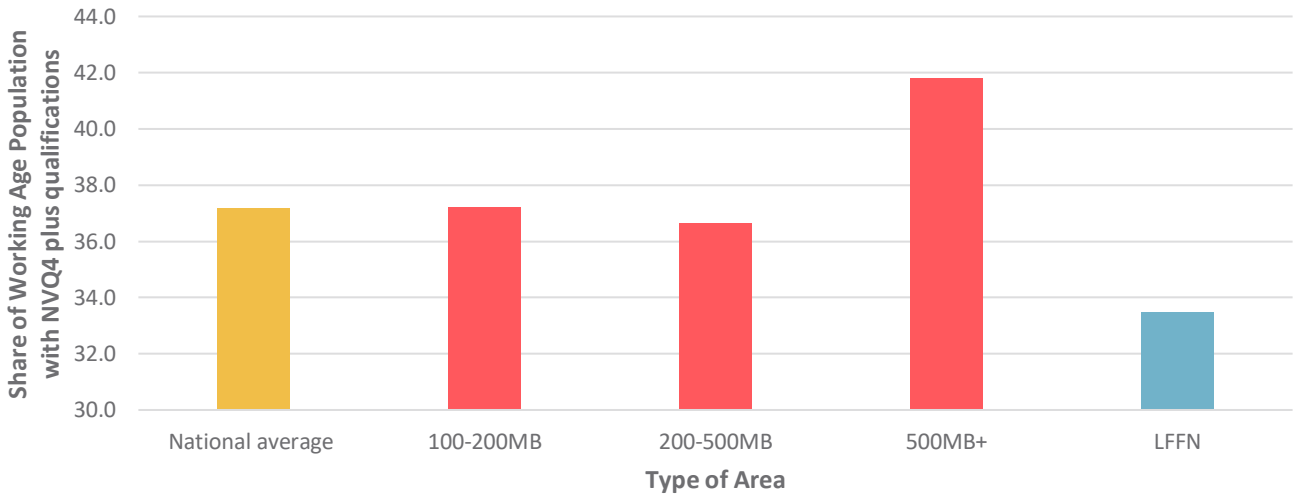


Source: Annual Survey of Hours and Earnings, Office for National Statistics.
Table Note. LA level figures have been weighted by the share of postcodes benefitting from enhanced connectivity.

Skills Supply

The figure below compares the areas under consideration in terms of local skills supply, as approximated by the share of the working age population in the local authority with NVQ level 4 qualifications or above. Those areas seeing improvements in connectivity of 100-200 Mbit/s and 200-500 Mbit/s had similar shares of the working age population with NVQ level 4 qualifications to the national average (around 37 percent). Postcodes benefitting from connectivity improvements of 500Mbit/s or above appeared to have much higher shares of the working age population holding degree level qualifications (almost 42 percent). By contrast, areas set to benefit from LFFN appear relatively disadvantaged in terms of the skills of local workers, with just 33 percent of the working age population holding an NVQ level 4 qualification or above, aligning with relatively low earnings in these areas, described immediately above in the section on wages.

Figure 4.10: Share of Working Age Population in Local Authority with NVQ level 4 qualifications or above



Source: Annual Population Survey, Office for National Statistics.

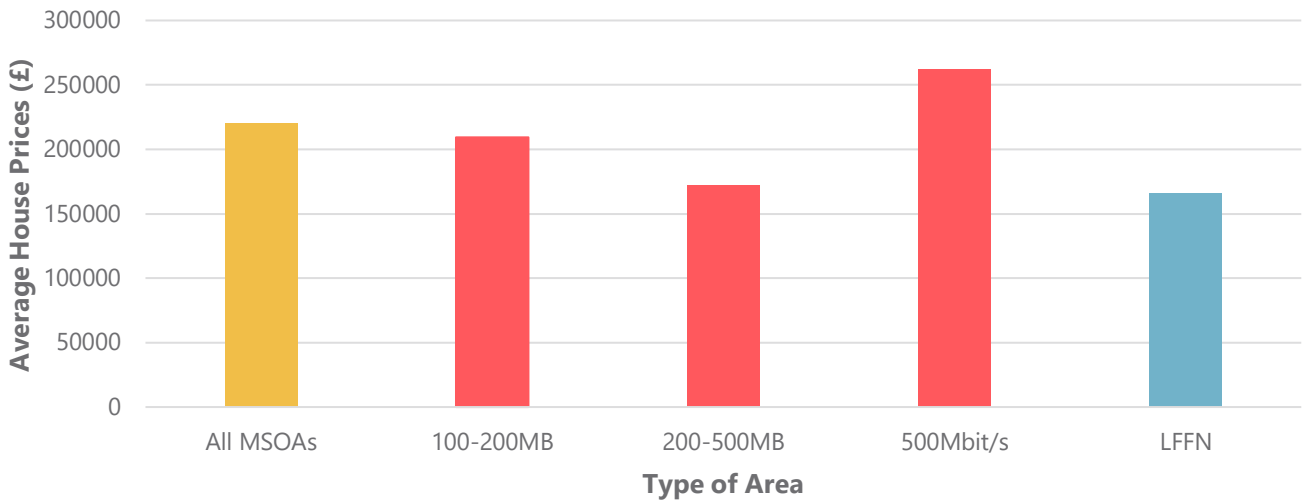
Table note. LA level figures have been weighted by the share of postcodes benefitting from enhanced connectivity.

House Prices

House prices were generally lower than the national average in those areas benefitting from 100-200 Mbit/s and 200-500 Mbit/s improvements in available download speeds. This likely reflects the greater density of these enhancements outside of the South East and London and where housing demand is lower. However, areas seeing the largest increases in available broadband speeds where characterised by high house prices (19 percent higher than the national average).

Postcodes set to benefit from LFFN tended to be located in areas with house prices comparable to those associated with 200-500 Mbit/s enhancements in connectivity (dominated by Kingston-Upon-Hull). This reinforces the general picture that LFFN is being primarily benefitting at lagging areas that may be seeing selective outmigration of skilled workers, rather than the more buoyant local economies that have benefitted from comparable enhancements in connectivity.

Figure 4.11: Average House Prices within the Neighbourhood, 2016



Source: House Price Statistics for Small Areas, Office for National Statistics.

Table note. MSOA level figures have been weighted by the share of postcodes benefitting from enhanced connectivity.

Implications

- The evidence set out in this paper suggests that large enhancements in connectivity have significant effects on local economic development. These effects are partly felt through raising the productivity of firms located on postcodes benefitting from those improvements (who appear able to reduce employment in response to greater available download speeds without loss of revenues). However, enhanced connectivity also triggers greater local economic dynamism, encouraging larger numbers of businesses to seek accommodation in those areas. This process may place pressure on rents, forcing some incumbent firms elsewhere (or out of business). Nevertheless, the net local effect is positive as incoming firms tend to be more efficient than outgoing firms. These effects appear to become more significant with larger speed increases—though there are substantial differences between areas benefitting from different magnitudes of improvements in connectivity, so it is unclear how far this link is causal in nature.

- LFFN is expected to benefit postcodes that are more economically dense than those that have benefitted from large improvements in connectivity to date. If making 1000 Mbit/s connectivity available in those postcodes has a similar effect to making 100-500 Mbit/s download speeds available, then this could result in annual productivity gains of £15.5m[58] per annum.

- However, the analyses set out above suggest that there are substantial differences between areas being targeted through LFFN and those that have benefitted from large increases in connectivity to date. Areas that have seen the largest gains in connectivity (mostly with 1Gbit/s connections), have typically been affluent areas outside of the major and minor cities with high productivity workforces. Areas that will benefit from LFFN are substantially more urbanised and characterised by low productivity, low wages and weaker supply of skills (and other indicators of economic disadvantage, such as low prices). Caution is therefore urged in assuming that similar results can be replicated by LFFN, particularly given wider research that stresses the complementarity between human capital and connectivity in influencing firm location decisions

[58] Assuming an effect on productivity of 2.5%, GVA per worker of £38,000, 16.7 workers per postcode and 972 postcodes (i.e. excluding purely residential postcodes).

(suggesting that higher level skills are required to take advantage of the opportunities created by higher levels of connectivity).

Nevertheless, LFFN areas appear most similar to those that have benefitted from improvements in available download speeds of 200-500 Mbit/s. These postcodes were primarily located in Kingston-Upon-Hull (an economically lagging post-industrial area) and the evidence from the analysis suggested that large improvements in connectivity can also produce economic benefits in these types of areas. Additionally, features of the LFFN—such as the self-selecting nature of the voucher programme—may facilitate the targeting of resources to those firms best able to exploit the technology. As such, expectations of productivity gains from the programme do not appear misplaced.

For more information

3 Thomas More Square
London
E1W 1YW

t: +44 (0)20 3059 5000

www.ipsos-mori.com
http://twitter.com/IpsosMORI

About Ipsos MORI's Social Research Institute

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