Department for Digital, Culture, Media & Sport

Superfast Broadband Programme – State aid Evaluation Report

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Glossary of key terms and acronyms

Category	Term / acronym	Meaning
Broadband / technology terminology	NGA	**Next Generation Access** – This refers to new or upgraded access networks that will allow substantial improvements in broadband speeds.[1] This includes Fibre to the Cabinet, Fibre to the Premises (Fibre to the Home), Wireless and Cable broadband connections.
	FTTP / FTTH	**Fibre to the Premises / Fibre to the Home** – This refers to an access network structure in which the optical fibre runs from the local exchange to the end user's living or office space.
	FTTC	**Fibre to the Cabinet** - An access network structure in which the optical fibre extends from the exchange to the cabinet. The street cabinet is usually located only a few hundred metres from the subscriber's premises. The remaining part of the access network from the cabinet to the customer is usually copper wire.
	Cable	Telecommunications infrastructure which utilises cable networks, such as Data Over Cable Service Interface Specification (DOCSIS-3) networks.
	Wireless	High-speed internet access where connections to the premises use radio signals rather than cables.
	GFAST	A type of connection which involves the deployment of additional fibre to a node that is very close to the premises to be served, normally located on a pole or in a chamber. The connection from the node to the premises retains the existing copper. This can achieve speeds up to four times faster than traditional FTTC connections.
	ADSL	**Asymmetric Digital Subscriber Line** - A technology used for sending data quickly over a conventional copper telephone line. It is used in current internet services with download speeds up to 24Mbps.
	SBB	**Standard broadband** - with download speeds of up to 30 Mbps.
	SFBB	**Superfast broadband** - download speeds from 30 Mbps up to 300 Mbps.
	UFBB	**Ultrafast broadband** - able to deliver download speeds equal or greater than 300 Mbps.
	LLU	**Local Loop Unbundling** - When communication providers can gain access to the network by placing their own equipment at the exchange. The communication providers then gain control of the line from the local exchange to the customer and the backhaul (the link between the local network and the global internet) runs from the local exchange to their core network.
	VULA	**Virtual Unbundling of the Local Loop** – an Openreach wholesale product used in the UK for the third party provision of superfast broadband services using VDSL (very high speed digital subscriber loop). It uses a single fibre based access infrastructure which is electronically unbundled and made available to all providers on an equal and non-discriminatory

[1] The term was first used by the European Commission in 2010 to refer 'to upgrades to ADSL networks which had previously relied on end to end copper connections for the delivery of broadband services' – see para 11 at https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32010H0572

Category	Term / acronym	Meaning
		basis.
Type of telecoms provider	ISP	**Internet Service Provider** – An organisation which provides households / businesses access to the internet. ISPs do not always own the infrastructure used to provide services, and can utilise the infrastructure owned by network providers to provide services.
	Network provider	Telecommunications providers which own infrastructure which is used to deliver internet services.
	Programme beneficiary	One of the five network providers that were awarded Superfast Broadband contracts.
	Alt-nets	**Alternative network** – Smaller network providers that are not reliant on the Openreach network.
Public sector organisations involved in delivery	BDUK	Building Digital UK.
	DCMS	Department for Digital, Culture, Media and Sport.
	Local Bodies	Local Authorities / devolved Governments responsible for delivering local Superfast Broadband Programme projects.
	NCC	**National Competency Centre** – an entity within BDUK which is responsible for ensuring the Superfast Broadband Programme complies with the European Commission State aid legislation.
Financial terms	IRR	**Internal Rate of Return** - a measure of an investment's expected future rate of return.
	WACC	**Weighted Average Cost of Capital** - the rate that a company is expected to pay on average to finance its assets.
	Capex	**Capital expenditure –** expenditure to buy/maintain/improve fixed assets.
	Opex	**Operational expenditure –** ongoing expenditure associated with delivering a product / running a business.
Economic and evaluation terms	Cost Benefit Analysis	A comparison of the monetary values of the costs and benefits of an intervention.
	Turnover	The amount of money generated by a business (value of sales).
	GVA	**Gross Value Added** – The additional value generated from economic activity (in monetary terms).
	Outcome	Outcomes are social or economic measures that could be affected by the programme (e.g. jobs, turnover, life satisfaction)
	Impact	Impacts are the effects on the outcome that are attributable to the programme over and above what would have occurred in the absence of the programme. Impacts occur over a longer time period.
	Benefit	A measurable improvement of a positive outcome (as perceived a by one or more stakeholders), which contributes towards one or more organisational objectives
	Efficiency	A measure of the extent to which a project, or policy's associated throughputs are increased
	Disagglomeration	A process by which companies or firms no longer need to be in close proximity to one another, and become more geographically dispersed.
	Opportunity Cost	The value of the best alternative use of resources or assets (the benefits foregone on alternatives courses of action when deploying resources or assets).
Superfast Broadband Programme terms	NBS	UK National Broadband Scheme (the Superfast Broadband Programme).
	Implementation Clawback	A mechanism to recover underspend. In the event of any underspend, the network provider was required to place unused funds in an Investment Fund to help resource further schemes or extend the contract coverage to a greater number of premises than originally offered.

Category	Term / acronym	Meaning
	Take-up clawback	If take-up proved to be higher than anticipated at the tendering stage, network providers were required to return a share of the excess revenues generated from additional take-up to the investment fund.
	OMR	**Open Market Review:** A process by which network providers outlined their existing broadband networks and their network roll out plans for the coming three years.
	'White' areas (postcodes)	Areas identified in the OMR process where there were no commercial plans to roll-out superfast broadband within three years.
	'Grey' areas (postcodes)	Areas identified in the OMR process where one provider was offering or expected to offer superfast broadband services within three years.
	'Black' areas (postcodes)	Areas identified in the OMR process where multiple providers were offering or expected to offer superfast broadband.
	SCT	**Speed and Coverage Template** - a list of premises or postcodes that were identified as 'white' in the OMR process and therefore eligible for subsidised infrastructure.
	PFM	**Project Financial Model –** a document which includes all of the financial information (build costs, expected take-up, WACC etc.), which is developed by programme beneficiaries at the start of the local project.
	C3 reports	A list of premises or postcodes where the Superfast Broadband Programme has provided upgraded connectivity.

1. Executive summary

Ipsos MORI and partners[2] were commissioned by the Building Digital UK (BDUK) directorate of the Department for Digital, Culture, Media and Sport (DCMS) in May 2019 to undertake the State aid evaluation of the UK National Broadband Scheme (the Superfast Broadband Programme). This document presents the final State aid evaluation report.

The Superfast Broadband Programme was announced in 2010 in response to concerns that the commercial deployment of superfast broadband infrastructure would fail to reach many parts of the UK. The Government established the programme to fund network providers to extend provision to areas where deployment was not commercially viable, on the expectation that doing so would result in economic, social and environmental benefits.

The scheme was initially backed by £530m of BDUK funding, with the aim of extending superfast coverage to 90 percent of UK premises by December 2016. These schemes were funded under the State aid judgement SA.33671 (2012/N).[3] This relates to Phase 1 and Phase 2 of the programme. Phase 3 of the Superfast Broadband Programme – the primary focus of this evaluation - was funded under a new State aid judgement covering contracts awarded between 2016 and 2018 (State aid SA. 40720 (2016/N)).[4] Contracts awarded under Phase 3 by mid-2020 involved £391m in public funding.

1.1 Evaluation aims and methodological approach

The aims and objectives of the State aid evaluation of the Superfast Broadband Programme are to provide evidence with respect to the seven key State aid evaluation questions, as set out in the National Broadband Scheme (NBS) evaluation plan. These questions are:

- Question 1: To what extent has the aid resulted in increased access to an NGA network being deployed in 'white' NGA areas?
- Question 2: To what extent has the target of the intervention taken-up Superfast Broadband connections and what speeds are available?
- Question 3: Has the aid had a significant incentive effect on the aid beneficiaries?
- Question 4: Has the aid had a material effect on the market position of the direct beneficiaries?
- Question 5: Is there evidence of changes to parameters of competition arising from the aid? (including third parties operating in the relevant intervention area(s))?
- Question 6: Is the gap funding model efficient compared to alternative schemes?
- Question 7: Did the aid lead to commercially sustainable networks?

The methodology used to undertake the State aid evaluation of the Superfast Broadband Programme follows the requirements set out in the UK National Broadband Scheme (NBS) evaluation plan[5] agreed between the European Commission and BDUK in 2016. Some changes to the agreed methodology have been made with the agreement of the European

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[2] Ipsos MORI's partners are: George Barrett, Richard George Feasey Plum Consulting and Simetrica.
[3] European Commission (2012) State aid SA.33671 (2012/N) – United Kingdom National Broadband scheme for the UK - Broadband Delivery UK https://ec.europa.eu/competition/state_aid/cases/243212/243212_1387832_172_1.pdf
[4] European Commission (2016) SA. 40720 (2016/N) – National Broadband Scheme for the UK for 2016-2020 https://ec.europa.eu/competition/state_aid/cases/263954/263954_1760328_135_4.pdf
[5] Department for Digital, Culture, Media & Sport (2017) National Broadband Scheme Evaluation Plan (Redacted version). Available at: https://www.gov.uk/government/publications/national-broadband-scheme-evaluation-plan (Accessed in January 2020)

Commission, owing to the stage of delivery of the local projects within the Superfast Broadband Programme and the availability of the data foreseen to undertake the analysis.

A summary of the methodological approach used for the evaluation is presented below:

- **Econometric analysis:** An assessment of the effects of Phase 3 contracts on superfast broadband coverage and take-up (Questions 1 and 2 of the State aid evaluation plan) was completed by implementing a series of econometric analysis that compared NGA, superfast and FTTP coverage and take-up in the areas benefitting from the programme to other postcodes that were eligible for subsidies but were not selected by network providers to benefit from broadband coverage delivered under Phase 3.

- **Modelling of expected Internal Rates of Return:** An assessment of the 'incentive effect' provided by the subsidies (Question 4 of the State aid evaluation plan) was completed by comparing the network provider's expected Internal Rate of Return (IRR) to their Weighted Average Cost of Capital (WACC).

- **Market share analysis:** An examination of the effect of the programme on the parameters of local competition was completed by exploring changes in the number of network providers active in the programme area, the technologies used to deliver broadband connections and their market shares between 2016 and 2020 (Question 4 and 5 of the State aid evaluation plan).

- **Cost benefit analysis:** A cost-benefit analysis of the programme was also completed to explore issues relating to the cost effectiveness of the Superfast Broadband Programme and the degree to which its costs were justified by its benefits. The analysis was completed in line with the principles of the HM Treasury Green Book[6] and were supported by a variety of econometric analyses examining the effect of subsidised coverage on businesses, workers, households and the public sector.

  The analyses followed a comparable methodology to prior evaluation studies exploring the economic impacts of the programme published in 2018[7]. However, the underlying data was only available at a higher level of geography (Output Area rather than postcode). The means that the impacts of the programme at the local level estimated in this report are lower than presented in previous studies. This is because the results based on data at the Output Area level are sensitive to displacement effects at the local level. For example, if improved broadband encourages firms to move small distances to take advantage of superior connectivity, this will have a positive effect on employment on the postcodes receiving enhanced coverage although there may be no overall change in employment at the level of the Output Area. For the purposes of the cost-benefit analysis, only productivity gains have considered a 'net impact' at the national level.

- **Supporting primary research:** The evaluation was supported by a programme of in-depth research with 40 Local Bodies that were involved in procuring contracts under the Superfast Broadband Programme and 16 telecommunications providers, a large-

[6] HM Treasury (2018) The Green Book: Central Government Guidance on Appraisal and Evaluation. Available at: https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-governent
[7] DCMS (2018) Economic and Public Value Impacts of the Superfast Broadband Programme

scale telephone survey of businesses (base 1,200) that were either located in areas where the network had been upgraded by the Superfast Broadband Programme in the years since 2016, or areas that were yet to receive superfast broadband coverage, and a series of 40 in-depth interviews with businesses in these areas.

- **Availability of data sources:** The evaluation used a range of datasets covering different time periods:

  - Connected Nations, published by Ofcom, was used to measure the impact of the programme on superfast broadband coverage and take-up (State aid Evaluation questions 1 and 2). This gave annual data between 2012 and 2019 describing broadband availability and take-up in each postcode in the UK. The most recent data described broadband coverage in September 2019.

  - Data from ThinkBroadband was used to assess the effect of the programme on the market shares of network providers and NGA technology data. Data was obtained for the years 2016 and 2020.

  - Economic outcomes were measured using a variety of datasets. ONS Secure Research Service accessed data included the Business Structure Database (BSD) and the Annual Survey of Hours and Earnings (ASHE). These provided data up to and including 2018 at the time of analysis. Valuation Office Agency Rating List (VOA) data was also used with this data providing information on the rental value of commercial property in both 2010 and 2017. Claimant Count experimental data obtained from National Offender Management Information System (NOMIS) was utilised for unemployment outcomes and covered the years from 2013 to 2019.

  - Wellbeing effects were also explored and made use of both Land Registry Price Paid data and the Annual Population Survey (APS). Land Registry data covered the period from 2013 to 2019 for this analysis with the APS data covering the period between 2011 and 2019.

1.2 Key findings

This section provides a brief overview of the key findings from this report. These focus on the seven State aid evaluation questions, and the wider economic and social benefits of the programme.

Question 1: To what extent has the aid resulted in increased access to an NGA network being deployed in 'white' NGA areas?

Phase 3 contracts increased the number of premises passed by NGA services by 2,300 to 16,600 on postcodes benefitting from subsidised coverage by the end of September 2019 (with the weight of evidence to the lower end of this range). The share of the 79,100 premises upgraded by the end of September 2019 that would not have otherwise benefitted from NGA coverage is estimated at 3 to 21 percent.

Phase 3 contracts increased the number of premises with superfast coverage by 10,800 to 29,300, and the number of premises with FTTP coverage by 19,000 to 30,300. The additionality of superfast and FTTP coverage was correspondingly higher at 14 to 55 percent of premises receiving subsidised coverage. This indicates that some premises benefitting from subsidised upgrades would have otherwise received NGA coverage that did not deliver superfast speeds. There was also evidence that Phase 3 contracts delayed the availability of superfast coverage for some premises that would have otherwise received it earlier.

The findings were broadly consistent with more general analysis examining the impacts of the programme since delivery began in 2013. These findings indicated that the additionality of subsidised coverage peaks one year after premises are upgraded (at around 60 percent), before decaying at a rate of approximately 14 percent per annum. This implies that in many cases, the programme has worked to accelerate the availability of superfast broadband.

The results suggest that the processes used to identify the commercial plans of providers were not fully effective in establishing premises that would not benefit from commercial deployments in the near term. Several explanations for this emerged from the research. Network providers reported that their investment cycles were determined over relatively short time horizons (12 to 24 months). The absence of immediate commercial deployment plans did not necessarily imply that investment was considered economically unviable. Network providers sometimes could not provide Local Bodies with deployment plans of sufficient detail or certainty to be incorporated when the areas eligible for subsidies were determined. Finally, the definition of areas eligible for investment was based on a static view of network provider's plans, which subsequently evolved in response to regulatory innovation and growth in demand.

Question 2: To what extent has the target of the intervention been used and what speeds are available?

The findings indicated that Phase 3 contracts reduced the number of premises with superfast connections by 1.1 to 2.4 premises per postcode by September 2019. There was no conclusive evidence that subsidised coverage had a positive or negative effect on the average download speeds of connections by September 2019. This is likely a product of the short window of time that had elapsed for businesses and households to take-up, and the effect of the programme in delaying the availability of superfast for some premises that would have otherwise benefitted from commercial deployments. It is premature to draw conclusions on the impact of the programme on take-up, and analysis exploring the effects of the programme since it was launched in 2013 suggested it produced a broad range of positive impacts on take-up in the longer term.

The results did indicate that Phase 3 contracts increased the average upload speeds of connections (by 0.9Mbps to 3.9Mbps) and the maximum download speeds of connections by 6.2Mbps to 16.9Mbps. This may reflect the effect of FTTP delivery, which has enabled users to obtain higher capacity connections that may have otherwise been available.

Question 3: Has the aid had a significant incentive effect on the aid beneficiaries?

Based on projections provided by network providers at the tendering stage, the proposed network build under Phase 3 contracts was expected to either generate losses or to deliver positive rates of return (Internal Rate of Return or IRR) that were substantially lower than the cost of capital faced by the network provider - a loss of **[redacted]** per annum versus a Weighted Average Cost of Capital (WACC) of **[redacted]**. If it is assumed that profit maximising firms are only incentivised to implement projects where the IRR exceeds the WACC, then public subsidies would have been needed to create a sufficient economic incentive to deliver these investments.

The analysis suggested that network providers consistently underestimated take-up in the tendering process for Phases 1 and 2. The projections of take-up in Phase 3 of the programme also appear understated given that network providers will have learned the likely levels of demand from their experiences with Phase 1 and 2 contracts. This means beneficiaries may have understated revenue projections, increasing the apparent level of public funding needed to make the project economically viable. However, after updating projections in line with take-up observed on Phase 1 and 2 contracts, the projected IRRs associated with Phase 3 projects without subsidy are not significantly higher than those expected at the tendering stage (a positive IRR of **[redacted]**). The projected IRRs of all Phase 3 contracts (without subsidy) are expected to be substantially lower than the WACC of the network provider.

The protections put in place by BDUK are likely to protect the public sector from the risk that it provided more than the minimum subsidy needed. Contracts have been designed such that network providers are required to return resources to the public sector if build costs are understated or if take-up proves higher than expected (leading to higher levels of profitability). While the provision of subsidies is expected to increase the IRRs on Phase 3 contracts to **[redacted]**, this falls to **[redacted]** once the activation of these contractual mechanisms is accounted for.

While the contracts have proven largely effective in containing subsidies to the minimum needed for the project to go forward, the public sector has incurred opportunity costs by tying resources up in the programme. BDUK may wish to consider whether seeking to contain these opportunity costs in future procurements could be justified.

Question 4: Has the aid had a material effect on the market position of the direct beneficiaries?

At a UK level, there has not been significant changes in the market share of programme beneficiaries in the broadband market between 2016 and 2020. Openreach dominates the market (even more so if Sky and TalkTalk are included in the Openreach market share, as these providers utilise the Openreach network), representing more than three quarters of the broadband market in both 2016 and 2020. The other beneficiaries of the Superfast Broadband Programme represented less than 0.5 percent of the market in both 2016 and 2020. A similar pattern is seen for the NGA market, with Openreach representing over 60 percent of the market in both 2016 and 2020, with the other programme beneficiaries representing less than 0.5 percent of the market.

In the areas where the Superfast Broadband Programme has been delivered, the programme appears to have had little impact on the market position of Openreach in either the overall broadband or NGA market, as Openreach maintains a dominant market position in both 2016 and 2020. However, the market share in both the overall broadband and NGA market for the smaller programme beneficiaries has increased between 2016 and 2020 in Phase 3 delivery areas which is not observed at a national level, suggesting the programme has positively affected the market share of the programme beneficiaries in these areas.

In areas where Openreach have delivered contracts, they have maintained their market share between 2016 and 2020 in both the overall broadband and NGA markets. However, in areas where the other, smaller programme beneficiaries have delivered contracts, the market share for Openreach has fallen (particularly in areas where Gigaclear have delivered contracts), with the market share of the other beneficiaries increasing. This suggests that the other beneficiaries are taking market share from Openreach in these areas.

Question 5: How far is there evidence of changes to parameters of competition arising from the aid?

At a UK level, the share of NGA broadband take-up as a proportion of total broadband take-up has increased markedly since 2016. NGA connections represented just over half of all broadband connections in 2016, but this has grown to over 70 percent of internet connections in 2020. Fibre to the Cabinet (FTTC) connections represented the largest proportion of NGA connections in both 2016 and 2020 (around a third of all broadband connections in 2016 and just over a half in 2020). This pattern was also observed in areas benefitting from the Superfast Broadband Programme.

The average number of infrastructure providers operating on the postcodes benefitting from subsidised upgrades rose from 2.3 to 2.6 between 2012 and 2020, indicating the programme has helped promote greater competition in these areas. Although there has been an increase in the number of network providers offering services in Superfast Broadband Programme areas, most non-beneficiary network providers tended to provide services to only a small number of postcodes within the Superfast Broadband project areas. This suggests there has not been a large degree of overbuild.

The number of ISPs operating in Superfast Broadband Programme areas has increased between 2016 and 2020. There are a higher number of ISPs with customers in Phase 1 contract areas than Phase 2 and Phase 3. This would be expected, given that the Phase 1 areas were larger and more commercially viable. Additionally, all Phase 1 contracts were delivered by Openreach, and the qualitative findings suggested that at present no ISPs were utilising the subsidised networks built by programme beneficiaries other than Openreach.

Question 6: Is the gap funding model efficient compared to alternative schemes?

The gross public sector cost (i.e. before clawback) per additional covered premises over three years was £890 for Phase 3 contracts (in 2019 prices). However, the public sector savings from the clawback mechanism is expected to reduce the net cost per additional covered premises from £890 to £790 for Phase 3 contracts (though again, given the early stage of delivery, these estimates are highly uncertain).

A review of the literature suggests that there are no evaluations providing quantitative estimates of the cost-effectiveness of comparable initiatives in bringing forward broadband coverage. As such, it has not been possible to benchmark the scheme to explore issues relating to how far the programme design was optimal. However, a study for the European Commission does provide estimates of the projected cost per covered premises, and it appears that the cost per premises covered for the Superfast Broadband Programme is lower than the projected costs for comparable schemes in the EU.[8]

Question 7: Did the aid lead to commercially sustainable networks?

None of the 51 Phase 3 contracts currently listed on the Superfast Broadband management system have had services withdrawn by the network provider. This means that there have been no premises which have not been upgraded as a result of a beneficiary withdrawing from the programme.

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[8] European Commission (2020) The role of State aid for the rapid deployment of broadband networks in the EU; Available at: https://ec.europa.eu/competition/publications/reports/kd0420461enn.pdf

However, a total of five contracts have been terminated. All of these contracts were awarded and terminated by the same Local Body and were awarded to the same beneficiary. These contracts were terminated by the Local Body, due to the inability of the beneficiary (and its supply chain) to deliver the network build outlined in their bids to the required quality within the specified timeframe of the contract. These contracts were not terminated due to the commercial viability of the contract.

Analysis of Phase 3 contracts shows that take-up is currently below the expected level of take-up at the start of the projects, and in some cases this is significantly lower than expectations. However, the lower level of take-up is expected, given that the delivery of Phase 3 contracts is behind schedule. The beneficiaries did not raise any concerns about the long-term level of expected take-up in the qualitative interviews, suggesting that they expect the networks to be commercially sustainable.

The pre-delivery Average Revenue Per User was compared to the Average Operational Cost per User, which showed that all the beneficiaries expected their revenue to be higher than their Operational Cost. Actual revenues and operational costs per user are not monitored by BDUK and therefore it is not possible to assess any updated average costs and revenues for beneficiaries.

Wider economy effects

The present value of net public spending required to deliver the Superfast Broadband Programme over the lifetime of Phase 1, 2 and 3 contracts was estimated to be £815m in nominal terms. This is less than estimated total cost of the programme of £1.9bn, as there is expected to be a large amount of clawback generated from the beneficiaries delivering the programme.

The findings of the evaluation indicate that the programme has led to a range of economic and social benefits in the areas benefitting from subsidised coverage between 2012 and 2018. The key results included:

- **Local employment impacts:** Subsidised coverage was estimated to have increased employment in the areas benefitting from the programme by 0.6 percent, leading to the creation of 17,600 local jobs by the end of 2018.

- **Turnover:** Subsidised coverage also increased the turnover of firms located in the areas benefitting from the programme by almost 1.0 percent by 2018, increasing the annual turnover of local businesses by £1.9bn per annum.

- **Number of firms:** The evidence indicated that a share of these local economic impacts were driven by the relocation of firms to the programme area. The evidence indicated that subsidised coverage increased the number of businesses located in the areas benefitting by around 0.5 percent – suggesting the programme may have encouraged the relocation of economic activity to rural areas.

- **Turnover per worker:** There were also signals of efficiency gains - turnover per worker of firms in the areas benefitting rose by 0.4 percent in response to subsidised coverage. This was not solely driven by more productive businesses moving into areas with improved broadband infrastructure. Firms that did not relocate over the period also saw their turnover per worker rise by 0.7 percent by 2018, indicating that subsidised coverage has also raised the efficiency of firms. However, the strength of these gains appeared to decay with time because these firms employed more workers as time passed.

- **Wages:** The impacts of the programme were also visible in wages. Employees working for firms located in the areas benefitting from subsidised coverage saw their hourly earnings increase by 0.7 percent in response to the upgrade. This gives greater confidence that the programme led to an increase in productivity.

- **Unemployment:** Local job creation also appeared to translate into reductions in unemployment, with the number of unemployed claimants falling by 32 for every 10,000 premises upgraded by 2018.

- **House prices:** The programme led to an increase in house prices (of between £1,700 and £3,500) suggesting that buyers valued the technology.

It is important to note that while most of these findings account for the possibility that businesses benefitting from the programme may have claimed market share from local competitors, they should not be interpreted as net economic impacts at the national level. At the national level, the programme is estimated to have resulted in:

- **Economic benefits:** The programme is estimated to have led to a cumulative total of £1.1bn in productivity gains between 2012 and 2019. This rises to between £1.6bn and £1.8bn over the 2012 to 2030 period.

- **Social benefits:** Based on its impacts on house prices between 2012 and 2019, the programme is estimated to have led to social benefits valued at between £0.7bn and £1.5bn.

The estimated Benefit to Cost Ratio (BCR) was £2.70 to £3.80 per £1 of net public sector spending based on its impacts between 2012 and 2019. Allowing for future economic benefits to 2030, the BCR is estimated to rise to £3.6 to £5.1 per £1 of net public sector spending.

Compliance

A sample of 15 project contracts were selected to evaluate the compliance of the programme with the State aid guidance. These project contracts were selected to represent different locations within the UK and contracts with each of the Phase 3 programme beneficiaries.

Across all the project contracts, there has been a high level of compliance with the State aid guidance. However, there are some gaps in the evidence provided for some projects. Given the other evidence that has been provided for these projects, it has been assessed that these are gaps in the evidence base, rather than evidence of non-compliance. The one area where there was evidence of a lack of compliance with European Commission Guidelines was around the timing of the Invitation to Tender (ITT) being issued, with this being more than a month after the public consultation exercise closed in most cases.

2. Introduction

Ipsos MORI and partners[9] were commissioned by the Building Digital UK (BDUK) directorate of the Department for Digital, Culture, Media and Sport (DCMS) in May 2019 to undertake the State aid evaluation of the UK National Broadband Scheme (the Superfast Broadband Programme). This document presents the final State aid evaluation report, examining the impacts of the programme between 2016 and 2020.

2.1 Superfast Broadband Programme

The Superfast Broadband Programme was announced in 2010 in response to concerns that the commercial deployment of superfast broadband infrastructure would fail to reach many parts of the UK. In June 2010 almost 3 million homes and businesses did not have access to broadband speeds of at least 2Mbps.[10] In June 2011 (the earliest data that is available), Superfast Broadband connections were available to 58 percent of premises in the UK.[11]

The Government established the programme to fund network providers to extend provision to areas where deployment was not commercially viable, on the expectation that doing so would result in economic, social and environmental benefits.

The scheme was initially backed by £530m of BDUK funding, with the aim of extending superfast coverage to 90 percent of UK premises by December 2016 (Phase 1). The programme was expanded in 2015, with a further £250m made available to extend coverage to 95 percent of premises by December 2017 (Phase 2). These schemes were funded under the State aid judgement SA.33671 (2012/N).[12]

Phase 3 of the Superfast Broadband Programme was funded under a new State aid judgement covering contracts awarded between 2016 and 2020 (State aid SA. 40720 (2016/N)).[13] Contracts awarded under Phase 3 by mid-2020 involved £391m in public funding. The scheme aims to provide superfast broadband coverage (or faster networks) in areas where availability remained below the 95 percent coverage target and extend superfast coverage beyond 95 percent where possible. This evaluation focuses primarily on contracts awarded under Phase 3 of the programme.

2.2 Evaluation aims and objectives

The aims and objectives of the State aid evaluation of the Superfast Broadband Programme are to provide evidence with respect to the seven key State aid evaluation questions, as set out in the National Broadband Scheme (NBS) evaluation plan:

- Question 1: To what extent has the aid resulted in increased access to an NGA network being deployed in 'white' NGA areas?

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[9] Ipsos MORI's partners are: George Barrett, Richard George Feasey Plum Consulting and Simetrica.

[10] https://www.gov.uk/government/publications/2010-to-2015-government-policy-broadband-investment/2010-to-2015-government-policy-broadband-investment#appendix-2-superfast-broadband-programme

[11] Ofcom (2011) Communications Infrastructure Report 2011: Fixed Broadband data; Available at: https://webarchive.nationalarchives.gov.uk/20200803095351/https://www.ofcom.org.uk/research-and-data/multi-sector-research/infrastructure-research

[12] European Commission (2012) State aid SA.33671 (2012/N) – United Kingdom National Broadband scheme for the UK - Broadband Delivery UK https://ec.europa.eu/competition/state_aid/cases/243212/243212_1387832_172_1.pdf

[13] European Commission (2016) SA. 40720 (2016/N) – National Broadband Scheme for the UK for 2016-2020 https://ec.europa.eu/competition/state_aid/cases/263954/263954_1760328_135_4.pdf

- Question 2: To what extent has the target of the intervention taken-up Superfast Broadband connections and what speeds are available?
- Question 3: Has the aid had a significant incentive effect on the aid beneficiaries?
- Question 4: Has the aid had a material effect on the market position of the direct beneficiaries?
- Question 5: Is there evidence of changes to parameters of competition arising from the aid? (including third parties operating in the relevant intervention area(s))?
- Question 6: Is the gap funding model efficient compared to alternative schemes?
- Question 7: Did the aid lead to commercially sustainable networks?

In addition to these seven key evaluation questions, the research has provided an assessment of compliance with the State aid judgement in the delivery of the programme (as required by the State aid evaluation plan). The evaluation also explores the overall benefits of the Superfast Broadband Programme to businesses, the public sector and households, as mentioned in section 3 of the State aid evaluation plan: BDUK will evaluate the wider outcomes and impacts of the programme, such as productivity, employment and public value; and undertake evaluations of the processes used to deploy the scheme.

2.3 Methodology

The methodology used to undertake the State aid evaluation of the Superfast Broadband Programme follows the requirements set out in the UK National Broadband Scheme (NBS) evaluation plan[14] agreed between the European Commission and BDUK in 2016. Some changes to the agreed methodology have been made with the agreement of the European Commission, owing to the stage of delivery of the local projects within the Superfast Broadband Programme and the availability of the data required to undertake the analysis foreseen. These limitations are set out in Section 2.4 of the report.

The methodology used is presented in detail in the Technical Annexes to this document, but a summary of the approach is detailed below:

- **Econometric analysis:** An assessment of the effects of Phase 3 contracts on NGA coverage and take-up (Questions 1 and 2 of the State aid evaluation plan) was completed by implementing a series of econometric analysis that compared areas benefitting from the programme to other postcodes that were eligible for subsidies. This was achieved by linking data on local broadband availability and take-up captured by Ofcom's regular Connected Nations report to management data compiled by BDUK describing the premises that were eligible for the programme. The underlying methodology was as robust as could be achieved within the constraints set by the design of the programme (achieving Level III on the Maryland Scientific Methods Scale). Full details of this analysis are set out in Technical Appendix 1.

- **Modelling of expected Internal Rates of Return:** An assessment of the 'incentive effect' provided by the subsidies was completed by comparing the network provider's expected Internal Rate of Return (IRR) to their Weighted Average Cost of Capital (WACC), before and after the award of subsidy. This analysis is motivated by the theoretical proposition that businesses in the private sector will maximise their profits if they implement all investment projects that generate expected returns that exceed

[14] Department for Digital, Culture, Media & Sport (2017) National Broadband Scheme Evaluation Plan (Redacted version). Available at: https://www.gov.uk/government/publications/national-broadband-scheme-evaluation-plan (Accessed in January 2020)

their cost of capital. However, the rates of return earned on contracts awarded cannot be observed directly because revenues and operational costs will be realised in the long-term (i.e. over 15 to 20 years) and cannot be monitored directly by BDUK. To address this challenge, a modelling exercise was completed in which the financial models put forward by network providers as part of the tendering process were updated to account for changes in expected capital costs and observed take-up of the superfast services made available. The analysis covered 20 of 51 contracts awarded under Phase 3 where the information needed to implement the modelling was available. Full details of this analysis are set out in Technical Appendix 2.

- **Market share analysis:** The effect of the programme on the parameters of local competition was explored by examining changes in the number of network providers active in the programme area and their market shares between 2016 and 2020. This was completed using network provider level data compiled independently by ThinkBroadband[15]. These analyses focused on changes over the period (in line with the methodology prescribed in the State aid evaluation plan) and achieve Level II on the Maryland Scientific Methods scale.

- **Cost benefit analysis:** A cost-benefit analysis of the programme was also completed to explore issues relating to the cost effectiveness of the Superfast Broadband Programme and the degree to which its costs were justified by its benefits. The analysis was completed in line with the guidance set out in the HM Treasury Green Book[16] and the approaches put forward for valuing economic and non-market impacts. The analysis was supported by a variety of econometric analyses examining the effect of subsidised coverage on businesses, workers, households and the public sector. These analyses employed a ‘pipeline’ design in which those areas benefitting from subsidised coverage in later years were compared to those benefitting in earlier years (again, achieving levels of robustness equivalent to Level III on the Maryland Scientific Method Methods Scale). Full details of this analysis are set out in Technical Appendix 3.

- **In-depth research with network providers and Local Bodies:** The evaluation was supported by a programme of in-depth research with 40 Local Bodies that were involved in procuring contracts under the Superfast Broadband Programme and 16 telecommunications providers (including all direct beneficiaries of the programme, network providers that tendered for but were not awarded contracts, network providers that did not tender for contracts, and internet service providers that could potentially make use of the infrastructure made available through the programme). The focus of the interviews was on understanding the mechanisms involved in producing the outcomes observed (including the role of processes adopted to manage the programme). Interviews were transcribed and analysed using the NVIVO qualitative analysis software package, with perspectives offered by the two groups triangulated against the key evaluation questions and, where possible, validated against the objective evidence available from monitoring information. Key findings were also validated in supplementary consultations with key BDUK officials responsible for the design and delivery of the programme.

15 ThinkBroadband is an independent organisation which collects information and data about internet coverage in the UK. It also runs an online ‘speed test’ function, where individuals can provide a limited amount of data about their broadband package and test the connection speed that they receive. www. https://www.thinkbroadband.com/

16 HM Treasury (2018) The Green Book: Central Government Guidance on Appraisal and Evaluation. Available at: https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-governent

- **Business surveys:** The evaluation also drew on the results of a large-scale telephone survey of businesses (base 1,200) that were either located in areas where the network had been upgraded by the Superfast Broadband Programme in the years since 2016, or were located on postcodes with planned upgrades that were yet to receive superfast broadband coverage. The achieved sample for the business survey included quotas for business size and sector, to ensure some control over the size and sector profiles of the businesses included in the survey rather than seeking to be strictly representative. The survey used an achieved sample of 1,200 rather than monitoring the response rates of a smaller population. The broader evaluation of the programme involves an on-going survey of residential beneficiaries to understand its social impacts, which will be reported in future publications.

2.4 Outcome measures and time-frames for the evaluation

The following table provides an overview of the primary outcome measures for the evaluation, data sources, and the time-frame over which effects are considered (which varies across data sources).

Table 2.1: Outcome measures and time-frames for evaluation

State aid evaluation question	Outcome indicators	Source	Time frame
1. To what extent has the aid resulted in increased access to an NGA network being deployed in 'white' NGA areas?	• Number of premises passed by NGA services • *Number of premises with superfast (30Mbps) coverage* • *Number of premises with Fibre-to-the-Premises coverage*	Connected Nations (Ofcom)	June 16 to September 19
2. To what extent has the target of the intervention been used and what speeds are available?	• Number of live NGA-delivered connections • *Number of premises connected to superfast (30Mbps) services* • Mean download speed of broadband connections • Mean upload speed of broadband connections	C3 reports, BDUK Connected Nations (Ofcom)	January 16 to September 19 June 2016 to September 2019
3. Has the aid had a significant incentive effect on the aid beneficiaries?	For each winning supplier: comparison of the supplier's expected Internal Rate of Return (with and without subsidy) versus their Weighted Average Cost of Capital	Modelling based on Project Financial Models (PFMs), observed costs (Finance Trackers), and reported take-up (C3 reports)	January 16 to September 19
4. Has the aid had a material effect on the market position of the direct beneficiaries?	For each winning supplier: • Supplier's market share of all active NGA lines within the relevant county/unitary local authority area(s) • The supplier's market share of all active NGA lines within the UK	Data provided by Thinkbroadband	2012 to 2020
5. Is there evidence of changes to parameters of competition arising from the aid? (Including third parties operating in the relevant intervention area(s))?	For each of the relevant county/unitary local authority area(s), and for the UK: • Take-up of NGA lines as a % of all broadband take-up • Market share (of take-up) for each NGA technology • Number of infrastructure providers offering NGA services	Data provided by Thinkbroadband	2012 to 2020

State aid evaluation question	Outcome indicators	Source	Time frame

6. Is the gap funding model efficient compared to alternative schemes?	Comparison against non-gap-funded UK and EU schemes in terms of: • Public funding per covered premises (using the maximum in-life coverage for closed schemes) • Public funding per live end user connection to the network (using the maximum in-life take-up for closed schemes) • Public funding per live end-user connection-years	The role of State aid for the rapid deployment of broadband networks in the EU (European Commission 2020)	N/A
7. Did the aid lead to commercially sustainable networks?	For each winning supplier, their actual versus original forecast: • Annual cashflow (before subsidy) • Take-up volumes • Average revenue per user • Average operational costs per user For the interventions funded by the 2016 NBS: • The number of projects, if any, from which services have been withdrawn (e.g. due to corporate insolvency, or project losses) • The number of premises covered by such projects, and the number of live connections for such projects • The % share of the overall 2016 NBS accounted for by such projects (in terms of number of projects, public funding, premises covered, take-up volumes)		

Outcome measures not originally included in the State aid evaluation plan have been italicised.

2.5 Limitations to the evaluation

There are some limitations to the evaluation that should be considered when interpreting the findings of the analysis. These are:

- **Progress with programme delivery:** At the time of the evaluation, many Phase 3 contracts were at comparatively early stages of delivery. Much of the data on which the evaluation is based was also only available to September 2019. Only 17 percent of the contracted number of premises to be upgraded were complete at this stage. This creates challenges in assessing the long-term additionality of the infrastructure upgrades, the effect of the programme on the market shares of beneficiaries, and the expected rate of return on the contracts awarded. To put the findings in medium-term context, the analyses were also completed for Phase 1 and 2 contracts to give a programme level view on the issues of interest (updating previous analyses completed to understand the effect of the Superfast Broadband Programme on NGA coverage[17]).

- **Causality:** The programme was not delivered as a Randomised Control Trial and econometric methods have been used to establish estimates of the causal effects of the programme. These methods are based on comparisons between postcodes that benefitted from coverage subsidised by the programme and other postcodes that were eligible for investment but not chosen by network providers when developing their proposals to deliver the schemes. This creates the possibility that there are systematic differences between those areas benefitting from the programme and the comparison group that could bias findings. The commercial viability of network upgrades in areas benefitting from the programme could be expected to be higher than in eligible areas that did not.[18] While steps have been taken to mitigate this risk, the results may overstate the impact of the programme due to unobserved confounding factors.

- **COVID-19:** The data deployed in this analysis ran to mid-2019 and does not allow for an analysis of the impacts of the programme in relation to COVID-19. It is plausible that the programme enabled benefits such as remote working, the delivery of public services (e.g. General Practitioner consultations) on-line and increased local resilience through supporting social distancing arrangements. However, if COVID-19 has induced greater demand for superfast services amongst residential consumers, the rates of return earned on Superfast contracts will also be higher than when projected based on historic growth in take-up. This could make some upgrades commercially viable that previously were not (implying that additionality in the longer term was overstated). These issues will be considered in a future assessment of the programme, as part of the final round of evaluation.

- **Data availability:** The NBS evaluation plan agreed in 2016 identified data sources to be used to undertake the analysis plan set out in the document. However, as noted above, not all this data could be made available to the evaluation team. The data that was not available and the alternative data sources used are presented in the table below. These changes were communicated to the European Commission by the BDUK Benefits and Evaluation team in May and October 2020.

[17] DCMS (2018) Economic and Public Value Impacts of the Superfast Broadband Programme.
[18] It should be noted that the number of remaining postcodes where Superfast Broadband is not available is now quite small, as Superfast Broadband coverage was over 95% in the UK.

Table 2.2: Unavailable data sources and alternatives used

Intended data source	Alternative data source	Key differences
It was anticipated that the Ofcom would provide premises level data on NGA coverage between 2016 and 2020 (relevant to Q1 and Q2).	Ofcom Connected Nations report September 2019.	The data runs to September 2019 and is only available at postcode level. As such, the analyses have lower spatial resolution and cover a less extensive period than envisaged. However, as sample sizes are substantial, this does not limit the precision of statistical analyses.
Actual data on revenues and operational costs are needed to observe network providers actual rate of return, but are not monitored by BDUK (relevant to Q3 and Q7).	Modelling was completed by applying assumptions regarding operational costs and average revenue per user to take-up (which is monitored by BDUK). Not all the local projects in Phase 3 of the programme had all the required information to calculate the IRRs needed for the evaluation.	This approach assumes that operational costs and average revenues per user are static over time and align with the assumptions put forward by network providers in tenders. This has meant that it has not been possible to address some aspects of Q7 (i.e. annual cashflows and average revenues costs and costs per user) and rates of return are modelled rather than observed in relation to Q3.
Network provider level returns provided to Ofcom to compile the Connected Nations report could not be made available for this analysis due to commercial sensitivities. An attempt was made to request these returns from key network providers in the UK, though some significant network providers refused to co-operate with the request, leaving significant omissions in the resultant dataset. As such, the anticipated data to address Q4 and Q5 was not available.	ThinkBroadband network provider coverage data and Speed Test data	ThinkBroadband data is not collected or validated by the telecommunications regulator, Ofcom. Take-up data by ISP is collected from Speed Tests undertaken by consumers, rather than information collected by ISPs and submitted to Ofcom. This limits the robustness of the answers to Q4 and Q5, as consumers providing speed tests may not be representative of the broader population. Sample sizes were often small at the level of the individual contract area, limiting the degree to which results can be broken down at this level.
Management information about ISPs utilising upgraded networks (to establish how far network providers have made use of open access arrangements) has not been monitored (relevant to Q5)	ThinkBroadband Speed Test data	ISPs utilising the upgraded networks has been identified from the ISPs operating in Superfast Broadband Programme areas (the postcodes which the programme has built networks to). This is not a comprehensive list of ISPs operating in these areas, as it is based on speed tests completed.
It was anticipated that benchmarks would be available providing estimates of the value for money associated with alternative scheme designs (relevant to Q6).	No evaluations have examined the cost-effectiveness of other types of broadband programmes in bringing forward superfast broadband coverage. However, projected costs per premise information for schemes across Europe have been analysed.	The absence of benchmarks makes it challenging to provide answers to questions relating to whether the scheme design was optimal and whether alternative designs may have produced superior outcomes.

2.6 Structure of the report

The remaining sections of this report are structured as follows:

- Section 3 provides an overview of the Superfast Broadband Programme and the analytical framework deployed in the evaluation;
- Section 4 provides an overview of the delivery of the programme and the degree to which it has complied with the provisions of the State aid judgement
- Section 4 outlines the evidence of the effectiveness of the Superfast Broadband Programme;
- Section 5 details the evidence of the direct impacts of the Superfast Broadband Programme on the programme beneficiaries;
- Section 6 presents the evidence of the indirect impacts of the Superfast Broadband Programme on programme beneficiaries;
- Section 7 shows the wider economic effects of the Superfast Broadband Programme on businesses, public service providers and households; and
- Section 8 describes the evidence of the proportionality and appropriateness of the intervention.

3. Superfast Broadband Programme

This section provides an overview of the Superfast Broadband Programme. This includes a description of the aims and objectives of the programme, how it was delivered and an overview of the processes by which it was expected to produce its intended impacts on broadband coverage and take-up, and associated economic and social benefits. This serves as an analytical framework guiding the definition of the evaluation questions and the interpretation of results.

3.1 Policy Aims and Objectives

The first Ofcom Infrastructure report in November 2011 showed that 58 percent of UK households had access to Next Generation Access (NGA) broadband services capable of delivering superfast broadband speeds (download speeds exceeding 30Mbps). NGA technologies encompass the installation of fibre-optic networks to connect the telephone exchange to the cabinets serving customers (Fibre-to-the-Cabinet, FTTC) or to their premises (Fibre-to-the-Premises, FTTP), improvements to cable networks, and wireless technologies that allow customers to obtain broadband services without a cabled connection to the network.

At the time, private investment in the required infrastructure was expected to be constrained in less densely populated areas of the UK. The costs of investing in the fixed infrastructure needed to provide these services are usually substantial. Where population density is low, this will reduce commercial viability as the consumer base will be smaller and the costs of network build may be higher (e.g. if properties are more distant from the serving telephone exchange).

The Superfast Broadband Programme was announced in 2010 to respond to these concerns that superfast broadband would fail to reach many parts of the UK. On the expectation that extending superfast broadband coverage to these areas would produce economic, social and environmental benefits, the Government established the programme to provide £530m of public resources to fund further deployment with the aim of increasing coverage to 90 percent of UK premises by early 2016. The programme was extended in 2015, with a further £250m made available to extend coverage to 95 percent by the end of 2017.

The Superfast Broadband Programme was extended a second time under a new State aid approval covering the 2016 to 2020 period. Contracts awarded under this State aid scheme (commonly known as Phase 3) are the focus of this evaluation report. These projects had a greater focus on gigabit connectivity (download speeds of 1000Mbps) than those funded in prior phases, aligning with broader Government objectives to increase FTTP coverage in the UK. This third phase evolved from a series of pilots that sought to explore how coverage could be extended to reach more than 95 percent of UK premises.

3.2 Theory of Change

3.2.1 Direct effects on superfast broadband availability

The Superfast Broadband Programme aims to provide subsidies to network providers to extend superfast broadband infrastructure to areas that would not otherwise benefit from commercial deployments. Subsidising network providers involves a risk that they seek public funds for (deadweight) investments that they would have made anyway, enabling them to earn a higher rate of return. The impact of the programme on the number of premises covered by superfast broadband services will be limited if funds are allocated to commercially viable schemes. The implementation of the programme incorporated several mechanisms to mitigate against these risks:

- **Allocation of subsidies:** Subsidies were allocated to Local Bodies based on BDUK's assessment of the gap funding[19] needed to upgrade each cabinet in the UK. In Phase 3, resources were allocated to achieve the greatest increase in coverage for the available resources. Several areas were deemed ineligible for BDUK support because existing commercial plans were already extensive.

- **Open Market Review (OMR) and public consultation:** Local Bodies were required to manage an OMR and public consultation process before they issued tenders. The first stage of this process involved requesting network providers to describe their commercial plans to roll-out basic and superfast broadband coverage over the next three years. This process classified premises into three groups:

  - **'White areas'** where there were no commercial plans to roll-out superfast broadband within three years.
  - **'Grey areas'** where one provider was offering or were expected to offer superfast broadband services within three years, and,
  - **'Black areas'** where multiple providers were offering or were expected to offer superfast broadband.

  This view of future superfast broadband availability was subject to a public consultation process, where the view was made available for comments for at least one month.

- **Tendering process:** Following the OMR and public consultation process, Local Bodies entered a tendering process to commission a network provider to deliver superfast coverage in the 'white' postcodes identified as eligible for subsidies. The tendering process in Phase 3 differed slightly from Phases 1 and 2. In the first two phases, a framework contract mainly was used to commission a network provider. In Phase 3, the tendering process involved an open procurement using an OJEU process. Local Bodies were also given the freedom to decide how to disaggregate the project – a single contract for the whole project or splitting the project geographically into multiple lots (allowing different network providers to bid for different lots).

- **Speed and Coverage Templates:** The view on the near term roll out of superfast broadband infrastructure obtained from the OMR was expressed in a Speed and Coverage Template (SCT) used in local tendering exercises by Local Bodies. The SCT provided a list of premises or postcodes that were identified as 'white' and eligible for subsidised infrastructure. Competing network providers completed the template by outlining which postcodes or premises they proposed to cover for the available funding (known as the 'build plan'). In this respect, the SCT is intended to limit scope for deadweight investments by restricting the target area for the programme to areas that would not otherwise benefit from commercial investments.

- **Project financial model:** In principle, a capital investment is commercially viable if the expected rate of return (IRR) is at least equal to the cost of capital faced by the

[19] The level of subsidy required to make the investment sufficiently profitable for the supplier.

investor. Network providers were required to provide a Project Financial Model (PFM) with their tender. This included estimates of the overall costs associated with delivering the project, take-up assumptions and expectations of future revenues and on-going operational costs. This model provided an estimate of the IRR associated with the project without subsidy, which could be compared with the network provider's Weighted Average Cost of Capital to determine the minimum level of subsidy needed to make the project commercially viable (i.e. a gap funding model).

- **Implementation clawback:** Protections against the risk that network providers overestimated their delivery costs were put in place by introducing a mechanism to recover underspend. The principle underlying contracts was that the network provider would fully invest its contracted funding. In the event of any underspend, the network provider was required to place unused funds in an Investment Fund to help resource further schemes or extend the contract to cover a greater number of premises than originally offered. Any unused public funding remained available for further investment.

- **Take-up clawback:** Further protections were introduced through 'take-up clawback' clauses in contracts. If take-up proved to be higher than anticipated at the tendering stage, network providers were required to return a share of the excess revenues to an Investment Fund which could be recycled to fund further coverage. Take-up clawback was capped so the amount returned to the public sector could not exceed the value of the subsidy awarded. The take-up clawback mechanism aimed to limit the extent to which network providers could earn excess returns on investments subsidised by the public sector.

3.2.2 Factors influencing additionality

While the programme involved actions to minimise the risk of deadweight losses associated with the contracts awarded, the following factors could influence the size of the impacts of the programme:

- **Information gathered through the OMR:** The level of additionality will be dependent on how far the OMR process was effective in accurately identifying 'white' postcodes where no commercial deployment of NGA networks was planned. If the OMR incorrectly identified 'black' or 'grey' areas as 'white' and eligible for subsidies, there is a danger that public funds are used to provide subsidised superfast infrastructure to areas that would otherwise have benefitted from commercial deployments. This could occur if the OMR process did not include the commercial plans of all relevant network providers or if network providers had incentives to understate their commercial plans. The OMR also provided a view of the commercial plans of network providers at a specific point in time, and the commercial viability of providing superfast coverage in rural areas may evolve with time. Growth in demand for superfast broadband services as well as technological and regulatory innovation may improve the expected profitability of investment sufficiently to make some premises or postcodes commercially viable after the OMR was completed.

- **Network provider behaviour during the tendering process:** As it is not possible to perfectly observe the commercial plans of infrastructure providers, the contractual mechanisms put in place give further protections against the risk that public sector resources are deployed to take forward schemes that were commercially viable. The implementation and take-up clawback mechanisms aimed to reduce how far network providers could exploit their superior information to overstate the gap funding requirement. The effectiveness of these mechanisms could be linked to the level of competition for the subsidies. Without competition, the network provider can transfer the risk of making unprofitable investments to the public sector by assuming low levels of take-up. This increases the apparent level of public funds required to make the project viable, with excess profits returned to the public sector only if the project was a commercial success. This would be less attractive in the presence of competition, as it would reduce the value for money associated with the tender (increasing the likelihood the procurement was lost to a competitor).

3.2.3 Indirect impacts on the market

The processes used to deliver the programme may also be expected to have the following indirect impacts on local connectivity:

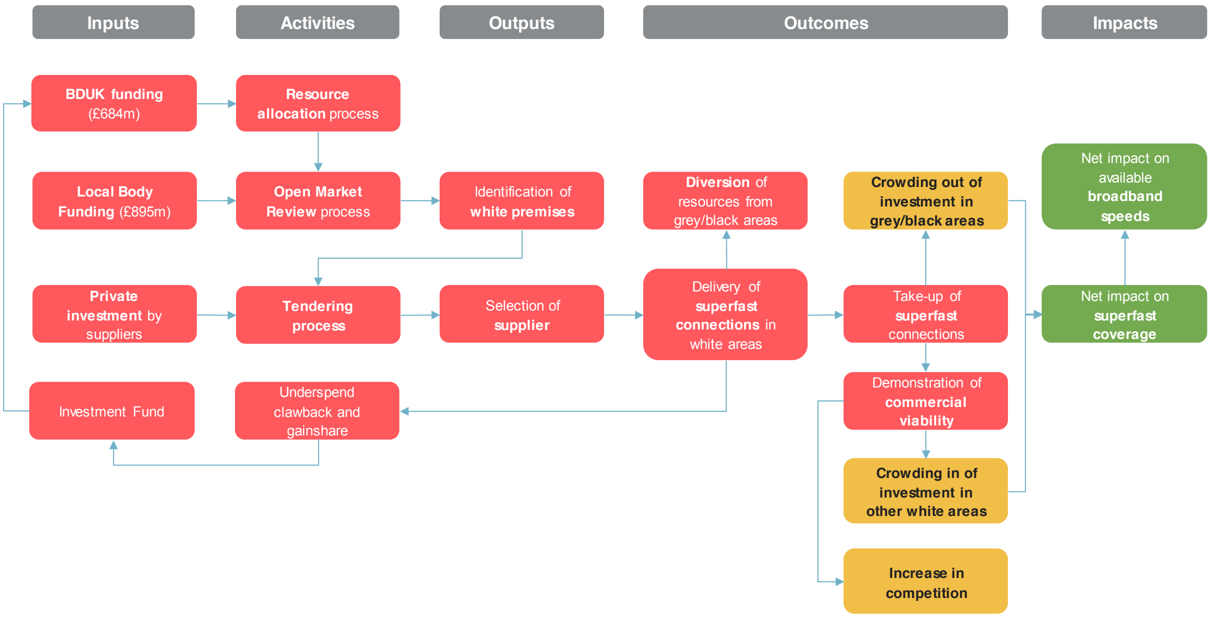
- **Crowding out:** The provision of subsidies for Superfast Broadband investment has the potential for two forms of 'crowding out':
  - **Discouragement effects:** The build plans of Phase 3 schemes were published, revealing the postcodes that would benefit from subsidised coverage. If network providers had plans to extend their networks to these areas that were not identified by the OMR process, the expected presence of subsidised competitors may reduce the profitability of those investments and, in some cases, lead to their abandonment.
  - **Price effects:** There may also have been negative impacts on 'grey' and 'black' areas if network providers faced capacity constraints – either in the labour market or in financial markets (for smaller network providers). If firms are not able to expand their overall capacity to deliver the programme investment, this may result in delays to, or abandonment of, parallel schemes. This risk is potentially greater for Phase 3 with these contracts entering delivery at a time when many network providers are beginning their commercial rollout of FTTP.
- **Crowding-in:** It is also possible that the programme helped demonstrate the commercial viability of infrastructure investment in the areas targeted, encouraging investments in other areas to maximise their returns. This would be visible in accelerated broadband coverage in 'white' areas that were not targeted by network providers. Successive announcements that the Government was providing further public subsidy could also have influenced network provider expectations, causing them to hold back investment expecting further funding to become available. Experiences with commercial deployments may also have demonstrated commercial viability.
- **Competition:** Finally, the programme may have led to changes in the parameters of competition and the market shares of infrastructure providers:
  - **Wholesale access requirements:** The programme was targeted at 'white' postcodes that could not sustain a single provider without subsidy and can be expected to create local monopolies. However, the programme required subsidised infrastructure providers to provide open and non-discriminatory wholesale access to physical infrastructure (ducts, poles, cabinets, masts), dark fibre, copper loop unbundling, and antenna on the subsidised portion of the network (with charges set with reference to benchmark wholesale market prices).

These requirements could stimulate additional competition in both wholesale or retail markets.

- **Overbuild:** Less directly, the nature of broadband technologies may have led to competitive distortions by increasing competition on 'grey' or 'black' postcodes. The cabinets upgraded to FTTC will serve multiple premises. Some of these premises will already have benefited from superfast coverage provided by competing infrastructure providers. Where the cabinet would not have been upgraded in the absence of the programme, the entry of a subsidised competitor may have eroded the market shares and/or the profitability of incumbents.

The figure below presents a summary of the discussion above.

Figure 3.1: Connectivity impacts of the Superfast Broadband Programme



3.2.4 Economic and social benefits

As set out in the State aid evaluation plan, the Superfast Broadband Programme was expected to produce a variety of downstream benefits for businesses, workers, households, the public sector and the environment. These expected benefits have been mapped in the BDUK Benefit Framework as set out in the table below. This report does not cover all anticipated benefits of the programme – for example, environmental benefits have been considered out of scope due to lack of robust data. A comprehensive theory of change, setting out the causal process by which subsidised coverage is expected to produce these economic and social impacts is provided in Technical Appendix 3 (Cost-Benefit Analysis).

Table 3.1: BDUK Benefits Framework

Benefit type	Outcome / Impact	Covered in the evaluation?
Productivity Growth	Increased Business Productivity	X
	New Businesses Established	X
	Increased ICT Skills and Wider Educational Attainment	X
Employment	Employment (safeguarded or new)	X
Public Sector Efficiency	More Efficient Delivery and Increased Access to Public Services	X
	Cross-Government Learning for Large Procurement Programmes	X
Digital Divide	Reduced Digital Divide	X
Public Value	Improved Quality of Life and Wellbeing	X
Public Value	Consumer Savings	
Stimulating the Broadband Market	Stimulated Private Sector Partnerships and Investment	
	Market Failure Addressed Through Appropriate Intervention	X
	Increased Competition in the Market, Including Small Suppliers	X
	Innovation and Knowledge of New Technologies	
	Increased Community Capacity in Procuring Infrastructure	
Environmental	Reduced Impact on the Environment	

Source: BDUK (2015) Benefits Realisation Framework

3.3 Programme context

This section provides a brief overview of the broader context in which the Superfast Broadband Programme has been delivered.

3.3.1 Overview of broadband services

Based on the typology adopted by Ofcom, there are four types of fixed-line internet services available to customers in the UK.[20]

- Narrowband, having the capacity of a standard voice channel (64 Kbps);
- Standard broadband (SBB), with download speeds of up to 30 Mbps;
- Superfast broadband (SFBB), with download speeds from 30 Mbps up to 300 Mbps;
- Ultrafast broadband (UFBB), able to deliver download speeds equal or greater than 300 Mbps.

According to Ofcom's Wholesale Broadband Access Market Review, the main Internet Service Providers (ISPs) offered average speeds for their retail services spanning 17 Mbps to 300 Mbps in 2018.[21]

[20] Ofcom (2018). Wholesale Broadband Access Market Review 2018. Accessed at: https://www.ofcom.org.uk/__data/assets/pdf_file/0010/115111/Draft-statement-Wholesale-broadband-access-market-review-2018.pdf on 5 November 2019.

The 2018 Connected Nations[22] report illustrated that the UK Government target of 95 percent coverage of at least 24 Mbps by 2018 had been reached.[23] Furthermore, 94 percent of all UK premises had access to superfast broadband (30 Mbps), up from 91 percent in the prior year. Superfast coverage was the highest in England (94 percent), followed by Wales (93 percent), Scotland (92 percent), and Northern Ireland (89 percent). However, only 90 percent of UK Small and Medium Size Enterprises (SMEs) were covered by superfast broadband. The UK Government expects Superfast Broadband coverage to reach 97 percent by the end of 2020.

Ultrafast coverage has also increased. In 2018, access to speeds of 300 Mbps and above was available to 50 percent of premises, increasing from 36 percent in 2017.[24] Ultrafast was available to 51 percent of customers in England and 44 percent in Scotland. Coverage in Northern Ireland and Wales was lower, at 38 percent and 29 percent respectively. Nevertheless, two percent of UK premises in 2018 still did not have access to "decent" connection speeds[25] – a percentage that ranged from five percent in Northern Ireland to two percent in England.

3.3.2 Broadband providers

Ofcom analysis suggests that there are four main Internet Service Providers (ISPs) in the UK retail broadband market: BT (with a market share of 37 percent), Sky (23 percent), Virgin Media (20 percent), and TalkTalk (16 percent). In addition to these, there are regional network providers such as KCOM, or other fixed-line broadband network providers such as Vodafone, which together have a market share of approximately 4 percent.[26] Small network providers are also present in rural areas, and normally provide broadband services based on satellite or mobile technologies.[27]

BT has an incumbent position in the market as a result of being the former national network provider. Openreach, a wholly-owned subsidiary of BT, owns the largest copper-based telecom network in the UK covering nearly every premise, and an extensive fibre backbone network reaching around 91 percent of all premises.[28] Most competitors rely on access to the Openreach network via wholesale agreements to provide services to customers. Ofcom regulation requires Openreach to offer wholesale access to its networks where possible.

Sky is the second-largest operator in the UK retail market after BT and delivers services by utilising wholesale network access products and installing proprietary equipment in a number

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[21] Ofcom (2018). Wholesale Broadband Access Market Review 2018. Accessed at: https://www.ofcom.org.uk/__data/assets/pdf_file/0010/115111/Draft-statement-Wholesale-broadband-access-market-review-2018.pdf on 5 November 2019.

[22] Ofcom (2018). Connected Nations 2018 UK Report. Accessed at: https://www.ofcom.org.uk/__data/assets/pdf_file/0020/130736/Connected-Nations-2018-main-report.pdf on 5 November 2019.

[23] There is no single agreed upon definition of 'superfast broadband'. The UK Government considers superfast broadband as having download speeds of 24 Mbps, whilst Ofcom and the European Commission define superfast broadband as connections of at least 30 Mbps. For details, Hutton, Georgina, and Baker, Carl (2018). Briefing Paper CBP06643. Superfast broadband in the UK. Accessed at: http://researchbriefings.files.parliament.uk/documents/SN06643/SN06643.pdf on 5 November 2019.

[24] Ofcom (2018). Connected Nations 2018 UK Report. Accessed at: https://www.ofcom.org.uk/__data/assets/pdf_file/0020/130736/Connected-Nations-2018-main-report.pdf on 5 November 2019.

[25] As per the Ofcom definition, "decent" connection speeds are of at least 10 Mbps and upload speeds of at least 1 Mbps.

[26] Frontier Economics (2018). Future Telecoms Infrastructure Review: Annex A. Accessed at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/727890/FTIR_Annex_A_-_FE_Report.pdf on 5 November 2019.

[27] Ofcom's (2018) Wholesale Access Market Review (page 4) indicated that broadband services via wireless, satellite, and mobile networks do not form part of the relevant market for an evaluation of fixed-line competition in the broadband market, thus operators relying on these technologies are outside the scope of this analysis.

[28] Ofcom (2018). Wholesale Broadband Access Market Review 2018. Accessed at: https://www.ofcom.org.uk/__data/assets/pdf_file/0010/115111/Draft-statement-Wholesale-broadband-access-market-review-2018.pdf on 5 November 2019

of exchanges – a process referred to as Local Loop Unbundling (LLU) and, more recently, through Virtual Unbundling of the Local Loop (VULA).[29] Another operator that has invested in unbundling Openreach's exchanges is TalkTalk, which provides services in the same way as Sky.

Virgin Media is the third-largest provider and the main competitor of Openreach in terms of broadband infrastructure, and in 2017 reached around 45 percent of all households.[30] Following recent fibre-coaxial network upgrades, most of the premises connected to Virgin Media's network are able to subscribe to services up to 300 Mbps.[31] Other providers include the vertically integrated Gigaclear and Hyperoptic, and CityFibre, which operate as infrastructure providers and have built FTTP networks in locations across the UK.

3.3.3 Regulation of the telecommunications market in the UK

EU regulation

Telecommunications markets in the EU were gradually opened to competition through a series of legislative measures beginning in 1998 and culminated ten years later with full liberalisation of services across the EU.[32] National Regulatory Authorities (NRAs) in Member States were established following the introduction of a new EU regulatory framework in 2002.[33]

The overarching regulatory framework for the electronic communications sector in Europe today is the European Electronic Communications Code (EECC).[34] This supersedes the Regulatory Framework for Telecommunications,[35] which was introduced in 2002 and modified in 2009. The EECC is currently being transposed in EU Member States and DCMS recently consulted on its implementation.[36] One of the provisions of this framework is a process to identify competition related market failures in the telecommunications market. This requires definition and analysis of relevant markets by National Regulatory Authorities (NRAs) under a procedure often known as 'Article 7.'[37] NRAs, such as Ofcom in the UK, are required to implement the market review process and where required by the presence of providers with significant market power (SMP), to impose suitable remedies to ensure compliance with the regulatory Framework. As part of this exercise, NRAs carry out nationwide consultations and consult with the relevant body in the European Commission on draft regulatory measures before they are adopted.[38]

Ofcom

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[29] Ofcom (2018). Wholesale Broadband Access Market Review 2018. Accessed at: https://www.ofcom.org.uk/__data/assets/pdf_file/0010/115111/Draft-statement-Wholesale-broadband-access-market-review-2018.pdf on 5 November 2019

[30] Frontier Economics (2018). Future Telecoms Infrastructure Review: Annex A. Accessed at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/727890/FTIR_Annex_A_-_FE_Report.pdf on 5 November 2019.

[31] Ofcom (2018). Connected Nations 2018 UK Report. Accessed at: https://www.ofcom.org.uk/__data/assets/pdf_file/0020/130736/Connected-Nations-2018-main-report.pdf on 5 November 2019.

[32] European Commission (2019). Overview. Telecommunications. Accessed at: https://ec.europa.eu/competition/sectors/telecommunications/overview_en.html on 14 November 2019.

[33] 3 Framework Directive 2002/21/EC and Access Directive 2002/19/EC.

[34] DIRECTIVE (EU) 2018/1972 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2018. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L1972&from=EN

[35] The Framework is based on the Framework Directive 2002/21/EC and the Better Regulation Directive 2009/140/EC

[36] https://www.gov.uk/government/consultations/implementing-the-european-electronic-communications-code

[37] See further information from the European Commission at https://ec.europa.eu/digital-single-market/en/news/definition-and-analysis-relevant-markets

[38] European Commission (2019). Overview. Telecommunications. Accessed at: https://ec.europa.eu/competition/sectors/telecommunications/overview_en.html on 14 November 2019.

Ofcom is the NRA in the UK and assumed its powers on 29 December 2003. Its competency spans telecommunications (fixed-line and mobile networks and services), postal services, TV and radio broadcasting, as well as the airwaves (radio spectrum) over which mobile, Wi-Fi and many other services operate.[39] It has concurrent powers under the UK Competition Act and cooperates with the European Commission's Directorate-General for Competition (DG COMP) to safeguard a level playing field in the telecoms market in the UK.[40]

Regulation of Openreach

Openreach Ltd is a fixed-line telecoms infrastructure company owned by BT Group, responsible for installation and maintenance across the UK's formerly national telecoms infrastructure. In 2006, Openreach was set up as a business division of BT that works on behalf of service providers (such as BT, Sky or TalkTalk) to maintain the local access network it covers and allows service providers to sell phone, broadband or TV services direct to customers using the network.

In 2016, after the Ofcom Digital Communications Review (DCR),[41] Ofcom announced that it required BT and Openreach to "legally separate" (i.e. set up Openreach as a subsidiary within BT Group). This was partly due to concerns that BT (through Openreach) could favour its own retail business over other Communications Providers (CPs) when making network investment decisions and in provision, operations and maintenance processes.[42] These decisions include strategic decisions around fibre rollout measures, the cost of services to providers wishing to access the network, and eventual prices offered to consumers.[43]

In early 2017, BT Group agreed to the separation, and in July 2017 Ofcom established an Openreach Monitoring Unit to assess the legal separation in practice. In November 2018, Ofcom stated that they were "broadly satisfied" with the legal separation of Openreach from BT, if commitment from BT and Openreach on the following was maintained:

- Strengthening independent decision making;
- Improve industry engagement through customer consultations; and
- Openreach commitment to investing in faster, better broadband through full fibre (FTTP).[44]

Following an Ofcom statement in June 2019,[45] Openreach established a Physical Infrastructure Access (PIA) portfolio that allows retail service providers to share Openreach duct and pole infrastructure. PIA may only be used for public electronic communications services/network build. A retail supplier may access the network through the following:

- Buy a license to install a sub duct or cable within an access duct; and/or
- Buy a license to attach and maintain equipment on existing Openreach poles.[46]

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[39] Gov.uk (2019). Ofcom. Accessed at: https://www.gov.uk/government/organisations/ofcom on 14 November 2019.
[40] European Commission (2019). Overview. Telecommunications. Accessed at: https://ec.europa.eu/competition/sectors/telecommunications/overview_en.html on 14 November 2019.
[41] See https://www.ofcom.org.uk/phones-telecoms-and-internet/information-for-industry/policy/digital-comms-review
[42] Ofcom (2016). Update on plans to reform Openreach. Accessed at: https://www.ofcom.org.uk/about-ofcom/latest/media/media-releases/2016/update-on-plans-to-reform-openreach on 14 November 2019.
[43] Ofcom (2018). New Ofcom rules to boost full-fibre broadband, 23 February 2018. Accessed at https://www.ofcom.org.uk/about-ofcom/latest/media/media-releases/2018/new-rules-boost-full-fibre
[44] Hutton, G. (2019). BT and Openreach House of Commons Briefing Paper, Number CP 7888, 11 January 2019.
[45] Ofcom (2019). Statement: Promoting competition and investment in fibre networks – review of the physical infrastructure and business connectivity markets. Accessed at: https://www.ofcom.org.uk/consultations-and-statements/category-1/review-physical-infrastructure-and-business-connectivity-markets on 14 November 2019.
[46] It should be noted that the majority of third party services are provided using LLUA/VULA mechanism, rather than through PIA.

Retail suppliers may also buy Points of Presence (PoPs) through Openreach's Access Locate product for the purposes of co-mingling equipment for other products, and/or through "pull-in" cables through Openreach infrastructure to a supplier's own PoP in the digital exchange (through a separate Cablelink product).[47]

[47] Openreach (2019). Physical Infrastructure Access. Accessed at: https://www.openreach.co.uk/orpg/home/products/ductandpoleaccess/ductandpoleaccess.do on 5 November 2019.

4. Programme Delivery

This section provides an overview of the delivery of the Superfast Broadband Programme over the period 2016 to 2019. This analysis draws predominantly on data collected by BDUK in the process of delivering the programme, and evidence from in-depth consultations with Local Bodies and network providers to explain the patterns observed. This section does not directly address the questions defined in the State aid evaluation plan and is provided to give context to the findings. It also provides an assessment of the degree to which the delivery of the programme has complied with the State aid legislation and guidance set out by the European Commission.

Key findings:

Fifty-one Phase 3 contracts were awarded to three network providers to make superfast broadband services available to 322,200 premises to superfast broadband services. These contracts covered 66,900 of 118,500 postcodes eligible for BDUK subsidies.

Network providers chose to direct subsidised investment in broadband to areas with low population density and levels of existing penetration of broadband technologies able to deliver superfast speeds (relative to the UK overall). These areas were characterised by features that would be likely to increase the cost of deployment.

Delivery of upgrades for Phase 3 of the programme began in 2018, and 79,100 premises received subsidised coverage by September 2019. This represents around 17 percent of the contracted premises to be upgraded. Delivery of Phase 3 was behind schedule. A range of explanations were put forward by stakeholders – including a need to rescope contracts at an early stage, the capacity of network providers and their suppliers, and stricter enforcement of requirements to complete a validated build plan before commencement of delivery.

4.1 Phase 3 target area

The Speed and Coverage Templates (SCTs) developed by Local Bodies before commencing the tendering process provides the list of the premises or postcodes that were eligible for BDUK investment. Postcodes were deemed eligible if they were not expected to benefit from commercial deployment of superfast broadband infrastructure over the next three years, as determined by the OMR and public consultation process ('white' postcodes, as described in Section 3).

A total of 63 Phase 3 SCTs were compiled for this analysis. These covered a total 157,900 postcodes in the UK[48], of which 118,500 were deemed eligible for investment. The spatial distribution of these postcodes is mapped in Figure 4.1 below. Details of these postcodes were linked to a variety of secondary datasets describing the baseline characteristics of local broadband networks in 2016. Postcodes eligible for investment through the programme differed in the following ways to postcodes across the UK (as shown in Table 4.1):

- **NGA and superfast coverage:** In 2016, 88 percent of postcodes in the UK received coverage from NGA broadband technologies. 77 percent of premises were able to

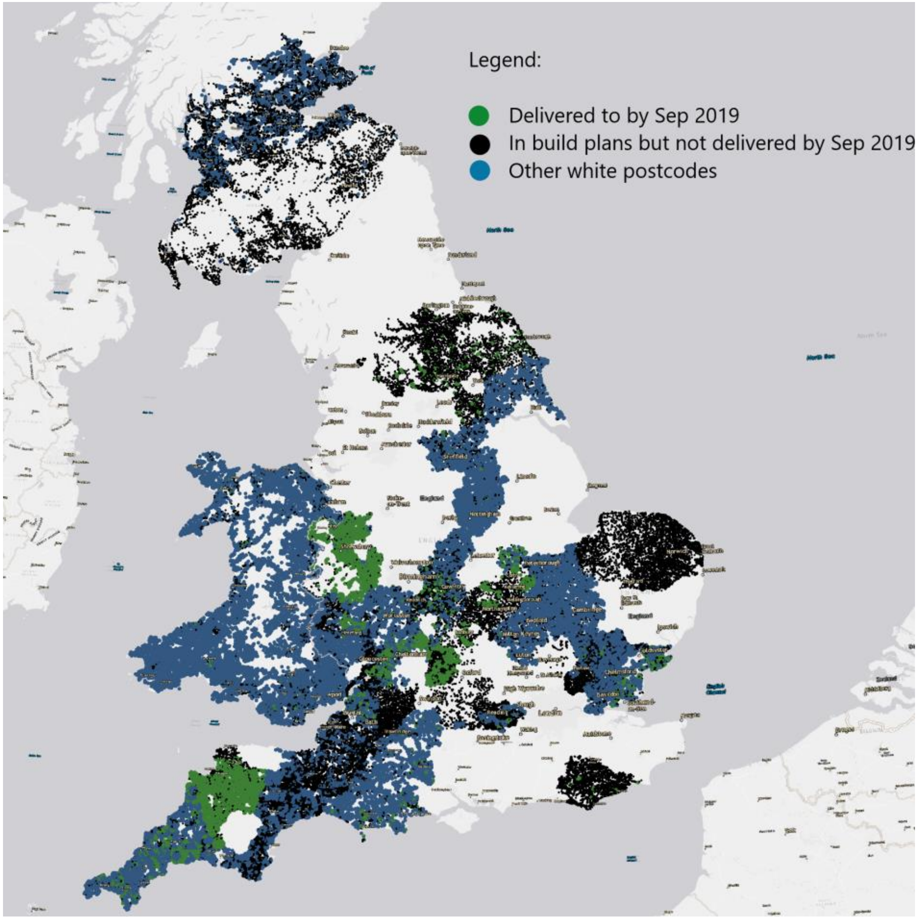
[48] The number of SCTs differs from the number of contracts as the tendering process was often divided into Lots in which a SCT was developed for each. However, in some cases, the same network provider was awarded multiple lots, resulting in a single contract.

access superfast (30Mbps) speeds. Both NGA and superfast coverage were substantially lower in the areas identified as eligible for the programme (29 percent Superfast Broadband coverage in areas that were included in Phase 3 build plans).

- **Network infrastructure:** Areas eligible for investment were characterised by features that would make it more challenging to bring forward NGA infrastructure on a commercial basis. Premises tended to be further from the exchange serving the building - more than 3,000m compared to an average of 2,400m across the UK overall. As the speed of broadband services provided using copper lines declines with distance, upgrading premises to superfast speeds involves greater costs by increasing the investment needed in fibre cables. The share of premises served by an exchange only line was also substantially higher (i.e. a line directly connected to the local exchange rather than passing through a cabinet). This would increase the cost of providing FTTC by requiring the installation of a new cabinet.

- **Demand density:** Population density (population per square kilometre) was substantially lower in areas eligible for investment than across the UK (less than half the national average). Local exchanges and cabinets also tended to serve smaller numbers of premises, and the unit cost of upgrading premises in the programme area to FTTC was estimated by BDUK at £324 in 2013 (relative to £179 across the UK). However, the areas eligible for BDUK investment were broadly equivalent to the rest of the UK in terms of local unemployment and employment rates and weekly earnings.

Figure 4.1: Map of Phase 3 postcodes in build plans, outside of build plans and premises upgraded by September 2019



Source: SCT templates, C3 Reports, Ipsos MORI analysis

Table 4.1 Characteristics of postcodes in Phase 3 build plans

Characteristic	Postcodes in Phase 3 build plans	Other 'white' postcodes	Ineligible/ other postcodes
Broadband availability and take-up in 2012			
% of postcodes with Next Generation Access, 2012	15.5	39.6	73.0
Average maximum download speed (Mbps) of connections, 2012	8.5	10.1	13.4
Average download speeds (Mbps) of connections, 2012	5.7	9.8	13.9
Broadband availability and take-up in 2016			
% of postcodes with Next Generation Access, 2016	72.9	79.8	96.1
% of postcodes with superfast (30Mbps) access, 2016	27.4	55.6	93.8
Number of premises with superfast connections 2016	1.7	5.2	8.1
Network characteristics in 2013			
Length of line from exchange to premises (m) 2013	3647	3081	2,161
Share of premises with exchange only lines (%) 2013	22.0	13.1	4.5
Delivery points at serving exchange 2013	6236	10874	17,566
Delivery points at serving cabinet 2013	247.0	303.5	380.2
% of postcodes in Virgin Media footprint 2013	0.8	14.8	48.3
Number of residential delivery points on the postcode 2013	11.5	15.1	19.6
Number of non-residential delivery points on the postcode 2013	1.0	1.1	0.7
Estimated cost to upgrade serving cabinet (£) 2013	67583	64585	61,711
Estimate upgrade cost per premises upgraded (£) 2013	332.1578	311.0	178.9
Area characteristics in 2013			
% of postcodes in rural areas 2013	80	55	14
Working age population (in Output Area), 2011	178	197	200
Population aged 65+ (in Output Area), 2011	58	56	50
Population density in OA (population per square km), 2011	666	1676	4,403
Premises density in OA (premises per square km) 2013	425	998	2,564
Gross weekly earnings in LA (£), 2013	503	542	518
Employment rate in LA (%), 2013	75	75.2	71
Unemployment rate in LA (%), 2013	6.4	7.2	8.2

Source: Connected Nations (Ofcom), BDUK modelling, Census 2011 (ONS), Annual Survey of Hours and Earnings (ONS), Annual Population Survey (ONS).

4.2 Phase 3 contracts

Fifty-one Phase 3 contracts were awarded to three network providers (34 to Openreach, 12 to Gigaclear, and four to Airband – a wireless provider) to upgrade 322,200 premises. These contracts covered 66,900 of the postcodes eligible for BDUK subsidies. Table 4.1 also describes the features of postcodes included by network providers in the build plans of Phase 3 contracts relative to other postcodes that were eligible for subsidised coverage:

- **Availability & coverage:** Superfast broadband penetration was lower in postcodes included in Phase 3 build plans than on other postcodes that were eligible for investment, in both 2012 and 2016. This is also reflected in measures of take-up, including the average and maximum speeds of connections and the number of superfast connections taken by consumers located on the postcode.

- **Network characteristics:** Areas in the build plans of Phase 3 contracts were also more likely to exhibit characteristics that would increase the costs of deployment. Premises included in the build plans of Phase 3 contracts were more likely to be served by exchange only lines, and were characterised by longer line lengths to the serving cabinet and exchange, and fewer delivery points per exchange/cabinet (i.e. lower demand density). BDUK modelling completed in 2013 also suggested that the estimated cost of upgrading the serving cabinet would be higher.

- **Area characteristics:** Postcodes included in the build plans of Phase 3 contracts were more likely to be rural in nature - 75 percent of postcodes designated (compared to 64 percent of postcodes eligible but not included in build plans). In addition, both population and premises density were lower in areas included in build plans. Employment and unemployment rates in the local authorities were very similar across groups, though average wages were lower in those areas included in Phase 3 build plans.

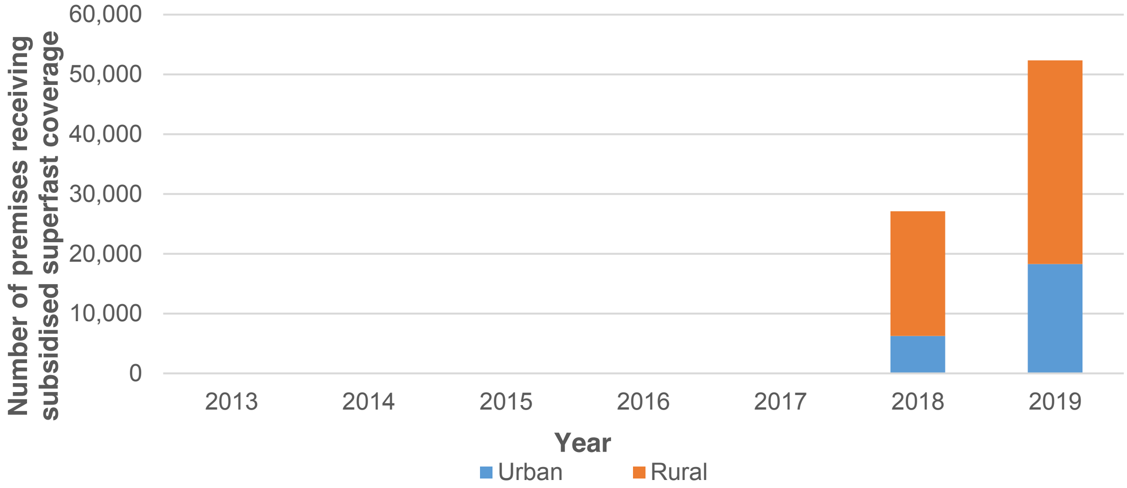
This indicates network providers selected premises that were costlier to upgrade and were characterised by a smaller customer base (the reverse of patterns observed for Phase 1 and Phase 2[49]). The areas excluded from build plans were characterised by relatively high levels of superfast broadband penetration and may have been characterised by small gaps in superfast broadband coverage. It may not have been cost effective to build out networks to fill these gaps in provision. Infrastructure providers may also have targeted communities with relatively low levels of existing penetration to maximise the size of the local markets that could be addressed.

4.3 Delivery of Phase 3 contracts

Delivery of upgrades began in 2018, as illustrated in Figure 4.2. Analysis of management data provided by BDUK showed that 79,100 premises received subsidised coverage by September 2019. This represents around 17 percent of the contracted premises to be upgraded and indicates that delivery of Phase 3 was behind schedule. While some contracts are not due to complete until 2024, 18 of the 51 contracts – accounting for 93,600 premises upgraded – were due to be completed by September 2019. A further ten contracts (accounting for a further 60,600 premises upgraded) were originally scheduled for completion by December 2019.

[49] BDUK (2018) Superfast Broadband Programme Evaluation: Annex A – Reducing the Digital Divide. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/734856/BDUK_SF_EVAL_ANNEX_A_REDUCING_THE_DIGITAL_DIVIDE.pdf (accessed August 2020).

Figure 4.2: Number of premises receiving superfast (30Mbps) subsidised coverage by September 2019, Phase 3



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

Qualitative research with Local Bodies and network providers awarded contracts explored the factors driving these delays:

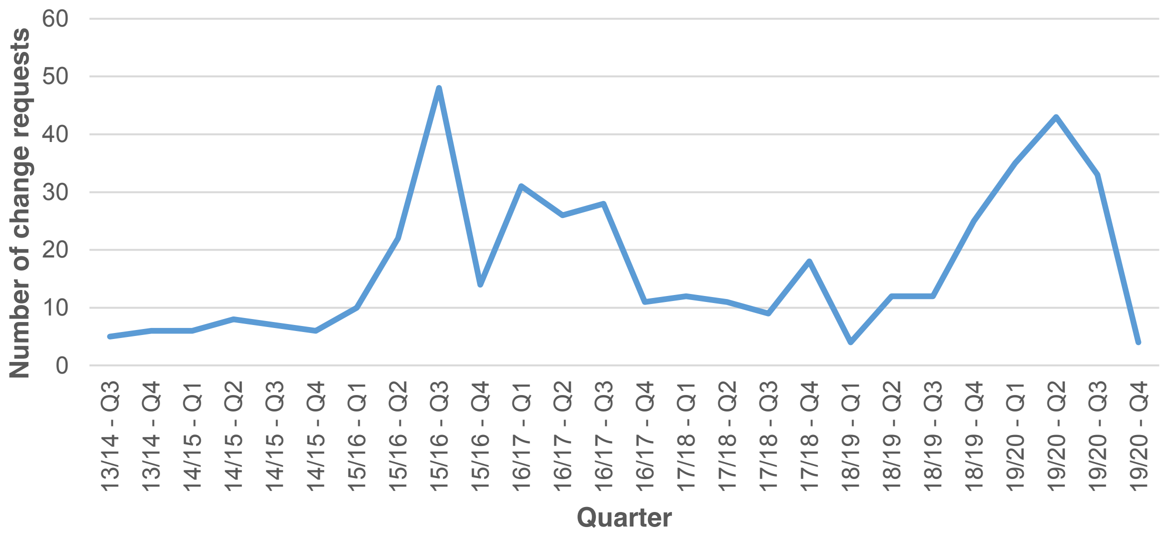
- **Change requests:** A key explanatory factor put forward was the need for formal requests for changes to contracts (as illustrated in Figure 4.3). This was often driven by a need to rescope[50] contracts to exclude areas that were incorrectly identified as eligible for BDUK subsidies during the OMR process (factors driving this are explored below). In general, the change requests were described as processes that take months to approve. In one case, a change request remained in discussion for up to three years. Providers generally considered that it took Local Bodies and BDUK a long time to agree and sign off change requests. However, two network providers did acknowledge that it could be time consuming to fully research and develop change requests, if it involved a lot of survey work or a lot of rescoping. This could take months to develop – though they also pointed out that it would take at least an equal amount of time to get the change requests signed off.

- **Capacity:** Interviews with Local Bodies highlighted a perception that there were some issues with a lack of capacity amongst providers throughout the programme. Civil engineering capacity was viewed to be limited with the contracts stretching sub-contractors delivering the infrastructure on the ground. Some interviewees saw this to be the result of the scale of delivery nationally, including a suggestion that some providers were prioritising commercial deployments at the expense of the delivery of the programme. Additionally, smaller network providers were not considered to have had the resource to expand in contract areas as quickly as anticipated and lacked the capacity to apply for wayleaves and other permissions, delaying delivery.

[50] Rescoping a contract means changing the geographical area / the postcodes included in the delivery plan of the contract – by removing some areas / postcodes and adding new ones. This happens where areas / postcodes included in the delivery plan are subsequently found to be ineligible. Descoping a contract means removing a geographical area / postcodes from a contract.

Some of these issues were acknowledged by the network providers. One stated that they had issues with new subcontractors, in terms of their capacity to deliver the work, the quality of the work provided and their ability to manage contracts. However, capacity issues were not universally acknowledged – one large provider stated that there had not been significant issues with build capacity for the programme and attributed delays primarily to contractual issues and change requests.

Figure 4.3: Number of change requests logged, 2013 to 2019 (Phase 1, 2 and 3)



Source: BDUK management data.

- **Milestone Zero:** Contracts awarded through the programme included an initial milestone (Milestone 0), to validate the build plan. In Phase 3, this milestone was reportedly more strictly enforced, with providers required to complete validated build plan before any physical work on the contract could begin (in prior Phases, they reported being able to start physical work and amend the build plan on an ongoing basis). One provider stated that the enforcement of Milestone 0 in the contract had caused delivery issues, mainly the ability to complete build within the allotted contract length. This is because the validation of the build plan often took a long time.

4.1 Validation of compliance with State aid guidance

This sub section assesses the extent to which the Superfast Broadband Programme Phase 3 contracts have complied with the guidance set out in State aid SA. 40720 (2016/N). An evaluation framework was developed to assess the compliance of Superfast Broadband projects at three stages of project delivery, with 10 main evaluation questions. These stages and questions are set out in the table below:

Table 4.2: Validation evaluation framework

Stage of programme	Evaluation question
B0: Ready to commence Procurement; and B1: Ready to commence network provider engagement	Did local projects provide appropriate information and data to underpin public funding?
	Did local projects use appropriate mechanisms to engage with all relevant network providers?
	Did Local Bodies / NCC take appropriate steps to ensure the validity of OMR responses?
B2: Ready to procure	Did the local project follow EC guidelines during the Open Public Consultation (OPC) phase?
	Did local projects accurately account for responses received during the OPC phase?
	Did the local project follow EC guidelines about the geographic areas to be covered by the intervention?
	Did the local project follow EC guidelines when issuing the ITT?
C: Ready to contract	Were the bids assessed in a manner compliant with EC guidelines?
	Have the Local Bodies provided contracts which are State aid compliant?
	Approval of Change requests

In order to undertake the validation exercise, the following documents have been reviewed by the research team:

- The State aid decision letter for projects;
- The State aid application form prepared by the Local Body delivering the project and submitted to the National Competency Centre (NCC) to secure funding for the project;
- The State aid approval summary spreadsheet – prepared by the NCC to record evidence of how the local project complied with State aid guidance and legislation;
- The Invitation to Tender (ITT) prepared by BDUK to use in the OJEU process;
- The contract signed by the programme beneficiary, including the network provider solution section;
- The documentation and evidence collected by the NCC to assess whether the projects would pass the B0, B1, B2 and C checkpoints; and
- The database of change requests submitted to the NCC, recording the changes requested and how these were handled by the NCC.

A sample of 15 project contracts were selected to evaluate the compliance of the programme with the State aid guidance. These project contracts were selected to represent different locations within the UK and contracts with each of the Phase 3 programme beneficiaries.

Across all the project contracts, there has been a high level of compliance with the State aid guidance. However, there are some gaps in the evidence provided for some projects. Given the other evidence that has been provided for these projects, it has been assessed that these are gaps in the evidence base, rather than evidence of non-compliance. The one area where there was evidence of a lack of compliance with European Commission Guidelines was around the timing of the Invitation to Tender (ITT) being issued, with this being more than a month after the public consultation exercise closed in most cases.

4.1.1 Ready to commence: Procurement and network provider engagement

There was evidence that just over half of the sampled projects (eight projects) completed a determination of project design questionnaire that provided evidence of a local broadband plan as part of the submission of the State aid application form. This provided evidence that a local broadband plan had been developed and used to inform the design of the local project. However, in the documentation for the remaining projects, there was no evidence of a local broadband plan. However, for all projects the NCC confirmed that the information provided in local broadband plan complied with the relevant legal basis from the European Commission, which suggests that there are local broadband plans that were reviewed by the NCC. It is most likely that these plans had been developed and sent to the NCC as part of applications for the Phase 1 and Phase 2 contracts, therefore Local Bodies did not include these again for their Phase 3 applications.

There was evidence that most of the projects had collected appropriate information to define the potential project intervention area. This information was collected through network provider engagement and the OMR process. Again, for the remaining projects there is no information in the evidence provided that the projects collected appropriate information, rather than confirmation that no or inappropriate information has been provided. Again, the NCC raised no concerns about the intervention area for these projects, which suggests that appropriate information has been provided but was not available to the evaluation team.

Most projects were able to provide evidence that a long list of relevant network providers had been invited to take part in the OMR process. This included all main network providers that were operating in their local area, as well as a longer list of potential network providers that could enter their local telecommunications market. The evidence assessed also showed that the projects had also followed up with network providers to encourage responses to the OMR process. This approach was assessed to be appropriate by the research team.

The projects provided evidence that they had received responses from the main network providers operating in their area. However, in some projects the network providers were not able to provide data at a premises level and only provided data at a postcode level, despite the projects asking for premises level data. Given that many network providers were unable to provide premise-level data, the NCC and the local project team decided that postcode level data would be acceptable for the projects and the NCC to robustly identify potential delivery areas.

Where relevant network providers had been invited to take part in the OMR process but had not submitted a response, the projects had not collected information (or the evidence had not been provided to the research team) as to why the network provider decided not to take part. Therefore, it is not possible to assess whether there were any systematic causes for non-responses across the programme. An analysis of network providers which provided coverage in 2016 in the 15 local areas covered in this exercise suggests that there were some providers which were active but did not provide a response to the OMR process. Some of the reasons why network providers did not take part in the OMR process were captured in the in-depth interviews with network providers, and these included small network providers not having the resources (either in terms of human resources or having the required technology to develop a response), and network providers being put off from submitting a response (for example previous responses to OMR processes being rejected).

The local project leads and the NCC were able to provide evidence that they had validated the OMR responses from network providers, to ensure that the responses were accurate and robust. This included excluding some responses from network providers where there were concerns that the submission was not accurate, comparing OMR responses to BDUK databases about coverage, and marking some postcodes as “under review” where the project and the NCC could not be certain of the designation of a postcode (for example due to a postcode being designated ‘white’ in this OMR exercise that had been designated as ‘grey’ in previous OMR processes). Where these changes have been made the changes were recorded in the evidence provided to the research team.

4.1.2 Ready to procure

All the projects analysed were able to provide evidence that they had undertaken a public consultation exercise, and most provided evidence that the exercise had been open for a month, in line with the European Commission guidelines. Most of the projects provided evidence that they had acknowledged the receipt of responses to the public consultation process, and explained how their responses had been used to inform the final intervention area. The projects also provided evidence as to how the responses had changed the intervention area (for example changing postcodes from 'white' to 'grey', or "under review"). However, not all responses to the public consultation resulted in changes to the intervention area. Where no action was taken, the projects did not provide evidence of the reasons why they decided not to amend the intervention area. However, the decision not to change the intervention area in line with the response to the public consultation was reviewed and confirmed by the NCC who raised no concerns to this.

In most cases the projects indicated that they had provided a response to all network providers that had submitted queries as part of the public consultation process, in line with European Commission guidance. Again, where this was not the case it has been assessed to be due to there being no evidence of a response being submitted, rather than evidence that no response was provided. Finally, in all cases there is evidence that the NCC reviewed the final intervention areas (following any changes made in the public consultation process) and were satisfied that the potential intervention area included only 'white' postcodes.

There appears to have been less compliance with the European Commission guidelines around the timing of issuing an ITT for the projects. This was supposed to be within a month of the closing of the OPC. However, most projects issued the ITT at least one month after the completion of the OPC process. No reasons were provided for this delay. Other than the delay in issuing the ITT, there is evidence that all projects followed European Commission guidance in issuing the ITTs, in terms of the information included in the ITT and that the tenders were open to all potential bidders. The NCC was aware of this issue, and although issuing guidance and encouraging local projects to meet this timeline, they had to respect that most projects did not have the resources in place to develop a procurement approach and issue an ITT within one month of the completion of the public consultation process.

4.1.3 Ready to contract

There was a high level of compliance at the ready to contract stage of the programme. All projects provided evidence that the assessments of bids received was technology neutral, in many cases providing the assessment criteria. Evidence was also provided that the successful bids included the required wholesale access agreements, confirmation that the solution needed to be NGA compliant and that the solution provided a step change. This information was validated by the NCC in all cases. All the projects and the NCC confirmed that the procurement was conducted in line with EU and UK public procurement rules and principles of equal treatment, non-discrimination, transparency and proportionality

Additionally, all of the contracts included the required references to wholesale access and pricing benchmarks, clawback mechanisms and the reporting and monitoring requirements. This is expected as BDUK issued a guide contract to all projects, and the projects assessed had all used this template (with some amendments, although not in the clauses that were assessed in this exercise.

5. Effectiveness

This section provides an assessment of the effectiveness of Phase 3 of the Superfast Broadband Programme in bringing forward NGA, superfast and FTTP coverage and its effects on speeds available and take-up. This section seeks to address the following questions set out in the State aid evaluation plan:

- Question 1: To what extent has the aid resulted in increased access to an NGA network being deployed in 'white' NGA areas?
- Question 2: To what extent has the target of the intervention been used and what speeds are available?

This section draws on an analysis of management data held by BDUK describing the delivery of the programme, econometric analyses exploring the net impacts of the programme on NGA and superfast coverage, and qualitative findings from research undertaken with Local Bodies, network providers and internet service providers. The findings of qualitative research were cross-referenced against available management information, secondary data sources where available and validated in consultation with officials within BDUK. Technical details of the econometric analysis are provided in Technical Appendix 1.

As delivery of Phase 3 contracts was at a comparatively early stage at the time of writing, additional analyses were completed looking at delivery of the overall programme to provide longer term insight into the effectiveness of the gap funding model adopted (covering both the 2012 to 2016 and 2016 to 2020 UK National Broadband Schemes).

Key findings:

Phase 3 contracts increased the number of premises passed by NGA services by 2,300 to 16,600 on postcodes benefitting from subsidised coverage by the end of September 2019 (with the weight of evidence to the lower end of this range). The share of the 79,100 premises upgraded by the end of September 2019 that would not have otherwise benefitted from NGA coverage is estimated at between 3 and 21 percent.

Phase 3 contracts increased the number of premises with superfast availability by 10,800 to 29,300, and the number of premises with FTTP coverage by 19,000 to 30,300. The additionality of superfast and FTTP coverage was correspondingly higher at between 14 and 55 percent of premises receiving subsidised coverage. This indicates that some premises benefitting from subsidised upgrades would have otherwise received from NGA coverage that did not deliver superfast speeds. There was also evidence that Phase 3 contracts delayed the availability of superfast coverage for some premises that would have otherwise received it earlier.

The findings were broadly consistent with more general analysis examining the impacts of the programme since delivery began in 2013. These findings indicated that the additionality of subsidised coverage peaks one year after premises are upgraded (at around 60 percent), before decaying at a rate of approximately 14 percent per annum. This implies that in many cases, the programme has worked to accelerate the availability of superfast broadband.

The results suggest that the processes used to identify the commercial plans of providers were not fully effective in establishing those premises that would not benefit from commercial deployments in the near term. Several explanations for this emerged from the research. Network providers reported that their investment cycles were determined over relatively short time horizons (12 to 24 months). The absence of immediate commercial deployment plans did not necessarily imply that investment was considered economically unviable. Network providers sometimes could not provide Local Bodies with deployment plans of sufficient detail or certainty to be incorporated when areas eligible for subsidies were determined. Finally, the areas eligible for investment were selected based on a static view of network provider's plans, which have evolved in response to regulatory innovation and growth in demand.

The findings indicated that Phase 3 contracts reduced the number of premises with superfast connections by 1.1 to 2.4 premises per postcode by September 2019. There was no conclusive evidence that subsidised coverage had a positive or negative effect on the average download speeds of connections by September 2019. This is likely a product of the short window of time that had elapsed for businesses and households to take-up the services enabled, and the effect of the programme in delaying the availability of superfast for some premises that would have otherwise benefitted from commercial deployments. It is premature to draw conclusions on the impact of the programme on take-up, and an analysis exploring the effects of the programme since it was launched in 2013 suggested it produced a broad range of positive impacts on take-up in the longer term.

The results indicated that Phase 3 contracts increased the average upload speeds of connections (by 0.9Mbps to 3.9Mbps) and the maximum download speeds of connections by 6.2Mbps to 16.9Mbps. This may reflect the effect of FTTP delivery, which has enabled users to obtain higher capacity connections that may have otherwise been available.

5.1 Key outcomes

The following analyses examine how far the programme produced an increase in superfast broadband coverage and take-up over and above what may have occurred in its absence. The following table provides an overview of the outcome measures defined for these analyses. As highlighted in the introduction, a broader range of outcomes were included in the study than originally envisaged in the State aid evaluation plan while alternatives needed to be used for some outcomes:

- **Measures of broadband availability:** The primary measure of broadband availability defined in the State aid evaluation plan was the number of premises passed by NGA coverage. This describes the number of premises able to receive broadband services from a technology capable of delivering superfast speeds (30Mbps). However, not all premises served by NGA technologies will be able to receive superfast speeds. As the primary goal of the programme was to increase the number of premises with superfast coverage, this was included as a secondary outcome for the evaluation. The focus of the programme also shifted to gigabit capable technologies as policy evolved. FTTP availability was included as a secondary outcome measure to capture this shift.

- **Take-up:** The State aid evaluation plan defined the number of live NGA connections as a key measure of take-up for the evaluation. The key data source for this measure (Connected Nations) does not provide details of the number of premises with NGA connections. However, it does provide the number of premises with a superfast (30Mbps) connection. This measure was used in place of the number of live NGA connections.

Data for the following analyses were taken from the annual Connected Nations dataset published by Ofcom. A discussion of the limitations associated with this data is provided in Technical Appendix 1.

Table 5.1 Key outcomes (Questions 1 and 2)

Outcome	Description
Question 1: To what extent has the aid resulted in increased access to an NGA network being deployed in 'white' NGA areas?	
Number of premises passed by NGA services	The number of premises able to access broadband through NGA technologies – wireless, FTTC, FTTP and Wireless. This the primary outcome measure defined for the evaluation in the State aid evaluation plan agreed between DCMS and the European Commission.
Number of premises with superfast (30Mbps)	The number of premises able to access speeds of 30Mbps. NGA technologies can deliver superfast speeds but will not always do so. This measure aligns more closely with the objectives of the programme.
Number of premises with FTTP coverage	The number of premises able to receive broadband services through FTTP. Phase 3 of the programme prioritised technologies capable of delivering Gigabit per second speeds which has concentrated investment in FTTP delivery.
Question 2: To what extent has the target of the intervention been used and what speeds are available?	
Number of connections of 30Mbps or higher	The number of households or businesses taking up a 30Mbps connection is used as a proxy for the number of live NGA connections (the outcome measure defined in the State aid evaluation plan agreed between DCMS and the European Commission).
Average download speed of connections	The average download speed of connections is a secondary outcome measure describing the effect of the programme on actual speeds used by households and businesses.
Average upload speed of connections	The average upload speed of connections is a secondary outcome measure describing the effect of the programme on actual speeds used by households and businesses.

5.2 Changes in NGA and superfast coverage in the programme areas

The following figure provides an overview of changes in NGA, superfast and FTTP coverage in areas covered by the build plans of Phase 3 contracts (based on Connected Nations data):

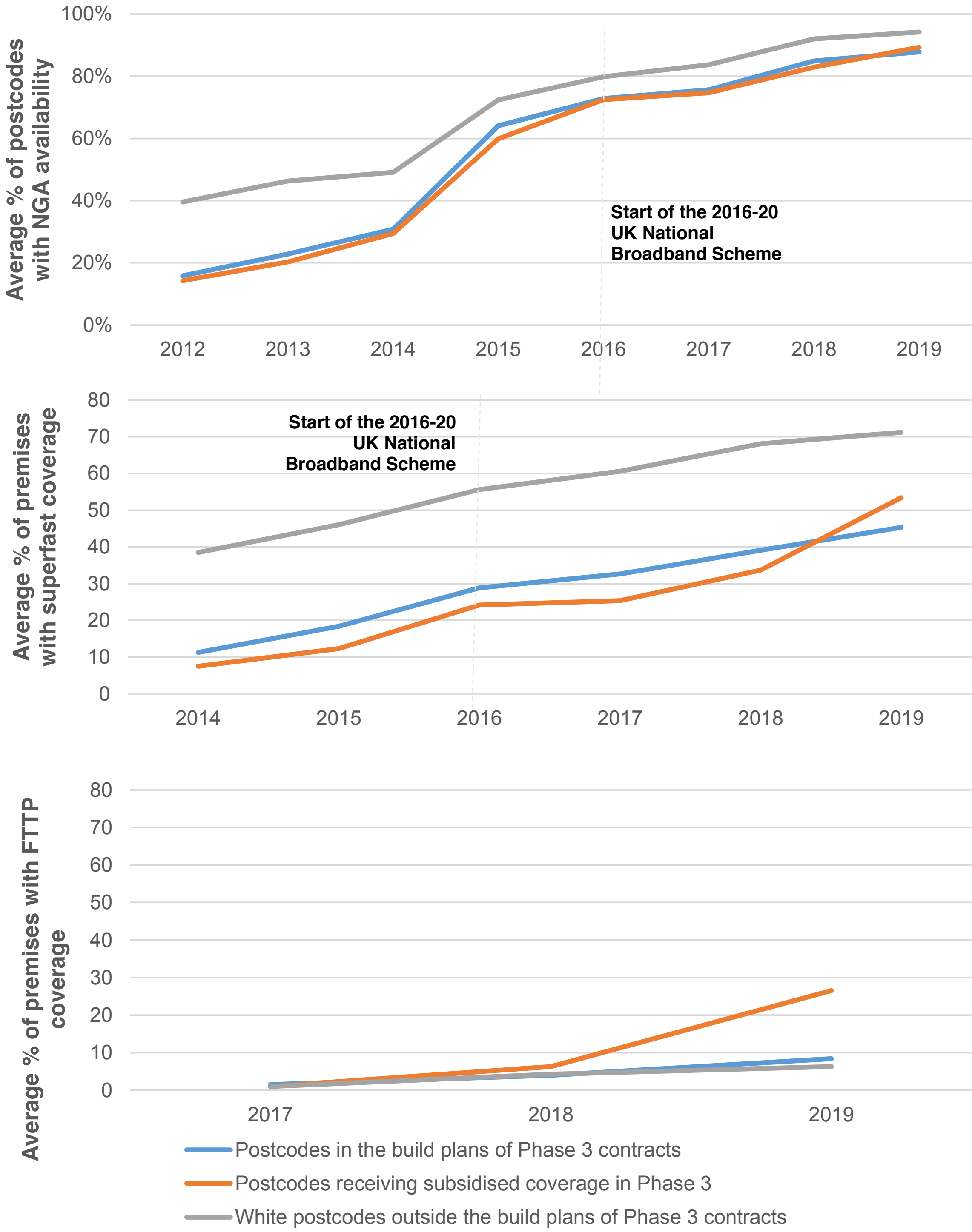
- **NGA coverage:** The percentage of premises on postcodes included in the build plans of Phase 3 contracts with NGA coverage rose from 73 percent to 88 percent between June 2016 and September 2019. NGA coverage rose at the same rate in areas receiving subsidised coverage by September 2019 and areas yet to be upgraded. It should be noted that this is based on a binary measure of NGA coverage[51] that is not sensitive to small changes in the share of premises with NGA coverage.

- **Superfast coverage:** The share of premises with superfast coverage rose at similar rates in areas covered by Phase 3 build plans and other 'white' postcodes between 2016 and September 2019 (from 27 to 45 percent and from 56 to 71 percent respectively). Superfast availability rose from 27 to 53 percent of premises in areas benefitting from subsidised upgrades by September 2019.

[51] A postcode was considered to have NGA coverage if more than 50 percent of the premises on the postcode were covered by NGA. This measure was adopted to facilitate comparability with the 2012 and 2013 Connected Nations reports, which gave a binary measure of whether NGA was available on the postcode.

- **FTTP:** The proportion of premises with FTTP coverage rose from 1 to 26 percent between 2016 and 2019 in areas benefitting from subsidised coverage. FTTP coverage grew substantially less rapidly on ‘white’ postcodes that were not included in the build plans of Phase 3 contracts (1 to 6 percent of premises).

Figure 5.1: Changes in Next Generation Access (NGA), superfast and FTTP coverage – areas in Phase 3 build plans and other 'white' postcodes, 2012 to 2019



Source: C3 reports, Ofcom Connected Nations, Ipsos MORI analysis. Data on FTTP coverage is only available from 2017.

5.3 Impacts on NGA, superfast and FTTP coverage

The analyses set out above suggest that the availability of superfast broadband services (though not NGA coverage) has increased more rapidly in the areas benefitting from subsidised coverage than other areas that were eligible for BDUK investment. This indicates that the programme may have had a positive impact on broadband availability. However, as highlighted in Section 3, there is a possibility that these areas would have received superfast coverage in the absence of the programme.

A robust assessment of the impact of the Superfast Broadband Programme requires the selection of appropriate comparison group of postcodes or areas that did not receive BDUK investment, to enable an assessment of what may have happened in the absence of the programme. This is problematic for the following reasons:

- **Targeting at 'white' areas:** Investment was targeted at 'white' premises or postcodes where network providers claimed they had no plans to roll-out superfast broadband coverage. As such, 'grey' and 'black' premises or postcodes are unlikely to provide a suitable counterfactual as they had been deemed commercially viable, and more likely to have received superfast coverage in the absence of the programme. The inclusion of these areas in a comparison group would understate the impact of the programme. Drawing a comparison group from the population of postcodes that were deemed eligible for subsidised coverage in the OMRs but were not included in the build plans of Phase 3 schemes helps address this problem.

- **Supplier choice:** However, this latter approach could be problematic as network providers were largely free to choose which eligible premises would be targeted from those identified in the OMR. It may be reasonable to assume that network providers selected those locations that were most commercially viable to maximise their returns. In Phase 3, factors such as existing penetration of NGA networks and the presence of competitors appeared to be significant in network provider's prioritisation decisions. Eligible postcodes not included in the build plans of Phase 3 schemes can be expected to differ in systematic ways to those benefitting from subsidised upgrades, which could bias results. For example, premises in 'white' areas that did not benefit from BDUK investment may have been the hardest to upgrade profitably, and the least likely to have received superfast coverage in the absence of the programme.

As such, basic comparisons between areas benefitting from the programme and other eligible postcodes that did not benefit from the programme will likely overstate its impacts. Addressing these issues requires the selection of appropriate statistical methods that can accommodate for both observable and unobservable differences between these two groups of areas. Full details of the statistical analyses completed to explore the effects of the programme on NGA access are provided in Technical Appendix 1. The following sections provide a summary of the methodologies employed and the core results.

5.3.1 Methodology

An assessment of the impacts of Phase 3 contracts on NGA, superfast and FTTP coverage was completed using the methods defined in the State aid evaluation plan, using Connected Nations data between 2016 and 2019. These included:

- **Difference-in-differences:** The most straightforward approach adopted involved comparing changes in the NGA, superfast and FTTP coverage on postcodes that received subsidised coverage between 2016 and 2019 to postcodes that were eligible for but did not receive BDUK investment. This approach is robust to unobserved differences between the two groups of postcodes that do not change over time, although no attempt was made in these analyses to control for observed differences.

- **Matching:** The above approach did not control for observable differences between those postcodes that received upgrades and areas that were eligible for subsidies but were not included in the build plans of Phase 3 schemes. As highlighted above, there were systematic differences between the two groups of areas which could bias the findings of difference-in-difference models. To address this issue, postcodes receiving subsidised coverage by 2019 were matched with other eligible postcodes where they shared similar characteristics – such as historic superfast broadband penetration, population density, and features of local broadband networks. Difference-in-difference models were then applied to the matched samples to reach estimates of the impact of the programme.

- **Panel methods:** The analyses described above focused on overall changes in NGA and superfast coverage between 2016 and 2019. However, as annual data was available, it was also possible to better account for the timing of the upgrade and its effect on broadband availability by applying 'fixed effects' models. These models examined the relationship between broadband availability and the timing of subsidised upgrades. Like difference-in-difference models, these approaches are robust to unobserved differences between postcodes that do not change with the time. However, they were also adapted to account for unobserved 'shocks' affecting all areas (such as influential regulatory changes). Estimates of the impacts of the programme derived from these models can be considered the most robust.

- **Prediction based on the comparison group:** The final approach developed a statistical model to describe the evolution of NGA, superfast and FTTP coverage on eligible postcodes that were not included in the build plans of Phase 3 schemes between 2016 and 2019, based on the characteristics of the postcode. The model was then applied to postcodes that did receive subsidised coverage to predict how NGA, superfast and FTTP coverage would have changed had the programme not been funded. It should be noted that these models did not account for unobserved differences between the two groups of postcodes, and estimates of impact derived from these models can be considered the least robust.

The results of these analyses have the potential to be distorted by the delivery of parallel programmes seeking to increase superfast broadband availability. Data was obtained on the delivery of the Gigabit Connectivity Voucher Scheme and the fibre networks being deployed as part of Wave One of the Local Full Fibre Network programme to help control for the possibility that the analyses mistakenly attributed the effects of these parallel programmes to Phase 3 delivery. Qualitative research with Local Bodies also highlighted that there were also parallel schemes being delivered at the local level. Systematic data on the delivery of these schemes could not be obtained and it should be noted that the findings also do not account for all public support for the development of local broadband networks.

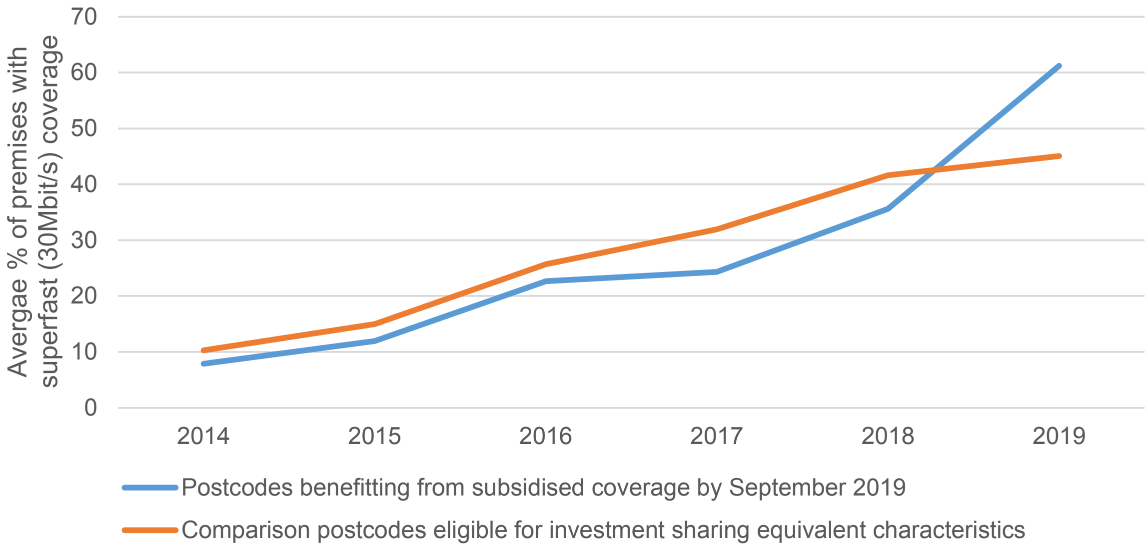
5.3.2 Impacts of Phase 3 contracts between June 2016 and September 2019

The results of the analysis indicated that the programme had a positive impact on NGA, superfast and FTTP availability in those postcodes benefitting from subsidised coverage by September 2019. However, the magnitude of these effects varied across the different approaches). This is illustrated in Figure 4.5 below which shows the increase in superfast broadband availability in postcodes benefitting from subsidised coverage and the matched sample of eligible postcodes that were excluded from Phase 3 build plans which shared similar characteristics:

- Superfast availability rose from 22 percent of premises in 2016 to just over 60 percent on postcodes that benefitted from subsidised upgrades by September 2019. Superfast availability rose in postcodes in the matched comparison group at a slower rate (from 25 percent to just over 45 percent).

- Most of this apparent impact on broadband availability occurred in the 2019 which aligns with the delivery profile of Phase 3 contracts. The figure also suggests the programme may have delayed the availability of superfast broadband services for some households that would have received coverage anyway. Growth in superfast availability was slower in areas benefitting from subsidised coverage between 2016 and 2018 (the period in which tendering exercises were being completed). This issue is explored in more depth below.

Figure 5.2: Evolution of superfast availability, postcodes receiving subsidised coverage by September 2019 and matched group of eligible postcodes, Phase 3



Source: Connected Nations, Ofcom, Ipsos MORI analysis

The statistical analyses provided estimates of the increase in share of premises benefitting from NGA, superfast and FTTP availability between 2016 and 2019 that could be attributed to the delivery of Phase 3 contracts. These estimates were applied to the number of premises on the postcodes benefitting from the programme to reach an estimate of the number of additional premises receiving subsidised coverage by September 2019. These results are summarised in Table 5.3 below:

On postcodes benefitting from subsidised coverage by September 2019, Phase 3 contracts were estimated to have increased the number of premises:

- Passed by NGA coverage by 2,300 to 16,600 (with the weight of results towards the lower end of this range, as illustrated in Figure 5.3).

- With superfast coverage (30Mbps) by 10,800 to 29,300.

- With FTTP coverage by 19,000 to 30,300.

The effect on superfast availability was larger than the effect on NGA availability. This indicates that a share of premises would have been passed by NGA coverage delivering sub-superfast speeds in the absence of the programme. The effect of the programme on FTTP availability was also larger than its effect on superfast availability – indicating that the priority given to gigabit speeds in tendering was effective in bringing forward full fibre networks. This may reflect the differing cost structures and payback periods of FTTC and FTTP, particularly if the latter involves more significant investment costs that cannot necessarily be recovered from the marginal increase in revenues.

Table 5.3 – Impacts of Phase 3 contracts on broadband availability by September 2019, postcodes benefitting from subsidised coverage

Measure of broadband availability	Estimated effect on availability by September 2019 (% of premises)		Increase in the number of premises with enhanced broadband availability	
	Min.	Max	Min.	Max
NGA availability	2.1	10.7	2,300	16,600
Superfast availability	9.9	25.2	10,800	29,300
FTTP availability	25.2	27.8	19,000	30,300

Source: Ipsos MORI analysis. The ranges show the low to high range implied by the statistical findings.

5.3.3 Implied additionality

The estimated number of additional premises benefitting from NGA, superfast and FTTP availability were compared to the total number of premises upgraded by the programme (79,100[52]) to provide an estimate of additionality (i.e. the share of premises upgraded that would not have received superfast coverage in the absence of the programme). The range of findings from the analysis are summarised in Figure 4.6, and suggest:

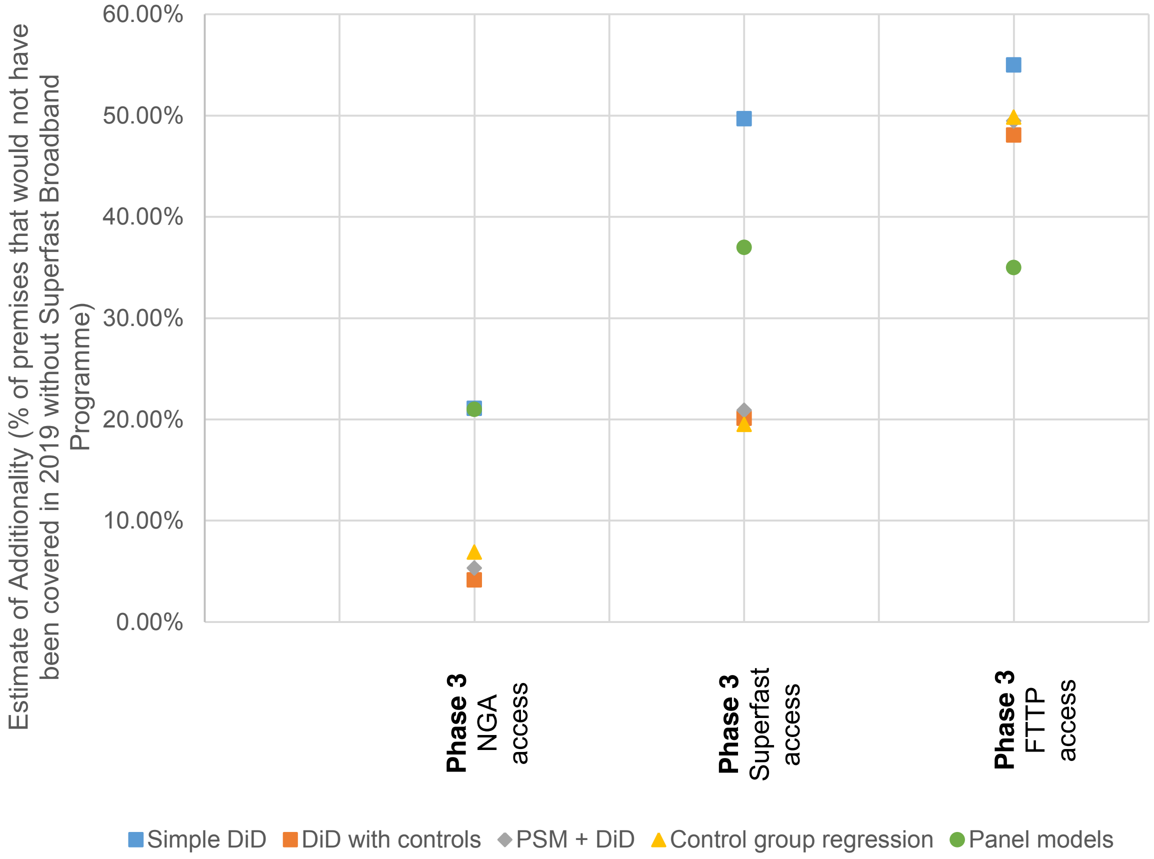
- Around 14 to 37 percent of premises upgraded to superfast (30Mbps) would not have received superfast coverage by 2019 in the absence of the programme. The more robust panel models pointed to estimated impacts towards the top end of this range. The additionality of FTTP coverage delivered through the programme was slightly higher and more consistent across different models (at 35 to 55 percent).

- The additionality of NGA coverage was lower at 3 to 21 percent of premises upgraded.

As highlighted below, these findings are consistent with results examining the impact of the programme overall. It should also be noted that additionality tends to peak around one year following the delivery of subsidised coverage (suggesting there may be lags in terms of the visibility of new coverage in the Connected Nations dataset). As this analysis focuses primarily on upgrades delivered in 2018 and 2019, it is likely that these results will understate the effects of the programme.

[52] 55,000 premises upgraded to FTTP.

Figure 5.3: Estimated share of premises upgraded that would not have otherwise received subsidised coverage by September 2019, Phase 3



Source: Ipsos MORI analysis

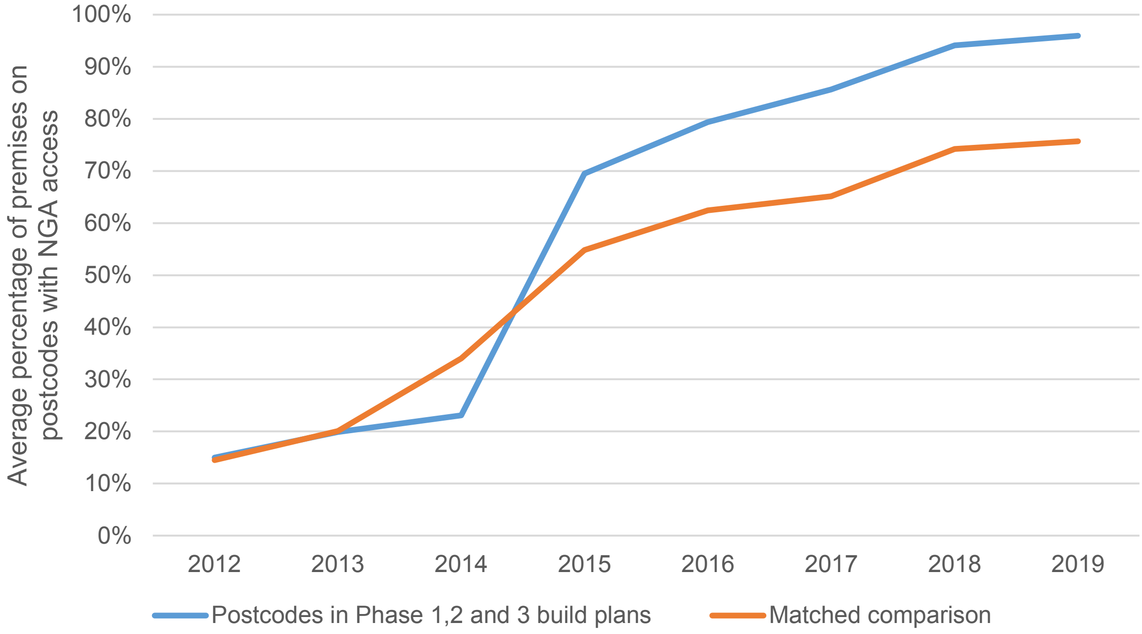
5.3.4 Effects on the whole Phase 3 target area

The analysis was repeated to examine the effect of the programme on all postcodes in the build plans of Phase 3 contracts (including the majority that had not yet received subsidised coverage by September 2019). Most of these results suggested that the programme had a negative effect on superfast availability by September 2019 - reducing the proportion of premises with superfast coverage by 3.2 to 10.3 percentage points. This is consistent with the observation above that the programme has delayed the delivery of superfast coverage for some households that would have benefitted from the programme anyway.

5.3.5 Impacts of Phase 1, 2 and 3 between 2012 and 2019

The delivery of Phase 3 contracts was at an early stage at the time of writing and it is premature to draw definitive conclusions on their long-term impacts. To provide a longer-term view on the impacts of the programme, similar analytical methods were applied to all contracts funded through the programme since delivery of Phase 1 began in 2013. As illustrated in Figure 5.4, the evolution of NGA coverage[53] in postcodes benefitting from the programme and other eligible postcodes has shown a broadly similar pattern to the effects of Phase 3 contracts on superfast availability. There is an apparent delaying effect in the first year (in 2014), before a significant increase in coverage in the following years.

Figure 5.4: Evolution of NGA availability, postcodes receiving subsidised coverage by September 2019 and matched group of eligible postcodes



Source: Ipsos MORI analysis

The longer time frame for these analyses supported an investigation into how the additionality of NGA coverage evolves with time. The figure below provides estimates of the additionality of subsidised coverage in the years before and after the upgrade and suggests:

- **Additionality:** Additionality peaks at just over 60 percent one year following the delivery of the upgrade. It is assumed that the increase in additionality is a result of lags between delivery of upgrades and the visibility of enhanced coverage in the Connected Nations dataset. If similar patterns hold for Phase 3 of the programme, this implies that the impacts reported above may be understated.

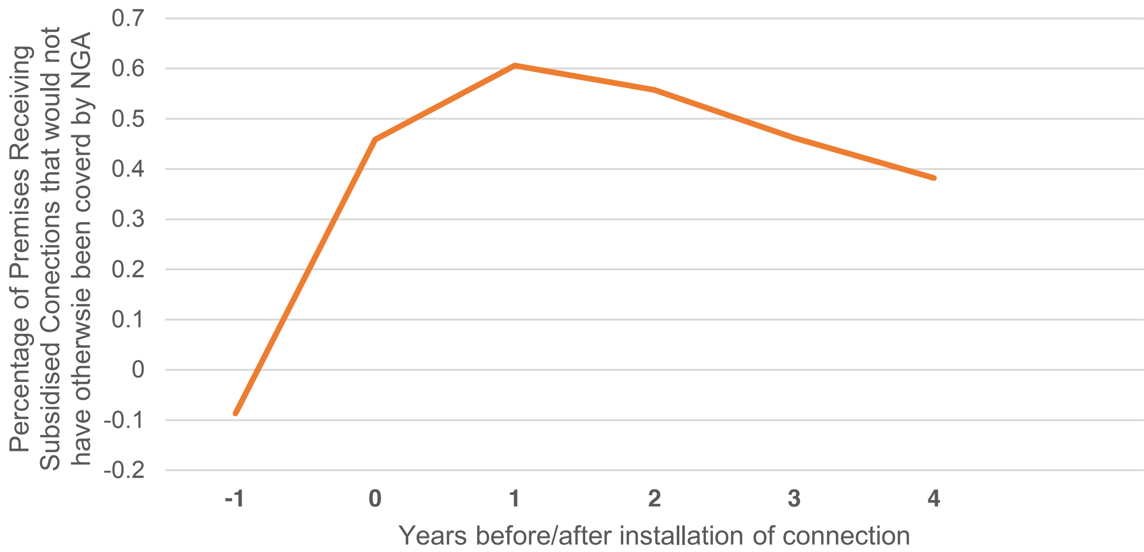
- **Decay over time:** The level of additionality decays from two years following the upgrade at a rate of around 14 percent per annum. This indicates that an important effect of the programme is to accelerate the availability of NGA coverage for some premises that would have otherwise received enhanced broadband coverage at a later stage.

- **Delaying effect:** Across the programme, subsidised coverage reduces superfast availability by 9 percent in the year before the upgrade. This suggests that a smaller

[53] Observations of superfast availability are not available from Connected Nations prior to 2014.

share of premises receive enhanced broadband coverage later than they otherwise would have (and that there are some social costs attached to the programme).

Figure 5.5: Estimated additionality of NGA Coverage over time, Phase 1 to 3



Source: Ipsos MORI analysis; BDUK C3 reports & Ofcom Connected Nations

5.3.6 Factors driving additionality

The preceding sections indicate that the OMR and public consultation processes were not fully effective in identifying premises that would not benefit from commercial deployments (if it was, then estimated additionality would be in the region of 100 percent). The qualitative research with Local Bodies and network providers were used to identify the factors that may explain these findings:

- **Quality of data:** Local Bodies interviewees expressed some concerns with the quality of the information provided by providers as part of the OMR process. Responses provided by Openreach in Phase 1 were seen to have caused issues leading to some areas being included in the intervention zone that already had superfast, and areas being wrongly excluded in others. Premise level data was seen to be less inaccurate with limited numbers of providers aware of their network at such a level. Efforts to descope areas that were wrongly included were undertaken during project delivery, though this absorbed a significant amount of resource on the part of the Local Bodies. These issues were somewhat less prominent in Phases 2 and 3 as the data supplied was described as having improved 'substantially' albeit with the lack of suitably granular data issues still present.

- **Investment cycles:** Many network providers reported difficulty in providing data for the OMR, as their plans were not always set out for the next three years. This was the case for both smaller and larger providers. This could be because the providers did not have robust plans for future deployment for the next three years (for example being more responsive to customer demand), or their plans were not specified in sufficient detail to be included. One provider stated that they could only provide (or were only willing to provide) concrete roll-out plans for 12 months, and not the 36 months requested – and their less robust plans for months 13-36 were rejected by Local Bodies. This meant that some 'prospective' plans were supplied to Local Bodies that were ultimately rejected (and to the degree that these plans were brought forward in practice, this will reduce additionality).

- **Mismatch between length of contracts and OMR:** Another issue with the OMR process is that there was sometimes a mismatch between the time-period covered by the OMR (three years) and the time-period covered by the delivery contract (which could extend beyond the three-year period covered by the OMR). As issues of commercial viability are dynamic, the OMR could become outdated with network providers introducing new programmes of commercial deployment on postcodes that were previously identified as eligible.

- **Static nature of the OMR:** The static nature of the OMRs, completed at the outset of each phase, posed a barrier to its ability to provide an accurate reflection of commercial coverage in the views of many Local Bodies. Some of those interviewed pointed towards the delivery of infrastructure in 'white' areas by providers that responded to the OMR as evidence of this. Wireless network providers were seen to be most readily able to change plans at relatively short notice and can encroach upon 'white' areas. One Local Body proposed regular reviews of the landscape after the setting of the intervention area, to include consultation with providers, to remain informed of changes in commercial plans. The static nature of the OMR also raised issues where regulatory innovation – such as changes in Physical Infrastructure Access (PIA) agreement with Openreach, which reportedly made areas more distant from existing networks more commercially viable for providers.[54] This was not factored into their original OMR responses, which meant these were no longer the best representation of their roll out plans.

- **Realism of plans:** Local Bodies also faced challenges in establishing the realism of the delivery plans put forward in the OMR. In addition, several Local Bodies outlined some suspicions of 'gaming' by providers leading to an overstatement of commercial plans to discourage competition thus contributing to the issues above. These Local Bodies pointed to areas in their locality that were put under review following the OMR and referral to the NCC (marked as 'grey' and monitored) and have not been delivered through the commercial plans outlined in the OMR.

- **Wireless:** Wireless broadband providers had further problems with the OMR process. Many had their responses rejected by Local Bodies (all wireless providers that were consulted had experienced having their responses rejected). The most common reason was that the Local Bodies did not recognise their technology as suitable to provide superfast speeds (despite the wireless network providers claiming they provided substantial technical evidence to the contrary and extensive businesses case materials). Wireless providers felt that they had to provide more details (and incur a higher cost) to submit OMR responses than wired broadband providers.

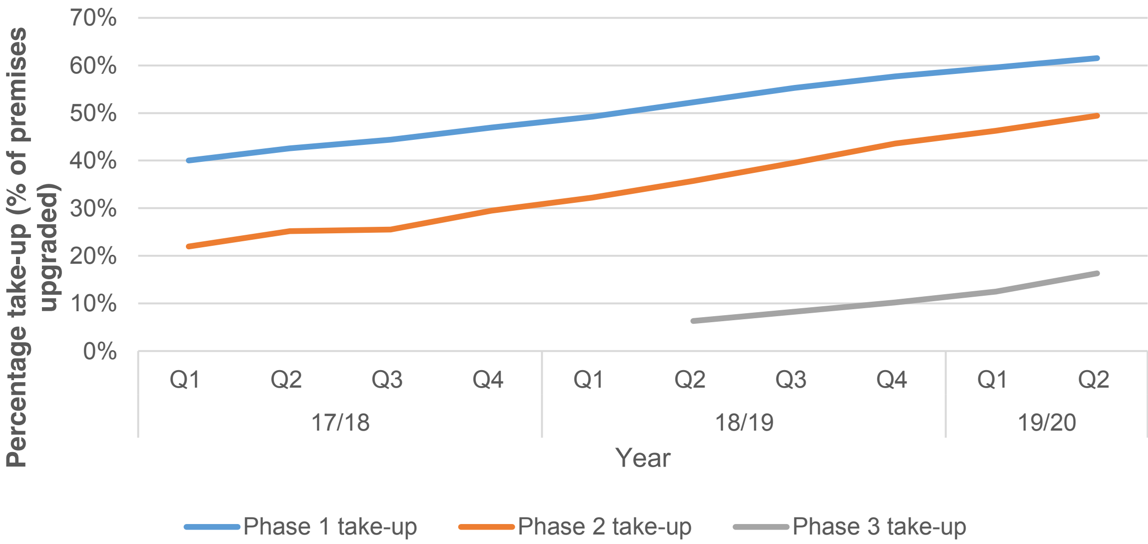
Despite concerns raised by the wireless providers, there are technical reasons why the Local Bodies took this approach, such as the placement of aerials, line of sight and number of premises on the network all affecting the ability of the network to deliver superfast speeds, and a lack of guarantees of the speed of service from Ofcom on wireless networks. Despite these concerns, a small number of programme contracts were awarded to wireless network providers.

[54] This relates to the Ofcom revision to Duct and Pole Access (DPA), which began in 216 and was adopted in 2018/19.

5.4 Take-up of NGA coverage

Take-up of subsidised coverage is monitored by BDUK (although the associated speeds of new connections are not). At the end of September 2019, a total of 15,400 connections had been made to newly upgraded services in Phase 3 contract areas. This was equivalent to 16 percent of the premises upgraded. As illustrated in the figure below, take-up of coverage made available through Phase 3 contracts has risen with time and growth in demand has broadly mirrored prior phases of the programme.

Figure 5.6: Reported take-up (%) of subsidised superfast connections to Q2 2019/20, Phase 1, 2 & 3



Source: Programme data (C3 reports); Ipsos MORI analysis.

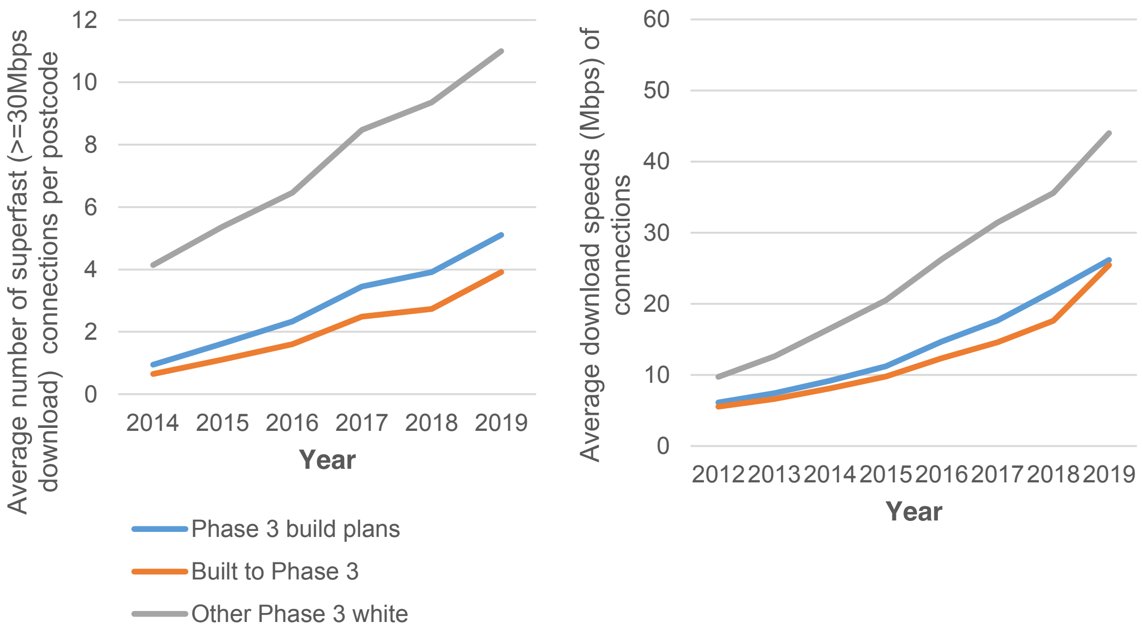
Given the small share of planned delivery that had come forward at the time of writing and the relatively low rates of take-up reported by the end of Q3 2019/20, there was little evidence of material changes in take-up measures in the programme area relative to other postcodes eligible for investment:

- **Number of superfast (30Mbps) connections:** The average number of superfast connections on postcodes in the build plans of Phase 3 schemes rose by 121 percent between 2016 to 2019 (from 2.3 to 5.1). Growth in the number of superfast connections rose slightly more rapidly (143 percent) on postcodes receiving subsidised coverage by 2019. However, demand for superfast connections also rose rapidly on other 'white' postcodes not included in the build plans of Phase 3 schemes (by 71 percent) over the same period.

- **Average download speeds:** The average download speeds of connections on postcodes included in the build plans of Phase 3 contracts rose from 14.7 Mbps to 26.2 Mbps between 2016 and 2019 (78 percent). Average download speeds rose more rapidly on postcodes receiving subsidised coverage by September 2019 (106 percent). However, growth in average download speeds was more rapid on postcodes that were not included in the build plans of Phase 3 schemes (115 percent) over the same period.

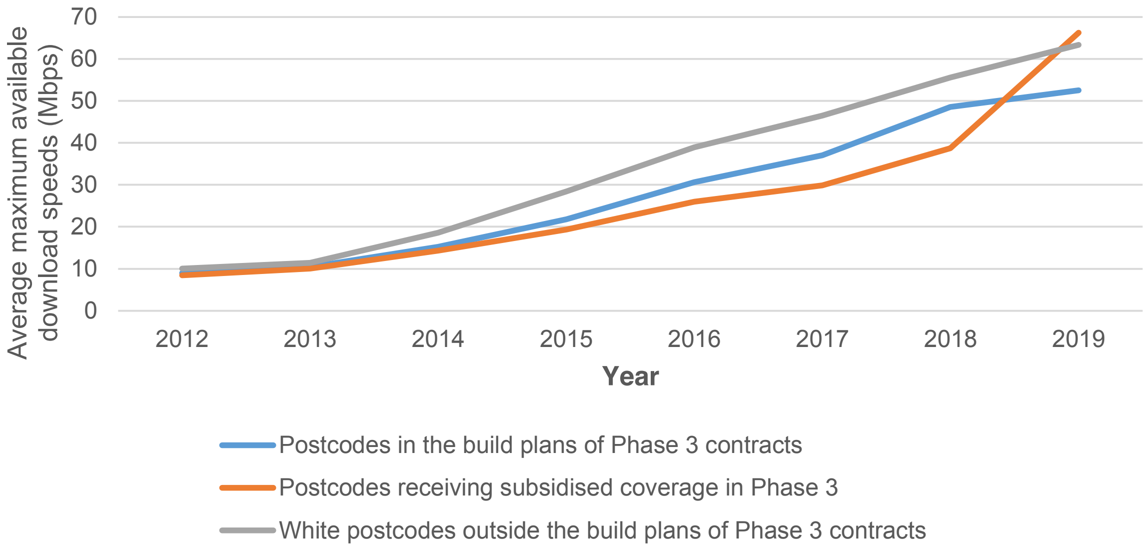
There were more marked differences in the maximum download speeds of connections (shown in the Figure below). Maximum download speeds on the postcodes included in the build plans of Phase 3 schemes rose at a similar rate to those on other 'white' postcodes. However, maximum download speeds rose most rapidly in those areas that had received subsidised coverage by September 2019 (reaching an average of 66 Mbps in September 2019). This evidence suggests that early adopters may be taking advantage of the faster speeds made available through FTTP (the availability of which was more widespread in these areas in 2019).

Figure 5.7: Number of superfast (30Mbps) connections and average download speeds of connections – areas in Phase 3 build plans and other 'white' postcodes, 2012 to 2019



Source: C3 reports, Ofcom Connected Nations, Ipsos MORI analysis.

Figure 5.8: Maximum download speeds of connections, areas in Phase 3 build plans and other 'white' postcodes, 2012 to 2019



Source: C3 reports, Ofcom Connected Nations, Ipsos MORI analysis.

5.4.1 Impacts on take-up

The statistical models described above were also applied to explore the effect of the programme on the take-up of superfast services - as visible in the number of premises with a live superfast connection (30Mbps or more), the average download speeds of connections, and the average upload speeds of connections. The results showed that:

- **Superfast connections:** The findings indicated that the programme led to a reduction in the number of premises with superfast connections (by 1.1 to 2.4 premises per postcode) by September 2019. This is likely explained by a combination of the effect of the programme in delaying the availability of superfast for some premises that would have otherwise benefitted from commercial deployments, and the limited time that had elapsed for businesses and households to take-up subsidised coverage by September 2019.

- **Average download speeds:** There was no conclusive evidence that the programme had a positive or negative effect on the average download speeds of connections by September 2019. The findings ranged from an effect of reducing average download speeds by 2.1Mbps to increasing download speeds by 2.2Mbps.

- **Maximum download speeds and upload speeds:** The results indicated that the programme increased the average upload speeds of connections (by 0.9Mbps to 3.9Mbps) and the maximum download speeds of connections by 6.2Mbps to 16.9Mbps. It is assumed that this reflects the effect of FTTP delivery, which has enabled some users to obtain higher capacity connections that may have been available from FTTC or other NGA technologies.

It is premature to draw any conclusions in relation to the impact of the programme on take-up. Take-up of superfast broadband services increases with time and the analysis of the long-term effects of the programme set out in Technical Appendix 1 highlights that, in the long-run, the programme has had positive effects on a wide range of take-up measures. As such, it will be important to revisit this analysis once more time has elapsed.

Table 5.4: Impacts of Phase 3 contracts on broadband take-up by September 2019, postcodes benefitting from subsidised coverage

Measure of broadband take-up	Estimated effect by September 2019 (% of premises)	
	Low	High
Average number of premises with connections with download speed of 30Mbps +	-2.4	-1.1
Average download speed of connections (Mbps)	-2.1	2.2
Average upload speed of connections (Mbps)	0.9	3.9
Maximum download speed of connections	6.2	16.9

Source: Ipsos MORI analysis

6. Direct impacts on aid beneficiaries

This section of the report provides evidence to answer the third and fourth State aid evaluation questions as set out in the NBS evaluation plan:

- Question 3: Has the aid had a significant incentive effect on the aid beneficiaries?
- Question 4: Has the aid had a material effect on the market position of the direct beneficiaries?

The evidence set out in this section is based on modelling of the expected profitability of contracts awarded under Phase 3 based – as far as possible – on observed costs and take-up. Full details of this modelling are provided in Technical Appendix 2, **[redacted]**. This section also provides evidence on the market share of those awarded contracts under Phase 3, based on data compiled by ThinkBroadband. Where relevant, additional information is provided from the qualitative interviews to help contextualise and interpret results.

Key findings:

Based on projections provided by network providers at the tendering stage, the proposed network build under Phase 3 contracts was expected either to generate losses or to deliver positive rates of return (Internal Rate of Return or IRR) that were substantially lower than the cost of capital faced by the network provider - a loss of **[redacted]** per annum versus a Weighted Average Cost of Capital (WACC) of **[redacted]**. If it is assumed that profit maximising firms are only incentivised to implement projects where the IRR exceeds the WACC, then public subsidies would have been needed to create a sufficient economic incentive to deliver these investments.

Network providers consistently underestimated take-up in the tendering process and projections for Phase 3 appear understated given experiences with Phase 1 and 2 contracts. This will have understated revenue projections and the IRRs (increasing the public funding required to make the project economically viable). However, after updating projections in line with take-up observed on Phase 1 and 2 contracts, the expected IRRs associated with Phase 3 projects without subsidy are not significantly higher than those expected at the tendering stage (moving to positive IRR of **[redacted]**). The projected IRRs of all Phase 3 contracts are expected to be substantially lower than WACC of the network provider.

The protections put in place by BDUK are likely to protect the public sector from the risk that it provided more than the minimum subsidy needed. Contracts have been designed in such a way that network providers are required to return resources to the public sector if build costs are understated or if take-up proves higher than expected (leading to higher levels of profitability). While the provision of subsidies is expected to increase the IRRs on Phase 3 contracts to a **[redacted]** return, this falls to **[redacted]** once the activation of these contractual mechanisms is accounted for.

While the contracts have proven largely effective in containing subsidies to the minimum needed for the project to go forward, the public sector has incurred opportunity costs by tying resources up in the programme. BDUK may wish to consider whether seeking to contain these opportunity costs in future procurements could be justified.

When examining the market position of the programme beneficiaries, it can be seen that there has not been significant changes in the market share of programme beneficiaries in the broadband market between 2016 and 2020, with Openreach dominating the market, with more than three quarters of the total broadband market and over 60 percent of the Next Generation Access (NGA) market in both 2016 and 2020. The other programme beneficiaries cumulatively make up less than 0.5 percent of the total broadband and NGA markets.

In the areas where the Superfast Broadband Programme has been delivered, the programme appears to have had little impact on the market position of Openreach in either the overall broadband or NGA market as Openreach maintains a dominant market position in both 2016 and 2020. However, the market share in both the overall broadband and NGA market for the smaller programme beneficiaries has increased between 2016 and 2020 in Phase 3 delivery areas which is not observed at a national level, suggesting the programme has positively affected the market share of the programme beneficiaries in these areas.

In areas where Openreach have delivered contracts, they have maintained their market share between 2016 and 2020 in both the overall broadband and NGA markets. However, in areas where the other, smaller programme beneficiaries have delivered contracts, the market share for Openreach has fallen (particularly in areas where Gigaclear have delivered contracts), with the market share of the other beneficiaries increasing. This suggests that the other beneficiaries are taking market share from Openreach in these areas.

6.1 Incentive effect of the State aid on programme beneficiaries

This section examines the strength of the incentive effect of State aid provided by the Superfast Broadband Programme. The aim of the analysis is to explore whether public subsidies were needed to provide an incentive to network providers to extend superfast networks to the areas targeted by the programme.

The motivation for this analysis stems from the results of classical economic theory that suggests the private sector will maximise profits by implementing all projects that generate a rate of return that at least equal their cost of capital. The rationale for the programme is underpinned by an assumption that there are some areas of the UK where investments in superfast broadband infrastructure will not generate a rate of return that exceeds the cost of capital. These investments would not be commercially viable, leaving some areas at risk of being excluded from superfast broadband coverage (producing a ‘digital divide’). The programme seeks to provide the minimum subsidy that would be required to make these investments commercially viable (i.e. the subsidy that would equalise the expected returns associated with the investment and the cost of capital faced by the network provider).

However, it is not feasible for the public sector to perfectly observe the expected costs and revenues associated with potential investments in superfast coverage before it awards subsidies. Network providers also have an incentive to seek subsidies for investments that would have been commercially viable in the absence of public support to maximise profitability and minimise risk exposure. The design of the programme anticipates this risk through the implementation of an Open Market Review process designed to encourage network providers to reveal their investment plans and to ensure that subsidies are directed towards premises that would not be covered by commercial deployments. The contracts are also designed to protect the public sector from the risk that the subsidy exceeds the minimum needed for the project to go forward (for example, if costs prove less significant than originally expected or if revenues exceed original expectations).

This section examines the effectiveness of these arrangements by comparing the expected rate of return on the contracts awarded (the Internal Rate of Return[55] or IRR) to the network providers' Weighted Average Cost of Capital (WACC)[56]. As highlighted in the State aid evaluation plan, if the actual IRR earned on the investments made exceeds the WACC before the subsidy was awarded, this would call into question the strength of the incentive effect provided by the subsidies. It should be noted that this may not hold true where there are market failures (e.g. a dominant supplier with market power may not be incentivised to implement an investment project if it earns a marginal rate of return).

6.1.1 Competition for Phase 3 contracts

The programme is based on a gap funding model that aims to provide the minimum level of subsidy required to make the project commercially viable. The level of gap funding to be provided is determined by the set of assumptions put forward by the tenderer in terms of the build cost, take-up, average revenue per user and operational costs. The tenderer can potentially use this process to transfer risk to the public sector by either assuming low levels of future take-up or overstating expected build costs – which will increase the level of gap funding required to make the project viable. This strategy is less feasible in the presence of competition, as it will reduce the value for money associated with the tender and increase the probability of not being awarded the contract.

In Phases 1 and 2, Local Bodies predominantly used the BDUK framework to procure the providers' services to deliver the infrastructure. This approach restricted the number of possible bidders to two (one of which did not engage for any tenders). In Phase 3, as required by the State aid judgement under which the programme was approved, procurements published through the OJEU were used by Local Bodies to target specific areas and/or clusters with the ability to target faster connection speeds, but the main benefits were expected to come from increased competition.

Data was not available on the number of bids received in response to the OJEU procurements to evaluate its effectiveness directly in generating larger numbers of bids. However, Local Bodies consulted highlighted a good degree of engagement from providers to Phase 3 procurement exercises with several bodies receiving five or six Expressions of Interest (EOIs). These translated into fewer responses to the full tender (between one and three). Nevertheless, there was a more even distribution of network providers awarded contracts, with Openreach being awarded just over two thirds of the contracts (69 percent), and Gigaclear being awarded a significant number of contracts (12 contracts, 23 percent).

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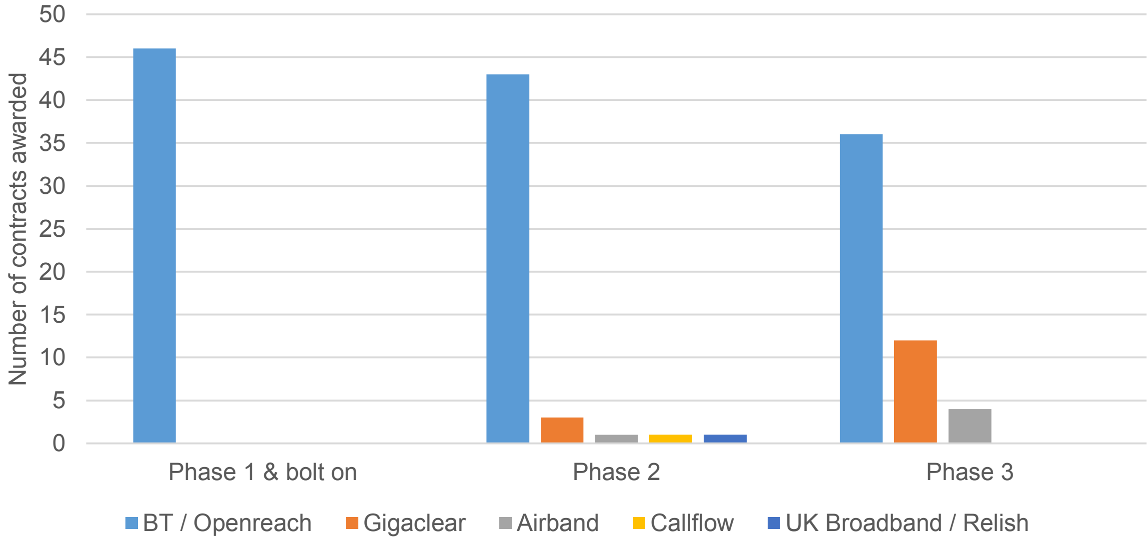
[55] The discount rate that sets the present value of an income stream to zero.

[56] For the purposes of this analysis, an average comparison between IRR and the network provider WACC has been made. A comparison to the marginal cost of capital would be preferable approach and may therefore produce different results from average rates.

Figure 6.1: Number of contracts awarded by beneficiary and Phase of programme



Source: Cora Management Information, June 2020

The table below provides a breakdown of funding for contracts awarded under Phase 1, 2 and 3 of the programme by source of funding. This table illustrates that the subsidy required as a percentage of the total cost of the project has remained constant over the three Phases of the programme (with the share of costs funded by the network provider rising from 24 percent in Phase 1 to over 27 percent in Phase 3). However, investment in postcodes covered by Phase 3 contracts should – in principle - have been less commercially viable than those covered by Phase 1. This could be taken as a signal that greater competition has helped to keep the gap funding requirement constant over time, above other possible explanations (such as the development of new methods or increased skills / knowledge of the beneficiary workforce).

Table 6.1: Superfast Broadband Programme expenditure by phase

	Phase 1 (contracts awarded 2012 – 2014)	**Phase 2 (contract awarded 2013 – 2016)**	**Phase 3 (contracts awarded after 2017)**
Average premises	95,405	16,952	6,197
Average contract value (£m)	£35.0	£13.8	£12.3
Funding source:			
BDUK funding	29%	26%	12%
Local Body funding	31%	22%	37%
ERDF / Defra funding	12%	1%	12%
Supplier CAPEX	24%	25%	27%
Supplier OPEX	0%	5%	4%
Funding generated from take-up clawback	3%	10%	5%
Funding generated from underspend	0%	11%	3%

Source: Cora Management Information, June 2020

Lotting[57] was also used in some areas to try to encourage further competition but views on its effectiveness were mixed with some areas forgoing this entirely given a lack of feasible geographic splits of the target areas. Where this approach was used, some Local Bodies thought it may have marginally increased the number of responses. In general, smaller providers engaged in the study highlighted a preference for smaller lots, though there was an acceptance that the lots needed to be of a suitable size to make them worthwhile bidding for. Additionally, the lots needed to be of a suitable size to ensure the management burden to Local Bodies and providers was appropriate (it is more difficult to manage many small contracts than one large one). Smaller providers also stated that they would be more able to bid for contracts following dividing up some of the areas (into lots).

However, when the ITTs came out, there were still restrictions on which organisations could apply (turnover of applicants and other qualification criteria). This restricted the level of competition that was possible, but again providers generally understood that there needed to be some restrictions to provide reassurance that the publicly funded networks would be completed.

6.1.2 Methodology for modelling future IRRs

The aim of the analysis is to compare the IRRs earned in practice by network providers against their cost of capital. However, this involves several challenges:

- **Data availability:** Network providers have a contractual obligation to provide BDUK with information on the actual costs of the network build and the share of premises upgraded that have been connected. However, network providers are not required to provide information on on-going operational costs or revenues earned (partly due to challenges in attributing operational costs to the infrastructure). As such, it is not possible to observe the profitability of the contracts awarded directly.

- **Time horizons:** The IRR associated with the network build is determined over long time horizons (i.e. fifteen to twenty years depending on the Phase). Due to the early stage of implementation for a large proportion of Phase 3 contracts, information on final build costs are not yet available and there are few quarters of reported information on take-up to provide meaningful comparisons against expectations.

The following general methodology was adopted in light of these constraints:

- **Phase 1 and 2:** A modelling exercise was completed to project the costs, revenues and IRR associated with Phase 1 and 2 contracts. The build costs – and any implementation clawback - associated with these contracts were either known (where the contract was complete) or revised expectations were available from BDUK where the project was at an advanced stage. Observations of take-up were available for an extensive period, though not for the fifteen-year period over which the IRR was originally calculated. A projection of future take-up was developed by projecting past trends forwards. Estimates of revenues, operational costs and take-up clawback were derived by applying assumptions provided by the network provider in their original PFM relation to the average revenue and operational cost per user to this

[57] Lotting is a process by which the local body divides their broadband project into multiple contracts (lots) rather than one single contract

revised take-up projection. These revised estimates of expected costs and revenues were used to provide an update to the expected IRR on the project.

- **Phase 3:** There was limited data available on the costs and take-up of most Phase 3 contracts owing to their comparatively early stage of implementation. Projections of the build costs associated with these contracts were developed by scaling initial expectations in light of changes in the number of premises to be upgraded. Information on actual take-up was generally insufficient to develop a projection by extrapolating past trends into the future, so an assumption was adopted that take-up would broadly follow patterns observed and projected for Phases 1 and 2.

A comprehensive overview of the methodology and data sources used is included in the Technical Appendix 2. However, the following limitations should be borne in mind:

- **Take-up:** Estimates of revenues, operational costs and take-up clawback are driven by a projection of future take-up. This projection is based on an extrapolation of past trends and actual take-up may be higher or lower than projected in practice. Deviations from these projections will have complex effects on the IRRs presented in the following sections. For example, while higher take-up than projected would imply higher revenues and higher IRRs, the network provider may need to return a higher share of the subsidy received to the public sector via the take-up clawback mechanism than expected.

- **Modelling of revenues:** The modelling of future revenues is based on price schedules put forward by the network provider in its PFM submitted as part of the tendering process. The analysis assumes that these prices are both accurate and are constant over the duration of the period. Additionally, the average revenue per user is based on the share of customers taking up FTTC and FTTP technologies assumed by the network provider in the documents submitted with its tender. In practice, prices may vary over time. For example, increased competition may place downward pressure on prices (resulting in lower revenues and lower IRRs than estimated in the following analyses). If demand for more expensive packages is higher than expected, this will result in higher revenues and higher IRRs than estimated. This cannot realistically be addressed in any future iterations of the evaluation unless BDUK were to begin monitoring the revenues earned by network providers on connections made to subsidised infrastructure.

- **Operational costs:** The modelling of operational costs was based on the forecast of operational costs provided by the network provider in the documents submitted with its tender, divided by the forecast number of customers, to provide an estimate of the operational cost per user. If actual operating costs per connection differ from these assumptions – for example, due to technological change – then the IRRs will be higher or lower than presented below.

- **Customer upgrades:** The analyses do not account for any revenues foregone by network providers as a result of any customers upgrading from existing packages. As such, the IRRs presented below will be systematically overstated (and the significance of this issue is unknown).

- **Internal focus:** The IRRs focus on the revenues earned and costs incurred by the network provider with the primary objective of establishing whether the network provider had an economic incentive to deliver the network build without a subsidy. However, it should be noted that there will likely be displacement of customers, revenues and profits from other network providers. While this issue does not affect the IRRs, the rates of return presented will not mirror the social rate of return.

6.1.3 Internal Rates of Return at the tendering stage

The expected rate of return on the contracts before and after subsidy are provided in the Project Financial Model completed by network providers as part of the tendering process. At the baseline, network provider projections suggested that:

- **Commercial viability without subsidy:** On average, Phase 3 contracts were expected to be loss making without a subsidy (delivering an IRR of **[redacted]**). There was substantial variation at the individual contract level, although no project was expected to deliver an IRR that exceeded the network provider's WACC (**[redacted]**). The expected profitability of investments proposed by network providers facing a higher cost of capital were broadly in line with those put forward by the dominant supplier which faced a lower cost of capital (a weighted average of **[redacted]** respectively). **[Redacted]**.

- **Commercial viability with subsidy:** The expected IRR associated with the contracts with subsidies averaged **[redacted]** per annum. This was lower than the average network provider's WACC (**[redacted])**. It is possible that the network providers saw residual value in the network build at the end of project lifetime. Additionally, delivery of the network build may have conferred other advantages to the network provider that are not captured by these analyses, such as reducing the marginal costs of deployment to adjacent areas.

- **Comparison with Phase 1 and 2:** The expected profitability of Phase 3 contracts without subsidy was expected to be higher than those associated with Phase 1 and 2 contracts, meaning that they would require a lower level of public support to make them economically viable. As illustrated below, this was driven primarily by more optimistic take-up assumptions adopted by network providers in tenders. This could have been driven by the higher levels of competition involved, which may have limited scope for network providers to use less optimistic take-up assumptions to transfer risk to the public sector. Alternatively, network providers may have seen relatively greater opportunities to develop local monopoly advantage in Phase 3, resulting in higher take-up. This is considered less plausible given that observed take-up on earlier Phases was substantially higher than anticipated.

6.1.4 Expected and actual costs

At the tendering stage, the expected costs associated with the network build (for the contracts in the scope of this analysis) were estimated by network providers to be approximately £169m. Based on information on actual costs to date:

- **Costs to date:** Network providers had incurred costs of £101m in delivering the network build based on information available at the time of writing.

- **Forecast future costs:** Across the portfolio, the future costs associated with the network build were expected to be £66m.

- **Expected versus forecast:** At the portfolio level, the forecast costs are broadly in line with expected costs and have little effect on the IRRs presented below. While there is variation at the contract level, this variance is primarily driven by differences in the contracted number of premises to be upgraded and any changes that have subsequently been agreed with the local body. The results do not factor in any possible differences in the expected and actual efficiency of the network build, and to the degree that these are significant, the estimated IRRs presented below will be overstated or understated.

Table 6.2: Modelled build costs for Phase 3 contracts

	Baseline build capex (PFM)	Actual build capex (Finance Tracker)	Additional modelled build capex	Total predicted build capex
Total costs	£168,865,826	£101,179,650	£66,555,338	£167,734,988

Source: Ipsos MORI analysis

6.1.5 Actual and predicted take-up

The take-up level represents the number of premises connected. It is a significant component of the analysis as it influences both the level of revenues earned by providers, operational costs, as well as subsidies to be returned to the public sector via the take-up clawback mechanism. There was little data available on the observed take-up of superfast services enabled by contracts delivered under Phase 3. However, there is extensive information on the take-up of coverage brought forward Phase 1 and Phase 2 that was used to inform expectations.

Figure 6.2 below shows the profile of expected take-up (as a percentage of premises passed) for Phase 1 and 2 contracts as set out in documents submitted by tenderers. This is compared to actual take-up as monitored by BDUK. The figures illustrate that actual take-up substantially exceeded expected take-up in both Phases 1 and 2 of the programme:

- **Phase 1:** In the long-run (ten years after the completion of the project), take-up was predicted to **[redacted]** of the premises passed. In practice, actual take-up exceeded this level in the third year of the contract and continued to increase to almost **[redacted]** by 2019/20.

- **Phase 2:** Expected take-up was predicted by network providers to **[redacted]** for Phase 2 contracts. Given that network providers had learned from Phase 1, some questions could be raised about the credibility of these expectations (i.e. observed take-up on Phase 1 contracts had already broadly reached this level at the time Phase 2 contracts were awarded). In practice, actual take-up of Phase 2 rose more quickly than for Phase 1 contracts and had reached **[redacted]** by 2019/20.

To model the expected rates of return on Phase 1 and 2 contracts, a generalised logistic function was used to forecast take-up beyond the point of latest available data in both phases, capped at a maximum value of 85 percent. This is in line with the assumption that the maximum take-up level is around 85 percent across the UK.[58]

[58] This capping was deemed appropriate through discussions with BDUK and with reference to Ofcom's Connected Nations 2018 report indicating average take-up of 85% across the UK. No time factor has been applied to decrease the assumed 15% of premises which do not take-up superfast broadband over time. Ofcom (2018). *Connected Nations 2018.* https://www.ofcom.org.uk/__data/assets/pdf_file/0020/130736/Connected-Nations-2018-main-report.pdf on 7 April 2020.

Figure 6.2: Predicted and actual take-up levels rates for Phase 1 and 2 contracts

[redacted]

Figure 6.3 below shows the profile of average take-up (as a percentage of premises passed) for Phase 3 contracts:

- **Expected take-up:** On average, network providers expected take-up to reach **[redacted]** in the long-term. This is higher than assumed for Phase 1 and 2 contracts, and increased the expected IRRs on Phase 3 contracts. However, there are questions around the plausibility of these assumptions given that take-up on Phase 1 and 2 contracts had already exceeded this value at the time many of these contracts were awarded.

- **Actual take-up:** There was limited data available on actual take-up of coverage brought forward under Phase 3 (shown in a solid blue line in the following figure). Take-up did lag expectations, but this is primarily driven by delays in delivery of the scheme rather than lower than expected demand for superfast services. However, as the associated revenues will be realised at later stages than originally expected, these delays will have the effect of reducing the IRR associated with the investments.

- **Projected take-up**: Owing to the limited data available on the take-up, it has been assumed that future take-up patterns will mirror the growth in demand observed for Phase 1 and 2 contracts (the dashed curve is based on the average of Phase 1 and 2). This is a source of additional uncertainty (particularly as most delivery is FTTP rather than FTTC) and will require revisiting in any future evaluation.

Figure 6.3: Actual and projected take-up of coverage brought forward under Phase 3

[redacted]

6.1.6 Expected and forecast revenue and operational costs

The take-up projection was used to estimate expected revenues and operational costs (based on the average revenue per user assumptions put forward by the tenderer and the estimated operational cost per user inferred from their financial projections). Figure 6.4 below presents the modelled revenue against the network provider predictions at the tendering stage. Total revenue across the Phase 3 portfolio is estimated to be in the region of **[redacted]**. The figure also highlights the effect of delays in the early years of the contract. **[redacted]**.

Figure 6.4: Network provider predictions of revenue against modelled data

[redacted]

Similarly, Figure 6.5 below presents modelled operating costs. Modelled operating costs in Phase 3 include network and wholesale connection opex, deployment closure costs, ongoing contractual reporting, wholesale cessation costs and wholesale migration costs. The analysis suggests that the level of operating costs is forecast to **[redacted].**

Figure 6.5: Baseline operating cost projections against modelled revenue for Phase 3 contracts (in scope)

[redacted]

6.1.7 Internal Rates of Return based on projected take-up, revenues and operational costs

Based on the updated revenue and cost projections set out in the preceding sections, the modelling indicated that:

- **Commercial viability without subsidy:** Although projected take-up is higher than assumed by network providers at the tendering stage, the IRR associated with the projects without subsidy are not significantly higher (moving from a **[redacted]** per annum loss to positive annual rate of return of **[redacted]**). This can be explained by the delays early in the contract, resulting in revenues being recognised later than originally expected. In all cases, the IRRs associated with the projects were expected to be substantially lower than WACC of the network provider (**[redacted]**[59]). Arguably, a subsidy would have been needed in all cases to create a sufficient economic incentive to deliver the scheme.

- **Commercial viability with subsidy:** The provision of subsidies increases the average IRR associated with the contracts to **[redacted]**. This exceeds the network providers WACC (**[redacted]**) and in 12 of the 20 cases the network provider would be expected to earn excess returns without the application of implementation and take-up clawback. However, it should be noted that the size of these excess returns is substantially smaller (on average) than those associated with Phase 1 and 2

[59] **[Redacted]**

contracts. Again, this provides a signal that the more competitive environment for Phase 3 contracts may have limited scope for network providers to transfer risk to the public sector.

6.1.8 Internal rates of return after implementation and take-up clawback

Estimates of clawback were developed based on predicted underspend associated with the network build and predicted take-up levels and involve substantial uncertainties. However, the modelling shows that the Phase 3 contracts could be expected to generate **[redacted]** of implementation clawback. Additionally, contracts were only expected to trigger small amounts of take-up clawback (with **[redacted]** of take-up clawback expected across the portfolio in the seven years after the physical work of each contract has been completed). This is again explained by the delays associated with the delivery of Phase 3 contracts. While take-up is projected to exceed original expectations, this is not expected to occur until relatively late on in the lifetime of the project (often beyond the final review point that takes place seven years into the contract).

Overall, the analysis suggests that the clawback mechanism may prove effective in limiting any excess returns that might be earned by network providers. Across the portfolio, the clawback mechanisms are expected to reduce the IRR associated with the contracts (on average) to **[redacted]** – broadly in line with ex-ante expectations (**[redacted]**). Additionally, at the individual contract level, only one is expected to deliver a rate of return that exceeds the WACC of the network provider (**[redacted]**).

6.1.9 Summary of results

The estimated Internal Rates of Return associated with Phase 3 (and Phase 1 and 2 contracts, for comparison) are summarised in Table 6.3. These can be compared to the network providers WACC of **[redacted]** percent. The key findings from this analysis indicate:

- **Commercial viability without subsidy at the tendering stage:** Based on projections provided by network providers at the tendering stage, the proposed network build under Phase 3 contracts was expected either to generate losses or to deliver positive rates of return that were substantially lower than the cost of capital faced by the network provider (a loss of **[redacted]** per annum versus a WACC of **[redacted]**).

- **Commercial viability without subsidy adjusted for take-up**: Take-up projections appear understated given network providers would have had information on take-up on Phase 1 and 2 contracts. This will have fed through to understated revenue projections and rates of return, increasing the level of gap funding required from the public notionally required to make the project economically viable. However, after updating projections in line with take-up observed on Phase 1 and 2 contracts, the expected IRRs associated with Phase 3 projects without subsidy are not significantly higher than those expected at the tendering stage (moving from **[redacted]** per annum loss to positive annual rate of return of **[redacted]**). In all cases, the IRRs associated with the projects were expected to be substantially lower than WACC of the network provider. Arguably, a subsidy would have been needed in all cases to create a sufficient economic incentive to deliver these contracts.

- **Effectiveness of contractual mechanisms:** The protections put in place by BDUK are likely to protect the public sector from the risk that it provided more than the minimum subsidy needed. Contracts have been designed in such a way that network providers are required to return resources to the public sector if build costs are understated or if take-up proves higher than expected (leading to higher levels of profitability). While the provision of subsidies is expected to increase the IRR on

Phase 3 contracts to **[redacted]**, this falls to **[redacted],** once the activation of these contractual mechanisms is accounted for.

- **Opportunity costs:** While the contracts have proven largely effective in containing subsidies to the minimum needed for the project to go forward, the public sector has incurred opportunity costs by tying resources up in the programme. BDUK may wish to consider whether seeking to contain these opportunity costs in future procurements could be justified. The evidence in this analysis indicates that increased levels of competition (in Phase 3 of the programme) limit the extent to which network providers can transfer risk to the public sector (as doing so results in less competitive tenders). However, other options could include using the information on the tail end of the distribution of observed take-up rates across Phase 1, 2 and 3 contracts to set a maximum level of subsidy to be offered as part of a given procurement. This may still allow network providers to understate profitability by adjusting revenues via price schedules (though if BDUK are able to monitor revenues earned on connections as well as volumes of customers, this may limit scope to do so).

- **Future competition:** The results of these analysis also do not factor the possibility that the network providers' market share and any excess profits are eroded by the entry of competitors via the open access arrangements required by the programme. This could only be realistically assessed if BDUK was able to monitor revenues earned by network providers alongside customer volumes (as this would help explore issues in relation to both market share and prices). It should be noted that this issue is likely to be more significant for vertically integrated operators that act as both wholesalers and retailers.

- **Scope for inefficiencies:** Clearly, there is also scope for inefficiencies arising from the leakage of subsidies into wages or other operating costs. These will not be visible in the analysis of rates of return and could not be captured in this analysis, but if this occurs it would reduce the value for money of the programme.

Table 6.3: Internal Rates of Return - Phase 1, 2 and 3 contracts

[Redacted].

6.2 Effects on market position of direct beneficiaries

The previous section suggests that the contracts developed by BDUK have broadly contained the risk that network providers earned excess returns on infrastructure subsidised by the public sector (though noting that at this stage, these findings are speculative owing to the early stage of the delivery of the programme). This section examines the degree to which those network providers benefitting from the programme have gained a material advantage over competitors. This assessment is based on descriptive analysis of changes in the market share of each network provider awarded contracts through the programme, based on speed test data provided by ThinkBroadband. The analysis here describes the market position at a national level, a Phase 3 programme level and a combination of all Phase 3 contracts delivered by the same beneficiary. This analysis differs slightly from that outlined in the State aid evaluation plan of analysing the market position at a local authority level and the contract level. The change in the analysis was to identify the impact of Phase 3 contracts on the market position rather than the impact of the programme as a whole, which the analysis at a local authority level would show. Additionally, the sample sizes available from the ThinkBroadband data would not support a robust analysis of beneficiary market position at the individual contract level. As this analysis is based on speed test data, there are some potential irregularities in the data, which are highlighted in Section 2 of the report. These should be taken into account when interpreting these findings – particularly at the smaller geographic levels.

ThinkBroadband is an independent organisation which collects information and data about internet coverage in the UK. It also runs an online ‘speed test’ function, where individuals can provide a limited amount of data about their broadband package and test the connection speed that they receive. The information provided and collected through individuals completing a speed test has been compiled into a dataset. It should be noted that the speed test data does not include all ISPs offering services in an area, or the number of ISPs with customers in each area. It measures the number of ISPs where customers have completed speed tests. Therefore, there could be inaccuracies in this data. Additionally, there are a number of contracts with low numbers of speed tests completed, therefore the analysis for these areas lacks robustness.

To assess the market position of each beneficiary of the programme, the ISPs which utilised each beneficiary was mapped. This information was collected from a web search of the ISP’s website, the Openreach website (which lists ISPs which utilise their wholesale products) and the ThinkBroadband website. A complete list of ISPs included in the dataset and the network providers they have been mapped to is included in Annex A.

6.2.1 UK market shares of network providers

The market share for network providers has been estimated from the proportion of speed tests completed for ISPs which were mapped to the network provider. The market share of all NGA connections (FTTC, FTTP, cable, wireless and satellite connections) for network providers has been estimated by the proportion of speed tests completed for ISPs which were mapped to the network provider that utilised these technologies.

- **Openreach:** At a UK level, connections supplied through the Openreach network dominate the market, with around 40 percent of take-up in all years being made through the Openreach network. This percentage increases if the Sky and TalkTalk networks are included as being provided through the Openreach network (as these networks utilise the Openreach network) to between 70 and 80 percent. Openreach has a less dominant position in relation to NGA connections, although its market share rises from 61 to 67 percent (including connections through Sky and TalkTalk).

- **Other network providers:** Other network providers awarded Superfast Broadband contracts represent a very small proportion of the broadband market – cumulatively less than one percent of the total broadband market in 2020 (see Table 6.4 below). Between 2016 and 2020, the market share of total broadband connections for the beneficiaries got smaller, driven by a decrease of the market share for Openreach (via Sky and TalkTalk). The smaller network providers also account for a very small proportion of the NGA broadband market – less than one percent of the market in 2020.

Table 6.4: Share of the total broadband market, Superfast Broadband beneficiaries

	Total broadband connections		NGA connections	
Network provider	**2016**	**2020**	**2016**	**2020**
Openreach	38.6%	39.6%	35.5%	37.0%
Openreach (plus Sky and TalkTalk)	78.1%	75.2%	60.5%	67.2%
Airband	0.0%	0.1%	0.1%	0.1%
Gigaclear	0.1%	0.2%	0.2%	0.3%
Callflow	0.0%	0.0%	0.0%	0.0%
UK Broadband / Relish	0.0%	0.0%	0.0%	0.0%
Total programme participants	**78.3%**	**75.5%**	**60.8%**	**67.6%**
Virgin Media	19.9%	17.1%	36.9%	23.3%

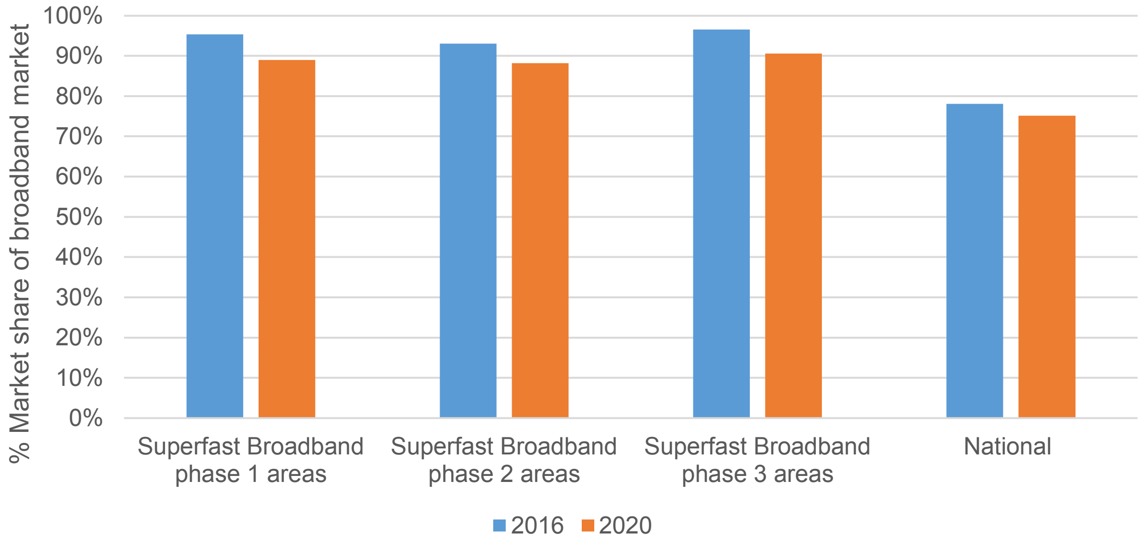
Source: ThinkBroadband speed test data

6.2.2 Overall market shares across Superfast Broadband contract areas

The market share of the broadband market for the network providers across the areas that the Superfast Broadband Programme has or is currently operating was analysed using the same approach. This approach was taken instead of examining the impact at a Local Authority level as at the Local Authority level it would not be possible to distinguish the impact of contracts awarded in different phases of the programme.

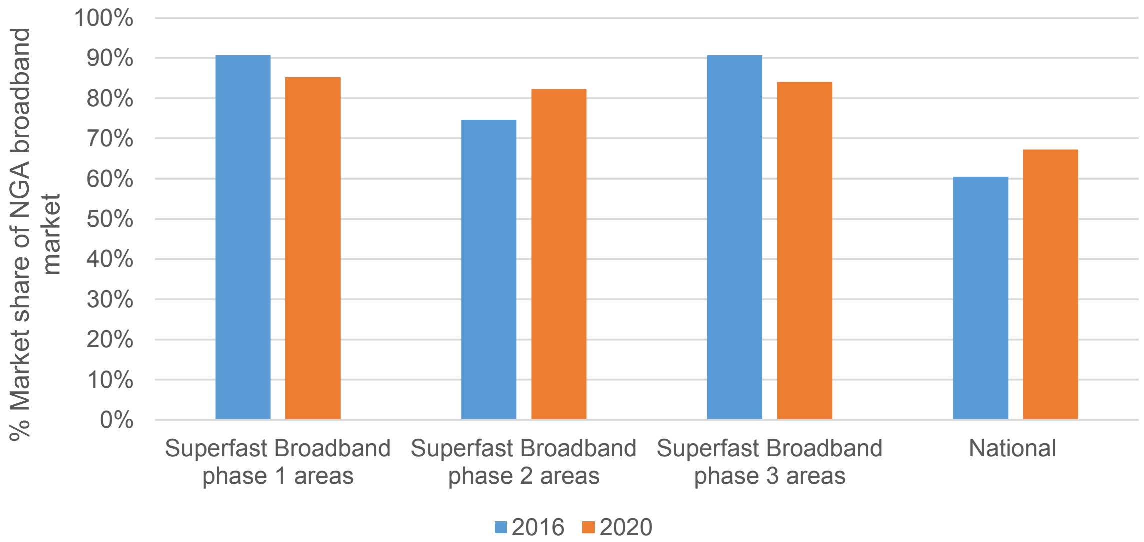
The market share for Openreach (including Sky and TalkTalk) across all these areas declined between 2016 and 2020, from around 95 to 90 percent of all connections. While this is higher than the national average (between 70 and 80 percent), the decline in market share aligns with national trends. In terms of NGA connections, while Openreach's national market share increased between 2016 and 2020, it fell in Phase 1 and Phase 3 contract areas while rising in Phase 2 contract areas (see Figures below).

Figure 6.6: Total broadband market share for Openreach (including Sky and TalkTalk) in Superfast Broadband delivery areas and nationally



Source: ThinkBroadband speed test data

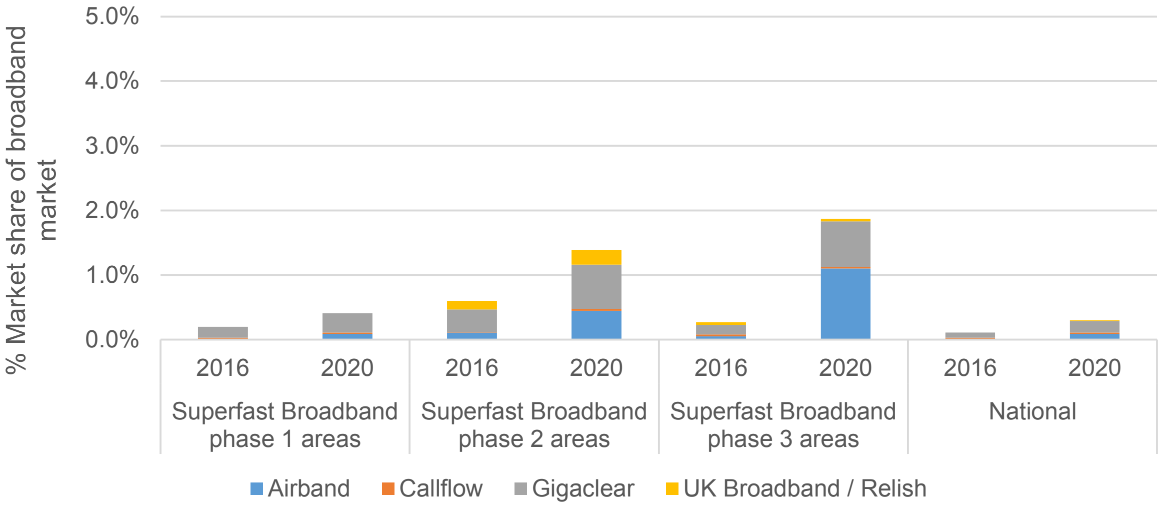
Figure 6.7 – NGA broadband market share for Openreach (including Sky and TalkTalk) in Superfast Broadband delivery areas and nationally



Source: ThinkBroadband speed test data

The market share for all broadband connections for all other network providers awarded contracts through the Superfast Broadband Programme is presented in the figure below. This shows that the market share of these network providers rose faster between 2016 and 2020 in contract areas than nationally. Airband and Gigaclear – who have been awarded more contracts – saw larger increases in market share in the Superfast Broadband delivery areas than Callflow and UK Broadband / Relish. Similar patterns are seen in terms of their share of NGA connections. However, the overall market share of these network providers is not significant in local or national terms (less than two percent of total broadband connections and less than 4 percent of NGA connections).

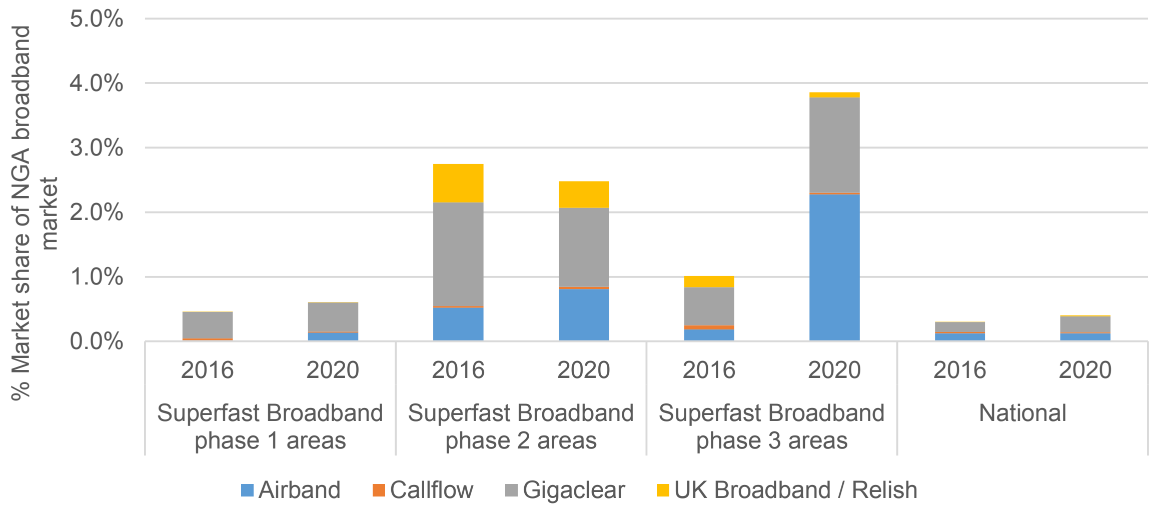
Figure 6.8: Total broadband market share for all other Superfast Broadband Programme beneficiaries in Superfast Broadband delivery areas and nationally[60]



Source: ThinkBroadband speed test data

NOTE: The scale of the market share in the figure is from 0 to 5 percent of the total market – caution when comparing to figure 6.6

Figure 6.9 – NGA broadband market share for all other Superfast Broadband Programme beneficiaries in Superfast Broadband delivery areas and nationally[61]



Source: ThinkBroadband speed test data

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[60] It should be noted that these market shares are based on relatively small sample sizes, and this should be taken into account when interpreting these findings.

[61] Ibid.

NOTE: The scale of the market share in the figure is from 0 to 5 percent of the total market – caution when comparing to figure 6.7

6.2.3 Market shares within Superfast Broadband contract areas

Further analysis was completed to look at changes in market share in the specific contract areas in which beneficiaries were operating (aggregated across all contract areas due to the small sample sizes available for individual areas). More details of the sample sizes in each project area is provided in Annex A. This analysis showed:

- **Openreach:** In Phase 3 contract areas where Openreach deliver the project, the market share of Openreach declined between 2016 and 2020 for both NGA connections and total broadband connections. As Openreach's national market share of NGA connections rose over this period, this does not suggest that Openreach acquired a substantial competitive advantage as a result of the aid it received from the Superfast Broadband Programme.

- **Gigaclear:** In areas where Gigaclear deliver the Phase 3 local project, its market share of total broadband connections rose from 7 percent to 25 percent between 2016 and 2020, while its share of NGA connections rose from 18 to 34 percent. This increase in market share appears to have been taken from Openreach (including Sky and TalkTalk) – whose market share of total broadband connections fell from 90 to 74 percent over the period, and whose share of NGA connections fell from 75 to 57 percent.

- **Wireless providers:** This pattern is repeated for areas where wireless providers have been contracted to deliver Superfast Broadband projects. The market share of total connections taken by wireless providers rose from 1 to 11 percent between 2016 and 2020, while their share of NGA connections rose from 3 to 23 percent. Again, this appears to have been achieved at the expense of the Openreach – which saw its market share of total broadband connections decline from 95 percent in 2016 to 81 percent in 2020 in these areas, while its share of NGA connections fell from 83 to 65 percent over the same period.

7. Indirect impacts

This section presents the evidence collected and analysed to answer State aid evaluation question 5 – i.e. how far is there evidence of changes to parameters of competition arising from the aid (including third parties operating in the relevant intervention areas)? As set out in the State aid evaluation plan, this question is addressed by examining the following parameters of competition: changes in NGA take-up as a proportion of total take-up; the share of take-up by NGA technology; the number of network providers offering NGA services; and the number of unique Internet Service Providers making use of the open access made available.[62]

Key findings

At a UK level, the share of NGA broadband take-up as a proportion of total broadband take-up has increased markedly since 2016. NGA connections represented just over half of all broadband connections in 2016, but this has grown to over 70 percent of internet connections in 2020. Fibre to the Cabinet (FTTC) connections represented the largest proportion of NGA connections in both 2016 and 2020 (around a third of broadband connections in 2016 and just over a half in 2020). This pattern was also observed in areas the Superfast Broadband Programme has delivered to, with an increase in NGA take-up in Phase 3 contract areas of over 20 percentage points between 2016 and 2020.

The average number of infrastructure providers operating on the postcodes benefitting from subsidised upgrades rose from 2.3 to 2.6 between 2012 and 2020, indicating the programme may have helped promote greater competition in these areas. Although there has been an increase in the number of network providers offering services in Superfast Broadband Programme areas, most non-beneficiary network providers tended to provide services to only a small number of postcodes within the Superfast Broadband project areas in 2020, as was the case in 2016. This suggests there has not been a large degree of overbuild.

The number of Internet Service Providers (ISPs) operating in Superfast Broadband Programme areas has increased between 2016 and 2020. There are a higher number of ISPs with customers in Phase 1 contract areas than Phase 2 and Phase 3. This would be expected, given that the Phase 1 areas were larger and more commercially viable, and more time has lapsed since project completion. Additionally, all Phase 1 contracts were delivered by Openreach, and the qualitative findings suggested that at present no ISPs were utilising the subsidised networks built by programme beneficiaries other than Openreach.

[62] As noted in Section 2, due to data restrictions it was not possible to assess the number of ISPs utilising the networks through the Open Access Agreements, as this data has not been collected. Therefore, this report explores the number of ISPs operating in the areas the programme has delivered to as a proxy of this indicator.

7.1 Parameters assessed and approach

The table below describes the analytical approach that has been used to provide evidence to answer the State aid evaluation question.

Table 7.1: Analysis used to provide answers to the State aid evaluation questions

Analysis	Evaluation question
Analysis of broadband take-up by technology. The market share of seven different types of broadband connection has been calculated. These are FTTP, FTTC, GFast, Cable, Fixed wireless / satellite connections, ADSL and other connections.	Question 5: • Take-up of NGA lines as a % of all broadband take-up
The market share by type of technology. Analysed at three levels: a UK national level; for all areas where the Superfast Broadband Programme has been delivered (portfolio level); and at an individual contract level. The market share has been calculated for each of these for 2016 and 2020.	Question 5: • Market share (of take-up) for each NGA technology
The number of network providers operating in the areas that the Superfast Broadband Programme has been delivered. The statistical analyses described in Section 4 were also extended to examine how far the programme had a causal effect on the number of network providers active in the programme area.	Question 5: • Number of infrastructure providers offering NGA services
The number of ISPs operating in an area. The number of ISPs operating has been estimated at a national, for all areas where the Superfast Broadband Programme has been delivered (portfolio level) and individual contract level for 2016 and 2020. It should be noted that the speed test data does not include all ISPs offering services in an area, or the number of ISPs with customers in each area. It measures the number of ISPs where customers have completed speed tests. Therefore, there could be inaccuracies in this data.[63] Additionally, there are a number of contracts with low numbers of speed tests completed, therefore the analysis for these areas lacks robustness.	Question 5: • *Number of unique operators making use of the open access made available under the 2016 NBS*[64]

7.2 Take-up of NGA lines as a percentage of all broadband take-up and Market share for each NGA technology

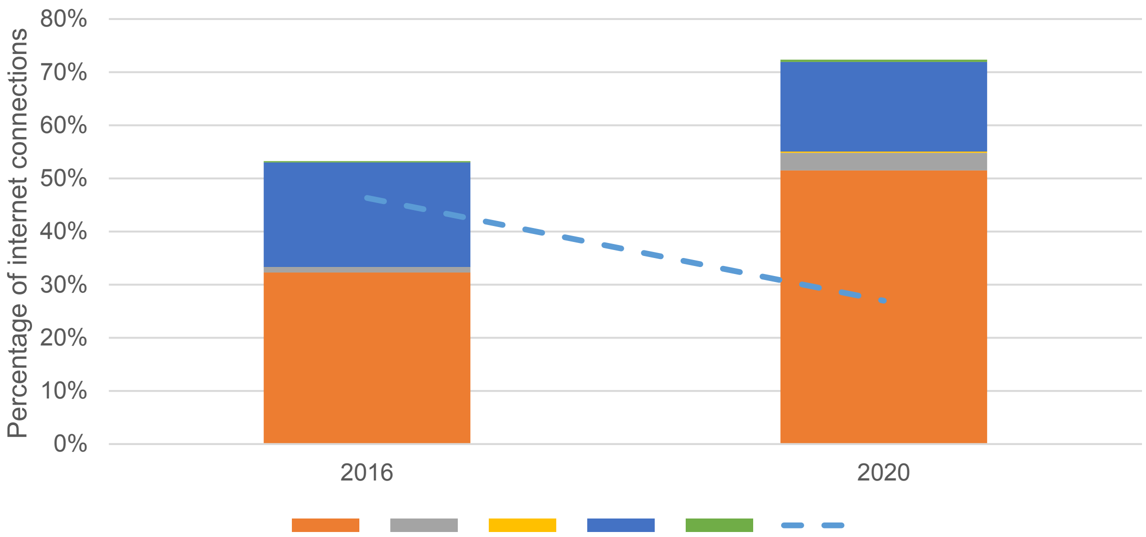
At a UK level, the share of NGA broadband take-up as a proportion of total broadband take-up has increased markedly since 2016. The figure below shows that take-up of NGA connections represented just over half of all broadband connections in 2016, but this has grown to over 70 percent of internet connections in 2020. FTTC connections represented the largest proportion of NGA connections in both 2016 and 2020 (around a third of broadband connections in 2016 and just over a half in 2020). FTTP and wireless connections

[63] It is not possible to estimate the degree to which the data may be inaccurate. However, the data is likely to become less accurate when analysing smaller geographic areas, and this should be taken account of when interpreting the results.

[64] Data has not been collected which shows the number of unique ISPs which have accessed networks through the open access made available under the 2016 NBS. Therefore, a proxy measure of the number of ISPs providing services in the areas where the Phase 3 contracts have been delivered has been analysed.

represented under five percent of the broadband market in 2020 and under two percent in 2016.

Figure 7.1: UK broadband take-up by technology type



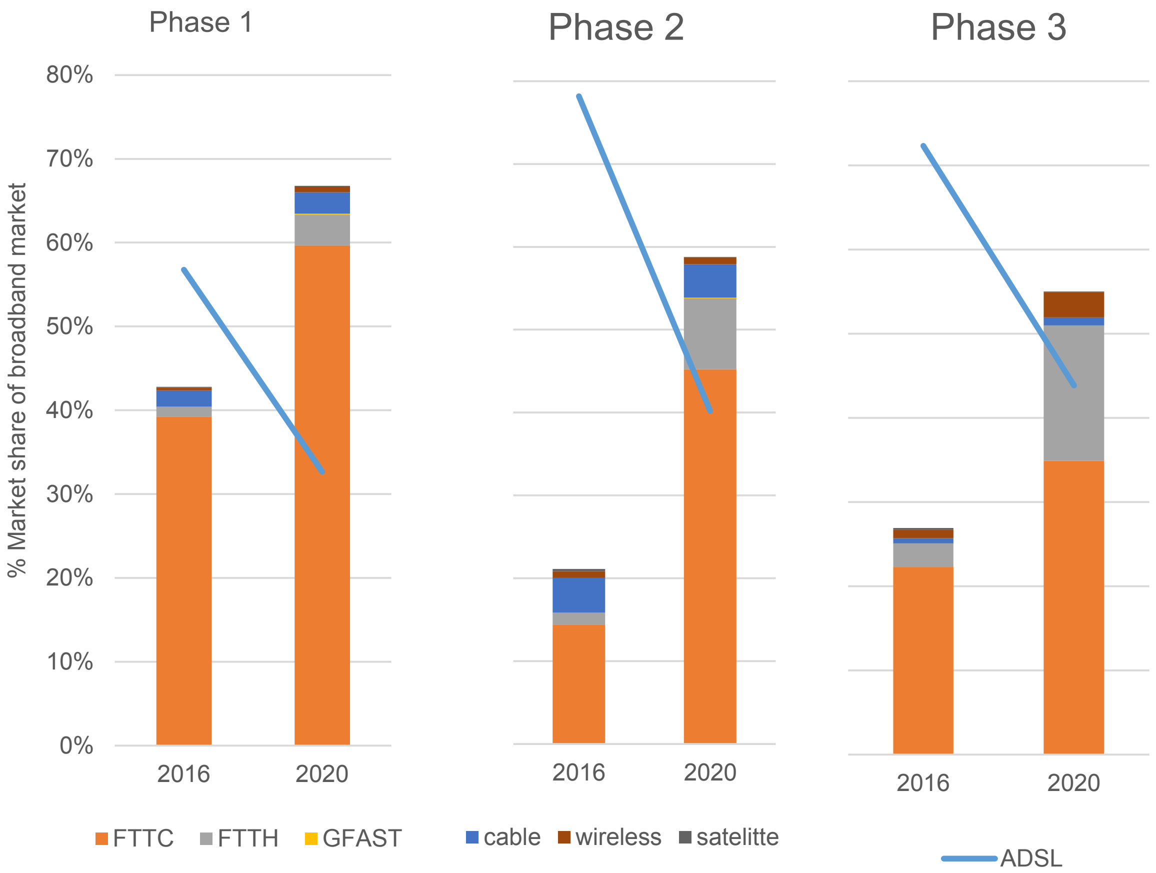
Source: ThinkBroadband speed test data

This analysis was undertaken separately for the delivery areas for Phases 1, 2 and 3 of the Superfast Broadband Programme as illustrated in the figure below. This found that between 2016 and 2020, there was an increase in NGA take-up in Phase 3 contract areas of nearly 30 percentage points. However, this lags the increase in NGA take-up in Phase 2 contract areas of 38 percentage points. This would be expected, as Phase 3 contracts are still being delivered, and consumers in these areas may not have the opportunity to take-up new NGA connections as of 2020. Additionally, as illustrated in Section 5, Phase 3 contracts did not have a positive impact on the number of superfast connections by September 2019. As such, it is unlikely that the programme has yet caused consumers to switch from ADSL to NGA in Phase 3 areas.

As with the national pattern, FTTC is the dominant technology for NGA connections, representing around one third of total broadband connections in 2016 and over half of broadband connections in 2020 in areas upgraded by the Superfast Broadband Programme areas.

FTTP and wireless connections are slightly more prevalent in Superfast Broadband delivery areas than nationally, representing 5.5 percent of connections in the delivery areas in 2020, and over 16 percent in Phase 3 contract areas. This would be expected as FTTP connections are being delivered by the Superfast Broadband Programme, particularly in Phase 3 contracts (with FTTP in Phase 3 areas representing more than three times the market share of Phase 1 areas). Local Bodies and network providers explained during qualitative interviews that the aim of the projects that they tendered for (particularly in Phase 1 and Phase 2 of the Superfast Broadband Programme) was to provide the maximum volume of Superfast Broadband coverage (in terms of number of premises upgraded) for the lowest possible price. In Phase 1 and Phase 2, the most economical mechanism of delivering Superfast Broadband speeds was mainly through FTTC technologies.[65] Additionally, the open nature of the competitions for Phase 3 contracts allowed smaller network providers to offer different technological solutions to Local Bodies.

Figure 7.2: Broadband take-up by technology type in Superfast Broadband delivery areas by Phase of delivery (% of connections)



Source: ThinkBroadband speed test data

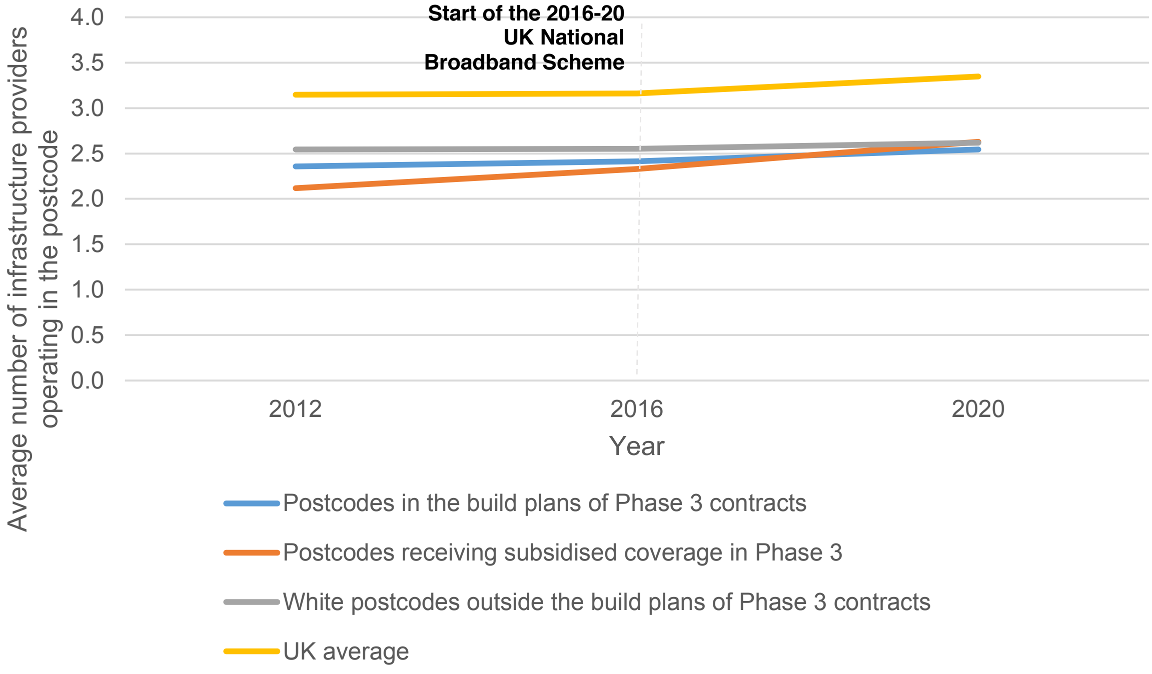
7.3 Number of infrastructure providers offering NGA services

The figure below shows the change in the number of network providers[66] operating in postcodes that were eligible for subsidies under Phase 3 contracts between 2016 and 2020. In 2016, the average number of infrastructure providers operating in the areas covered by Phase 3 build plans was lower than in other areas that were eligible for Superfast Broadband

[65] Wireless technologies could also be used in some areas to provide Superfast Broadband connection speeds economically. However, in Phase 1 no wireless providers were able to tender for contracts, and some Local Bodies were confident that wireless solutions could deliver superfast speeds to the entire target population (doubts about the technological capabilities).
[66] Data included network providers owning and operating their own networks (not including ISPs) regardless of whether or not they provided a superfast network.

support (but did not receive any). The average number of infrastructure providers operating on the postcodes benefitting from subsidised upgrades rose from 2.3 to 2.6 between 2012 and 2020, whilst the average number in other areas that were eligible for support (but did not receive any) rose from 2.5 to 2.6. This may indicate that the programme has helped promote greater competition in these areas, although as discussed in below, the coverage of non-beneficiary network providers in the upgraded areas is thought to be relatively low.

Figure 7.3: Changes in the average number of infrastructure providers operating in areas in Phase 3 build plans and other 'white' postcodes, 2012 to 2020



Source: C3 reports, ThinkBroadband coverage dataset, Ipsos MORI analysis.

There were a large number of network providers offering services in Superfast Broadband areas in 2020, and this has increased since 2016. For all Phase 3 contract areas combined, there were 30 network providers offering services in these areas, compared to 13 in 2016. These numbers are lower than in Phase 1 and Phase 2 contract areas (44 network providers in Phase 1 areas in 2020 and 38 in Phase 2).

However, most non-beneficiary network providers tended to provide services to only a small number of postcodes within the Superfast Broadband project areas. Non-beneficiaries had a maximum coverage of nine percent of the delivery areas in Phase 1 contracts, 12 percent in Phase 2 contracts and three percent in Phase 3 contracts (all Virgin Media), and below three percent for all other network providers in all phases (with the highest levels of coverage among wireless network providers). This suggests there is not a large degree of overbuild in Superfast Broadband Programme areas.

This finding was reinforced during the qualitative interviews with network providers. Some non-beneficiaries (particularly small wireless network providers) stated that they would try to avoid building Superfast Broadband networks to the areas that were receiving subsidised coverage. This was because they felt that it would not be commercially viable to have superfast broadband networks in these areas.

However, other non-beneficiaries were more confident in their ability to compete with subsidised networks, and although they would not actively pursue building networks in areas that were being upgraded by the programme, they would not alter plans they had already developed to roll out networks to areas that subsequently received Superfast Broadband Programme support.[67] This was because they were confident of maintaining their customers due to brand loyalty and quality of service provision. Additionally, one large network provider stated that some non-beneficiaries were rolling out new networks in programme delivery areas that had been classified as not being upgraded in the OMR process (and that the non-beneficiary had not claimed to be delivering to in the OMR process). This is possible, as there were challenges relating to the OMR process and network providers' ability to provide accurate information for the OMR (see previous section).

Therefore, it was expected that the programme areas have seen an increase in the number of network providers operating in the delivery areas, but equally it is expected that these other network providers only cover the Superfast Broadband Programme delivery areas at the fringes. It also demonstrates that there is no evidence that the programme crowded out infrastructure investment, in aggregate, in Phase 3 areas, although the current value Phase 3 investments is modest.

Table 7.2: Coverage on non-beneficiaries in Superfast Broadband delivery areas, 2020

Network provider	Phase 1	Phase 2	Phase 3
Virgin	9.28%	12.11%	3.62%
Vfast wireless	2.68%	0.74%	0.00%
Kijoma wireless	1.39%	1.06%	0.51%
Boundless wireless	0.71%	0.96%	0.50%
Solway comms wireless	1.41%	0.74%	0.16%
Greenco wireless	0.83%	1.72%	0.00%
Truespeed wireless	0.21%	0.00%	0.72%
Gigafast FTTP	0.22%	0.08%	0.22%
Hyperoptic FTTP	0.14%	0.11%	0.04%
Glide FTTP	0.11%	0.31%	0.37%

Source: ThinkBroadband coverage dataset

7.4 Number of unique operators offering services in Phase 3 contract areas

The number of ISPs with customers in the UK (proxied as the number of ISPs where customers have completed a speed test on the ThinkBroadband website) has increased over time. In 2020, over 150 ISPs had customers in the UK (see figure below).[68]

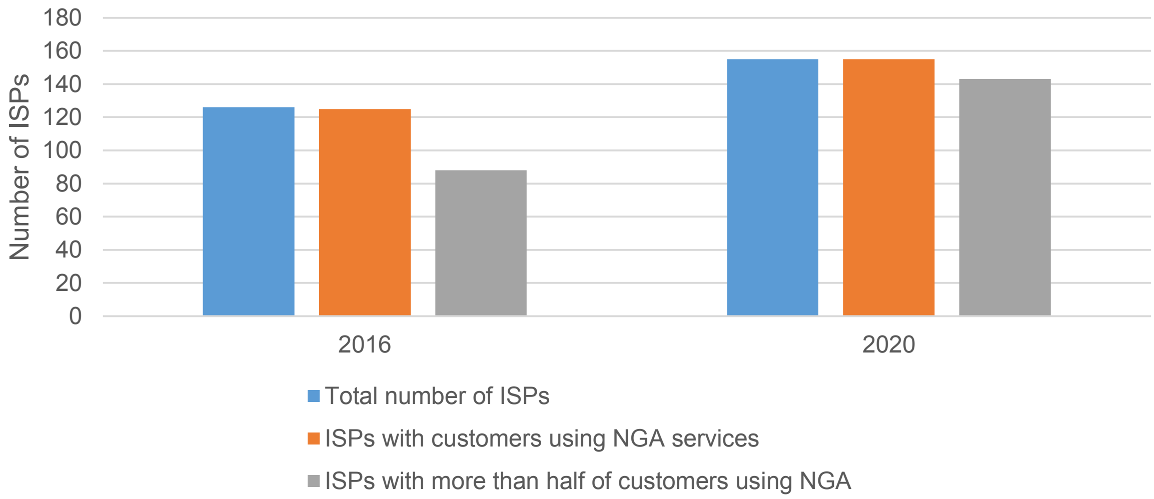
In both 2016 and 2020, nearly all ISPs provided NGA services to at least one customer in the UK (only one ISP did not have an NGA customer in the dataset in 2016, and all ISPs had at least one customer receiving NGA services in 2020). However, there were changes between 2016 and 2020 in the proportion of customers which were utilising NGA

[67] This point relates to both network providers that are currently competing with the beneficiaries in programme delivery areas, and network providers that intend to compete with the beneficiaries in these areas in the future, but have not rolled out their plans as yet.

[68] This includes both ISPs which own their network (for example Virgin Media) and ISPS which utilise wholesale network products.

connections between ISPs. In 2016, around 70 percent of ISPs had over half of their customer base using NGA connections – in 2020 this had grown to 92 percent of ISPs.

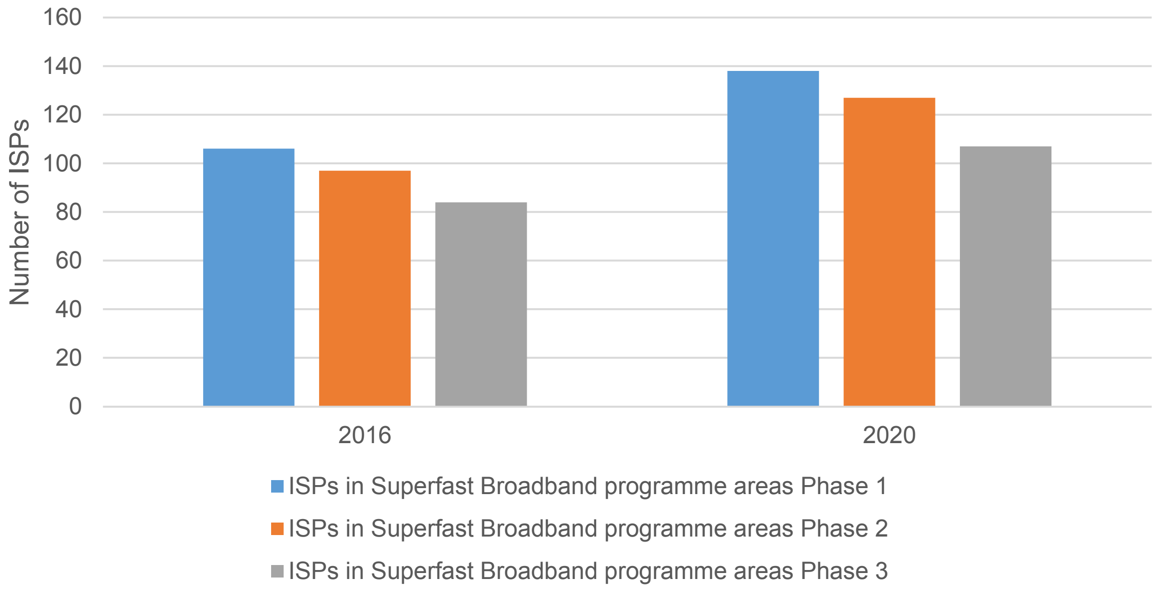
Figure 7.7: Number of ISPs offering services in the UK, 2016 and 2020



Source: ThinkBroadband speed test data

A similar pattern to that seen nationally is observed in the Superfast Broadband delivery areas. There has been an increase in the number of ISPs with customers between 2016 and 2020. When comparing between phases, it can be seen that there are a higher number of ISPs with customers in Phase 1 contract areas than Phase 2 and Phase 3. This would be expected, as Phase 1 contracts covered a larger number of premises and in more economically viable areas, providing a larger market for different ISPs to access.

Figure 7.8: Number of ISPs offering services in the Superfast Broadband delivery areas by Phase, 2016 and 2020

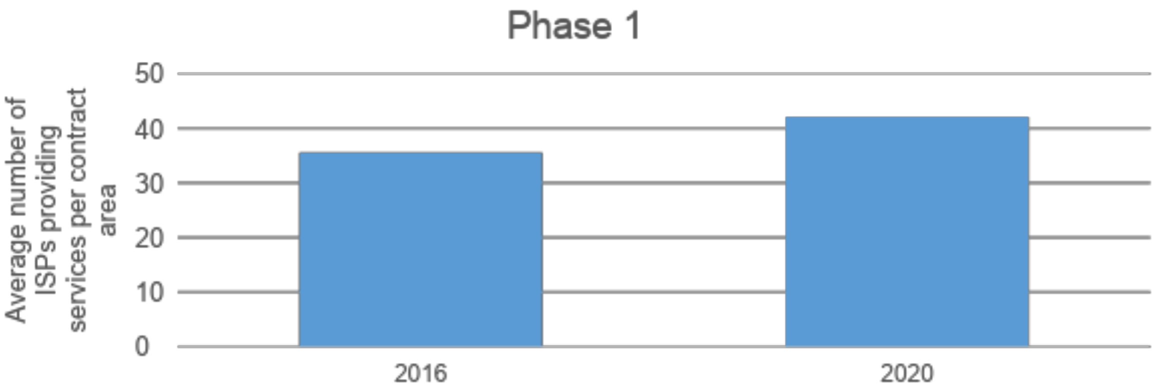


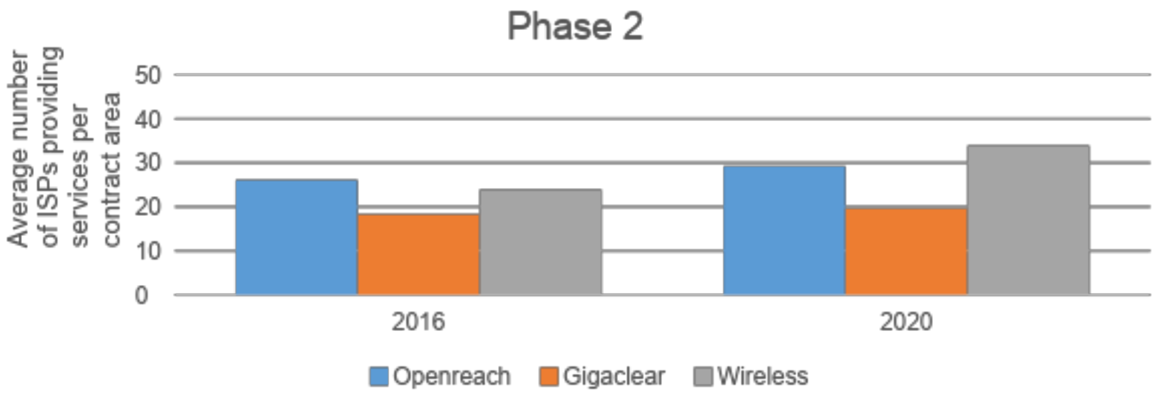
Source: ThinkBroadband speed test data

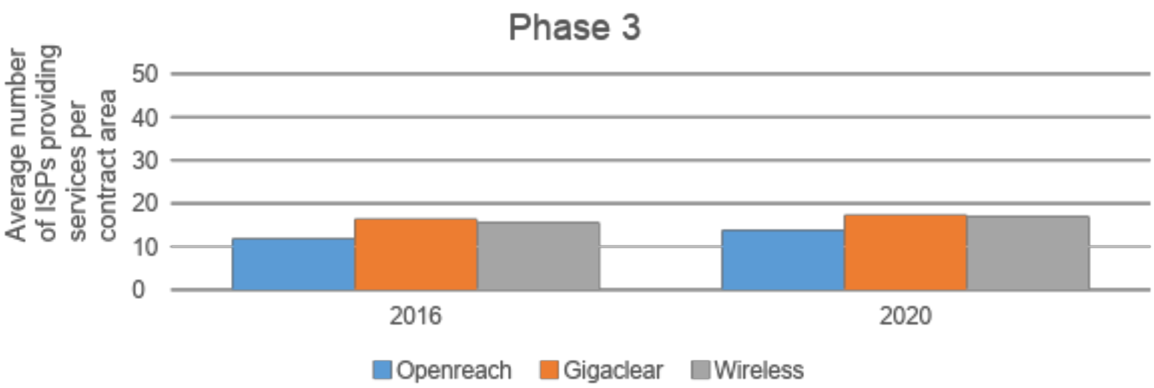
Interviews with the programme beneficiaries suggest that most of the ISPs offering services in the Superfast Broadband Programme delivery areas will be utilising the Openreach network. Other beneficiary interviews suggested that although there were wholesale access requirements in place on the networks they had built as part of the programme, these had not been utilised yet by other ISPs. One of the main reasons cited for this was that these beneficiaries do not have a large number of existing ISPs which utilise any of their networks (outside the ones constructed for the Superfast Broadband Programme) so do not have an existing customer base for their new networks. They anticipate that as their business matures and other ISPs start using their wider network that ISPs will also begin to utilise the networks built through the programme. As all of Phase 1 contracts were delivered by Openreach, it would be expected that these contract areas had the highest number of ISPs operating in the area.

The qualitative findings on use of Superfast Broadband Programme networks by ISPs is reinforced by an analysis of the data by beneficiary. Particularly in Phase 1 and Phase 2, the number of ISPs providing services in an area is higher in areas where Openreach have delivered the contract than in areas where Gigaclear have delivered contracts. In Phase 3, this pattern is less clear cut but, as noted, there are currently fewer ISPs offering services in Phase 3 areas than in Phase 1 and 2 contract areas.

Figure 7.9: Average number of ISPs offering services in the Superfast Broadband project areas by Phase and beneficiary, 2016 and 2020


Phase 1
Average number of ISPs providing services per contract area
50
40
30
20
10
0
2016
2020


Phase 2
Average number of ISPs providing services per contract area
50
40
30
20
10
0
2016
2020
Openreach
Gigaclear
Wireless


Phase 3
Average number of ISPs providing services per contract area
50
40
30
20
10
0
2016
2020
Openreach
Gigaclear
Wireless

8. Wider Economy Effects

This section of the report summarises the results of a series of econometric analyses exploring the economic and social impacts of the programme, and provides an overall cost-benefit analysis of the Superfast Broadband Programme. Full details of these analyses are provided in Technical Appendix 3. As Phase 3 of the programme was at an early stage of delivery, and its economic and social benefits had not been realised, this section focuses on the costs and benefits of the whole programme (Phases 1, 2 and 3).

Estimates of the impacts of the programme have been obtained by linking records of the delivery of the programme to a wide range of administrative and secondary data sources providing annual data on a variety of economic and social impacts of interest (e.g. the productivity of firms located in the areas served by the programme). Statistical analyses focused on comparisons between individuals, firms or properties that benefitted from the programme at different points in time, with those receiving coverage used as a counterfactual for those benefitting earlier.

Key findings:

Lifetime costs (2012 to 2030)
The present value of net public spending required to deliver the Superfast Broadband Programme over the lifetime of Phase 1, 2 and 3 contracts (i.e. from 2012 onwards) was estimated to be £815m in nominal terms. This is less than estimated total cost of the programme of £1.9bn, as there is expected to be a large amount of clawback generated from the beneficiaries delivering the programme.

Local economic and social impacts between 2012 and 2018
The findings of the evaluation indicate that the Superfast Broadband Programme led to a range of economic and social impacts in the areas benefitting from subsidised coverage between 2012 and 2018 (i.e. over and above what may have happened in the absence of the programme). The key results included:

- **Local employment impacts:** Subsidised coverage was estimated to have increased employment in the areas benefitting from the programme by 0.6 percent, leading to the creation of 17,600 local jobs by the end of 2018.

- **Turnover:** Subsidised coverage also increased the turnover of firms located in the areas benefitting from the programme by almost 1.0 percent by 2018, increasing the annual turnover of local businesses by £1.9bn per annum.

- **Number of firms:** The evidence indicated that a share of these local economic impacts was driven by the relocation of firms to the programme area. The evidence indicated that subsidised coverage increased the number of businesses located in the areas benefitting by around 0.5 percent – suggesting the programme may have encouraged the ‘disagglomeration’ of economic activity to rural areas.

- **Turnover per worker:** There were also signals of efficiency gains - turnover per worker of firms in the areas benefitting rose by 0.4 percent in response to subsidised coverage. This was not solely driven by more productive businesses moving into areas with improved broadband infrastructure. Firms that did not relocate over the period also saw their turnover per worker rise by 0.7 percent by 2018, indicating that subsidised coverage has also raised the efficiency of firms. However, the strength of these gains appeared to decay with time – while subsidised coverage had a stable effect on turnover, impacts on employment increased with time.

- **Wages:** The impacts of the programme were also visible in wages. Employees working for firms located in the areas benefitting from subsidised coverage saw their hourly earnings increase by 0.7 percent in response to the upgrade. This gives greater confidence that the programme led to an increase in productivity.

- **Unemployment:** Local job creation also appeared to translate into reductions in unemployment, with the number of unemployed claimants falling by 32 for every 10,000 premises upgraded.

- **House prices:** The programme led to an increase in house prices (of between £1,700 and £3,500) suggesting that buyers valued the technology.

National economic and social benefits between 2012 and 2019, and to 2030

The findings above describe the effect of the programme on the areas that benefitted from subsidised coverage. However, these results do not account for possible negative effects in areas that did not benefit from the programme. For example, as the programme encouraged firms to move to the areas benefitting from enhanced broadband coverage, there will have been offsetting loss of jobs in the areas from which those firms relocated. Allowing for these types of offsetting effects, at the national level, the programme is estimated to have resulted in:

- **Economic benefits:** The programme is estimated to have led to £1.1bn in productivity gains between 2012 and 2019. This rises to an estimate of £1.6bn to £1.8bn over the period from 2012 to 2030.

- **Social benefits:** Based on its impacts on house prices between 2012 and 2019, the programme is estimated to have led to social benefits valued at between £0.7bn and £1.5bn.

The estimated Benefit to Cost Ratio (BCR) was between £2.70 and £3.80 per £1 of net public sector spending based on its impacts between 2012 and 2019. Allowing for future economic benefits to 2030, the BCR is estimated to rise to between £3.6 and £5.1 per £1 of net public sector spending.

8.1 Costs

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

The value of clawback will not be known until the contracts have been fully wound down seven years post completion. The modelling described in Section 6 was used to develop estimates of the lifetime net public costs (i.e. net of implementation and take-up clawback). Details of this analysis is set out in Technical Appendix 2, but a summary is provided in the following table. This illustrates:

- **Gross public spending:** The value of expected public spending of the lifetime of these contracts was estimated at £743m in 2019 prices (£634m in present value terms) based on data available in June 2020.

- **Net public spending:** However, after accounting for implementation and take-up clawback, it was estimated that the net cost of the contracts to the public sector was £334m (in 2019 prices). A large share of the difference was accounted for by the level of take-up clawback associated with Phase 1 contracts, which were projected to be delivered at a net cost to the public sector of £60m against forecast public spending of £304m (in 2019 prices, £87m in present value terms).

- **Time costs:** As highlighted in Section 5, the clawback mechanisms employed in the delivery are expected to be highly effective in returning resources to the public sector. For example, of the 28 contracts modelled under Phase 1, 12 were expected to be delivered at no nominal cost to the public sector. However, a significant share of the costs is driven by the opportunity cost of temporarily tying up public sector resources in the programme. While the nominal net expected cost of the 28 Phase 1 contracts modelled was £34m, the present value of these expected costs (in real terms) was £86.9m. This implies that around 60 percent of the costs of these projects will be in the form of inflation (i.e. future payments will be received in nominal terms and will be worth less in real terms in future years) and social preference for consumption today versus consumption in the future. These time costs will partly be offset by interest payments made to BDUK that could only be accounted for in the modelling of projects that had been completed.

For 28 of the 34 unmodelled contracts **[redacted]** under Phases 1 and 2, BDUK had prepared forecasts of future implementation and take-up clawback which were used as the basis for estimating the expected costs to the public sector. These forecasts are based on lower long-run take-up than assumed in the modelling described in Section 6, and may understate the levels of take-up clawback that may ultimately be returned to the public sector. For Phase 3 contracts (where delivery was at very early stages), **[redacted]**, no adjustment was made for possible future implementation and take-up clawback. As such, the overall estimated net cost of the programme (£832m in present value terms, in 2019 prices), is likely to be overstated.

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

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

Phase	Number of contracts	Forecast public funding (£m)		Forecast underspend clawback (£m)		Forecast take-up clawback (£m)		Net cost to the public sector (£m)	
		Nom.	PV	Nom.	PV	Nom.	PV	Nom.	PV
Modelled contracts									
Phase 1	28	303.9	277.0	-34.1	-30.0	-210.0	-160.1	59.9	86.9
Phase 2	31	340.2	279.7	-11.1	-8.4	-126.7	-89.2	202.4	182.1
Phase 3	20	98.9	77.4	-21.8	-17.2	-5.0	-3.2	72.1	57.0
Total	**79**	**743.1**	**634.1**	**-66.9**	**-55.6**	**-341.7**	**-252.5**	**334.4**	**326.0**
Unmodeled contracts									
Phase 1	17	700.7	654.7	-80.0	-63.3	-338.1	-248.5	282.6	342.9
Phase 2	17	135.9	116.1	0.0	0.0	-34.0	-23.9	102.0	92.2
Phase 3	31	88.4	71.1	0.0	0.0	0.0	0.0	88.4	71.1
Total	**65**	**925.0**	**842.0**	**-80.0**	**-63.3**	**-372.1**	**-272.4**	**472.9**	**506.2**
Overall programme									
Phase 1	45	1004.7	931.7	-114.1	-93.3	-548.2	-408.6	342.4	429.8
Phase 2	48	476.1	395.8	-11.1	-8.4	-160.7	-113.1	304.3	274.3
Phase 3	51	187.3	148.5	-21.8	-17.2	-5.0	-3.2	160.5	128.1
Total	**144**	**1,668.1**	**1,476.1**	**-147.0**	**-119.0**	**-713.9**	**-524.9**	**807.2**	**832.2**

Source: Ipsos MORI analysis; CORA; BDUK

This analysis focuses on delivery of the programme to March 2019. While Phase 1 and 2 of the programme were largely complete at this stage, Phase 3 contracts were at relatively early stages of delivery (around 79,100 premises had been upgraded under Phase 3 contracts (around 17 percent of the 322,242 contracted). This was factored into the analysis by adjusting down the net costs of Phase 3 in proportion to the share of contracted delivery completed by this stage. This gave a total cost for the programme of £727m. This does not include administrative costs incurred by BDUK and the Local Bodies in their management of the programme because these costs were not monitored on a systematic basis.

Table 8.2: Expected net public sector costs (£m, 2019 prices) of delivery to March 2019

Contract phase	Net cost to the public sector, net of clawback (£m present value)	% of contracted premises delivered	Costs included in the analysis
Phase 1	429.8	~100	429.8
Phase 2	280.7	~100	274.3
Phase 3	128.1	17	22.6
Overall	**838.6**		**726.7**

Source: Ipsos MORI analysis; CORA; BDUK

8.2 Additionality

The results set out in the subsection 8.1 explore the impacts of subsidised coverage. However, the results do not factor in the likelihood that much of this coverage may well have been achieved through commercial deployments in the absence of the programme. As noted, estimates of the additionality of the coverage funded through the programme are described in Section 5 and set out in full in Technical Appendix 1, which examined the share of the premises involved that would not have been upgraded in the absence of the programme (and how this evolved with time). These findings suggested that:

- **Evolution over time:** The level of additionality is estimated to peak in the year after the premises were upgraded at 61 percent. Additionality decayed between the second and fourth year following the upgrade at a rate of 14 percent per annum. These patterns were broadly stable over Phase 1, 2 and 3 of the programme. This is consistent with a view that the programme substantially accelerated the deployment of superfast connectivity. However, in the absence of the programme, rising demand and take-up as well as regulatory innovation would have led to greater commercial viability over time. This would have induced commercial deployments in many areas in the longer term in the absence of the programme.

- **Projected additionality:** A high to low range for the future additionality of the programme was developed on the following basis:

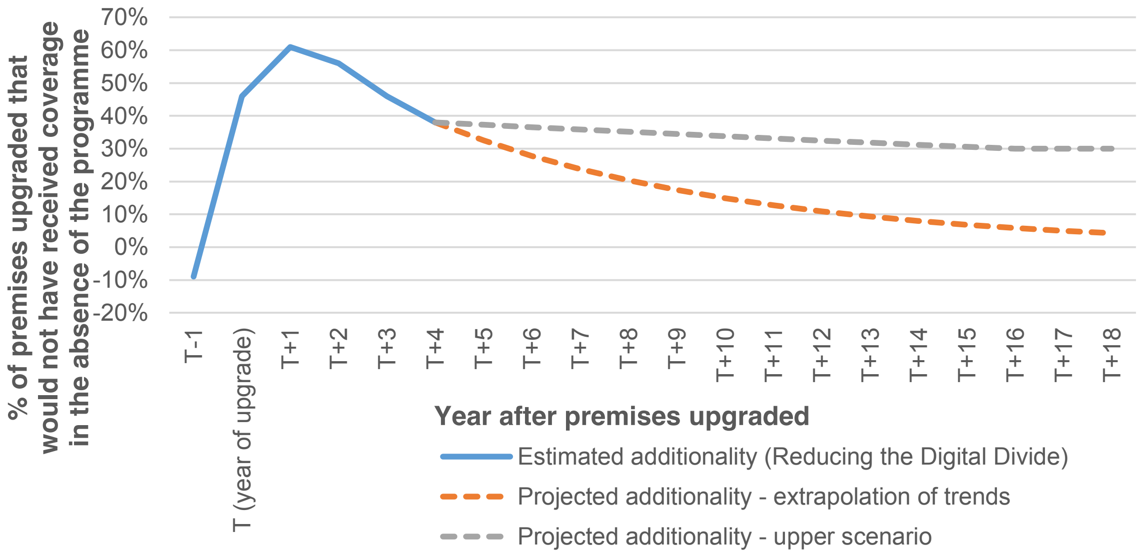
  - **Extrapolation of trends:** A lower bound scenario was developed by extrapolating the trends implied by the results over the duration of the appraisal period. This implied a higher rate of decay (14 percent per annum) and the rate of additionality fell to 4 percent over 14 years. This would capture scenarios in which unforeseen technological innovations enable the hardest to reach premises to be served profitably.

  - **Future telecoms infrastructure review:** A projection of past trends may produce an overly pessimistic view of future additionality. The Future Telecoms Infrastructure Review was prepared on the basis that the final 10 percent of premises (3m of 30.5m in the UK) would never receive commercial investment in full fibre connectivity. This assumption was used to explore the sensitivity of results to a more optimistic view of additionality in the long-run as follows. In 2019, Ofcom's Connected Nations report suggests that 95 percent of premises received superfast coverage. This is equivalent to 29m premises and implies that around 1.5m of the 'last 10 percent' received superfast coverage by 2019. By 2019, 5.3m premises had received subsidised coverage – implying that just under 30 percent would never receive commercial deployments. In this scenario, this share is treated as a notional limit for additionality and the rate of additionality is assumed to decay from 38 percent to 30 percent over 14 years (a rate of decay of 2.0 percent per annum). As this assumption is based on the viability of FTTP rather than FTTC infrastructure, this scenario will likely overstate the long-run additionality associated with the investments (and has been developed primarily to probe the stability of the core findings to alternative assumptions).

- **Delaying effect:** The evidence also suggested that nine percent of premises upgraded would have otherwise received superfast coverage one year earlier in the absence of the programme (see Section 5). This is consistent with evidence from the qualitative research with network providers that suggested that the OMR process could lead to some postcodes being marked as eligible for investment where commercial deployment plans were insufficiently developed or certain. The likelihood that a subsidised competitor would emerge would discourage investment in these areas. This delaying effect will have negative economic and social costs in the short-term and this is modelled using a negative value for additionality in the year prior to the upgrade.

The figure below displays the assumed additionality profile over time.

Figure 8.1: Additionality profile over time



Source: Ipsos MORI analysis

Technical Appendix 3 tabulates the estimated number of additional premises passed based on this additionality profile. The gross number of premises passed is based on BDUK's Broadband Performance Indicator[69] for the period 2012/13 to 2017/18. Delivery for 2018/19 is taken from BDUK's Table of Local Broadband Projects. Under the two additionality scenarios, the number of additional premises upgraded are largely equivalent by 2018/19 but diverge by 2029/30 (giving a long-term range for the number of additional premises upgraded of 500,000 to 1.7m).

8.3 Economic impacts

8.3.1 Local economic impacts between 2013 and 2018

A series of econometric analyses linking records of the postcodes benefitting from subsidised coverage to a variety of administrative and secondary datasets were used to explore the local economic impacts of the programme. These results are set out in detail in Technical Appendix 3 and provide estimates of the effect of the programme on the areas that have benefitted from subsidised coverage. It is important to note that while most of these findings account for the possibility that businesses benefitting from the programme may have claimed market share from local competitors, **they should not be interpreted as net economic impacts at the national level**. The key results included:

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[69] https://www.gov.uk/government/collections/broadband-performance-indicators; Accessed November 2020

- **Local employment impacts:** Subsidised coverage was estimated to have increased employment in the areas benefitting from the programme by 0.6 percent, leading to the creation of 17,600 local jobs by the end 2018.

- **Turnover:** Subsidised coverage also increased the turnover of firms located in the areas benefitting from the programme by almost 1.0 percent by 2018, increasing the annual turnover of local businesses by £1.9bn per annum.

- **Number of firms:** The evidence indicated that a share of these local economic impacts was driven by the relocation of firms to the programme area. The evidence indicated that subsidised coverage increased the number of businesses located in the areas benefitting by around 0.5 percent – suggesting the programme may have encouraged the 'disagglomeration' of economic activity to rural areas.

- **Turnover per worker:** There were also signals of efficiency gains - turnover per worker of firms in the areas benefitting rose by 0.4 percent in response to subsidised coverage. This was not solely driven by more productive businesses moving into areas with improved broadband infrastructure. Firms that did not relocate over the period also saw their turnover per worker rise by 0.7 percent by 2018, indicating that subsidised coverage has also raised the efficiency of firms. However, the strength of these gains appeared to decay with time – while subsidised coverage had a stable effect on turnover, impacts on employment increased with time.

- **Wages:** The impacts of the programme were also visible in wages. Employees working for firms located in the areas benefitting from subsidised coverage saw their hourly earnings increase by 0.7 percent in response to the upgrade. This gives greater confidence that the programme led to an increase in productivity.

- **Unemployment:** Local job creation also appeared to translate into reduced unemployment, with the number of unemployed claimants falling by 32 for every 10,000 premises upgraded.

8.3.2 Mechanisms of impact

The ways in which the Superfast Broadband Programme supported businesses to upgrade their broadband connection and how this helped businesses generate the economic benefits described above was explored in a quantitative survey of 1,200 businesses and qualitative interviews with 40 businesses. This found that:

- The Superfast Broadband Programme had allowed businesses to upgrade their internet connection, with nearly half of businesses now reported using fibre connections (either FTTP or FTTC connections) in areas where the Superfast Broadband Programme had delivered improved connectivity compared to 30 percent in comparator areas. This increased the connection speeds that businesses were able to receive, but just as importantly for businesses it improved the reliability of their connection (meaning their connection was less likely to 'drop out' or become unavailable).

- The most commonly reported perceived impact of improved connections were enhanced customer services (72 percent), utilising the Internet of Things (55 percent), cloud-based computing (51 percent) and promoting flexible working (50 percent). Fewer businesses reported introducing new goods or services or opening up new markets. This suggests that the benefits of the subsidised coverage may have arisen primarily through enhanced operational efficiency.

- Examples of this operational efficiency were explored in the qualitative interviews, and included:

  - **Transferring documents:** Businesses described the difficulties they had transferring large documents between employees, customers and clients, with a lack of confidence that documents would be shared and long upload times being required (both to upload files to a server, cloud computing or via email). One company stated that they used to have to build in “upload times” into their project timelines, to ensure that deadlines could be met. With the improved connections, the time required to share documents was reduced, meaning that staff did not have to spend as long facilitating the sharing of documents and freeing time to spend on other tasks.

  - **Using online administrative systems:** Businesses reported a reluctance to use online systems with their previous internet connection, such as online accountancy, sales or website management services. This was because of a lack of confidence that their connection speed (and reliability) would enable them to use these services. With the faster internet connections, some businesses have started to use these systems. Additionally, while many businesses reported using cloud computing with their previous internet connection, some switched from having servers on their premises (or rented elsewhere) to using cloud based storage. The businesses that reported using cloud based storage with their previous internet connection stated that it was inefficient, but had improved since they upgraded their internet connection. Finally, a small number of businesses reported switching from an existing business line for their telephone system to having a phone system run through their internet connection. This tended to reduce their overhead costs (or at least be cost neutral). Businesses that had utilised an internet based phone system reported that it would have been difficult to do this on their previous connection due to a lack of reliability in their connection (meaning that their phone system would also be unavailable).

  - **Reduced travel times and expense:** Businesses reported that the improved speed and reliability meant that there was a reduction in travel times and expense. This was because their previous connections were too slow or unreliable to undertake specific tasks. For example, one business owner reported having to travel to public facilities in a city rather than using a connection where the business was based because it was too slow to undertake the tasks required. Other businesses reported that they would have to go to visit clients to resolve tasks that can now be resolved remotely (such as IT support) because of the poor connection speed they could access at their business address.

- Although few businesses reported introducing completely new services, some businesses did state that they had introduced new ways of working or offers to customers. These included being able to video conference, either internally or externally with customers. Previously their poor internet connection speed prevented video conferencing. Some other businesses reported being able to offer remote IT support to customers, which meant that they spent fewer man hours resolving problems (as travel time was reduced) but also allowed them to support multiple clients at the same time, thus increasing their efficiency.

- Businesses also reported that the improved connectivity had a positive impact on the volume of training they provide. This is because employees can access online training facilities or attend virtual conferences. The online training modules were reported to be less expensive than classroom based learning (in some cases free with software packages the businesses had purchased) while maintaining a high level of quality. This, coupled with reduced travel costs for training and conferences (both in terms of travel cost and time – meaning workers could be at their desk instead of travelling to and from training) meant training budgets could extend to include more training hours per year.

8.3.3 National economic benefits

In line with the HM Treasury Green Book, it is assumed that the local economic impact of the programme will largely be neutralised by offsetting effects elsewhere in the economy (displacement). While businesses located in areas receiving subsidised coverage have expanded their sales, this will have come at the expense of loss of market share for competing firms (who may be located locally or elsewhere in the UK).

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

As such – and in line with the principles of the HM Treasury Green Book - only the effects of the programme in terms of raising productivity are considered to qualify as economic benefits at the national level. The evaluation provided a range of results to indicate that the programme has supported improvements in productivity – including raising the turnover of per worker and wages of employees of firms located in areas benefiting from subsidised coverage. The effect of the programme was also visible in commercial rental values – which rose by 1.8 percent in response to the upgrade.

GVA based measure of economic benefit

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

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

- **Short-term impact on GVA per premises upgraded.** It was assumed that firms did not change the shares of labour and other inputs used in production in response to the subsidised coverage, and the effect on turnover per worker can be interpreted as an improvement in productivity. Applying the average GVA as a percentage of turnover across the UK as whole over the 2008 to 2018 period (31 percent)[70], this gives an effect on GVA per premises upgraded of £140 (per annum).

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

These results were applied to the profile of additional premises upgraded set out in the subsection 8.2. Summary results covering the 2011/12 to 2018/19 period (benefits to date) and the 2011/12 to 2029/30 period (including projected benefits) are set out in the table below. The present value of GVA benefits (with a baseline of 2012/13) are estimated at £1.1bn by 2018/19 and between £1.6bn and £1.8bn by 2029/30.

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

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

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

Source: Ipsos MORI analysis.

Unemployment impacts

The results of the evaluation suggested that for every 10,000 premises upgraded there was a corresponding on-going reduction in the number of unemployed claimants of 32.1 claimants. The extent to which these effects might be understood as net economic benefits will be linked to how far the programme drew individuals out of (or helped them avoid) extended periods of involuntary worklessness in which they were not productively deployed (rather than short-term episodes of unemployment[71]).

[70] Source: Annual Business Survey, ONS. Ten year average of GVA as a percentage of turnover used to avoid bias from annual fluctuations in GVA to turnover ratio.
[71] Though some of these episodes will have otherwise evolved into long-term unemployment.

The data available did not permit an analysis of the effects of the programme on long-term unemployment directly as claimant counts at the local level do not provide information on the duration of claims. However, the prior evaluation of the programme (using different data series[72]) suggested that for every individual taken out of unemployment by the programme, 0.29 individuals were taken out of long-term employment. Assuming this applies to the results obtained in this study, it is estimated that for every 10,000 premises upgraded, the number of long-term claimants fell by 9.2.

Assuming the effects on long-term unemployment represent the effect of the programme on the overall productive capacity of the economy, and valuing the output produced by those individuals at £15,480 per annum[73], it is estimated that these effects could have led to an additional £125m in national economic output (GVA) by 2019 (in present value terms). This effect is estimated to rise to between £237m to £306m in the longer term (though to the extent this is driven by relocation of economic activity, there may have been corresponding increases in long-term unemployment elsewhere).

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

Period	Undiscounted (£m)	Discounted (£m)
GVA from the reduction in long-term unemployment 2011/12 to 2018/19 (£m)	144.5 – 144.9	124.9 – 125.2
GVA from the reduction in long-term unemployment 2011/12 to 2029/30 (£m)	303.5 – 409.9	237.1 – 305.9

Source: Ipsos MORI analysis.

8.4 Social benefits

8.4.1 Evidence of social benefits

The analysis also extended to exploring the social benefits of the programme. These effects may arise directly from their consumption of superfast broadband services or indirectly (e.g. by enabling greater remote working, reducing commuting times and/or improving the quality or efficiency of public services). These types of well-being or utility benefits for individuals are more challenging to explore because they can be directly quantified or monetised in the same way as the economic impacts described in the preceding section. A range of complementary approaches were adopted to explore the value of the programmes to consumers and households using econometric methods (again, set out in full in Technical Appendix 3):

- **House prices:** The first approach was to explore the effect of the programme on house prices (a “revealed preference” approach). The underlying assumption is that if households place a value on superfast connectivity, this will be reflected in an increase in what they are willing to pay to obtain access to the scarce asset. The price premium paid for houses with superfast connectivity should therefore represent the present value of the future net benefit they expect to gain from access to faster internet services. The findings of the study suggested that the programme led to an increase in house prices (of 0.6 to 1.2 percent, or £1,700 to £3,500) suggesting that

[72] DCMS (2018) Economic and Public Value of the Superfast Broadband Programme.
[73] 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). Economic benefits have been valued on the basis of wages in line with the DfT Transport Appraisal Guidance module on employment effects.

buyers valued the technology. These estimates also compare to the results of a previous study estimating the per household benefit of upgrading rural areas of the UK to FTTC of £3,145 (based on an analysis of the impact of upgrading local exchanges to ADSL during the 2000 to 2010 period)[74].

- **Subjective well-being:** A second approach was adopted examining the impacts of the programme on self-reported levels of subjective well-being (a "stated preference" approach, which was used in the previous evaluation of the programme). However, the findings provided mixed evidence as to how far there was an overall impact on the subjective well-being of residents. Modelling of the effect of the programme on subjective well-being showed no significant effects on the total population, although there was evidence of variable effects across age groups – with positive effects on those aged 65 and above and neutral or negative effects on other age groups. It should be noted that these analyses focused on changes in the well-being of those living in properties before and after the upgrade (and could be distorted by migration patterns).

- **Public services:** These issues were explored further by examining the effects of the programme on local education and health services. While not providing direct measures of well-being, these analyses provided supplementary evidence of some of the potential drivers of the social impacts of the programme, as well as exploring its public sector benefits. The results of the evaluation also provided some signals of possible disbenefits associated with superfast broadband coverage in rural areas. There was evidence that the programme had stimulated migration to the areas benefitting from subsidised coverage. For example, the number of patients registered with GP surgeries increased by 3.2 to 5.9 percent on average in response to the upgrade, and there were some suggestions that the number of pupils in schools benefitting from subsidised coverage increased. Migration may have altered the composition of local populations and could partly explain the mixed results on overall subjective well-being – for example, if those migrating to the programme area came largely from urban areas (as residents of urban areas typically report lower levels of well-being).[75] Increased population growth appears to have placed pressure on some public services which could offset positive well-being effects arising from consumption of faster broadband services. For example, increased numbers of patients registered with primary care providers did not come with an equivalent increase in capacity, and subsidised coverage appears to have reduced satisfaction with continuity care, ability to obtain appointments, and their overall satisfaction with their GP surgery.

The mixed nature of the evidence suggests that the social impacts of the programme are complex and further research is needed to understand these effects in more depth. More research is being completed as part of the broader evaluation programme to address these gaps in understanding. This includes a face-to-face survey of households benefitting from subsidised coverage and analysis of the Oxford Internet Survey (OXIS) being undertaken by BDUK.

8.4.2 Valuation of social impacts

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

[75] There is potential endogeneity in the model, in that house price growth could be influenced by local planning policies, which may also influence the choice of postcodes in be included in a local project by the programme beneficiary.

The social benefits of the programme were valued using the house price gains estimated through the econometric analysis. This 'revealed preference' is considered more robust than the available alternatives as it is based on observed market prices. However, the mixed findings create some challenges in interpreting the impact of the programme on house prices, and the following approach was adopted:

- **Scope of welfare gains:** The effect of the programme on house prices reflects the valuation of the marginal buyer, whose preferences may differ in substantial ways to the broader population benefitting from subsidised coverage. As noted, there was mixed evidence as to how far the subjective well-being of residents increased in response to the programme. As such, it can be anticipated that the general population do not value access to superfast broadband services as highly as those purchasing properties. To mitigate against the risk of overstating the value of the social benefits brought about by the programme, it was assumed that effect on house prices reflected the welfare benefits accruing to the population of households that moved to the programme area rather than all residential premises receiving subsidised coverage. This implicitly assumes that other residents derived no value from improved superfast broadband infrastructure or that the benefits they derive are offset by other factors (such as increased congestion or reductions in social cohesion). As such, the findings below should be considered a 'lower bound' to the value of social benefits arising from the programme.

- **Valuation:** To reach an estimate of the welfare gains, the estimated house price premium of £1,700 to £3,500 was applied to the number of houses sold in the programme area after the premises was upgraded (813,500). This gave a gross value of the price uplift of £1.4bn to £2.9bn.

- **Expectations:** An assumption was applied that consumers had reasonably formed expectations regarding the likelihood that homes would receive superfast coverage in the future. As such, the impact of the programme on house prices is interpreted as the present value of the total welfare gains associated with having access to superfast coverage immediately (and possibly other relevant features of the home, such as proximity to newly relocated employers) as opposed to coverage at some uncertain point in time in the future.

- **Additionality:** Flowing from this, the gross value of the price uplift was adjusted in light of short-term additionality (an average of 54 percent up to two years following the upgrade) to reflect the possibility that the premises would have otherwise received subsidised coverage in the absence of the programme at the time of purchase. However, the value of the price uplift was not adjusted further in the long-term as it was assumed that the possibility that the property would have received superfast coverage in the future was factored into willingness to pay. As such, the present value of welfare benefits to 2019 and to 2030 are equivalent (and estimated at £741m to £1.5bn).

- **Net effects:** To the extent that house prices were driven by migration induced by the programme, these may not represent net benefits as there may be offsetting effects elsewhere. Additionally, there is a possibility that the house price uplift may be linked to the programme's effects in attracting additional economic activity to the area (in which case, there may be an element of double counting with the economic benefits).

The following table provides a summary of the results.

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

Period	Low house price premium	High price premium
Land value uplift (£m, present value)	741.9	1,536.8

Source: Ipsos MORI analysis; CORA; BDUK

8.5 Benefits to cost ratio

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

- **Benefits from 2012 to 2019:** The short-term BCR (based on benefits to date) is estimated at between £2.7 and £3.8 per £1 of net lifetime public sector costs. This exceeds the hurdle rate of return normally applied in the appraisal of public sector programmes and suggests that the programme has already delivered a strong rate of return.

- **Benefits from 2012 to 2030:** In the long-run (allowing for future economic benefits), the BCR is estimated to rise to £3.6 to £5.1 per £1 of net public sector spending.

- **Sensitivity:** It should also be noted that investment in the programme can also be justified on the long-term economic benefits alone. Excluding the welfare effects inferred from house prices (which are less certain), the BCR is estimated to range from £2.5 (low future additionality) to £2.8 (high future additionality). The narrow nature of this range indicates that the benefit to cost ratio is not heavily dependent on the assumptions made regarding future additionality.

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

Table 8.6: Benefit to Cost Ratios, 2012 to 2019 and 2012 to 2030

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

Source: Ipsos MORI analysis

9 Proportionality and appropriateness

This section addresses the final questions defined in the State aid evaluation plan:

- Question 6: Is the gap funding model efficient compared to alternative schemes?
- Question 7: Did the aid lead to commercially sustainable networks?

The analyses in this section focus on the unit cost of delivery associated bringing forward the programme (in gross and net terms) and the degree to which the networks brought forward have proven commercially sustainable.

However, as highlighted in the introduction, some aspects of the analyses envisaged in the State aid evaluation plan have proven infeasible due to data availability. Firstly, a review of the literature suggests that there are few evaluations from other EU countries providing ex-post quantitative estimates of the cost-effectiveness of comparable initiatives in bringing forward broadband coverage. As such, it has not been possible to robustly benchmark the scheme to explore issues relating to how far the programme design was optimal. Secondly, actual revenues and operational costs per user are not monitored by BDUK and consideration of those aspects of commercial sustainability are limited to the assumptions put forward by network providers in their tenders.

Key findings:

At the point of agreeing contracts to deliver the Superfast Broadband Programme local projects, the expected gross public sector costs per covered premises was £342 for the Superfast Broadband Programme, although there was significant variation across the various phases. Phase 1 had the lowest gross public sector cost per premises passed of £266. Phase 3 had the highest public sector cost per premises at over £1,216. This is expected given the proportion of full fibre build expected in Phase 3 delivery which was expected to come at a higher cost and the comparative commercial viability of the premises being upgraded. However, for premises covered so far by Phase 3 projects (to March 2019), the current expected cost per premises passed was £500, significantly less than the original expected costs.

The expected public sector costs factoring in the savings from the clawback mechanisms was also estimated, and is expected to reduce the net cost per additional covered premises from £890 to £790 for Phase 3 contracts (though, again, given the early stage of delivery, these estimates are highly uncertain).

Whilst an attempt has been made to compare the costs per connection for the programme to comparative schemes, there is little evidence on comparable interventions. There are very few studies that have sought to examine the cost-effectiveness of broadband programmes, and one study attempts to estimate the projected cost per premises passed for different EU schemes. This showed that in general, the Superfast Broadband Programme had a lower cost per premises passed than the expected cost for most other EU schemes. The lack of evaluation evidence (ex-post) may in part be because of a relative lack of public programmes on the same scale as the Superfast Broadband Programme and a consequent lack of published evaluative work. This means it is difficult to form conclusions as to the effectiveness of the gap funding model, although it does appear that the cost per premises covered for the Superfast Broadband Programme is lower than the projected costs for comparable schemes in the EU.

The commercial sustainability of the networks funded by the Superfast Broadband Programme have been assessed by examining current and expected take-up of connections and a comparison of the average operational cost per unit and the average revenue per unit of the network.

The expected take-up of connections was expected to be between 36 percent and 86 percent, and this is expected to be achieved by between 2019/20 and 2032/33. Actual take-up is currently below the expected level of take-up at the start of the projects, and in some cases is significantly lower than expectations. However, the lower level of take-up is expected, given that the delivery of Phase 3 contracts is behind schedule (see Section 4 of the report). Additionally, no network providers indicated in their interviews that they did not expect take-up to reach the expected levels in the future.

The estimated quarterly Average Revenue Per Unit is higher than the quarterly Average Operational Cost per Unit for programme beneficiaries. This suggests that the beneficiaries will still expect the networks to be sustainable in the long run.

9.1 Gap funding model efficiency

This section provides answers to the State aid evaluation question 6: Is the gap funding model efficient compared to alternative schemes? It provides the key State aid evaluation metrics of the public funding per covered premises and a comparison of these values against comparator schemes. It has not been possible to provide the metric of public funding per live end user connection-years due to a lack of available data.

9.1.1 Initial expected public sector cost per covered premises

Data on the costs of delivering the Superfast Broadband Programme have been drawn from BDUK monitoring data and the outputs of the modelling exercise described in Section 6 (and used in Section 8 to support the cost-benefit analysis). A total of £1.9bn of public sector funding was committed across Phase 1, 2 and 3 contracts with a total of 5.5 million contracted premises passed. This equates to an ex-ante gross public sector cost per premises covered of £342. There was significant variation across the various phases. Phase 1 had the lowest gross public sector cost per premises passed of £266. Phase 3 had the highest public sector cost per premises at over £1,216. This is expected given the proportion of FTTP build expected in Phase 3 delivery which was expected to come at a higher cost.

Table 9.1: Contracted cost per premises passed by Phase

Contract phase	Contracted public sector cost[76] (£m)	Contracted premises passed	Gross public subsidy per gross premises passed (£)
Phase 1	1,169.1	4,388,618	266.39
Phase 2	332.6	830,654	400.39
Phase 3	391.9	322,242	1,216.29
Overall	1,893.6	5,541,514	341.72

Source: Ipsos MORI analysis; CORA; BDUK

[76] In nominal terms, not in present value terms. Taken from CORA management extract

9.1.2 Current expected (actual) public sector cost per covered premises

The table below provides estimates of the current expected public funding per covered premise by March 2019 (following the approach outlined in Section 8). As highlighted, current expectations of public spending (before implementation and take-up clawback) differ significantly to the contracted costs outlined above (primarily driven by underspend on Phase 1 contracts). The expected gross public spend per premises passed was lower overall at £280 (rather than £342) and the expected gross public spend per covered premises in Phase 3 fell from £1,216 to just above £497 (primarily due to expected underspend, though note that these projections are highly uncertain at this stage).

Factoring in the likelihood that some of those premises passed to date would otherwise have received coverage through commercial deployments, the table below also includes the estimated number of additional covered premises. This applies estimated additionality over the first three years following delivery (to align with the period covered by the OMR process) of 56 percent. The gross public sector cost (i.e. before clawback) per additional covered premises over three years was £500 (in 2019 prices).

Table 9.2: Expected gross cost per premises and additional premises passed

Contract phase	Expected public sector cost (£m)	Premises passed by March 2019	Additional covered premises to date	Expected Gross public subsidy per gross covered premises (£)	Expected Gross public subsidy per additional covered premises (£)
Phase 3 to date	25.5	51,285	28,720	500	890
Overall	**1476.1**	**5,268,398**	**2,950,303**	**280**	**500**

Source: Ipsos MORI analysis; CORA; BDUK. 2019 prices.

9.1.3 Net public sector cost per additional covered premises over three years

The table below outlines the expected public sector costs factoring in the savings from the clawback mechanisms. This is expected to reduce the net cost per additional covered premises from £890 to £790 for Phase 3 contracts (though, again, given the early stage of delivery, these estimates are highly uncertain).

Table 9.3: Net public sector cost per additional covered premises

Contract phase	Net public sector cost (£m)	Additional covered premises	Net public subsidy per additional covered premises (£)
Phase 1	429.8	2,818,651	150
Phase 2	274.3	500,273	550
Phase 3	22.6	28,720	790
Overall	726.7	3,353,638	220

Source: Ipsos MORI analysis; BDUK

9.1.4 Benchmarking

Whilst an attempt has been made to compare the costs per connection outlined for the programme above, there remains little evidence on comparable interventions. There are very few studies that have sought to examine the cost-effectiveness of broadband programmes in the EU ex-post. This may in part be because of a relative lack of public programmes on the same scale as the Superfast Programme and a consequent lack of published evaluative work. However, there are some examples where the expected unit cost of premises passed has been estimated. It should be noted that these are projected public sector costs per gross premises passed, rather than observed costs. The estimated costs are:[77, 78]

- In Austria, the cost per premises passed was approximately £1,900 and £3,600 across two projects.
- In Germany, projects estimated the average of cost per premises passed was between £1,100 and £9,300.
- In Finland, the projected cost per premises passed was estimated to be between £1,300 and £5,800 across three projects.
- In Hungary there are multiple projects, and the average cost per premises passed was estimated to be between £200 and £660
- In Ireland, the estimated cost per premises passed was £4,900.
- In Italy, several projects estimated that the cost per premises passed was between £230 and £330.
- In Portugal there are several projects and the estimated cost per premises passed was estimated to be between £220 to £810.

These show that in most countries, the average cost per premises upgraded is higher than the cost observed in the Superfast Broadband Programme.

A recent study evaluating parts of the SuperConnected Cities Programme (SCCP)[79] in the UK did include a cost benefit analysis of the Connection Voucher Scheme element of that programme. This made vouchers up to a value of £3,000 available to small to medium sized businesses (SMEs) to put towards upgrading their internet connection. To be granted, the connection would need to provide at least superfast speeds but was technology agnostic. The study found the average cost of subsidised connections through this programme was £1,400, although this also varied substantially by technology type (ranging from £1,100 for FTTC connections to £2,800 for Fixed Wireless / Microwave connections). The cost per installation was estimated at £1,400, though each installation led to a further 4.7 additional connections per postcode. This equated to an estimated cost per additional connection of £290. However, this is not directly comparable to the figures above as it focuses on the cost of connections rather than the cost of coverage.

9.2 Commercial sustainability of networks

The NBS evaluation plan sets out the key indicators to be assessed to draw conclusions about whether the Superfast Broadband Programme has led to the development of commercially sustainable networks. These included an assessment of the actual versus original forecast annual cashflow (before subsidy)[80], take-up volumes, average revenue per user, average operational costs per user for each winning network provider.

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[77] European Commission (2020) The role of State aid for the rapid deployment of broadband networks in the EU. Available at: https://ec.europa.eu/competition/publications/reports/kd0420461enn.pdf
[78] Values converted from € to £ using exchange rates from xe.com
[79] Description of project available at: https://www.gov.uk/government/news/superconnected-cities-scheme-helps-14000-small-businesses
[80] It has not been possible to evaluate this indicator due to a lack of data

9.2.1 Withdrawn contracts

The evaluation plan also envisaged an assessment of the number of projects, if any, from which services have been withdrawn (e.g. due to corporate insolvency, or project losses), the number of premises covered by such projects, and the number of live connections for such projects, and percentage share of the overall 2016 NBS accounted for by such projects (in terms of number of projects, public funding, premises covered, take-up volumes).

For the interventions which have been funded under State aid SA. 40720 (2016/N), of the 51 contracts currently listed on the Superfast Broadband management system, none have had services withdrawn by the network provider. This means that there have been no premises which have not been upgraded as a result of a beneficiary withdrawing from the programme.

However, a total of five contracts which were awarded under State aid SA. 40720 (2016/N) have been terminated. All of these contracts were awarded and terminated by the same Local Body and were awarded to the same beneficiary. These contracts were terminated by the Local Body, rather than the beneficiary. The reason for the termination was the inability of the beneficiary (and its supply chain) to deliver the network build outlined in their bids to the required quality within the specified timeframe of the contract.

As mentioned in Section 2 of the report, the Superfast Broadband Programme has not collected data on the number of ISPs utilising the networks that have been funded by the programme. Therefore, it has not been possible to complete the assessment of commercially sustainable networks as set out in the NBS evaluation plan. Additionally, as Phase 3 contracts have not been completed at the time of the evaluation, the beneficiaries are not yet at the post subsidy stage, meaning it is difficult to assess their position pre and post subsidy. The cash flow by contract has been assessed in Section 5 of this report (as part of the assessment of the impact on direct beneficiaries).

9.2.2 Actual vs expected take-up

The expected levels of take-up of Superfast connections by end users was included in beneficiaries' PFM submission, and included take-up by quarter and by technology type. The level and speed of take-up varied by contract, beneficiary and connection type. A summary of the expected take-up of Phase 3 contracts is provided in the table below. This shows that the beneficiaries are expecting take-up of connections through their networks of between 36 percent and 86 percent, and are expecting to reach these levels of take-up by between 2019/20 and 2032/33.

Table 9.4: Expected take-up by beneficiary and technology type for Phase 3 contracts

[redacted]

The expected level of take-up presented in the PFMs by the beneficiaries was compared to the reported level of take-up by the beneficiaries to the Superfast Broadband Programme in June 2020. This comparison is presented in the table below. This shows that take-up is currently below the expected level of take-up at the start of the projects, and in some cases is significantly lower than expectations. However, the lower level of take-up is expected, given that the delivery of Phase 3 contracts is behind schedule (see Section 4 of the report).

In the qualitative interviews, the beneficiaries were asked about their forecasted level of take-up and whether they expected this to be achieved. No beneficiary responded that they expected take-up to be significantly below their forecasted level. Additionally, the evidence from Phase 1 and Phase 2 contracts on take-up (see Technical Appendix 3) suggests that take-up for Phase 3 contracts will continue to rise in the future and that the expected levels of take-up will be observed or more probably exceeded in the Phase 3 contract areas.

Table 9.5 – Actual versus expected take-up by beneficiary and technology type, June 2020

[redacted]

9.2.3 Original forecast average revenue / cost per user[81]

Beneficiaries reported the Average Revenue Price per Unit (ARPU) in the PFM. On average, the ARPU for FTTC is £22.21 and for FTTP is £46.94 across the Phase 3 portfolio. The total average operational cost over the lifetime of the programme is highlighted in the table below, alongside an average quarterly operational cost.[82] This has been calculated by dividing the operational cost provided by the beneficiaries in their PFM by the expected level of take-up. It can be seen that the estimated quarterly ARPU is higher than the quarterly Average Operational Cost per Unit, suggesting that the beneficiaries will still expect the networks to be sustainable in the long run.

Table 9.6: Expected Average Operational Cost per User and Average Revenue per Unit for Phase 3 contracts prior to delivery

[redacted]

[81] Due to the early stages of delivery of most of the Phase 3 contracts, and a lack of data, it is not possible to estimate the actual average revenue and actual average cost per connection at the moment.
[82] It should be noted that the operational cost does not include the capital expenditure required to construct the network.

10 State aid conclusions

This section provides a brief overview of the key findings from this report. These focus on the seven State aid evaluation questions, and the wider economic and social benefits of the programme.

Question 1: To what extent has the aid resulted in increased access to an NGA network being deployed in 'white' NGA areas?

Phase 3 contracts increased the number of premises passed by NGA services by 2,300 to 16,600 on postcodes benefitting from subsidised coverage by the end of September 2019 (with the weight of evidence to the lower end of this range). The share of the 79,100 premises upgraded by the end of September 2019 that would not have otherwise benefitted from NGA coverage is estimated at 3 to 21 percent.

Phase 3 contracts increased the number of premises with superfast coverage by 10,800 to 29,300, and the number of premises with FTTP coverage by 19,000 to 30,300. The additionality of superfast and FTTP coverage was correspondingly higher at 14 to 55 percent of premises receiving subsidised coverage. This indicates that some premises benefitting from subsidised upgrades would have otherwise received NGA coverage that did not deliver superfast speeds. There was also evidence that Phase 3 contracts delayed the availability of superfast coverage for some premises that would have otherwise received it earlier.

The findings were broadly consistent with more general analysis examining the impacts of the programme since delivery began in 2013. These findings indicated that the additionality of subsidised coverage peaks one year after premises are upgraded (at around 60 percent), before decaying at a rate of approximately 14 percent per annum. This implies that in many cases, the programme has worked to accelerate the availability of superfast broadband.

The results suggest that the processes used to identify the commercial plans of providers were not fully effective in establishing premises that would not benefit from commercial deployments in the near term. Several explanations for this emerged from the research. Network providers reported that their investment cycles were determined over relatively short time horizons (12 to 24 months). The absence of immediate commercial deployment plans did not necessarily imply that investment was considered economically unviable. Network providers sometimes could not provide Local Bodies with deployment plans of sufficient detail or certainty to be incorporated when the areas eligible for subsidies were determined. Finally, the definition of areas eligible for investment was based on a static view of network provider's plans, which subsequently evolved in response to regulatory innovation and growth in demand.

Question 2: To what extent has the target of the intervention been used and what speeds are available?

The findings indicated that Phase 3 contracts reduced the number of premises with superfast connections by 1.1 to 2.4 premises per postcode by September 2019. There was no conclusive evidence that subsidised coverage had a positive or negative effect on the average download speeds of connections by September 2019. This is likely a product of the short window of time that had elapsed for businesses and households to take-up, and the effect of the programme in delaying the availability of superfast for some premises that would have otherwise benefitted from commercial deployments. It is premature to draw conclusions on the impact of the programme on take-up, and analysis exploring the effects of the programme since it was launched in 2013 suggested it produced a broad range of positive impacts on take-up in the longer term.

The results did indicate that Phase 3 contracts increased the average upload speeds of connections (by 0.9Mbps to 3.9Mbps) and the maximum download speeds of connections by 6.2Mbps to 16.9Mbps. This may reflect the effect of FTTP delivery, which has enabled users to obtain higher capacity connections that may have otherwise been available.

Question 3: Has the aid had a significant incentive effect on the aid beneficiaries?

Based on projections provided by network providers at the tendering stage, the proposed network build under Phase 3 contracts was expected to either generate losses or to deliver positive rates of return (Internal Rate of Return or IRR) that were substantially lower than the cost of capital faced by the network provider - a loss of **[redacted]** per annum versus a Weighted Average Cost of Capital (WACC) of **[redacted]**. If it is assumed that profit maximising firms are only incentivised to implement projects where the IRR exceeds the WACC, then public subsidies would have been needed to create a sufficient economic incentive to deliver these investments.

The analysis suggested that network providers consistently underestimated take-up in the tendering process for Phases 1 and 2. The projections of take-up in Phase 3 of the programme also appear understated given that network providers will have learned the likely levels of demand from their experiences with Phase 1 and 2 contracts. This means beneficiaries may have understated revenue projections, increasing the apparent level of public funding needed to make the project economically viable. However, after updating projections in line with take-up observed on Phase 1 and 2 contracts, the projected IRRs associated with Phase 3 projects without subsidy are not significantly higher than those expected at the tendering stage (a positive IRR of **[redacted]**). The projected IRRs of all Phase 3 contracts (without subsidy) are expected to be substantially lower than the WACC of the network provider.

The protections put in place by BDUK are likely to protect the public sector from the risk that it provided more than the minimum subsidy needed. Contracts have been designed such that network providers are required to return resources to the public sector if build costs are understated or if take-up proves higher than expected (leading to higher levels of profitability). While the provision of subsidies is expected to increase the IRRs on Phase 3 contracts to **[redacted]**, this falls to **[redacted]** once the activation of these contractual mechanisms is accounted for.

While the contracts have proven largely effective in containing subsidies to the minimum needed for the project to go forward, the public sector has incurred opportunity costs by tying resources up in the programme. BDUK may wish to consider whether seeking to contain these opportunity costs in future procurements could be justified.

Question 4: Has the aid had a material effect on the market position of the direct beneficiaries?

At a UK level, there has not been significant changes in the market share of programme beneficiaries in the broadband market between 2016 and 2020. Openreach dominates the market (even more so if Sky and TalkTalk are included in the Openreach market share, as these providers utilise the Openreach network), representing more than three quarters of the broadband market in both 2016 and 2020. The other beneficiaries of the Superfast Broadband Programme represented less than 0.5 percent of the market in both 2016 and 2020. A similar pattern is seen for the NGA market, with Openreach representing over 60 percent of the market in both 2016 and 2020, with the other programme beneficiaries representing less than 0.5 percent of the market.

In the areas where the Superfast Broadband Programme has been delivered, the programme appears to have had little impact on the market position of Openreach in either the overall broadband or NGA market, as Openreach maintains a dominant market position in both 2016 and 2020. However, the market share in both the overall broadband and NGA market for the smaller programme beneficiaries has increased between 2016 and 2020 in Phase 3 delivery areas which is not observed at a national level, suggesting the programme has positively affected the market share of the programme beneficiaries in these areas.

In areas where Openreach have delivered contracts, they have maintained their market share between 2016 and 2020 in both the overall broadband and NGA markets. However, in areas where the other, smaller programme beneficiaries have delivered contracts, the market share for Openreach has fallen (particularly in areas where Gigaclear have delivered contracts), with the market share of the other beneficiaries increasing. This suggests that the other beneficiaries are taking market share from Openreach in these areas.

Question 5: How far is there evidence of changes to parameters of competition arising from the aid?

At a UK level, the share of NGA broadband take-up as a proportion of total broadband take-up has increased markedly since 2016. NGA connections represented just over half of all broadband connections in 2016, but this has grown to over 70 percent of internet connections in 2020. Fibre to the Cabinet (FTTC) connections represented the largest proportion of NGA connections in both 2016 and 2020 (around a third of all broadband connections in 2016 and just over a half in 2020). This pattern was also observed in areas benefitting from the Superfast Broadband Programme.

The average number of infrastructure providers operating on the postcodes benefitting from subsidised upgrades rose from 2.3 to 2.6 between 2012 and 2020, indicating the programme has helped promote greater competition in these areas. Although there has been an increase in the number of network providers offering services in Superfast Broadband Programme areas, most non-beneficiary network providers tended to provide services to only a small number of postcodes within the Superfast Broadband project areas. This suggests there has not been a large degree of overbuild.

The number of ISPs operating in Superfast Broadband Programme areas has increased between 2016 and 2020. There are a higher number of ISPs with customers in Phase 1 contract areas than Phase 2 and Phase 3. This would be expected, given that the Phase 1 areas were larger and more commercially viable. Additionally, all Phase 1 contracts were delivered by Openreach, and the qualitative findings suggested that at present no ISPs were utilising the subsidised networks built by programme beneficiaries other than Openreach.

Question 6: Is the gap funding model efficient compared to alternative schemes?

The gross public sector cost (i.e. before clawback) per additional covered premises over three years was £890 for Phase 3 contracts (in 2019 prices). However, the public sector savings from the clawback mechanism is expected to reduce the net cost per additional covered premises from £890 to £790 for Phase 3 contracts (though again, given the early stage of delivery, these estimates are highly uncertain).

A review of the literature suggests that there are no evaluations providing quantitative estimates of the cost-effectiveness of comparable initiatives in bringing forward broadband coverage. As such, it has not been possible to benchmark the scheme to explore issues relating to how far the programme design was optimal. However, a study for the European Commission does provide estimates of the projected cost per covered premises, and it appears that the cost per premises covered for the Superfast Broadband Programme is lower than the projected costs for comparable schemes in the EU.[83]

Question 7: Did the aid lead to commercially sustainable networks?

None of the 51 Phase 3 contracts currently listed on the Superfast Broadband management system have had services withdrawn by the network provider. This means that there have been no premises which have not been upgraded as a result of a beneficiary withdrawing from the programme.

However, a total of five contracts have been terminated. All of these contracts were awarded and terminated by the same Local Body and were awarded to the same beneficiary. These contracts were terminated by the Local Body, due to the inability of the beneficiary (and its supply chain) to deliver the network build outlined in their bids to the required quality within the specified timeframe of the contract. These contracts were not terminated due to the commercial viability of the contract.

Analysis of Phase 3 contracts shows that take-up is currently below the expected level of take-up at the start of the projects, and in some cases this is significantly lower than expectations. However, the lower level of take-up is expected, given that the delivery of Phase 3 contracts is behind schedule. The beneficiaries did not raise any concerns about the long-term level of expected take-up in the qualitative interviews, suggesting that they expect the networks to be commercially sustainable.

The pre-delivery Average Revenue Per User was compared to the Average Operational Cost per User, which showed that all the beneficiaries expected their revenue to be higher than their Operational Cost. Actual revenues and operational costs per user are not monitored by BDUK and therefore it is not possible to assess any updated average costs and revenues for beneficiaries.

Wider economy effects

The present value of net public spending required to deliver the Superfast Broadband Programme over the lifetime of Phase 1, 2 and 3 contracts was estimated to be £815m in nominal terms. This is less than estimated total cost of the programme of £1.9bn, as there is expected to be a large amount of clawback generated from the beneficiaries delivering the programme.

The findings of the evaluation indicate that the programme has led to a range of economic and social benefits in the areas benefitting from subsidised coverage between 2012 and 2018. The key results included:

- **Local employment impacts:** Subsidised coverage was estimated to have increased employment in the areas benefitting from the programme by 0.6 percent, leading to the creation of 17,600 local jobs by the end of 2018.

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[83] European Commission (2020) The role of State aid for the rapid deployment of broadband networks in the EU; Available at: https://ec.europa.eu/competition/publications/reports/kd0420461enn.pdf

- **Turnover:** Subsidised coverage also increased the turnover of firms located in the areas benefitting from the programme by almost 1.0 percent by 2018, increasing the annual turnover of local businesses by £1.9bn per annum.

- **Number of firms:** The evidence indicated that a share of these local economic impacts were driven by the relocation of firms to the programme area. The evidence indicated that subsidised coverage increased the number of businesses located in the areas benefitting by around 0.5 percent – suggesting the programme may have encouraged the relocation of economic activity to rural areas.

- **Turnover per worker:** There were also signals of efficiency gains - turnover per worker of firms in the areas benefitting rose by 0.4 percent in response to subsidised coverage. This was not solely driven by more productive businesses moving into areas with improved broadband infrastructure. Firms that did not relocate over the period also saw their turnover per worker rise by 0.7 percent by 2018, indicating that subsidised coverage has also raised the efficiency of firms. However, the strength of these gains appeared to decay with time because these firms employed more workers as time passed.

- **Wages:** The impacts of the programme were also visible in wages. Employees working for firms located in the areas benefitting from subsidised coverage saw their hourly earnings increase by 0.7 percent in response to the upgrade. This gives greater confidence that the programme led to an increase in productivity.

- **Unemployment:** Local job creation also appeared to translate into reductions in unemployment, with the number of unemployed claimants falling by 32 for every 10,000 premises upgraded by 2018.

- **House prices:** The programme led to an increase in house prices (of between £1,700 and £3,500) suggesting that buyers valued the technology.

It is important to note that while most of these findings account for the possibility that businesses benefitting from the programme may have claimed market share from local competitors, they should not be interpreted as net economic impacts at the national level. At the national level, the programme is estimated to have resulted in:

- **Economic benefits:** The programme is estimated to have led to a cumulative total of £1.1bn in productivity gains between 2012 and 2019. This rises to between £1.6bn and £1.8bn over the 2012 to 2030 period.

- **Social benefits:** Based on its impacts on house prices between 2012 and 2019, the programme is estimated to have led to social benefits valued at between £0.7bn and £1.5bn.

The estimated Benefit to Cost Ratio (BCR) was £2.7 to £3.8 per £1 of net public sector spending based on its impacts between 2012 and 2019. Allowing for future economic benefits to 2030, the BCR is estimated to rise to £3.6 to £5.1 per £1 of net public sector spending.

Compliance

A sample of 15 project contracts were selected to evaluate the compliance of the programme with the State aid guidance. These project contracts were selected to represent different locations within the UK and contracts with each of the Phase 3 programme beneficiaries.

Across all the project contracts, there has been a high level of compliance with the State aid guidance. However, there are some gaps in the evidence provided for some projects. Given the other evidence that has been provided for these projects, it has been assessed that these are gaps in the evidence base, rather than evidence of non-compliance. The one area where there was evidence of a lack of compliance with European Commission Guidelines was around the timing of the Invitation to Tender (ITT) being issued, with this being more than a month after the public consultation exercise closed in most cases.

Annex A – Additional ThinkBroadband data tables

Table A1.1 – Network providers included in ThinkBroadband dataset

Network providers in ThinkBroadband			
Airband (including Airband wireless and Airband FTTP)	fibre nest persimmon fttp	kcom lightstream fttp	tove valley fttp
aylesbury vale fttp	FibreFirst FTTP	kijoma wireless	trooli fttp
b4rn fttp	fullfibreltd fttp	lothian wireless	truespeed fttp
balquhidder fttp	gigaclear fttp	ofnl ifnl fttp	vfast wireless
blackfibre fttp	gigafast fttp	Openreach (including Openreach WBC and Openreach FTTP)	virair wireless
boundless wireless	glide fttp	purefibre fttp	Virgin (including virgin rfog fttp, virgin gig1 gigabit 1000 50, virgin cable)
box broadband fttp	gnetwork fttp	raveningham residents fttp	vision fibre fttp
Callflow	grain connect fttp	reeth wireless	voneus wireless
Cityfibre (including Cityfibre and Gigler)	greenco wireless	Relish (including Relish fibre, Relish wireless and Relish swindon wireless)	Wessex (including Wessex fibre and Wessex wireless)
colchester fttp	hampshire broadband fttp	ridgehill residents fttp	Wight (including Wight ftttp, Wight wireless and Wight cable)
Community Fibre FTTP	hereford cic fttp	ruralcomms wirelss	zoom wireless
County Broadband (including County Broadband Wireless and County Broadband FTTP)	hiwifi wireless	sky llu	zzoomm fttp
ecom fttp	hyperoptic fttp	solway comms wireless	
f4rn fttp	internetty fttp	spectrum internet wireless	
factco fttp	its fttp	talktalk llu	

Table A1.2 – Mapping ISP to Network Provider in ThinkBroadband dataset

ISP	Network provider	ISP	Network provider	ISP	Network provider
186k	Openreach	**AAISP**	Openreach	**AB Internet**	Openreach
Ai Networks	Openreach	**Air Broadband**	OFNL / Gigaclear	**Airband**	Airband
Amatis Networks	Openreach	**AOL**	Openreach	**AQL**	Openreach
Ask4	Ask4	**Avanti Satellite Broadband**	Avanti	**Avonline**	Openreach
Aylesbury Vale Broadband	Aylesbury Vale	**B4RN**	B4RN	**Beeline Broadband**	Beeline
Bentley Walker Satellite Broad	Bentley	**bigblu**	biblu	**Boundless Communicati ons**	Boundless
Box Broadband	Pure	**Bridge Fibre**	Openreach	**BT**	Openreach
BT Business Broadband	Openreach	**BT WiFi**	Openreach	**Buckminster Broadband**	Openreach
Cable and Wireless	Vodafone	**CableCom Networking**	Openreach	**Call Flow Solutions**	Callflow
Cerberus Networks	Openreach	**CityFibre**	Cityfibre	**Claranet SOHO**	Openreach
CloudScape	Openreach	**Commsworld**	Openreach	**Community Fibre**	Community Fibre
connexin	Openreach	**CORETX(C4L)**	Openreach	**Cotswold Wireless**	Cotswold
County Broadband	County Broadband	**Daisy Wholesale**	Openreach	**Datanet**	Openreach
Demon Internet	Vodafone	**Dragon WiFi**	Dragon	**Dyfed Superfast**	Openreach
Eclipse Internet	Openreach	**Ecom**	Ecom	**EE**	Openreach
Elite	Openreach	**Entanet**	Cityfibre	**Evolving Networks**	Openreach
Exa Networks	Openreach	**Exascale**	Fluiddata	**exponential-e**	Openreach
Fast	Openreach	**FastNet**	Openreach	**Fibre for Rural Nottinghams hir**	B4rn
Fibre Nest	Openreach	**FidoNet**	Openreach	**Fluidata**	Openreach
FluidOne	Openreach	**G Network**	G Network	**Gamma**	Openreach
GCI (Edge Telecoms)	Openreach	**Gigabeam**	Gigabeam	**Gigaclear**	Gigaclear
Giganet	Openreach	**Glide Business**	Glide	**Goscomb Technologies**	Openreach
Gradwell	Openreach	**Green Co**	Openreach	**HighNet**	Openreach
HiWiFi	HiWifi	**Hotchilli Internet**	Openreach	**hSO**	Openreach
Hyperoptic	Hyperoptic	**I Love Broadband**	Sky	**ICUK**	Openreach

IDNet	Openreach	**ineedbroadband**	Fullfibreco	**Internet For Business**	Openreach
InTouch Systems	Intouch	**IP River**	TalkTalk	**its Technology**	Openreach
Jersey Telecom	Jersey	**Juice Broadband**	Juice	**KCOM**	KCOM
Keycom	Keycom	**Kijoma Broadband**	Kijoma	**LonsdaleNET**	Lonsdale
Lothian Broadband	Openreach	**Luminet (Urban Wimax)**	Luminet	**M247**	Openreach
Merula Limited	Openreach	**Michaelston-y-Fedw Internet CI**	Michaelston-y-Fedw Internet CI	**O2**	Openreach
O2 Wifi	Openreach	**Oakford Technology**	Openreach	**Optimity**	optimity
Orbital Net	Openreach	**Origin Broadband**	Openreach	**Pembs Wifi**	Openreach
Pine Media	Pine	**Plusnet**	Openreach	**Post Office**	talktalk
Pure Broadband	Pure	**PureFibre (Also Derwenthorpe +**	Pure	**Quickline**	Quickline
Redcentric	Openreach	**Relish**	Relish	**Resqnet Wireless Broadband**	Resqnet
RM Broadband	Openreach	**Satellite Internet**	Openreach	**Scotnet**	Openreach
SeeTheLight(IFNL)	OFNL	**SES Satellite Broadband**	SES	**Sky**	Sky
Sky Corporate	Sky	**Solway Communications**	Solway	**Spectrum Internet**	Sectrum
Spitfire	Openreach	**Stream Networks**	Openreach	**Structured Communications Ltd**	Openreach
Sure	Openreach	**SW Internet**	SW	**SWS Broadband**	Openreach
TalkTalk	TalkTalk	**TalkTalk Business**	TalkTalk	**Technological**	Openreach
Telcom Networks	Openreach	**Tesco Broadband**	TalkTalk	**The Cloud**	Openreach
Timico	Openreach	**toob**	Toob	**Total Web Solutions Ltd**	Openreach
Tove Valley Broadband	Tove	**Truespeed Communications**	Truespeed	**Trunk Networks**	Openreach
UK Broadband	UKB/Relish	**uno Communications**	Openreach	**Userve (Unitron Systems)**	Userve
vaioni	Openreach	**Velocity1**	Openreach	**Vfast Internet**	Openreach
Virgin Media	Virgin	**Virgin Media Business**	Virgin	**VISPA**	Openreach
Vivaciti	Openreach	**Vodafone Broadband**	Vodafone	**Voipfone**	Openreach
Voneus	Voneus	**W3Z Wireless Broadband**	W3Z	**Watchfront**	Openreach

Waveney Internet	Openreach	**webmate**	Openreach	**Wessex Internet**	Wessex
wifinity	wifinity	**Wight Fibre**	Wight fibre	**Wild West Net**	Wild West Net
wildcard networks	Wildcard	**WiSpire**	WiSpire	**Zen Internet**	Openreach
Zoom Internet	zoom	**Zzoomm**	Zzoom		

Table A1.3 – Number of completed speed tests by contract area

Contract	Beneficiary	Phase	Speed tests – total		Speed tests - NGA	
			2016	*2020*	*2016*	*2020*
SUFF101	Openreach	1	17,988	12,071	6,947	7,288
SUFF201	Openreach	2	8,936	6,941	1,543	3,458
SUFF202	Openreach	3	-	-	-	-
BEDS101	Openreach	1	7,191	4,299	3,344	2,830
BEDS201	Openreach	2	3,340	2,777	513	1,619
BEDS202	Openreach	3	8	3	2	0
BEDS203	Openreach	3	10	8	0	0
BERK101	Openreach	1	3,144	1,810	1,647	1,297
BERK201	Gigaclear	2	3,337	2,041	1,177	1,133
BERK202	Callflow	2	-	-	-	-
BERK203	Gigaclear	3	132	123	44	63
BERK204	Openreach	3	527	631	141	282
BUCK101	Openreach	1	10,709	6,847	5,555	4,719
BUCK201	Openreach	2	8,160	7,054	1,043	3,274
CAMB101	Openreach	1	20,532	13,642	9,846	9,053
CAMB101a	Openreach	2	-	-	-	-
CAMB202	Openreach	3	-	-	-	-
CHES101	Openreach	1	14,165	9,198	6,170	5,732
CHES201	Openreach	2	4,026	3,215	689	1,039
CMBR101	Openreach	1	21,241	12,705	8,958	8,535
CMBR201	Openreach	2	2,516	1,727	250	858
DRBY101	Openreach	1	17,805	10,880	7,589	7,053
DRBY201	Openreach	2	3,658	2,566	537	1,001
DEVO101	Openreach	1	73,065	42,252	28,234	25,301
DEVO201	Airband	2	-	-	-	-
DEVO205	Airband	3	1,767	1,771	392	855
DEVO101a	Openreach	1	-	-	-	-
DORS101	Openreach	1	17,020	10,930	8,078	7,505
DORS201	Openreach	2	908	725	167	304
DORS202	Openreach	3	525	570	63	175
DURH101	Openreach	1	18,322	10,304	8,642	7,199

DURH201	Openreach	2	3,512	2,303	632	1,383
DURH202	Openreach	2				
EYRK101	Openreach	1	8,585	5,278	4,020	3,667
EYRK201	Openreach	2	2,412	1,584	655	792
EYRK202	Openreach	3	1,407	1,171	266	442
ESUS101	Openreach	1	11,530	7,382	4,715	4,398
ESUS201	Openreach	2	1,577	1,118	212	454
ESUS202	Openreach	3	240	210	90	123
ESSX101	Openreach	1	12,487	8,119	5,966	5,711
ESSX201	Openreach	2	10,926	9,032	1,614	5,112
ESSX202	Gigaclear	2	649	338	137	165
ESSX203	Gigaclear	3	266	166	97	82
ESSX204	Gigaclear	3	403	315	70	158
ESSX205	Openreach	3	1,248	965	342	404
ESSX206	Openreach	3	622	744	133	296
ESSX207	Gigaclear	3	-	-	-	-
ESSX208	Openreach	3	29	22	18	15
ESSX209	Openreach	3	132	105	27	33
ESSX210	Openreach	3	-	-	-	-
ESSX211	Openreach	3	-	-	-	-
ESSX212	Openreach	3	-	-	-	-
MANC101	Openreach	1	6,207	3,598	2,827	2,608
MANC101a	Openreach	2	-	-	-	-
HAMP101	Openreach	1	14,281	10,119	6,242	6,360
HAMP201	Openreach	2	10,630	8,033	2,046	3,914
HERE101	Openreach	1	26,049	15,021	9,018	8,426
HERE201	Gigaclear	2	2,383	1,139	734	667
HERE202	Gigaclear	3	-	-	-	-
HERE204	Gigaclear	3	2,516	1,554	631	898
HERE205	Gigaclear	3	992	674	268	365
HERE206	Gigaclear	3	1,366	735	358	432
HERE203	Openreach	3	684	398	153	217
HERE207	Openreach	3	340	199	83	93
HERE208	Airband	3	-	-	-	-
HIGH101	Openreach	1	34,981	21,504	10,948	11,683
IOFW101	Openreach	1	3,035	2,152	1,278	1,178
KENT101	Openreach	1	25,332	16,789	11,073	10,363
KENT201	Openreach	2	4,107	2,683	601	1,422
KENT202	Openreach	2				
LANC101	Openreach	1	24,219	15,598	10,520	10,143
LANC201	Openreach	2	1,812	1,088	343	532
LEIC101	Openreach	1	24,219	15,598	10,520	10,143

LEIC201	Openreach	2	1,812	1,088	343	532
LEIC202	Openreach	3	-	-	-	-
LINC101	Openreach	1	33,284	20,674	14,290	12,712
LINC201	Openreach	2	3,602	2,380	370	952
MERS101	Openreach	1	7,674	4,169	3,862	2,937
NCST101	Openreach	1	1,349	797	567	614
NORF101	Openreach	1	32,439	22,589	14,192	14,721
NORF201	Openreach	2	9,139	6,636	1,623	3,439
NORF202	Openreach	3	-	-	-	-
NLNC101	Openreach	1	5,131	2,985	2,721	2,184
NLNC201	Openreach	2	1,457	658	650	390
NYRK101	Openreach	1	21,838	15,317	9,763	10,402
NYRK201	Openreach	2	4,767	3,079	1,226	1,529
NYRK202	Openreach	3	-	-	0	0
NTNS101	Openreach	1	10,361	6,381	5,399	4,561
NTNS201	Openreach	2	3,983	2,596	910	1,654
NTNS202	Gigaclear	3	274	218	87	134
NTNS203	Gigaclear	3	111	140	48	68
NIRE101	Openreach	1	10,004	5,989	3,202	2,746
NIRE201	Openreach	2	8,798	7,544	1,576	3,259
NTHM101	Openreach	1	8,524	5,767	3,499	3,635
NTHM201	Openreach	2	1,910	1,455	264	512
NOTT101	Openreach	1	10,397	5,413	5,461	3,950
NOTT201	Openreach	2	5,132	2,730	1,561	1,254
NOTT202	Openreach	3	1	2	0	0
OXFD101	Openreach	1	15,719	9,887	7,647	7,058
OXFD101a	Openreach	2	-	-	-	-
OXFD202	Openreach	3	23	9	19	4
OXFD204	Airband	3	-	-	-	-
SCOT101	Openreach	1	121,922	80,100	43,566	49,146
RUTL101	Openreach	1	1,299	998	804	755
RUTL201	Openreach	2	292	142	102	101
RUTL202	Openreach	2	169	94	30	39
SHRP101	Openreach	1	12,404	7,118	4,549	4,317
SHRP201	Openreach	2	957	926	103	386
SHRP202	Airband	3	1,616	1,109	490	581
SYRK201	Openreach	2	16,060	11,015	3,604	7,469
SYRK202	Openreach	3	502	258	117	125
STAF101	Openreach	1	16,007	8,810	7,539	6,015
STAF201	Openreach	2	4,180	2,907	662	1,003
SURR101	Openreach	1	12,372	8,655	6,175	5,569
SURR201	Openreach	2	1,252	1,082	169	410

WALE101	Openreach	1	120,026	74,848	47,817	45,923
WALE101a	Openreach	2	-	-	-	-
WALE201	Openreach	3	387	251	121	136
WALE202	Openreach	3	748	356	332	231
WALE203	Openreach	3	551	389	208	237
WILT101	Openreach	1	13,988	8,268	6,674	5,660
WILT201	Openreach	2	81	45	44	37
WILT202	Gigaclear	3	473	327	180	115
WILT203	Openreach	3	566	400	134	138
SGLO101	Openreach	1	3,053	1,892	1,613	1,421
SGLO201	Openreach	2	1,169	816	241	434
SGLO202	Openreach	3	260	277	175	265
WORC101	Openreach	1	10,902	6,525	4,686	4,186
WORC201	Openreach	2	4,285	2,742	930	1,314
WORC202	Openreach	3	286	307	52	84
WWCK101	Openreach	1	7,895	5,145	3,903	3,700
WWCK201	Openreach	2	4,357	3,450	718	1,613
WWCK202	Openreach	3	571	599	0	0
WYRK101	Openreach	1	7,895	5,145	3,903	3,700
WYRK201	Openreach	2	4,357	3,450	718	1,613
WSUS101	Openreach	1	9,326	5,905	4,283	3,867
WSUS201	Openreach	2	2,459	1,735	251	688
BLAC201	Openreach	2	6,346	3,765	2,622	2,830
TELF201	Openreach	2	2,760	1,417	854	950
CORN201	Openreach	2	2,835	2,038	389	640
CORN202	Openreach	3	1,450	1,301	98	88
SWIN201	UKB	2	3,823	2,725	981	1,468
WOXF201	Gigaclear	3	1,488	1,119	524	707
HERT202	Openreach	3	-	-	-	-
BKSR202	Openreach	3	-	-	-	-
SGOV202	Openreach	3	-	-	-	-
SGOV203	Openreach	3	-	-	-	-

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State aid evaluation of the UK National Broadband scheme

Technical Appendix 1 - Reducing the Digital Divide

Ipsos MORI

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Glossary

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

Executive summary

This summary presents the key results of a series of analysis exploring the impact of the Superfast Broadband programme on superfast broadband and full fibre availability, competition and take-up of superfast broadband services. The analysis focuses predominantly on the impacts of Phase 3 of the programme. However, an analysis of overall programme was also completed to enable inferences regarding the possible future impacts of coverage subsidised through Phase 3.

Programme overview

The analysis tackles three key evaluation questions defined in the State aid evaluation plan[1] agreed between BDUK and the European Commission. These are:

- **Question 1:** To what extent has the aid resulted in increased access to a Next Generation Access (NGA) network in white NGA areas?
- **Question 2:** To what extent has the target of the intervention been used and what speeds are available?
- **Question 6:** Is the gap funding model efficient compared to alternative schemes?

Estimates of the impact of the programme have been derived by comparing postcodes receiving subsidised coverage by 2019 to other postcodes that were eligible for subsidies but were not targeted by network providers. The comparisons used a variety of statistical methods, guided by the methodology agreed between the DCMS and the European Commission in the State aid evaluation plan. The key outcomes investigated are summarised in the following table.

Key outcomes

Outcome	Overview
NGA coverage	The percentage of premises able to access broadband through NGA technologies – wireless, FTTC, FTTP and Wireless. This the primary outcome measure defined for the evaluation in the State aid evaluation plan agreed between DCMS and the European Commission.
Superfast coverage	The percentage of premises able to access speeds of 30Mbps. NGA technologies are capable of delivering superfast speeds but will not always do so (for example, if the premises is too far from the cabinet). This measure more closely aligns with the objectives of the programme.
FTTP coverage	Phase 3 of the programme prioritised technologies capable of delivering Gigabit per second speeds which has concentrated investment in FTTP delivery.
Number of network providers	The State aid evaluation plan defines the programme's effect on the number of network providers active on a postcode as key aspect of interest in assessing the impact of the programme on the market.
Number of connections of 30Mbps or higher	The number of households or businesses taking up a 30Mbps connection is a primary outcome measure defined in the State aid evaluation plan agreed between DCMS and the European Commission.
Average download speed of connections	The average download speed of connections is a secondary outcome measure describing the effect of the programme on actual speeds used by households and businesses.
Maximum download speed of connections	This describes the maximum capacity of the connection taken by households or businesses and is a secondary outcome measure describing how the connectivity made available through the programme is used.
Average upload speed of connections	The average upload speed of connections is a secondary outcome measure describing the effect of the programme on actual speeds used by households and businesses.

[1] DCMS (2017) National Broadband Scheme Evaluation Plan. Available at: https://www.gov.uk/government/publications/national-broadband-scheme-evaluation-plan

Background

Although State aid approval for the programme was granted in 2016, delivery of Phase 3 contracts began in 2018. By September 2019 almost 79,100 premises had received subsidised coverage. This equates to around 17 percent of the forecast total premises to be upgraded (and as highlighted in the main evaluation report, there have been delays for a variety of reasons). The findings set out below only capture the short-term effects of the programme and BDUK management data indicates that the last Phase 3 contract is expected to complete in 2024.

Further refinements were made to these approaches to test the robustness of the findings and to widen the scope of the analysis. This included expansion of the treatment group to include all areas in build plans, the application of a propensity score matching (PSM) approach as well as longitudinal panel models that exploit the nature of the panel data available (see subsection 2.3 for more details). Each approach has its inherent advantages and disadvantages that are explained in the text, but the focus is on the broad view across the methods used. However, the longitudinal panel models should be considered to offer the most robust findings over the PSM results with both the simple difference-in-difference and control group regression approaches considered least robust.

Key findings

The statistical models provided a broadly consistent view on the effects of the programme on areas that had received subsidised coverage by September 2019:

- **Impact on broadband coverage:** Coverage subsidised through Phase 3 of the programme led to positive impacts on broadband availability. These impacts included a small positive impact on NGA availability (an increase in the proportion of premises with NGA coverage of 2 to 11 percentage points with most estimates towards the bottom end of this range). However, subsidised coverage increased the proportion of premises able to access superfast speeds by 10 to 25 percentage points and the proportion of premises with FTTP coverage by 25 to 28 percentage points (aligning with the relatively stronger focus of Phase 3 on gigabit connectivity). These findings indicate that many premises benefitting from the programme would have otherwise received some form of enhanced broadband coverage. However, in most cases these enhancements would not have delivered superfast speeds and would have involved the deployment of an inferior technology.

- **Competition:** The results consistently suggest that the programme has promoted additional competition and has increased the number of network providers offering broadband services in the target area (by around 0.2 providers on average). The areas benefitting from the programme were less well served by fewer broadband suppliers than other areas of the UK, and this may bring benefits to consumers in the longer-term (e.g. in the form of lower prices or wider choice).

- **Impact on take-up:** Subsidised coverage has reduced the share of households and businesses that have a superfast connection and the average download speeds of connections. This may be explained by the relatively early stage at which the impacts have been estimated. Only seventeen percent of the contracted premises upgraded had been delivered over the period covered by this analysis (and most these in the final year covered by this analysis). Take-up typically lags availability - it took six years for take-up to reach 60 percent of premises upgraded through Phase 1. As such, it is premature to consider the impact of the programme on take-up. However, the observation of negative effects on the number of premises with superfast connection indicates that for some households or businesses, the programme made superfast services available at a later date than they would have otherwise been received (an issue considered in more depth below).

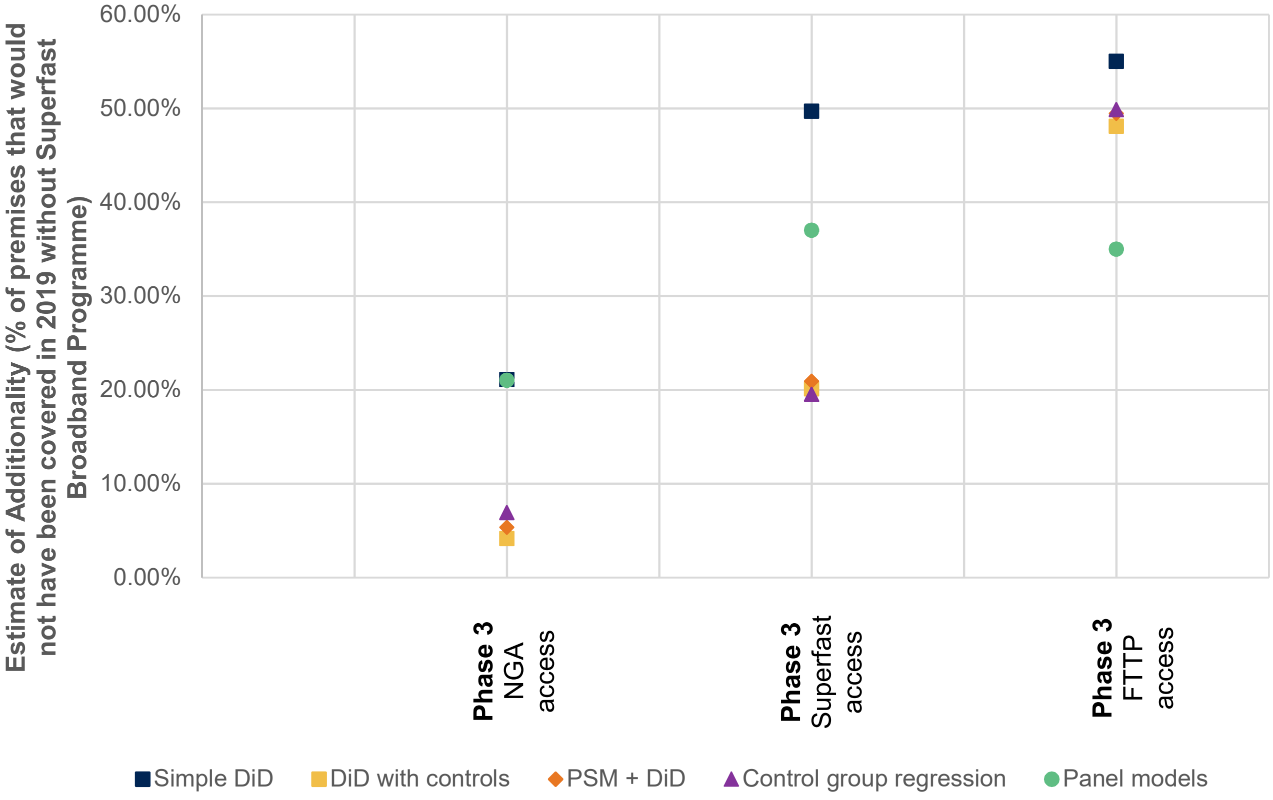
Additionality of subsidised broadband infrastructure

The findings were used to provide an estimate of the overall number of premises benefitting from NGA, superfast and FTTP availability by September 2019. These estimates have been derived by multiplying the estimated increase in the share of premises with enhanced broadband availability resulting from the programme by the number of premises on the postcode:

- **NGA coverage:** The programme is estimated to have led to 2,300 to 16,600 additional premises with NGA coverage. Additionality (i.e. the share of premises benefitting from superfast coverage that would not have in the absence of the programme) is estimated at between 4 and 21 percent, with the most estimates towards the lower end of this range.
- **Superfast availability:** The programme is estimated to have increased the number of premises that can access superfast broadband services (30Mbps or above) by 10,800 to 29,300 by the end of September 2019. The associated rate of additionality ranges from 14 percent to 37 percent.
- **FTTP coverage:** Subsidised coverage is estimated to have led to 19,000 to 30,300 additional premises with FTTP coverage. The rate of additionality ranges from 35 percent to 55 percent (with most estimates in the region of 50 percent).

The range of findings are depicted in the following figure.

Estimated share of premises upgraded that would not have otherwise received subsidised coverage by September 2019, Phase 3



Impacts on the programme area

The analyses were also extended to explore the impacts of the programme on all postcodes included in the build plans of Phase 3 schemes (i.e. including those areas that had not yet benefitted from subsidised coverage) to explore any unintended outcomes of the programme. These findings are summarised in the following table. The results suggest that the programme had a negative effect on enhanced broadband availability across the programme area. This suggests that the programme has worked to delay enhanced broadband availability for some households and businesses that yet to receive subsidised coverage.

The factors driving this pattern are discussed in the main evaluation report. However, this pattern was also observed in relation to the impacts of Phase 1 and 2. The results set out in Section 5 point to a general pattern in which the programme delays the availability of enhanced broadband coverage for around 10 percent of premises. As the programme had only delivered a relatively small share of the contracted premises within the period covered by this analysis, it is likely that this 'delaying effect' is dominating the results when the whole programme area is considered.

Impacts of Phase 1, 2 and 3

As the findings above focus on the short-term effects of Phase 3 contracts at a point where they were at a comparatively early stage of completion. To explore the longer-term effects of the programme, the analysis was extended to the 2012 to 2019 period by incorporating Phase 1 and 2. The findings showed:

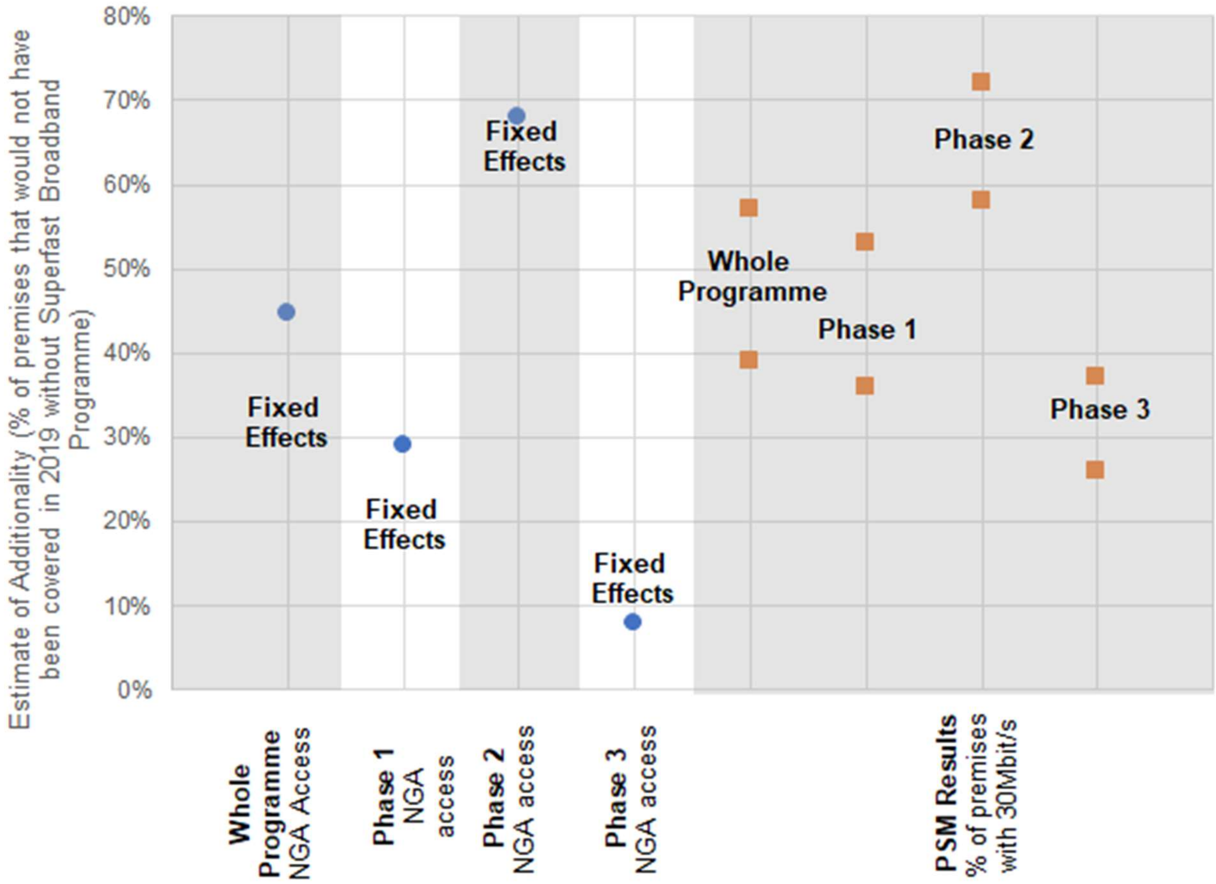
- **Impacts on NGA coverage:** The results indicated that the Superfast Broadband programme increased the share of premises in the programme area with NGA availability by almost 25 percent. The impacts of the programme on NGA coverage appear to have peaked in 2018. This suggests that postcodes that have not benefitted from the programme have started receive commercial deployment of NGA coverage (suggesting that in part, one of the effects of the programme is to accelerate the availability of enhanced infrastructure).

- **Impact on superfast broadband availability:** The impact of the programme on superfast broadband availability continued to rose to 34 percent of premises on the postcodes in the build plans of local schemes by 2019. The effects of the programme on superfast availability were larger than for NGA, and the results do not suggest that these impacts have begun to decay. This would indicate that while some areas benefitting from the programme may have received NGA coverage in the absence of the programme, these technologies would not necessarily have delivered superfast speeds (in common with the findings set out in the preceding section).

- **Phase 1:** The impact of Phase 1 schemes peaked in 2016. Differences between NGA and superfast broadband coverage on postcodes in the build-plans of Phase 1 schemes and the comparison group got smaller in 2018 and 2019. This suggests these earlier schemes had a significant effect in accelerating access to superfast broadband coverage, although some premises would have otherwise benefitted from upgrades at a later point in time.

  Additionality: The matching approach utilised, aggregating the estimated effects on average number of premises with superfast broadband coverage to estimate the total number of additional premises with superfast broadband coverage by 2019, suggests that between 1.6m and 2.3m additional premises benefitted from superfast broadband coverage that would not have done without the programme by 2019. This implies an overall rate of additionality at between 39 and 57 percent. The analysis produced a variety of estimates of additionality using different methods which are summarised in the figure overleaf.

Summary of additionality estimates across methods



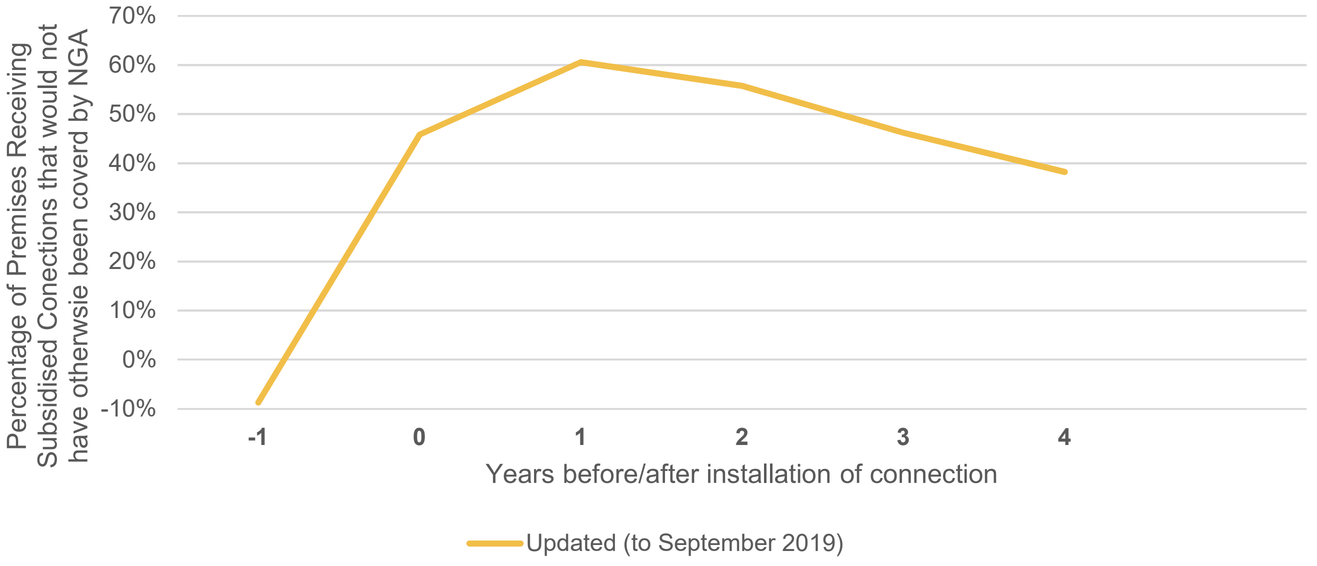
Source: Ipsos MORI analysis; BDUK C3 reports & Ofcom Connected Nations

- **Additionality over time:** The analysis indicated that additionality peaked in the first year following the delivery of the upgrade (at around 60 percent) before decreasing with time. This indicates that the programme has brought forward superfast coverage for some premises that would have otherwise received it at a later stage. There were also signals that the programme delays coverage for some households or businesses that would have received it earlier. Factors driving these patterns are explored in the main evaluation report.

- **Crowding-out:** Overall, the analysis suggested a small degree of crowding out from delivery to a postcode in the 0 to 10km distance but also a small degree in areas 10km to 20km away and then areas 20 to 30km away, all within the year of delivery. One year after, the opposite is true for areas 10 to 20km away and 20km to 30km. The level of crowding out estimated overall was negligible.

- **Take-up:** The impact on take-up has increased with time, suggesting that effects on take-up have lagged effects on coverage. For example, while the effect of Phase 1 contracts on the average download speeds of connections were relatively limited by 2016 (three years after delivery of the programme started), these effects appeared to be substantial in 2019.

Estimates of additionality of NGA Coverage over time



Source: Ipsos MORI analysis; BDUK C3 reports & Ofcom Connected Nations

1 Introduction

This technical appendix sets out the results of a series of analysis exploring the impact of the Superfast Broadband Programme on superfast broadband and full fibre availability, competition and take-up of superfast broadband services. The analysis focusses predominantly on the impacts of Phase 3 of the programme. However, an analysis of the overall programme was also completed to enable inferences regarding the possible future impacts of coverage subsidised through Phase 3.

1.1 Background

The Superfast Broadband programme was announced in 2010 to respond to concerns that the commercial deployment of superfast broadband would fail to reach many part of the UK due to the cost of installing the technology relative to expected revenues.[2] On the expectation that extending superfast broadband coverage to these areas would produce economic, social and environmental benefits that would not be captured by suppliers, the Government established the programme to provide £530m of public resources to fund further deployment with the aim of enabling 90 percent of UK premises to access superfast broadband speeds by early 2016. The programme was extended in 2015, with a further £250m made available to extend coverage to 95 percent by the end of 2017.

The Superfast Broadband Programme was extended a second time under a new State aid approval[3] covering the 2016 to 2020 period. Contracts awarded under this State aid scheme (commonly known as Phase 3) are the focus of this analysis. These projects had a greater focus on full fibre connectivity than those funded in prior phases, aligning with broader Government objectives to increase Fibre to the Premises (FTTP) coverage in the UK. This third phase evolved from a series of pilots that sought to explore how coverage could be extended past 95 percent of UK premises. At the time of writing, there were 51 Phase 3 projects underway (across 51 lots[4]) supported by £187m of public funding[5]. However, as these projects were at relatively early stages of delivery, the following analysis also explores the longer-term impacts of Phase 1 and Phase 2 schemes.

1.2 Evaluation questions

This analysis tackles three key evaluation questions defined in the State aid evaluation plan[6] agreed between BDUK and the European Commission. These are:

[2] DCMS and Rt Hon Jeremy Hunt MP (2010) Media Keynote Speech, the Hospital Club. Available at: https://www.gov.uk/government/speeches/media-keynote-speech (accessed August 2020).
[3] European Commission (2016) SA. 40720 (2016/N) – National Broadband Scheme for the UK for 2016-2020. Available at: https://ec.europa.eu/competition/state_aid/cases/263954/263954_1760328_135_4.pdf (accessed August 2020).
[4] As recorded in a June 2020 CORA management information extract. A lot was defined as an individual contract for a specified subset of areas within a scheme area.
[5] This is out of a total of 51 Phase 3 projects as listed in the Superfast Broadband Management Information
[6] DCMS (2017) National Broadband Scheme Evaluation Plan. Available at: https://www.gov.uk/government/publications/national-broadband-scheme-evaluation-plan

- **Question 1:** To what extent has the aid resulted in increased access to a Next Generation Access[7] (NGA) network in white[8] NGA areas?
- **Question 2:** To what extent has the target of the intervention been used and what speeds are available?
- **Question 6:** Is the gap funding model efficient compared to alternative schemes?

1.3 State aid evaluation methodology

The methodology used for the analysis builds on the approach set out in the State aid evaluation plan. This involved two main approaches:

- **Difference-in-differences:** This approach compares changes in NGA coverage and take-up between June 2016 and September 2019 on postcodes benefitting from Phase 3 contracts and a comparison group of postcodes that were identified as white in the relevant Open Market Review processes but were not included in the build plans of Phase 3 contracts. The State aid evaluation plan defined postcodes that benefitting from the programme as those that had received subsidised coverage by September 2019 (i.e. areas in the build plans of these schemes, but had not yet benefitted from the programme, were not considered part of the treatment group).
- **Modelling of coverage in white postcodes (control group regression approach):** This involved the development of a statistical model to explain the evolution of NGA coverage and take-up on white postcodes that were not included in the build plans of Phase 3 contracts between 2016 and 2019. This model was used to predict NGA coverage on postcodes benefitting from Phase 3 contracts in the counterfactual scenario in which the programme had not been funded. Predicted NGA coverage was subtracted from observed coverage to estimate the impact of the programme.

Several extensions have been made to this methodology to extend the scope of the analysis and probe its robustness:

- **Range of outcomes:** The focus of the methodology defined in the State aid evaluation plan was on NGA coverage and take-up. This choice was based on the data available at the time. However, the availability of NGA services is only an approximation of the goal targeted by the programme, which is to bring forward superfast (30Mbps) coverage in areas that would not otherwise benefit from commercial deployments. NGA technologies may not always deliver superfast speeds (for example, if premises are too distant from a serving cabinet upgraded to FTTC). Improvements in data availability has enabled a broader range of outcomes to be explored – including superfast coverage and take-up and FTTP availability. Additionally, it was possible to compile postcode level data on the number of network providers. This enabled a partial examination of the impacts of the programme

[7] Next Generation Access networks are defined in the 2013 Broadband Guidelines as having the following characteristics: (i) deliver services reliably at a very high speed per subscriber through optical (or equivalent technology) backhaul sufficiently close to user premises to guarantee the actual delivery of the very high speed; (ii) support a variety of advanced digital services including converged all-IP services and (iii) have substantially higher upload speeds (compared to basic broadband networks). NGA networks were considered at the time to include (i) fibre-based access networks (Fibre to the Cabinet and Fibre to the Premises), (ii) advanced upgraded cable networks, and (iii) certain advanced wireless access networks capable of delivering reliable high speeds to the subscriber. See European Commission (2013) EU Guidelines for the application of State aid rules in relation to the rapid deployment of broadband networks. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52013XC0126(01)&from=GA (accessed August 2020).

[8] White areas are defined in the 2013 Broadband Guidelines as those in which there is no broadband infrastructure and it is unlikely to be developed in the near future. Ibid.

on local competition using econometric methods (which was not envisaged in the State aid evaluation plan).

- **Selection on observables:** The difference-in-differences approach set out in the State aid evaluation plan did not account for systematic but observable differences between the proposed treatment and comparison groups that could bias results. Several additional steps were taken to control for observable differences between the two groups. This included adding control variables to regression based difference-in-difference models and using statistical matching methods to ensure that postcodes benefitting from the programme were only compared to postcodes outside of Phase 3 build plan where they shared similar characteristics.

- **Intention-to-treat estimates:** The State aid evaluation methodology focused on the impact of the programme on those postcodes that had received subsidised coverage by the time of the analysis. This could potentially lead to biased estimates of the impact of the programme if there are systematic but unobserved differences between those postcodes that received subsidised coverage early in the build programme and those expected to benefit in the future. Supplementary analyses were also carried out using all postcodes in the build plans of Phase 3 contracts as the treatment group for the analysis that are more robust to this potential issue.

- **Time horizons:** Finally, the data available for this analysis ran to September 2019. At this point, only a small share of expected delivery under Phase 3 had been brought forward (around 15 percent). It was too early to draw conclusions regarding questions about the long-term impact of Phase 3 contracts on coverage and take-up. To provide a longer-term view, an analysis was completed exploring the effects of all contracts funded through the Superfast Broadband programme (extending the scope of the analysis to include Phase 1 and 2 contracts awarded under the 2012 to 2016 UK National Broadband Scheme).

2 Analytical framework

This section sets out an overall framework for the analysis. This defines the key hypotheses the evaluation is aiming to test and provides an overarching theoretical framework for the analysis (i.e. a theory of change). The framework was initially developed through a combination of consultations with BDUK officials and the application of economic theory to the delivery model adopted to implement the programme. It was subsequently refined in response to evidence gathered from the programme of depth interviews with network providers completed as part of the wider evaluation.

2.1 Theoretical framework

The Superfast Broadband programme aims to increase the number of premises covered by superfast broadband infrastructure. This objective is achieved by subsidising network providers to extend their networks to areas that would not be commercially viable otherwise.

2.1.1 Programme delivery model

Making subsidies available for infrastructure delivery involves a risk that private providers have an incentive to seek public funds for (deadweight) investments that they would have made anyway, enabling them to earn a higher rate of return. The impact of the programme on the number of premises covered by superfast broadband services will be limited where public resources are allocated to schemes that would have been considered commercially viable otherwise. A range of mechanisms were in the implementation of the programme were introduced to mitigate against these risks:

- **Allocation of subsidies:** Subsidies were allocated to Local Bodies (responsible for tendering and awarding contracts to deliver infrastructure upgrades) based on BDUK's assessment of the gap funding[9] needed to upgrade each cabinet in the UK. In Phase 1, BDUK funding was allocated based on local shares of the gap funding requirement to reach the initial target of 90 percent superfast coverage in each area. In Phase 2, resources were allocated based on the gap funding needed to reach 95 percent coverage at the national level at the lowest cost[10]. For Phase 3, resources were allocated to achieve the greatest increase in coverage for the available funding (which included locally available resources brought by the Local Body potentially from past contracts or matched to potential sources such as ERDF or DEFRA funding). Several local authorities were deemed ineligible for BDUK support because existing commercial plans were already extensive.

- **Open Market Review (OMR) and public consultation:** Local Bodies were required to manage an OMR and public consultation process before they issued tenders. The first stage of this process involved requesting suppliers to describe their commercial plans to roll-out basic and superfast broadband coverage over the next three years. This process classified premises (postcodes in Phase 1 and 2) into three groups:

  - **White areas** where there were no commercial plans to roll-out superfast broadband within three years.
  - **Grey areas** where one provider was offering or expected to offer superfast broadband services within three years, and,

[9] The level of subsidy required to make the investment sufficiently profitable for the supplier.

[10] However, under initial calculations, this would have resulted in Wales, Scotland and Northern Ireland receiving a smaller share than would be implied by their population shares. A share of funds available equivalent to population share was allocated to the two DAs, while resources were distributed across England in the manner suggested.

- **Black areas** where multiple providers were offering or expected to offer superfast broadband.

This view on future superfast broadband availability was then subject to public consultation.

- **Tendering:** This view on the near term roll out of broadband at the local level was expressed in a Speed and Coverage Template (SCT) used in local tendering exercises in which local authorities sought to procure additional investment in local telecommunications infrastructure. Only 'white' premises or postcodes were eligible for subsidised infrastructure, with competing providers outlining which postcodes/premises they proposed to cover for the available funding. Network providers were required to provide a Project Financial Model (PFM), which included estimates of the overall costs associated with delivering the project, take-up assumptions and expectations of future revenues and on-going operational costs. This model provided an estimate of the internal rate of return (IRR) associated with the project without subsidy. The subsidy offered aimed to equalised the IRR over a seven-year period with the suppliers Weighted Average Cost of Capital (WACC)[11].

- **Underspend:** Protections for the public sector against the risk that suppliers overestimated their delivery costs were put in place by introducing a mechanism to recover underspend. The principle underlying contracts was that the supplier would fully invest its contracted funding. In the event of any underspend, the supplier was required to place unused funds in an Investment Fund to help resource further schemes or extend the contract coverage to a greater number of premises than originally offered. Any unused public funding also remained available for further investment.

- **Take-up clawback:** Further protections for the public sector were introduced through 'take-up clawback' clauses in contracts. If take-up proved to be higher than anticipated at the tendering stage then suppliers were required to return a share of the excess revenues to the investment fund based on the investment ratio (and again, these funds could be recycled to support further coverage). Take-up clawback was capped such that the amount returned to the public sector could not exceed the value of the subsidy awarded.

2.1.2 Factors influencing additionality

While the programme involved mitigating actions to minimise the risk of deadweight associated with the contracts awarded, several factors could potentially influence the size of the impacts of the programme:

- **Accuracy of information gathered through the OMR:** The level of additionality associated with the programme will be critically dependent on the degree to which the OMR process was effective in accurately identifying 'white' postcodes where no commercial deployment of NGA networks was planned. If the OMR incorrectly identified 'black' or 'grey' areas as 'white' and eligible for subsidies, there is a danger that public funding could be awarded to provide subsidised superfast infrastructure to areas that would otherwise have benefitted from commercial deployments. Possible threats to the accuracy of the information gathered through the OMR include:

  - **Comprehensiveness:** The OMR process would need to reveal the commercial plans of all network providers that could credibly deploy superfast networks over the timescales of interest. This required Local Bodies to engage effectively with local network providers, as if some potential providers did not provide their commercial plans then there is a risk that some postcodes or premises are mistakenly identified as 'white' and eligible for subsidies. The comprehensiveness of the data gathered is also linked to the standards of evidence applied by Local Bodies when reviewing the credibility of the commercial plans provided by network providers. Evidence from

[11] This assumes that the minimum IRR on the project should equal the supplier's cost of capital for the project to be viable.

the broader evaluation of the programme indicated that in some cases, network providers were unable to provide plans with a minimum level of granularity, detail or certainty and their submissions were dismissed. If these plans were (or would have been) taken forward, this would have resulted in some postcodes or premises mistakenly marked as eligible for subsidies. Qualitative research with Local Bodies provides some evidence that there were some network providers that were reluctant to provide their commercial deployment plans as this could influence the investment decisions of their competitors.

 - **Strategic behaviour during the OMR process:** It could be anticipated that some network providers would see an incentive to understate their commercial plans during the Open Market Review process if it would increase the likelihood they could obtain subsidies for investments they would have made anyway. However, suppliers that did not intend to seek subsidies (for example, if they were discouraged by the open wholesale access requirements) may have experienced incentives to overstate their commercial plans to preserve local market dominance or prevent the emergence of subsidised competitors. This latter issue may not affect additionality as it would imply postcodes were mistakenly marked as ineligible for subsidies, but could have economic or social costs (e.g. if the publication of the resultant coverage maps promoted investments in areas where superfast coverage did not ultimately come forward).

 - **Dynamic nature of commercial deployments:** The OMR provided a static view of future commercial deployment plans. However, network providers operate in a dynamic environment in which the deployment plans evolve in response to new information. On-going increases in demand for superfast services observed since the programme was launched will increase the potential revenues that can be earned, making some investments profitable that previously were not. Regulatory innovation[12] has reportedly allowed competing network providers to more efficiently access Openreach's Physical Infrastructure Access (PIA) product, reducing the cost of network deployment via access to the dominant provider's ducts and poles. The length of investment planning cycles (reportedly 12 to 24 months) will also inhibit the ability of network providers to supply concrete deployment plans for extensive periods in the future. As such, some 'white' postcodes may become 'black' over time, potentially resulting in some premises receiving superfast coverage earlier than they otherwise would have.

- **Network provider behaviour during the tendering process:** Given that it is not possible to perfectly observe the future commercial plans of network providers, the contractual mechanisms put in place provided further protection against the risk that public sector resources were deployed to take forward schemes that were commercially viable. The underspend and take-up clawback mechanisms aimed to reduce the ability of network providers to exploit their superior information to overstate the gap funding requirement. Overstatement of costs at the tendering stage would be recovered via the underspend clawback mechanism[13]. A share of any understatement of future revenues would also be recovered via take up clawback mechanism. Understating expected costs or overstating take-up expectations (e.g. to improve the competitiveness of tenders submitted) could result in the supplier ultimately taking a loss. It should be noted, however, that these protections are internal to the relevant infrastructure provider and would not limit subsidies being allocated to schemes that overbuild or discourage planned deployments by competing suppliers.

[12] Such as Ofcom's remedies for Openreach's Physical Infrastructure Access product announced in the 2018 Wholesale Local Access Review See Ofcom (2018) Wholesale Market Review: Statement – Volume 3 (physical infrastructure access remedy). Available at https://www.ofcom.org.uk/__data/assets/pdf_file/0023/112469/wla-statement-vol-3.pdf (accessed August 2018).

[13] Unless subsidies encourage less efficient delivery.

The effectiveness of these mechanisms is potentially linked to the level of competition for the subsidies awarded. In the absence of competition, the infrastructure provider can potentially transfer the risk of making unprofitable investments to the public sector by assuming low levels of take-up. This strategy would increase the level of gap funding required to make the project viable, which would be returned to the public sector only if the project was a commercial success. This approach would be less viable in the presence of competition, as it would reduce the value for money associated with the tender (increasing the likelihood the procurement was lost to a competitor). Phase 3 contracts were all awarded through an open OJEU process and multiple tenders attracted multiple bids. However, in Phase 1 and 2, while Local Bodies had the option of procuring through an open OJEU process, most elected to procure through a Framework Agreement established by BDUK that only had one credible supplier (BT/Openreach).

- **Delivery of parallel programmes:** BDUK is delivering several parallel programmes aiming to stimulate deployment of FTTP (demand led interventions). These include the Gigabit Connection Voucher Scheme (GBVS) and the Local Full Fibre Network (LFFN) programme.

2.1.3 Indirect impacts

The above processes may also be expected to have the following indirect impacts on local connectivity:

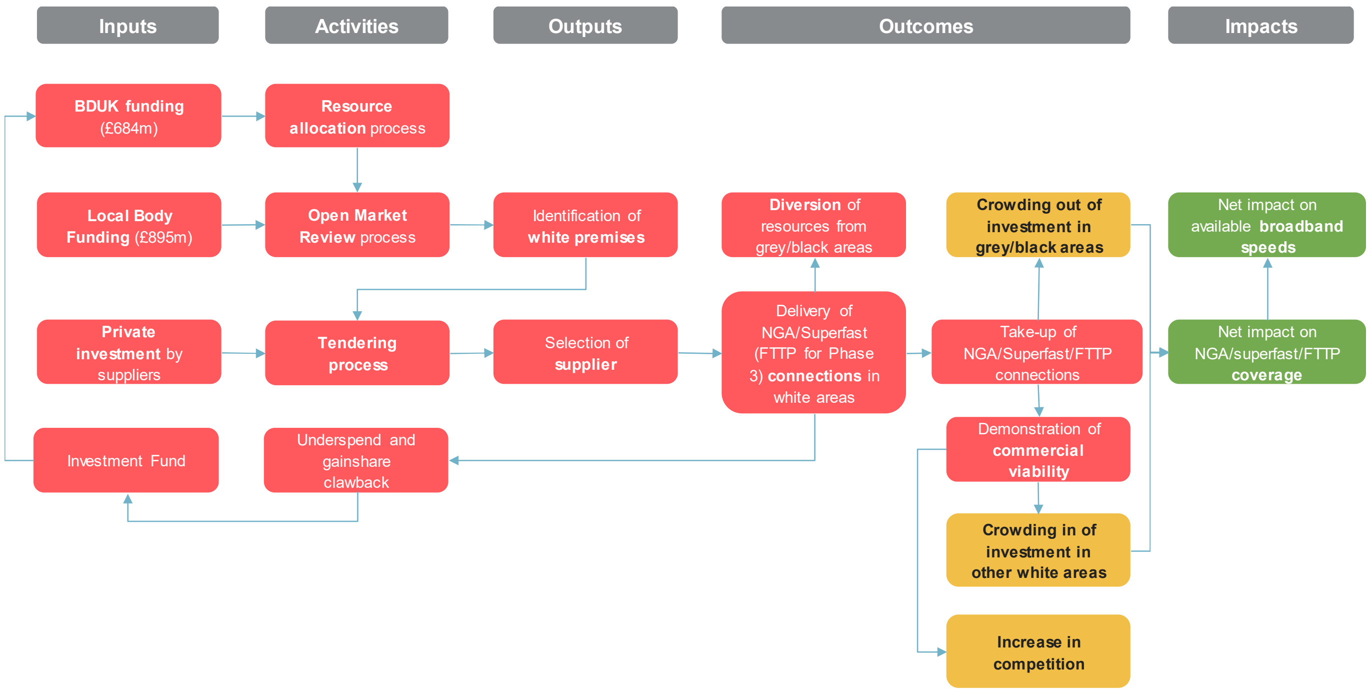
- **Crowding out:** The provision of subsidies for Superfast Broadband investment has the potential for two forms of 'crowding out':
  - **Discouragement effects:** The build plans of Phase 3 schemes were published and revealed those 'white' postcodes that would benefit from subsidised coverage. In cases where other suppliers had plans to extend their networks to these areas that were not identified by the OMR process, the presence of subsidised competitors may have reduced the profitability of those investments and in some cases, led to their abandonment.
  - **Price effects:** There may also have been negative impacts on 'grey' and 'black' areas if suppliers faced capacity constraints – either in the labour market or in credit markets (for smaller suppliers). If firms are not able to expand their overall capacity to deliver the programme of subsidised infrastructure improvements, then this may result in delays or abandonment of schemes planned without subsidy, offsetting the effects of the programme in 'white' areas. Consultations with BDUK suggested that this risk was acknowledged and mitigated by the timing of the first two phases programme, which began as the main suppliers were completing the bulk of their commercial roll-out. The risk is potentially greater for Phase 3 with these contracts entering delivery at a time when suppliers are beginning their commercial rollout of FTTP.
- **Crowding-in:** Take-up of subsidised superfast broadband availability was higher than expected (at least during Phase 1 of the programme). It is possible that the programme helped demonstrate the commercial viability of infrastructure investment in the areas targeted, encourage investments in other areas to maximise their returns. This would be visible in the form of accelerated broadband coverage in 'white' areas that were not targeted by suppliers. However, successive announcements that the Government was providing further public subsidy could also have influenced supplier expectations, causing them to hold back investment expecting further funding to become available. Experiences with commercial deployments may also have demonstrated commercial viability. In this case, crowding-in effects could not be wholly attributed to the programme.

- **Competition:** Finally, the programme may have led to changes in the parameters of competition and the market shares of network providers:
  - **Wholesale access requirements:** In principle, the programme was targeted at 'white' postcodes that could not sustain a single provider of superfast infrastructure without subsidy. As such, the programme can be expected to create local monopolies. However, the programme required subsidised network providers to provide open and non-discriminatory wholesale access to physical infrastructure (ducts, poles, cabinets, masts), dark fibre, copper loop unbundling, and antenna on the subsidised portion of the network (with charges set with reference to benchmark wholesale market prices). These requirements could potentially stimulate additional competition in both wholesale or retail markets.
  - **Overbuild:** Less directly, the nature of broadband technologies may have led to competitive distortions by increasing competition on 'grey' or 'black' postcodes. The cabinets upgraded to FTTC technologies will serve multiple premises. Some of these premises will have benefited from superfast coverage provided by competing network providers. While BDUK will not have funded the upgrade of these premises, the cabinet itself may not have been upgraded in the absence of the programme. In these cases, the entry of a subsidised competitor may have eroded the market shares and/or the profitability of incumbent providers.

2.1.4 Logic model

The logic model below summarises the processes described above and some of the expected impacts of the programme. This focus of this report is on the net impact of the programme on superfast coverage and available broadband speeds. Evaluation questions relating to the effectiveness of the resource allocation process are addressed as part of the wider evaluation of the Superfast Broadband programme and are not considered in this appendix.

Figure 2.1: Logic model – connectivity impacts of the Superfast Broadband programme



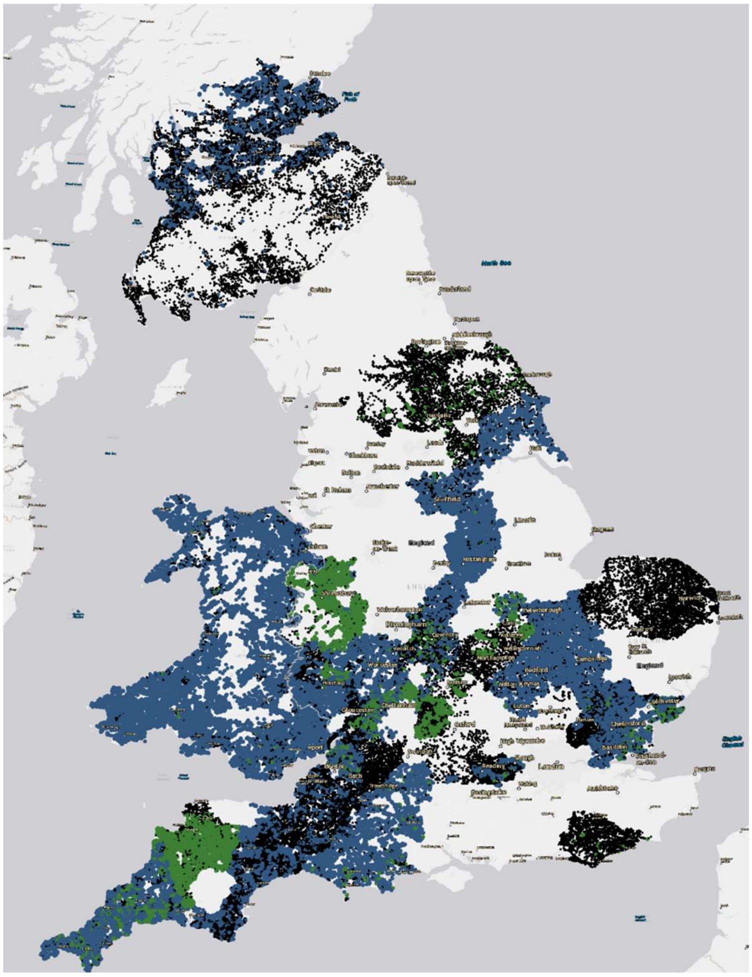
3 Programme overview

This section provides an overview of the delivery of the Superfast Programme between 2012 and 2019 with an emphasis on the delivery of the Phase 3 contracts that form the focus of the State aid evaluation. This section draws on an analysis of management data describing the target areas of contracts awarded under the programme and delivery of the programme to September 2019. A more detailed discussion of the datasets driving this analysis is provided in Annex A.

3.1 Target area for Phase 3 contracts

The target areas for the programme were defined in Speed and Coverage Templates (SCTs) developed by Local Bodies based on the Open Market Review. The template defines which postcodes or premises where there are no commercial plans to deploy superfast (white postcodes), and are therefore eligible for subsidised coverage. The templates are completed by network providers as part of the tendering process, describing which postcodes or premises will be upgraded as part of the proposed network build (the build plan). As illustrated in Table 4.1, Phase 3 contracts covered smaller areas than those awarded under Phase 1 and 2. Premises on 67,000 postcodes were included in the build plans of Phase 3 contracts (four percent of the postcodes in the UK). This compares to 249,000 in Phase 1 and 95,000 in Phase 2. Premises on a 52,000 postcodes were identified as eligible for the programme but were not included in the build plans of Phase 3 contracts.

Figure 3.1: Eligible postcodes inside and outside of the build plans of Phase 3 schemes



Source: SCT templates, C3 Reports, Ipsos MORI analysis; green denotes built to as of September 2019, black are in build plans to be delivered to and blue are other white postcodes

It should be noted that the SCTs do not provide a complete record of white, grey and black premises across the UK. SCTs were only available for those areas for which contracts were awarded. Additionally, the premises listed in Phase 3 SCTs only provided partial coverage of the territory covered by the relevant Local Body (Phase 1 and 2 SCTs were more comprehensive in this respect).

Table 3.1: Overview of Speed and Coverage Templates, Phase 1, 2 and 3 contracts

Status	Phase 1		Phase 2		Phase 3	
	Number	% of postcodes in UK	Number	% of postcodes in UK	Number	% of postcodes in UK
White postcode within build plan defined in SCT	248,521	16.2	95,266	6.2	66,926	4.4
White postcode out of build plan defined in SCT	99,959	6.5	77,748	5.1	51,534	3.4
Grey or black postcode in SCT	524,124	34.1	744,233	48.5	39,472	2.6
Total	**872,604**	**56.8**	**917,247**	**59.8**	**157,932**	**10.4**
Number of SCTs	38		46		63	

Source: SCT templates, Ipsos MORI analysis

3.2 Characteristics of postcodes benefitting from the programme

The postcodes included in the build plans of Phase 3 contracts were linked to several other datasets (as described in the appendix) to obtain information on their characteristics before the programme began. An overview of their key features in relation to other white postcodes that did not benefit from the programme is provided in the Table 4.2. The table highlights that those postcodes included in the build plans of local schemes differed in several ways from other postcodes eligible for investment through the programme:

- **Availability & coverage:** Superfast broadband penetration was lower in postcodes included Phase 3 build plans than on other white postcodes that were eligible for investment, in both 2012 and 2016. This is also reflected in measures of take up, including the average and maximum speeds of connections and the number of superfast connections taken by consumers located on the postcode.

- **Network characteristics:** Areas in the build plans covered by Phase 3 contracts were also more likely to exhibit characteristics that would increase the costs of deployment or reduce commercial viability. Premises included in the build plans of Phase 3 contracts were characterised by longer line lengths to the serving cabinet - which are more expensive to upgrade as copper lines from the serving cabinet are less able to deliver superfast speeds, requiring additional investment in fibre. Demand density was also lower – with lower numbers of delivery points per exchange/cabinet and lower population and premises density. This reduces the number of customers that can potentially be served and the potential revenues that can be earned. BDUK modelling completed in 2014 also suggested that the estimated cost of upgrading the serving cabinet would be higher.

- **Area characteristics:** Postcodes included in the build plans of Phase 3 contracts were more likely to be rural in nature (75 percent of postcodes compared to 64 percent of postcodes eligible but not included in build plans). Employment and unemployment rates in the local authorities were very similar across groups, though average wages were lower in those areas included in Phase 3 build plans.

This indicates network providers selected premises that were costlier to upgrade and were characterised by weaker demand side characteristics. This is the reverse of the patterns observed for Phase 1 and Phase 2[14]. This may be related to the comparatively high levels of penetration in white postcodes that were not included in the build plans of Phase 3 contracts. Where existing levels of penetration is high, the remaining premises not served may be concentrated in relatively small pockets. It may not be cost effective to build out networks to fill these gaps in provision. Network providers may have targeted communities with low levels of existing penetration to maximise the size of the local markets that could be addressed.

Table 3.2: Characteristics of postcodes included in Phase 3 build plans

Characteristics	Postcodes in Phase 3 build plans	Postcodes receiving subsidised coverage by Sep. 2019	White postcodes not included in Phase 3 build plans
Broadband availability and take-up in 2012			
% of postcodes with Next Generation Access	15.5	39.6	73.0
Average maximum download speed (Mbps) of connections[15]	8.5	10.1	13.4
Average download speeds (Mbps) of connections	5.7	9.8	13.9
Broadband availability and take-up in 2016			
% of postcodes with Next Generation Access	72.9	79.8	96.1
% of postcodes with superfast (30Mbps) access	27.4	55.6	93.8
Average number of premises on postcode with superfast connections[16]	1.7	5.2	8.1
Network characteristics in 2013			
Length of line from exchange to premises (m)	3647	3081	2,161
Share of premises with exchange only lines (%)	22.0	13.1	4.5
Delivery points at serving exchange	6236	10874	17,566
Delivery points at serving cabinet	247.0	303.5	380.2
% of postcodes in Virgin Media footprint	0.8	14.8	48.3
Number of residential delivery points	11.5	15.1	19.6
Number of non-residential delivery points	1.0	1.1	0.7
Estimated cost to upgrade serving cabinet (£)	67583	64585	61,711
Estimate upgrade cost per premises upgraded (£)	332.1578	311.0	178.9
Area characteristics in 2013			
% of postcodes in rural areas	80	55	14
Working age population (in Output Area)	178	197	200
Population aged 65+ (in Output Area)	58	56	50
Population density in OA (population per square km)	666	1676	4,403
Premises density in OA (premises per square km)	425	998	2,564
Gross weekly earnings in LA (£)	503	542	518
Employment rate in LA (%)	75	75.2	71
Unemployment rate in LA (%)	6.4	7.2	8.2

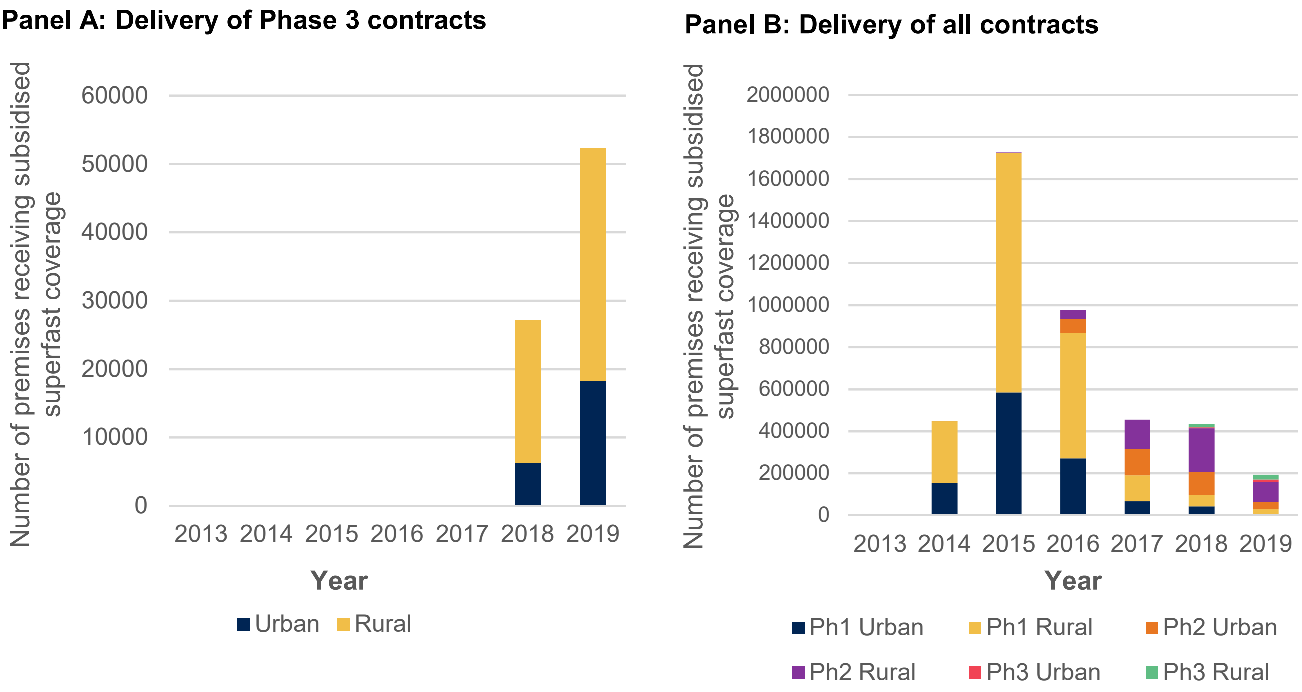
Source: Ipsos MORI Analysis

[14] BDUK (2018) Superfast Broadband Programme Evaluation: Annex A – Reducing the Digital Divide.
[15] Note that this does not factor in the number of premises on a postcode able to reach a certain maximum download speed
[16] There were around 11.3 premises per postcode on postcodes in the build plans of Phase 3 schemes.

3.3 Delivery

Delivery of Phase 3 of the Superfast Broadband programme was at an early stage at the time of writing. Delivery of the programme began in 2018 and analysis of C3 reports provided by BDUK indicated that almost 79,100 premises had received subsidised coverage by September 2019 (over 9,300 postcodes). Seventeen percent of the forecast total premises to be upgraded had been achieved by September 2019 As highlighted in the main evaluation report, the programme was behind schedule, and the final contract is now expected to complete in 2024. As illustrated in panel B of the Figure 3.1, delivery of Phase 3 contracts represented a relatively small share of overall programme delivery in 2018 and 2019.

Figure 3.2: Number of premises receiving superfast (30Mbps[17]) coverage subsidised by BDUK, areas for which Phase 1, Phase 2, and Phase 3 SCTs are available, 2013 to September 2019[18]



Source: C3 reports, Ipsos MORI analysis. Note that delivery has been assigned to the period covered by the relevant annual Connected Nations report and do not always cover a 12-month period (see Annex A for more details on this).

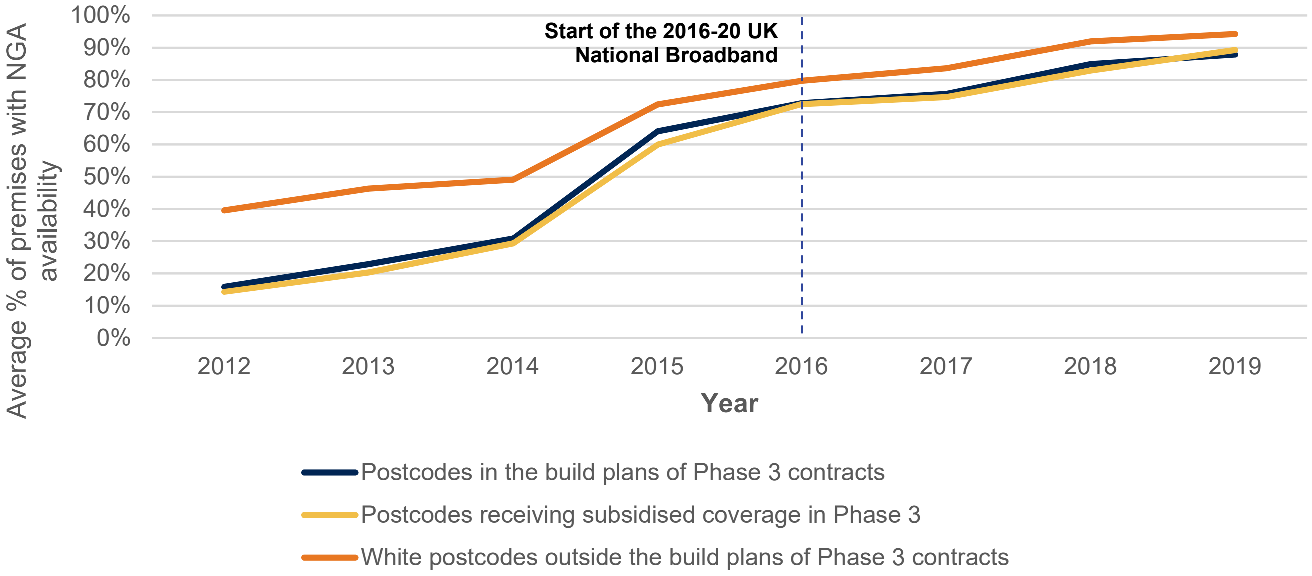
3.4 Changes in connectivity in the target area

The following figure shows changes in availability of Next Generation Access (NGA) broadband (FTTC, FTTP, Wireless or cable) between 2012 and 2019 on white postcodes included and excluded from the build plans of Phase 3 contracts. The percentage of postcodes included in the build plans of Phase 3 contracts with NGA coverage rose from 72 percent to 88 percent between June 2016 and September 2019. NGA coverage was persistently higher on white postcodes outside of Phase 3 build plans (rising from 80 percent to 94 percent over the same period).

[17] 24MBits for Phase 1 and Phase 2

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

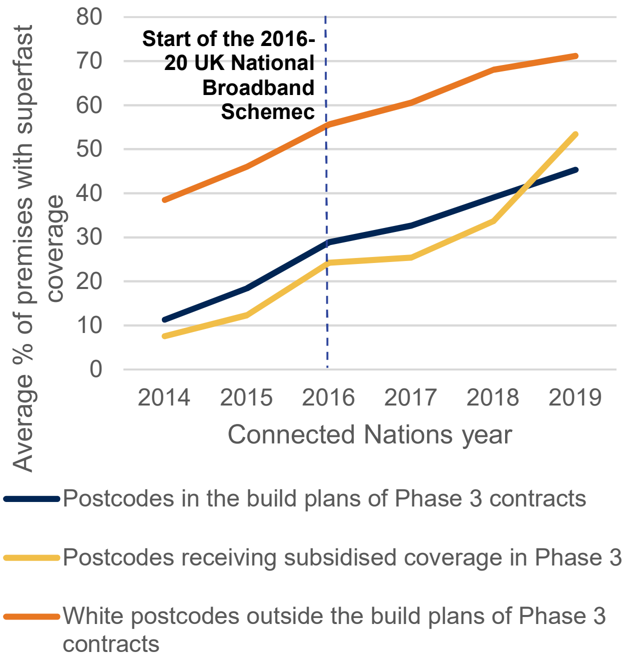
Figure 3.3: Changes in Next Generation Access (NGA) coverage – areas in Phase 3 build plans and other white postcodes, 2012 to 2019

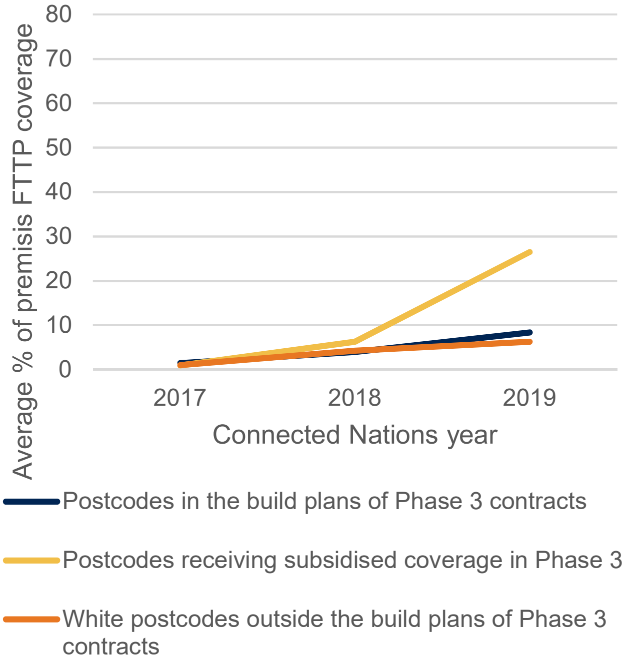


Source: C3 reports, Ofcom Connected Nations, Ipsos MORI analysis.

Superfast coverage rose at similar rates in areas covered by Phase 3 build plans and other white postcodes between 2016 and September 2019 (from 29 to 45 percent and from 55 to 71 percent respectively). Superfast coverage expanded rapidly (from 24 to 56 percent of premises) in those areas benefitting from subsidised upgrades by September 2019. FTTP coverage also rose more rapidly in the programme area than on other white postcodes.

Figure 3.4: Changes in superfast broadband (at least 30Mbps) and FTTP coverage (% of premises), areas in Phase 3 build plans and other white postcodes, 2012 to 2019

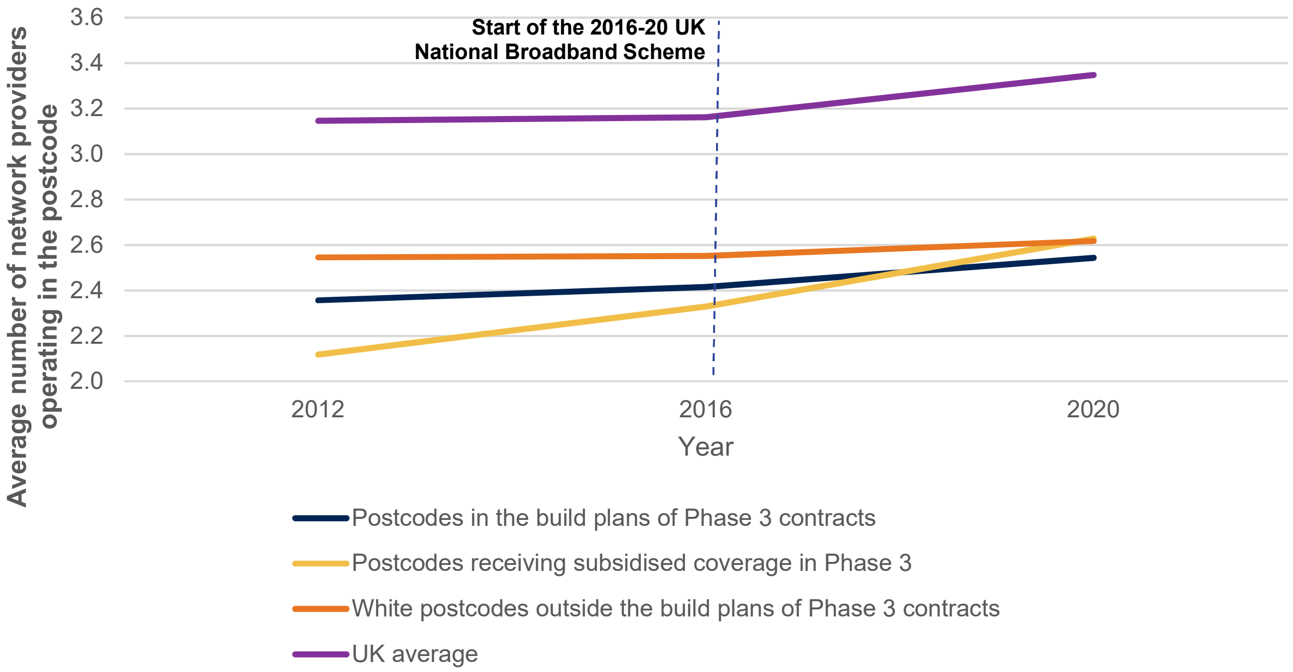




Source: C3 reports, Ofcom Connected Nations, Ipsos MORI analysis. Note data on FTTP coverage is only available from 2017 onwards.

Figure 4.5 shows the change in the number of network providers[19] operating in postcodes that were eligible for subsidies under Phase 3 contracts between 2012 and 2020. In 2016, the average number of network providers operating in the areas covered by Phase 3 build plans was lower than in other white postcodes. This indicates providers were targeting postcodes with less intensive local competition. The average number of network providers operating on the postcodes benefitting from subsidised upgrades rose from 2.3 to 2.6, indicating the programme may have helped promote greater competition in these areas.

Figure 3.5: Average number of network providers operating in areas in Phase 3 build plans and other white postcodes, 2012 to 2020



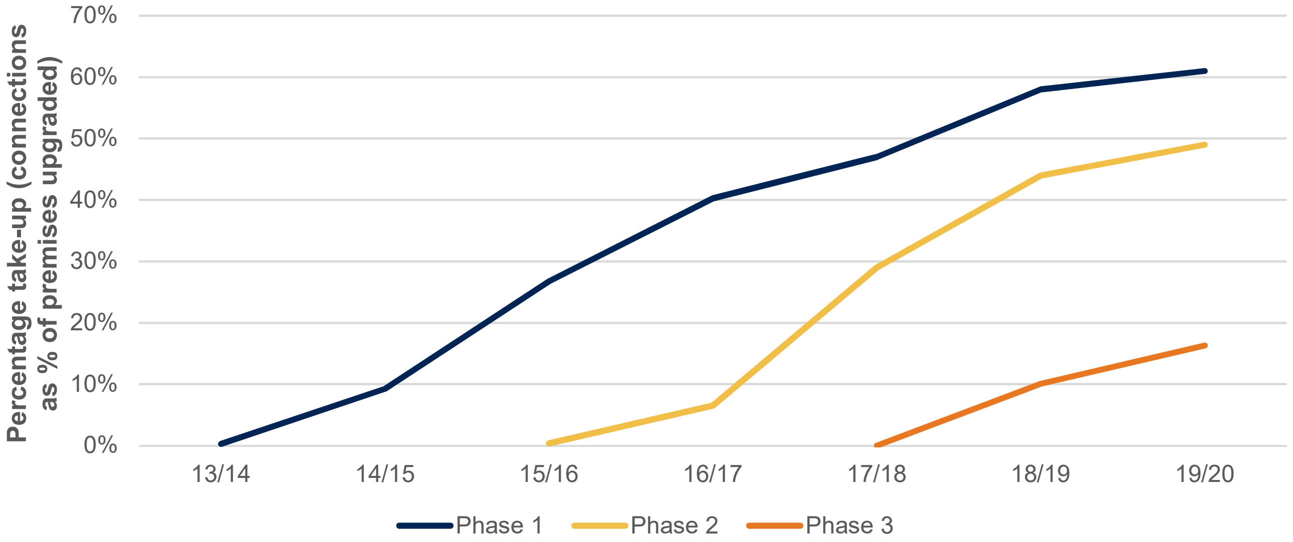
Source: C3 reports, ThinkBroadband, Ipsos MORI analysis.

3.5 Take-up of subsidised coverage

At Q2 2019/20, a total of 15,369 premises were connected to superfast broadband services made available through the programme. There has been steady rise in take-up since the programme began as illustrated in Figure 4.6 below. In terms of connections as a share of premises upgraded, take-up as a percentage of premises upgraded reached 61 percent for Phase 1, 49 percent for Phase 2 and 16 percent for Phase 3.

[19] Data included network providers owning and operating their own networks (not including ISPs) regardless of whether or not they provided a superfast network.

Figure 3.6: Number of connections as a percentage of premises upgraded Q2 2019/20, Phase 1, 2 & 3



Source: Programme data (WSS C3 reports); Ipsos MORI analysis. Note that 2019/20 is an incomplete year.

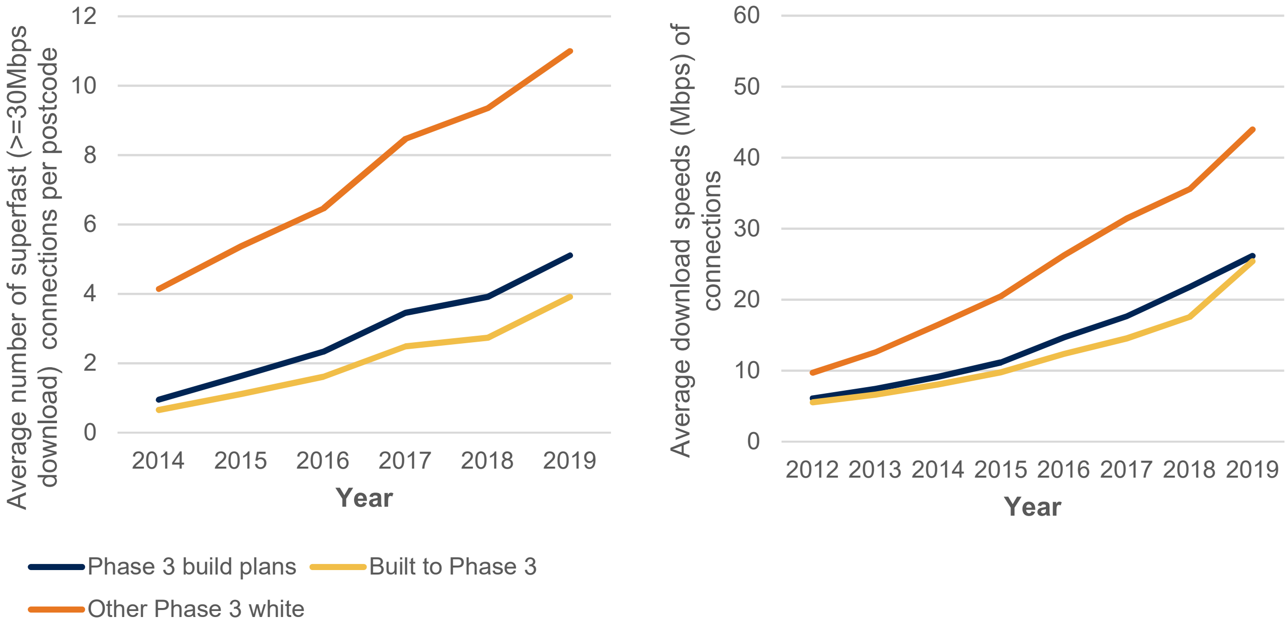
There was little evidence of material changes in take-up measures in the programme area relative to other white postcodes by September 2019:

- **Number of superfast (30Mbps) connections:** The average number of superfast connections on postcodes in the build plans of Phase 3 schemes more than doubled between 2016 to 2019 (121 percent increase from 2.3 to 5.1). Growth in the number of superfast connections rose slightly more rapidly (by 143 percent) on postcodes receiving subsidised coverage by 2019. Demand for superfast connections also rose on other white postcodes not included in the build plans of Phase 3 schemes, with the number of superfast connections rising by 71 percent on these postcodes over the same period.

- **Average download speeds:** The average download speeds of connections on postcodes included in the build plans of Phase 3 contracts rose from 14.7 Mbps to 26.2 Mbps between 2016 and 2019 (78 percent). Average download speeds rose more rapidly on postcodes receiving subsidised coverage by September 2019 (106 percent). Growth in average download speeds was more rapid on postcodes that were not included in the build plans of Phase 3 schemes (115 percent) over the same period.

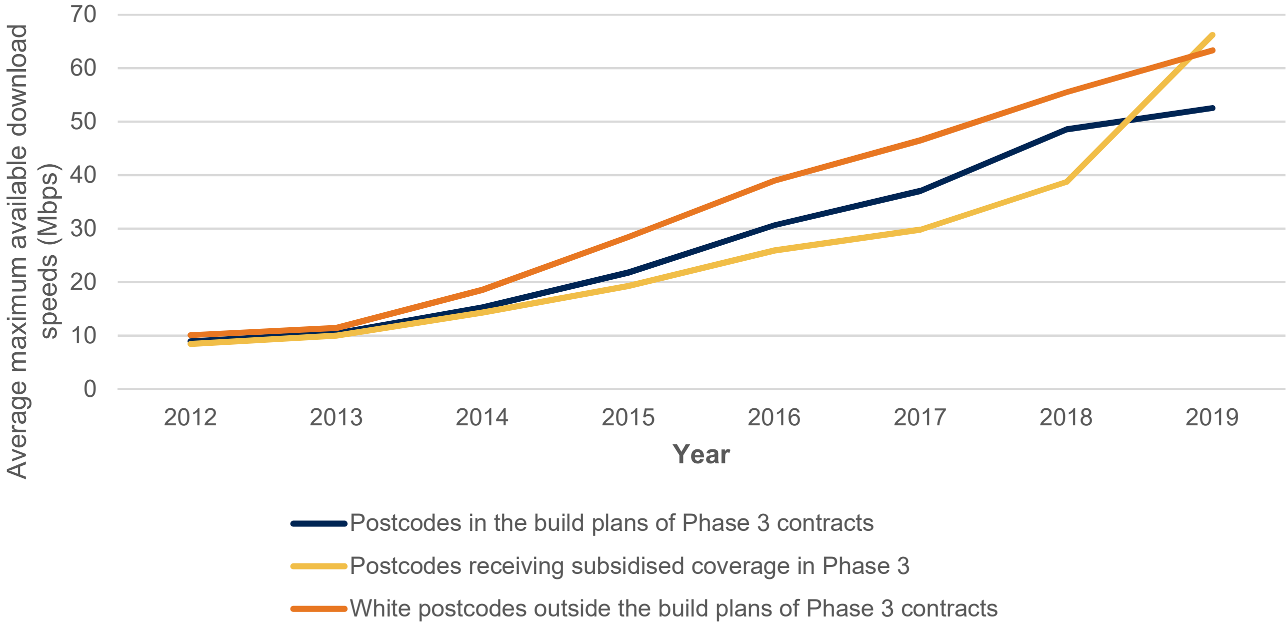
There were more marked differences in the maximum download speeds of connections (shown in Figure 3.7). Maximum downloads speeds on the postcodes included in the build plans of Phase 3 schemes rose at a similar rate to those on other white postcodes. However, maximum download speeds rose most rapidly in those areas that had received subsidised coverage by September 2019 (reaching an average of 66 Mbps in September 2019). This evidence suggests that early adopters may be taking advantage of the faster speeds made available through FTTP (the availability of which was more widespread in these areas in 2019).

Figure 3.7: Number of superfast (30Mbps) connections and average download speeds of connections – areas in Phase 3 build plans and other white postcodes, 2012 to 2019



Source: C3 reports, Ofcom Connected Nations, Ipsos MORI analysis[20].

Figure 3.8: Maximum download speeds of connections, areas in Phase 3 build plans and other white postcodes, 2012 to 2019



Source: C3 reports, Ofcom Connected Nations, Ipsos MORI analysis.

[20] Data on superfast connections only available from 201 onwards in Ofcom Connected Nations data

4 Phase 3 connectivity impacts

This section provides an assessment of the impact of Phase 3 contracts on the connectivity outcomes by September 2019. The methodology for this analysis builds on the approaches defined in the State aid evaluation plan for the programme.

4.1 Data

The data utilised in the analysis set out in this paper was derived from a variety of sources. The table below provides an overview of the datasets used. A more detailed review, covering the processing steps and issues relating to comprehensiveness and quality, is provided in Annex A.

Table 4.1: Datasets used in the analysis

Dataset	Description
Connected Nations (Ofcom)	Ofcom's Connection Nations report provided the evidence on the key outcomes of interest for the analysis including broadband availability and average download speeds at a postcode level (which gives an indication of take-up of available speeds) between 2012 and 2019. The data provided a snapshot of local connectivity in June of each year up to and including the 2016 release. The 2017 release provided a snapshot in May of that year and the 2018 and 2019 releases providing a snapshot for September.
ThinkBroadband	ThinkBroadband is an independent organisation that collects information about broadband coverage in the UK. ThinkBroadband made data on broadband coverage by supplier (stating which suppliers offer broadband services) by postcode. The data was made available for the years 2012, 2016, and 2020.
Speed and Coverage Templates (SCTs)	Details of eligible ('white') postcodes and the postcodes included in the build plans of local schemes are generally captured within Speed and Coverage Templates (SCTs) that are completed by providers as part of the tendering exercise. BDUK supplied Ipsos MORI with all available SCTs, which covered almost all local schemes that had been contracted under Phase 1, 2 and 3 by September 2019.
C3 reports	Claimed delivery of premises upgraded 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 September 2019 gave details of some 6.3m premises that were claimed to have been upgraded by providers.
Network infrastructure	BDUK supplied a range of other data describing the pre-programme characteristics of postcodes in the UK which served as control variables for the analysis. These primarily described the characteristics of local networks in 2013 in terms of factors likely to influence the costs of upgrading serving cabinets or the final speeds attained.
Area level characteristics	Measures of local population density, the size of the working age population and population aged 65 percent were taken from the 2011 Census. Measures of gross weekly earnings, unemployment, and employment were derived from the Annual Survey Hours and Earnings and the Annual Population Survey respectively.
GBVS and LFFN	BDUK made available details of the delivery of the Gigabit Voucher Scheme and Wave One LFFN projects. This allowed the analysis to control for the possible influence of these parallel schemes in the analysis.

4.2 Evaluation design issues

4.2.1 Key outcomes

The key outcomes of interest for the following analysis are summarised in the following table. The outcomes cover a mix of supply and demand side variables. More details on how these variables are measured is provided in the appendix.

Table 4.2: Key outcomes

Outcome	Overview
NGA coverage	The percentage of premises able to access broadband through NGA technologies – wireless, FTTC, FTTP and Wireless. This the primary outcome measure defined for the evaluation in the State aid evaluation plan agreed between DCMS and the European Commission.
Superfast coverage	The percentage of premises able to access speeds of 30Mbps. NGA technologies are capable of delivering superfast speeds but will not always do so (for example, if the premises is too far from the cabinet). This measure more closely aligns with the objectives of the programme.
FTTP coverage	Phase 3 of the programme prioritised technologies capable of delivering Gigabit per second speeds which has concentrated investment in FTTP delivery.
Number of network providers	The State aid evaluation plan defines the programme's effect on the number of network providers active on a postcode as key aspect of interest in assessing the impact of the programme on the market.
Number of connections of 30Mbps or higher	The number of households or businesses taking up a 30Mbps connection is a primary outcome measure defined in the State aid evaluation plan agreed between DCMS and the European Commission.
Average download speed of connections	The average download speed of connections is a secondary outcome measure describing the effect of the programme on actual speeds used by households and businesses.
Maximum download speed of connections	This describes the maximum capacity of the connection taken by households or businesses and is a secondary outcome measure describing how the connectivity made available through the programme is used.
Average upload speed of connections	The average upload speed of connections is a secondary outcome measure describing the effect of the programme on actual speeds used by households and businesses.

4.2.2 Definition of the treatment and comparison group

A credible assessment of the impact of the Superfast Broadband programme requires the selection of appropriate comparison group of postcodes or areas that did not receive BDUK investment, to enable an assessment of what may have happened in the absence of the programme. This is problematic for the following reasons:

- **Targeting at white areas**: Investment was targeted at white premises where commercial operators claimed they had no plans to roll-out superfast broadband coverage without public subsidies. As such, 'grey' and 'black' premises or postcodes are unlikely provide a suitable counterfactual as they had been deemed commercially viable, and therefore were more likely to have received superfast coverage in the absence of the programme. The inclusion of these areas in a comparison group would understate the impact of the programme. Drawing the comparison group from the population of postcodes that were deemed 'white' in the OMRs but were not included in the build plans of Phase 3 schemes helps ameliorate this problem.

- **Supplier choice:** However, selecting the comparison group from white postcodes not included in build plans does have some caveats. Suppliers were largely free to choose which white premises were targeted from those identified in the OMR. It is reasonable to assume that suppliers selected those locations that were most commercially viable to maximise their returns. In Phases 1 and 2, suppliers appeared to seek to minimise the net costs of delivering the contract, though in Phase 3 other factors (such as existing penetration of NGA networks and the presence of competitors) appeared to be significant. White postcodes not included in the build plans of Phase 3 schemes are likely to differ in systematic ways to those that benefit from subsidised upgrades, and in ways that may be correlated with the outcomes of interest. Those premises in white areas that did not benefit from BDUK investment may have been the hardest to upgrade profitably, and the least likely to have received superfast coverage in the absence of the programme. Basic comparisons between areas benefitting from the programme and other white postcodes will likely overstate the impact of the programme. Addressing these issues requires the selection of appropriate analytical methods that control for both observable and unobservable differences between these two groups of areas.

- **Crowding out:** If there are potential limits to the level of resources that suppliers can bring to bear in the delivery of the programme, resulting from either availability of skilled labour or, for smaller suppliers, credit market constraints, then the delivery of the superfast programme may have had negative impacts outside of white areas. As such, there is a risk of upward bias in any estimates of the impact of the programme on infrastructure that draw on areas that did not receive BDUK investment, since superfast coverage would have otherwise been higher in the comparison group.

The State aid evaluation plan defines the treatment and comparison groups to be used in the analysis. The former is defined as postcodes that have been included in Phase 3 build plans and had at least one premise upgraded by the end of September 2019[21]. While this approach enables an assessment of the effects of the programme that have benefitted from subsidised upgrades, this also introduces possible biases driven by unobserved differences between those areas that have benefitted from early delivery and those benefitting at a later stage. Such an approach will also fail to capture the effects of the programme (e.g. in terms of delaying superfast rollout) on areas that were yet to benefit from subsidised upgrades. To address this, all analyses have also been completed using an expanded definition of the treatment group to include all postcodes within build plans for Phase 3.

Given these complexities, several methods have been applied to explore the effects of the programme which are outlined in detail below (including the methods identified in the State aid evaluation plan and some additional methods deployed to enhance the robustness of those results).

4.3 Simple difference-in-differences

As described in the State aid evaluation plan, a simple difference-in-difference approach was deployed to establish an estimate of the change in broadband availability takes the before-and-after weighted[22] mean of the outcomes of interest for the analysis (i.e. the percentage of premises with NGA, superfast and FTTP coverage) for both the control and treatment groups to give the change in coverage in NGA white areas due to intervention.

$$\Delta outcome_{intervention1619} = (outcome_{T19} - outcome_{T16}) - (outcome_{C19} - outcome_{C1}\ )$$

The percentage change in coverage between 2016[23] and 2019 attributable to the programme is equal to the difference in outcomes in 2019 and 2016 for postcodes benefitting from the programme $(outcome_{T19} - outcome_{T16})$ and the comparison group of postcodes that were eligible in Phase 3 but not included in build plans $(outcome_{C19} - outcome_{C1}\ )$[24].

The difference-in-difference model is robust to time invariant but unobserved differences between postcodes that could bias results. However, estimates may be biased by unobserved but time varying differences between areas (the ‘parallel trends’ assumption). As noted in the preceding section, trends in coverage in those areas included in Phase 3 build plans diverged substantially from those in other white

[21] Note that the state aid plan sets out June 2020. This was the date at which Ofcom data was expected to be made available for 2020 when the plan was approved. The release dates of Ofcom data have since changed to December of the relevant year and now provide a snapshot as of September of that year.
[22] Weighted by total premises per postcode
[23] This is 2017 for FTTP given lack of inclusion of this variable in the 2016 Connected Nations data
[24] Note that T subscript denotes the Treatment Group, and the C subscript denotes the Control Group.

postcodes. As such, the results provided below are presented as a reference case for more robust methods explored below.

The simple difference-in-difference analysis showed:

- **Postcodes benefitting from subsidised upgrades:** These models indicated that the Phase 3 increased the percentage of premises covered by NGA, superfast and FTTP by 11, 25 and 28 percentage points respectively on postcodes that had benefitted from subsidised coverage by September 2019. In terms of take-up measures, the programme was associated with small negative impacts on the number of superfast connections, though effects on the maximum download speeds of connections were positive (around 16Mbps on average). This is consistent with patterns identified in the previous section, that suggested that the programmes effects on FTTP coverage have encouraged early adopters to access faster connections though impacts on volume take-up measures are not yet visible.
- **Postcodes in Phase 3 build plans:** As might be expected given the small share of planned Phase 3 delivery that had been brought forward by September 2019, the estimated impacts were substantially smaller when the models were applied to all postcodes in the build plans of Phase 3 schemes. The estimated impacts on the percentage premises covered by NGA, superfast, and FTTP were 3.1, 6.1 and 3.5 percentage points respectively. Additionally, the estimated impact on all take-up measures were negative.

Table 4.3: Estimated impact of Phase 3 schemes on coverage and take-up, simple difference-in-difference results

	Change in outcome between 2016/17[25] & 2019			Change in outcome between 2016/17[26] & 2019		
Outcome	Other white postcodes	Treatment group	Estimated impact	Other white postcodes	Treatment group	Difference
Treatment group	Postcodes delivered to by September 2019			All postcodes in Phase 3 build plans		
			Coverage outcomes			
NGA availability (% of premises)	11.1	21.8	10.7	11.1	14.3	3.1
Superfast availability (% of premises)	13.8	39.0	25.2	13.8	19.9	6.1
FTTP availability (% of premises)	4.8	33.5	27.8	4.8	8.3	3.5
			Take-up outcomes			
Average download speeds of connections (Mbps)	17.0	15.0	-2.1	17.0	12.4	-4.6
Maximum download speeds of connections (Mbps)	35.9	52.7	16.9	35.9	25.0	-10.9
Average upload speeds of connections (Mbps)	4.3	8.2	3.9	4.7	4.3	0.4
Number of connections with download speed of 30Mbps+	6.1	3.7	-2.4	6.1	4.5	-1.6

Source: Ipsos MORI analysis; All differences statistically significant at the 99% confidence level

[25] 2017 for FTTP
[26] ibid

4.4 Regression based difference-in-differences

The specification defined in the State aid evaluation plan does not account for differences in the observable characteristics of areas, which could bias results. As highlighted above, suppliers were expected to prioritise those postcodes that could be made commercially viable with less subsidy. As a result, the findings in the preceding section could overstate the impact of the programme. An equivalent regression based difference-in-differences approach was also adopted that controlled for observable differences between postcodes using a vector of control variables as follows:

$$\Delta outcome_i = \beta_0 + \beta_1 TD + \boldsymbol{\beta x_i} + \epsilon_i$$

In this specification, the change in the outcome of interest between 2016 and 2019 for postcode i ($\Delta outcome_i$) is determined by a dummy variable, TD, (taking the value of 1 if the postcode was in the treatment group and 0 otherwise) in addition to a vector of control variables, $\boldsymbol{x_i}$ capturing the baseline characteristics of the postcodes and pre-programme trends in connectivity (presented below).

4.4.1 Control variables

The data available allowed us to consider the following characteristics of postcodes prior to the roll-out of the programme in 2013/14 and some coverage and take-up characteristics in 2016:

- **Connectivity in 2012 and 2016:** Pre-programme levels of connectivity were considered by including observations of NGA access in all years from 2012 to 2016. Superfast coverage from 2014 to 2016 was also included as a matching variable.

- **Competition:** The number of network providers operating in the postcode in 2012 and 2016. This inclusion was driven by the apparent tendency of Phase 3 suppliers to avoid areas where NGA penetration (and by implication depth of local competition) was higher.

- **Percentage of postcodes in the LA and the Output Area with NGA access in 2012 and 2013:** In Phase 3, the data suggested that suppliers tended to avoid postcodes with high levels of NGA penetration. The expectation was that postcodes located in areas with local authorities and neighbourhoods with low NGA coverage in 2012 and 2013 would have been more likely to have been included within the build plans of local schemes, on the assumption that the Open Market Review process was effective in revealing the commercial plans of providers.

- **Line length from the exchange to the cabinet to the postcode in 2013:** The length of the line between the serving exchange and the postcode will partly determine the costs associated with enabling superfast broadband speeds, with costs increasing with the overall length of the line. The expectation was that postcodes benefitting from BDUK investment would be associated with longer line lengths than 'grey' and 'black' postcodes, but shorter line lengths than white postcodes that were not included within the build plans of local schemes.

- **Number of premises with exchange only lines in 2013:** Premises that are connected directly to the exchange will cost more to enable with superfast broadband speeds as this requires the installation of a new cabinet. The prior expectation was that postcodes with a higher number of premises with exchange only lines would be less likely to be included within the build plans of local schemes owing to these additional costs.

- **Delivery points at the serving cabinet and the serving exchange:** The attractiveness of upgrading available broadband services to superfast speeds will also be linked to the number of premises that benefit from the upgrade. As such, it was anticipated those postcodes with fewer delivery points at the serving cabinet and exchange would be less commercially attractive and carry a lower likelihood of being included within the build plans of local schemes, relative to other white postcodes.

- **Whether the postcode was in the Virgin Media footprint in 2013:** Data was made available on whether the postcode was within the Virgin Media footprint in 2013. The availability of Virgin Media at a postcode could reduce the likelihood that it was included in local schemes – signalling the presence of a competitor and reducing the commercial benefits associated with providing upgraded services. However, when comparing white postcodes, where Virgin Media may have had no immediate plans to roll out superfast broadband services, competing providers may see an attraction in providing superfast to the postcodes to enable them to gain a competitive advantage, increasing the likelihood that the postcode was included in the build plans for local schemes.

- **Estimated cost to upgrade the serving cabinet or exchange only lines:** BDUK developed estimates of the cost of upgrading the cabinets or exchange only lines in 2013 to support the resource allocation process. The expectation was that those cabinets with higher predicted upgrade costs (or higher upgrade costs per premises upgraded) would be less likely to be included within the build plans for local schemes (or at least those that involved higher upgrade costs per premises upgraded).

- **Population density:** The likelihood that a postcode was upgraded was also thought to be linked to the density of the local population, with denser eligible areas the most likely to be included within the build plans of local schemes. This was measured using information from the 2011 Census describing the size of the resident population at an Output Area level.

- **Age of population:** The size of the resident population of working age and aged 65 and over was included to provide measures of overall potential demand for superfast broadband services.

- **Other factors influencing demand:** Demand for superfast broadband services was also assumed to be linked to the characteristics of the local economy. Information on gross weekly earnings, employment rates and unemployment rates was included to provide these types of measure.

- **GBVS and LFFN:** A supplementary set of analyses were also undertaken to control for the delivery of parallel programmes that may have also contributed to changes in connectivity locally. This included controls for the number of GBVS vouchers awarded to upgrade other premises in the relevant output area to FTTP, and proximity to the fibre rings or public sector buildings upgraded by Wave One LFFN pilot projects[27]. It should be noted that there are other BDUK (e.g. Wave 2 and 3 LFFN pilots) and locally funded programmes (e.g. broadband voucher schemes administered by Local Enterprise Partnerships) that could produce similar results to the Superfast Broadband programme. Data on the delivery of these schemes could not be compiled for the purposes of this study (and as such, there is a residual risk that some outcomes attributed to the Superfast Broadband programme were the results of parallel programmes).

[27] These controls took the form of dummy variables denoting whether or not a postcode was located within 50m, 100m, 500m or 1km of a GBVS voucher or an LFFN intervention area (in turn defined as a postcode within 1km of planned LFFN build).

4.4.2 Results

The results using a regression approach are presented in Table 4.3 below. The results of models without control variables were identical to those obtained using simple differences-in-differences. Controlling for the pre-programme characteristics of postcodes led to smaller estimates of the impact of the programme, suggesting that the results of the simple difference-in-difference analyses were biased upwards (as expected):

- **Coverage on postcodes benefitting from subsidised upgrades:** The results suggested that the Phase 3 schemes increased the share of premises covered by NGA, superfast and FTTP by 2.6, 10.4, and 24.4 percentage points respectively (in those postcodes benefitting from subsidised upgrades by September 2019). These results indicate the programme has increased superfast coverage in some areas and had an important effect on the quality of infrastructure in others – the results imply 13 percent[28] of premises would have otherwise received superfast made available through inferior technologies to FTTP.

- **Coverage on all postcodes in the build plans of Phase 3 SCTs:** The findings also indicated that the programme had a negative overall effect on NGA and superfast coverage across all postcodes in the build plans of Phase 3 SCTs. This would indicate that the programme has worked to delay superfast coverage in some areas included in the scope of Phase 3 schemes.

- **Competition:** The models were consistent in suggesting that the programme had a positive effect on the number of network providers operating in the postcodes of interest. The results indicated that that the network providers increased by 0.1 to 0.2 on average (depending on whether the focus is on postcodes benefitting from subsidised upgrades or all postcodes in the build plans of Phase 3 schemes). This indicates that Phase 3 has worked to promote greater levels of competition.

- **Speeds and take-up:** However, the results indicated that the programme had a negative impact on take-up of superfast connections (regardless of whether the focus is on postcodes benefitting from subsidised upgrades or all postcodes in the build plans of Phase 3 schemes). This could be explained by the delays with the delivery of the programme. Subsidised superfast coverage has not come forward as rapidly as originally anticipated. This may have delayed access to superfast services for those consumers that would have benefitted from superfast coverage in the absence of the programme.

The addition of controls for the GBVS and LFFN did not materially alter the estimated impacts, indicating that the estimated impacts are not confounded by the delivery of parallel schemes. Additionally, most models were estimated using Ordinary Least Squares. This could produce biased results for those outcomes that were bounded at zero and one (e.g. NGA availability cannot exceed 100 percent and cannot fall below zero percent). Robustness checks were completed by estimating models (Model 4 and Model 8) with a Tobit specification that allowed for censoring at 0 and 100. Results from these models did not suggest that OLS was biased in this case. The following table summarises the results of these analyses. The full results of the regressions (including coefficients associated with control variables) are provided in the statistical annex (Annex D).

[28] I.e. 24.4 minus 10.4.

Table 4.4: Estimated impact of Phase 3 schemes on coverage and take-up, regression based difference-in-difference results

Outcome	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Treatment postcodes	Postcodes delivered to by Sep. 2019				All postcodes in Phase 3 build plans			
Modelling approach	OLS	OLS	OLS	Tobit	OLS	OLS	OLS	Tobit
Postcode controls	No	Yes	Yes	Yes	No	Yes	Yes	Yes
LFFN/GBVS controls	No	No	Yes	Yes	No	No	Yes	Yes
Number of observations	60,597	21,479	21,479	21,479	118,454	109,964	109,964	109,964
Adjusted R-squared	0.0108	0.7014	0.7016	0.5742	0.0020	0.6092	0.6094	0.4962
Coverage outcomes								
NGA availability (% of premises)	10.7	2.6	2.6	2.1	3.1	-1.8	-1.8	-1.9
Superfast availability (% of premises)	25.2	10.4	10.5	10.2	6.1	-3.2	-3.1	-3.4
FTTP availability (% of premises)	28.7	24.1	24.4	24.3	3.5	1.6	1.6	1.4
Number of network providers	0.2	0.2	0.2	n/a	0.0	0.1	0.1	n/a
Take-up outcomes								
Average download speeds of connections (Mbps)	-2.1	-1.4	-1.5	n/a	-4.6	-2.0	-2.0	n/a
Maximum download speeds of connections (Mbps)	16.9	6.2	6.2	n/a	-10.9	-4.0	-4.1	n/a
Average upload speeds of connections (Mbps)	3.9	0.9	0.9	n/a	0.4	-0.2*	-0.2*	n/a
Number of connections with download speed of 30Mbps+	-2.4	-1.1	-1.1	n/a	-1.6	-0.9	-0.9	n/a

*Source: Ipsos MORI analysis; All coefficients significant at the 99% confidence level unless marked with *.*

4.5 Difference-in-difference with matched samples

The preceding set of analyses controlled for observable differences between the areas benefitting from the programme. These analyses were refined further by selecting a comparison group of white postcodes that were observationally equivalent to those included in the build plans of Phase 3 schemes. This was achieved using a propensity score matching (PSM) matching approach. This involved matching postcodes in the treatment and control groups based upon their characteristics in the years before 2016. This was implemented by:

- Developing statistical models that compared the characteristics of white postcodes that were and were not included in the build plans of local schemes and predict the likelihood that each postcode was included in a scheme.
- White postcodes that were not included in the build plans of Phase 3 schemes – but shared a similar predicted likelihood of being included to those postcodes that were addressed by those build plans - were considered to be 'matched' and formed part of the comparison group.
- Postcodes that did not feature in the build plans of local schemes and did not share a similar likelihood of inclusion within the build plan of a local scheme were dropped from the sample, and did not form part of the comparison group.

4.5.1 Control variables

This approach offers an unbiased estimate of the impact of the programme if it is possible to control for all factors that influenced the inclusion of a postcode within the build plan of a Phase 3 scheme. Postcodes were matched on the same vector of control variables described in subsection 4.4.1.

As noted, a matching approach will only be effective in providing an unbiased assessment of the impact of the programme if these characteristics described above capture all factors that could influence both the selection of postcodes into BDUK funded schemes and the likelihood that they will receive enhanced broadband connectivity. There also will be other factors influencing the cost of installation that are not captured in the above, e.g. local topography. Additionally, there are potentially unobserved features of postcodes that may be correlated with both their inclusion in the programme and the likelihood that superfast broadband coverage would have come forward without public subsidy.

4.5.2 Matching models

Propensity scores were generated by applying a probit model that sought to explain the likelihood a given postcode was included in the build plan of a Phase 3 scheme on the vector of control variables described in subsection 4.4.1 above[29]. These models were estimated with and without controls for the average and maximum downloads speeds of connections (owing to the large amount of missing data on these variables for 2012 and 2013).

The results of the probit models associated with the two selected matching models are set out in Table 7.4 in Annex B and largely confirmed expectations regarding how the observable characteristics of postcodes would influence their inclusion within local schemes. There was a relatively high degree of consistency in the direction and size of the estimated coefficients when information on historic average download speeds was also included as a matching variable.

However, the available data did not explain a high share of the variance in the decisions made by tenderers to include postcodes in the build plans of Phase 3 schemes (9 to 13 percent). This rose to 18 and 20 percent when restricting the analysis to those postcodes benefitting from subsidised upgrades by September 2019. This does indicate there may be unobserved factors (e.g. topography or planning constraints) that have influenced suppliers' decisions on which postcodes to target. The degree to which this is consequential will depend on how far those factors are correlated with the outcomes of interest.

4.5.3 Quality of the matched sample

Matching was completed using a nearest neighbour technique in which each postcode in the build plans of Phase 3 schemes were matched to the postcode in the comparison sample with the closest propensity score[30]. Common support was imposed by dropping any postcode from the comparison sample that had a propensity score that was higher than the highest – or lower than the lowest – propensity score associated with postcodes included within the build plans of Phase 3 schemes. Individual postcodes in the comparison sample could form a match with multiple postcodes that received BDUK subsidies.

An overview of the resultant matched samples is provided in Table 4.4 below. The matching approach reduced the mean standardised bias (the average percentage differences in the characteristics of the treatment and the comparison sample) to between 1.4 and 4.2 percent (from between 11.4 and 30.2).

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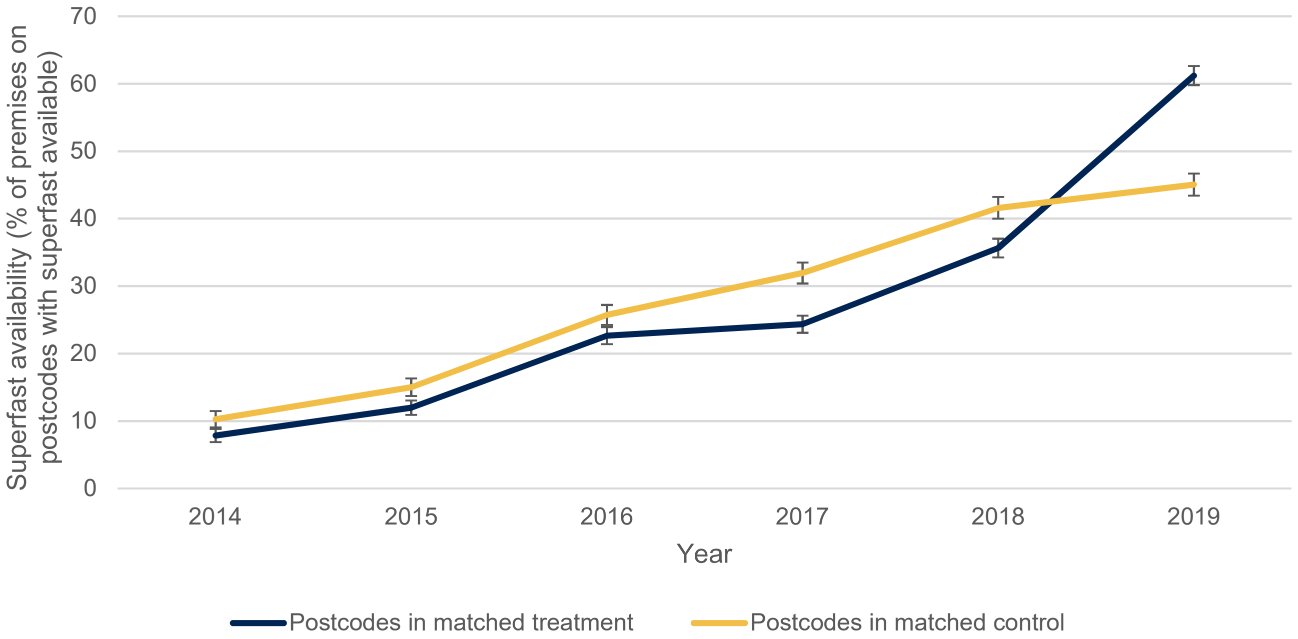
[29] The model took the form: $\Delta outcome_i = \beta_0 + \beta_1 TD + \boldsymbol{\beta x_i} + \epsilon_i$

[30] This took the form of a Probit model: Pr(Yi = 1|Xi) = $\phi(Xi\beta)$. In this model, Y is a binary indicator describing whether postcode i was included within the build plan of a local scheme (1 = yes, and 0 = no) and X is a vector of factors describing the characteristics of the postcode that are thought to influence its inclusion in the scheme.

There were limited significant differences between the treatment and comparison samples on most characteristics included in the matching models, however the models were not fully effective in eliminating all observable differences between the treatment and comparison samples. The models tended to produce a comparison sample with a larger number of delivery points in the serving exchange and in the serving cabinet.

As illustrated in the table below, there were very few postcodes dropped from the matching implying that the postcodes within each of the groups were relatively similar overall. The models including take-up and speed outcomes as controls performed more effectively with fewer dropped postcodes in the treatment group. The figure below uses the matched samples produced from the first model in Table 4.4 below to plot the evolution in superfast availability in matched areas over time. This indicates an apparent delaying effect in the programme area between 2016 and 2018 relative to the comparison area, though with a substantial increase in coverage in 2019 (correlating with the increase in the delivery of Phase 3 observed in Section 3).

Figure 4.1: Evolution of superfast availability, matched samples 2014 to 2019



Source: Ipsos MORI analysis

Table 4.5: Overview of Characteristics of Matched Samples

Treatment group	Postcodes delivered to by September 2019						Postcodes in the build plans of Phase 3 schemes					
Controls included	No speed controls			Speed controls included			No speed controls			Speed controls included		
No. of treated postcodes in matched sample	8,832			3,578			62,627			25,117		
Number of unmatched postcodes	73			39			160			84		
Mean standardized bias (pre-match)	30.2			20.6			23.3			11.4		
Mean standardized bias (post-match)	4.2			3.1			1.5			1.4		
Variable	Treated	Control	Sig.	Treated	Control	Sig.	Treated	Control	Sig.	Treated	Control	Sig.
Number of suppliers in postcode (2012)	2.14	2.18	*	2.25	2.28		2.37	2.39	**	2.41	2.43	**
Number of suppliers in postcode (2016)	2.35	2.38	*	2.44	2.46		2.43	2.43		2.47	2.47	
Superfast % of premises (2014)	7.85	7.99		6.60	6.50		11.57	11.05	**	9.68	9.28	*
Superfast % of premises (2015)	11.97	12.92	*	12.90	12.29		18.50	17.27	***	20.56	19.23	***
Superfast % of premises (2016)	22.67	25.90	***	25.23	24.42		28.40	27.47	***	33.34	32.15	**
NGA % or premises (2012)	0.16	0.17	**	0.14	0.15		0.16	0.16	*	0.12	0.12	
NGA % or premises (2013)	0.25	0.30	**	0.23	0.27	***	0.25	0.26	***	0.20	0.21	**
NGA % or premises (2014)	0.33	0.37	***	0.32	0.36	***	0.34	0.34	*	0.31	0.32	*
NGA % or premises (2015)	0.59	0.61	***	0.60	0.60		0.65	0.66	**	0.66	0.67	*
NGA % or premises (2016)	0.70	0.73	**	0.70	0.72	*	0.74	0.74		0.75	0.75	
% of postcodes in LA with NGA, (2013)	0.39	0.40	***	0.40	0.40		0.41	0.41	*	0.40	0.40	
% of postcodes in LSOA with NGA, (2013)	0.28	0.31	***	0.27	0.30	**	0.27	0.28	**	0.23	0.24	*
Line Length (m)	7.98	7.98		7.90	7.94	*	7.92	7.91		7.78	7.80	
Final speed	6.47	6.34		6.88	6.86		6.72	6.87	***	7.26	7.35	*
Premises with EO lines 2013	2.27	2.21		3.64	3.40		2.25	2.35	*	3.75	3.81	
Delivery points at serving exchange	6655.10	7615.50	***	6643.20	7496.20	***	6412.70	6505.70	*	6005.40	6127.20	
Delivery points at serving cabinet	215.91	227.50	***	233.75	251.44	***	249.81	250.56		267.63	269.02	
Virgin Media availability	0.00	0.00		0.00	0.00		0.01	0.01	*	0.00	0.00	
Estimated Upgrade Cost (£)	65519	66026		67349	68004		67571	67281	*	68993	68599	
Cost Per Premises Upgraded	351.57	341.75		327.02	309.84	*	333.43	331.48		284.93	275.31	**
Working Age Population	198.07	201.21	**	198.10	204.02	**	176.86	179.97	***	176.25	180.44	***
Population Aged 65 and Over	65.15	67.02	***	65.72	65.40		57.49	58.23	***	58.55	59.93	***
(Log) Population Density	4.30	4.36	*	4.66	4.66		4.53	4.54		4.99	4.98	
(Log) Premises Density	3.73	3.81	*	4.07	4.08		3.98	3.99		4.42	4.42	

Gross Weekly Wages (in LA)	496.17	492.14	***	500.52	498.95		503.69	502.96	*	502.94	500.61	**
Employment Rate (in LA)	74.60	74.52		74.64	74.55		74.23	74.33	**	73.95	74.10	**
Unemployment Rate (in LA)	6.16	6.00	***	6.14	6.01	*	6.38	6.30	***	6.45	6.39	*
Number of premises with superfast available (2014)	1.64	1.60	***	1.50	1.46		2.55	2.42	**	2.32	2.24	
Number of premises with superfast available (2015)	2.32	2.33		2.96	2.85		3.79	3.52	***	4.97	4.75	
Number of premises with superfast available (2016)	3.87	4.05		5.48	5.18		5.42	5.21	**	7.77	7.58	
Number of superfast connections (2016)				1.12	0.98	*				1.63	1.60	*
Number of superfast connections (2015)				0.64	0.59					0.92	0.91	
Number of superfast connections (2014)				0.23	0.23					0.29	0.29	
Average Download Speeds (2012)				5.09	5.10					5.56	5.54	
Maximum Download Speeds (2012)				8.29	8.22					8.97	8.98	
Average Download Speeds (2013)				5.64	5.67					6.23	6.23	
Maximum Download Speeds (2013)				9.78	9.95					10.47	10.58	*
Average Download Speeds (2014)				6.86	6.91					7.66	7.69	
Maximum Download Speeds (2014)				14.19	14.54					15.70	15.92	
Average Download Speeds (2015)				8.40	8.30					9.58	9.59	
Maximum Download Speeds (2015)				18.72	18.54					22.06	22.08	
Average Download Speeds (2016)				10.86	10.39	**				12.82	12.83	
Maximum Download Speeds (2016)				24.86	23.74					30.25	30.38	
Average Upload Speeds (2014)				0.87	0.85					0.95	0.95	
Average Upload Speeds (2015)				0.87	0.85					0.95	0.95	
Average Upload Speeds (2016)				1.52	1.50					1.77	1.73	**

*Source: Ofcom Connected Nations, C3 Reports, SCTs, Ipsos MORI analysis; *** represents differences significant at 99 percent, ** at 95 percent and * at 90 percent*

4.5.4 Results

As noted above, the results of matching models are only robust to the degree that that can account for all observable factors that influenced the selection of postcodes into the build plans of Phase 3 schemes. To account for unobserved (but time invariant) differences between the matched treatment and comparison group, the matched samples generated above were used to implement the difference-in-difference models described in subsection 4.3. The key results are set out in Table 4.5 below (full regression tables are provided in Annex E). However, there was very little difference in the estimated results to those associated with the difference-in-difference models described above.

Table 4.6: Estimated impact of Phase 3 schemes on coverage and take-up, regression based difference-in-difference results

Treatment postcodes	Model 9 Postcodes delivered to by September 2019	Model 10 Postcodes in the build plans of Phase 3 schemes
Model specification	OLS	OLS
Postcode Controls	Yes	Yes
LFFN/GBVS Controls	Yes	Yes
Matched Sample	Yes	Yes
Number of observations	5,980 to 14,851	34,073 to 87,110
Adjusted R-squared	0.014 to 0.352	0.001 to 0.597
Coverage outcomes		
NGA availability (% of premises)	2.7	-1.9
Superfast availability (% of premises)	10.6	-3.2
FTTP availability (% of premises)	25.0	1.7
Number of network providers	0.2	0.1
Take-up outcomes		
Average download speeds of connections (Mbps)	-1.2	-2.0
Maximum download speeds of connections (Mbps)	7.7	-4.3
Average upload speeds of connections (Mbps)	1.0	-0.1*
Number of connections with download speed of 30Mbps+	-1.3	-0.8

*Source: Ipsos MORI analysis; All coefficients significant at 99 percent confidence level unless marked **

4.6 Longitudinal panel models

The difference-in-difference models outlined in subsections 4.4 and 4.5 account for observed differences between postcodes included in the build plans of Phase 3 schemes and the comparison group of other white postcodes. The models also account for unobserved but time invariant differences between the two groups. A final set of supplementary set of analyses were developed to probe the robustness of the results further by accounting for unobserved but time specific shocks that could affect all areas (the COVID-19 pandemic could be an example of this, if it prompted consumers to upgrade their connections to enable remote working).

This was achieved by exploiting the longitudinal nature of the data available using the following panel model specification:

$$outcome_{it} = \beta_0 + \beta_1 CP_{it} + \theta t + \alpha_i + \gamma_t \ + \epsilon_i$$

Here, the outcome for postcode i in year t is determined by the cumulative number of premises upgraded in the area by year t (CP_{it}) with the effect given by β_1. This model allows for the inclusion of both entity fixed effects ($\boldsymbol{\alpha_i}$) which account for any time invariant observed and unobserved characteristics of postcodes as well as time fixed effects (γ_t) that account for any time specific shocks influencing connectivity or take-up across all areas. In addition, the equation includes time trends at the national level (t).

The specification of these models captures the relationship between the timing of subsidised upgrades and changes in coverage. As such, the results can be compared to those preceding analyses focusing on areas that benefitted from subsidised coverage but not to those that explore the impact of the programme on all postcodes included in the build plans of Phase 3 schemes. The apparent effects of Phase 3 in delaying the availability of superfast coverage for some premises is explored in more detail in the following chapter.

The comparison group for these analyses comprises of postcodes that were eligible for Phase 3 funding but weren't upgraded by September 2019. In addition, postcodes updated in later years form a part of the control group for those upgraded in earlier years with them switching to the treatment group in the year the postcode was upgraded.

4.6.1 Results

Table 4.6 below outlines the findings of the analyses. The definition of the treatment variable differs to those employed in the preceding analyses (which used a dummy variable classifying whether the postcode was upgraded or not). As results, the regression coefficients are not directly comparable – effects are expressed as the average effect per premises upgraded per postcode. The findings indicated:

- **NGA, superfast and FTTP availability:** As with other models, the panel models showed that NGA, superfast and FTTP increased in response to the delivery of subsidised coverage. For each premises upgraded, the number of premises with NGA, superfast and FTTP availability rose by 0.41, 0.49 and 0.39 respectively. These results did not vary substantially when models were augmented to control for time-specific shocks affecting all areas, national trends and the delivery of parallel programmes. The findings can be interpreted as a direct measure of additionality (i.e. the share of premises upgraded that would not have had enhanced coverage in the absence of the programme).

- **Number of network providers:** The panel models found that for each premises upgraded an additional 0.02 suppliers were operating on the postcode implying an increase in local competition. These findings were again robust to time-specific shocks affecting all areas, national trends and the delivery of parallel programmes.

- **Take-up:** The results showed a similar pattern of findings for take-up measures as preceding analyses. These findings indicated that the programme had a small negative effect on the number of superfast connections (-0.01 per premises upgraded). However, for each premise upgraded on a postcode, average speeds taken up increase by a negligible amount whilst maximum speeds rose between 1.3 and 2.5 Mbps.

Table 4.7: Estimated impact of subsidised coverage on superfast availability and take-up – Phase 3 2016 to 2019

Outcome	Model 11	Model 12	Model 13	Model 14	Model 15
Type	FE	FE	FE	FE	Tobit
Postcodes included			All white postcodes		
Time fixed effects	No	Yes	Yes	Yes	Yes
Time trends	No	No	Yes	Yes	Yes
GBVS controls	No	No	No	Yes	Yes
Number of observations	355,008 to 947,672	355,008 to 947,672	355,008 to 947,672	355,008 to 947,672	355,008 to 947,672
Adjusted R-squared	0.029 to 0.121	0.805 to 0.244	0.105 to 0.244	0.081 to 0.243	0.101 to 0.347
Coverage outcomes (effects per premise upgraded per postcode)					
Number of premises with NGA access	0.41	0.25	0.25	0.26	0.21
Number of premises with superfast access	0.49	0.38	0.38	0.38	0.37
Number of premises with FTTP availability	0.39	0.37	0.37	0.37	0.35
Number of network providers	0.02	0.02	0.02	0.02	0.02
Take-up outcomes (effects per premise upgraded per postcode)					
Average download speed of connections (Mbps)	0.58	0.06	0.06	0.06	0.06
Maximum available speed of connections (Mbps)	2.52	1.47	1.47	1.47	1.45
Average upload speeds of connections (Mbps)	0.34	0.22	0.22	0.22	-
Number of superfast connections	0.09	-0.01	-0.01	-0.01	-0.01

Source: Ipsos MORI analysis; All coefficients significant at 99 percent

4.7 Control group regression to predict counterfactual treatment group coverage

The second approach outlined in the state aid evaluation plan involves the application of regression techniques to the control group. This regression took the following form:

$$outcome2019_i = \beta_0 + \boldsymbol{\beta x_i} + \epsilon_i$$

Where, the i subscript denotes observation number i, β_0 is a constant, $\boldsymbol{x_i}$ is a vector of explanatory variables which are believed to influence the outcomes in an area, $\boldsymbol{\beta}$ is a vector of the regression coefficients for those explanatory variables, and ϵ_i is an error term. A logistic regression function was used for NGA availability whilst tobit models were used for outcomes bounded by 0 and 100 (the percentage of premises with superfast or FTTP coverage). A negative binomial function was utilised for the number of suppliers.

Details of the regression models are set out in the annex C. The fits of the models did vary with some models able to account for larger proportions of the variation in the outcomes than others. The models performed better at predicting the number of suppliers and the number of superfast enabled premises with high R squared statistics at 0.91 and 0.83 respectively (implying the models accounted for 91 percent and 83 percent of the variation in these outcomes). In terms of speed outcomes, the model predicting the maximum available speed for a postcode accounted for 70 percent of the variation. However, the remainder of the models had R squared statistics (or pseudo R squared) between 30 and 55 percent and would suggest that these models did not capture all the relevant independent variables required to predict the outcomes.

The regression coefficients are then applied to the treatment group postcodes to estimate what would have happened in the absence of the scheme (counterfactual). The difference between this estimated outcome and the actual observed outcome is then taken for the areas in the control group giving another estimate of the causal effect of the programme on the outcomes of interest.

4.7.1 Results

Application of the control group regression approach found largely similar results to the difference-in-difference with some exceptions where the treatment group comprised of only built to postcodes:

- **NGA, Superfast & FTTP % availability:** These results were very close to those presented in the difference in difference regression analysis above for these outcomes. The change in NGA coverage was marginally higher here at 3.5 percentage points compared to 2.7 whilst the change in superfast coverage was slightly lower at 9.9 percentage points compared to 10.6. Results for FTTP using this approach showed an additional 25.2 percentage points in FTTP coverage attributable to the programme in line with the DiD findings above.

- **Number of suppliers:** This approach also found that treatment postcodes had on average 0.2 more suppliers operating in them which is again consistent with prior findings presented above using a difference-in-difference approach.

- **Take-up outcomes:** Application of the control group regression approach identified similar effects on both maximum speeds and the number of superfast connections but found a small positive impact on the average speed of connections within treated postcodes[31].

The findings on both the percentage of premises on postcodes with superfast and FTTP availability outcomes in this approach are not consistent to the results directly exploring the number of premises superfast and FTTP enabled respectively. This is a weakness of this approach. Using all postcodes in build plans:

- **NGA, Superfast & FTTP % availability:** These results found negative levels of additionality for NGA and superfast coverage implying crowding out (and supporting the hypothesis that many of these postcodes would have seen some coverage come forward in the absence of the programme with this potentially delayed). The estimated level of additionality for FTTP delivery was also very low potentially reflecting the lack of delivery brought forward through Phase 3 to date.

- **Number of suppliers:** This approach found no significant differences between the estimated counterfactual number of suppliers in 2020 and actuals.

- **Take-up outcomes:** Differences were much smaller in this case compared to the models including only built to areas but still positive in terms of speeds taken.

[31] These results are contradictory to those obtained through difference-in-difference analysis and it is not clear why. These control group models should however be considered less robust in comparison to the panel models presented in subsection 5.6.

Table 4.8: Control group coverage regression results – Phase 3 in 2019

	Counterfactual	Actual	Difference	Counterfactual	Actual	Difference
Treated postcodes	Delivered as of Sep 2019			All in build plans		
Coverage outcomes:						
Change in % NGA availability	87.6	91.1	3.5***	90.1	87.3	-2.8**
Change in % SFB availability	50.8	60.7	9.9***	55.2	44.9	-10.3***
Change in % FTTP availability	10.2	35.4	25.2***	9.0	9.8	0.7*
Change in number of suppliers	2.4	2.6	0.2*	2.5	2.5	0.0
Change in superfast enabled premises	10.4	8.4	-2.1**	11.8	7.7	-4.1***
Change in FTTP enabled premises	2.6	4.1	1.5**	1.9	1.2	-0.7**
Take-up outcomes:						
Change in average download speed (Mbps)	24.8	27.0	2.2*	25.3	26.1	0.7*
Change in max download speed (Mbps)	69.5	76.5	7.0***	57.1	57.8	0.7
Change in average upload speed (Mbps)	10.9	7.5	3.4***	6.3	6.8	-0.5**
Change in number of superfast connections (Mbps)	4.8	3.7	-1.2**	5.5	4.8	-0.7*

*Source: Ipsos MORI analysis; *** represents differences significant at 99 percent, ** at 95 percent and * at 90 percent*

4.8 Overview of findings

4.8.1 Overview of results

The table below provides a summary of the estimated impact of the programme on areas benefitting from subsidised coverage under Phase 3 of the programme by September 2019 (note that these do not include the results of the panel models as these provide a direct estimate of additionality as discussed below). The models provided a consistent view on the effects of the programme:

- **Impact on broadband coverage:** Coverage subsidised through Phase 3 of the programme led to positive impacts on broadband availability. These impacts included a small positive impact on NGA availability (an increase in the proportion of premises with NGA coverage of 2 to 11 percentage points with most estimates towards the bottom end of this range). However, subsidised coverage increased the proportion of premises able to access superfast speeds by 10 to 25 percentage points and the proportion of premises with FTTP coverage by 25 to 28 percentage points (aligning with the relatively stronger focus of Phase 3 on gigabit connectivity). These findings indicate that many premises benefitting from the programme would have otherwise received some form of enhanced broadband coverage. However, in most cases these enhancements would not have delivered superfast speeds and would have involved the deployment of an inferior technology.

- **Competition:** The results consistently suggest that the programme has promoted additional competition and has increased the number of network providers offering broadband services in the target area (by around 0.2 providers on average). The areas benefitting from the programme were less well served by fewer broadband suppliers than other areas of the UK, and this may bring benefits to consumers in the longer-term (e.g. in the form of lower prices or wider choice).

- **Impact on take-up:** Subsidised coverage has reduced the share of households and businesses that have a superfast connection and the average download speeds of connections. This may be explained by the relatively early stage at which the impacts have been estimated. Only seventeen percent of the contracted premises upgraded had been delivered over the period covered by this analysis (and most these in the final year covered by this analysis). Take-up typically lags availability - it took six years for take-up to reach 60 percent of premises upgraded through Phase 1. As such, it is premature to consider the impact of the programme on take-up. However, the observation of negative effects on the number of premises with superfast connection indicates that for some households or businesses, the programme made superfast services available at a later date than they would have otherwise been received (an issue considered in more depth below).

Table 4.9: Estimated impact of Phase 3 on areas benefitting from subsidised coverage by September 2019

Outcome	Difference-in-Differences	Propensity Score Matching with Difference in Differences	Control group regression
NGA availability (% of premises)	2.1 to 10.7	2.7	3.5
Superfast availability (% of premises)	10.2 to 25.2	10.6	9.9
FTTP availability (% of premises)/	24.3 to 27.8	25.0	25.2
Number of network providers	0.2 to 0.2	0.2	0.2
Average download speeds of connections (Mbps)	-2.1 to -1.5	-1.2	2.2
Maximum download speeds of connections (Mbps)	6.2 to 16.9	7.7	7.0
Average upload speeds of connections (Mbps)	0.9 to 3.9	1.0	3.4
Number of connections with download speed of 30Mbps+	-2.4 to -1.1	-1.3	-1.2

Source: Ipsos MORI analysis/.

4.8.2 Additionality of subsidised broadband infrastructure

The findings have been used to provide an estimate of the overall number of premises benefitting from NGA, superfast and FTTP availability by September 2019. These estimates have been derived by multiplying the estimated increase in the share of premises with enhanced broadband availability resulting from the programme by the number of premises on the postcode:

- **NGA coverage:** The programme is estimated to have led to 2,300 to 16,600 additional premises with NGA coverage. Additionality (i.e. the share of premises benefitting from superfast coverage that would not have in the absence of the programme) is estimated at between 3 and 20 percent, with the most estimates towards the lower end of this range.

- **Superfast availability:** The programme is estimated to have increased the number of premises that can access superfast broadband services (30Mbps or above) by 10,800 to 29,300 by the end of September 2019. The associated rate of additionality ranges from 14 percent to 37 percent.

- **FTTP coverage:** Subsidised coverage is estimated to have led to 19,000 to 30,300 additional premises with FTTP coverage. The rate of additionality ranges from 35 percent to 55 percent (with most estimates in the region of 50 percent).

Table 4.10: Estimated additionality of NGA coverage across methods

	Impact on outcome	Number of premises on postcodes	Number of premises upgraded	Premises enabled attributable to programme	Implied additionality
NGA availability					
Simple DiD	10.7	108,814	79,100	11,643	14.7%
DiD regression with controls	2.1	108,814	79,100	2,285	2.9%
Matched sample regression	2.7	108,814	79,100	2,938	3.7%
Control group regression	3.5	108,814	79,100	3,808	4.8%
Panel models	-	108,814	79,100	16,611	21.0%
Superfast availability					
Simple DiD	25.2	108,814	79,100	27,421	34.7%
DiD regression with controls	10.2	108,814	79,100	11,099	14.0%
Matched sample regression	10.6	108,814	79,100	11,534	14.6%
Control group regression	9.9	108,814	79,100	10,773	13.6%
Panel models	-	108,814	79,100	29,267	37.0%
FTTP availability					
Simple DiD	27.8	108,814	55,000	30,250	55.0%
DiD regression with controls	24.3	108,814	55,000	26,442	48.1%
Matched sample regression	25	108,814	55,000	27,204	49.5%
Control group regression	25.2	108,814	55,000	27,421	49.9%
Panel models	-	108,814	55,000	19,250	35.0%

Source: Ipsos MORI analysis

4.8.3 Impacts on the programme area

The analyses were also extended to explore the impacts of the programme on all postcodes included in the build plans of Phase 3 schemes (i.e. including those areas that had not yet benefitted from subsidised coverage) to explore any unintended outcomes of the programme. These findings are summarised in the following table. The results suggest that the programme had a negative effect on enhanced broadband availability across the programme area. This suggests that the programme has worked to delay enhanced broadband availability for some households and businesses that yet to receive subsidised coverage.

The factors driving this pattern are discussed in the main evaluation report. However, this pattern was also observed in relation to the impacts of Phase 1 and 2. The results set out in Section 5 point to a general pattern in which the programme delays the availability of enhanced broadband coverage for around 10 percent of premises. As the programme had only delivered a relatively small share of the contracted premises within the period covered by this analysis, it is likely that this 'delaying effect' is dominating the results when the whole programme area is considered.

Table 4.11: Estimated impact of Phase 3 on all postcodes in the build plans of Phase 3 schemes by September 2019

Outcome	Difference-in-Differences	Propensity Score Matching with Difference in Differences	Control group regression
NGA availability (% of premises)	-1.8 to 3.1	-1.9	-2.8
Superfast availability (% of premises)	-3.4 to 6.1	-3.2	-10.3
FTTP availability (% of premises)/	1.4 to 3.5	1.7	0.7
Number of network providers	0.0 to 0.1	0.1	-
Average download speeds of connections (Mbps)	-4.6 to -0.2	-2.0	0.7
Maximum download speeds of connections (Mbps)	-10.9 to -4.1	-4.3	-
Average upload speeds of connections (Mbps)	0.4 to -	-0.1	-0.5
Number of connections with download speed of 30Mbps+	-1.6 to -0.9	-1.3	-0.7

Source: Ipsos MORI analysis. '-' denotes that the result was not statistically significant.

5 Programme Connectivity Impacts

This section presents the results of the analysis undertaken to explore the impacts of the whole programme to date including Phase 1, 2 and 3 delivery. This analysis was completed to explore the effects and additionality of subsidised coverage over time to support a broader assessment of the costs and benefits of the programme and its cost-effectiveness in bringing forward coverage.

5.1 Data

The data utilised in the analysis set out in this section is the same as that described in the previous chapter. A more detailed review, covering the processing steps and issues relating to comprehensiveness and quality, is provided in Annex A.

5.2 Evaluation design issues

5.2.1 Defining the population of white postcodes

Phase 3 of the programme extends the Superfast Broadband Programme to new areas that were previously designated as 'white' in Phases 1 and 2 of the programme. This reduced the size of the population of white postcodes that can potentially provide comparators for the programme as a whole. The definition of comparator groups for each phase are presented below:

- **Phase 1:** The comparator group for Phase 1 is defined as postcodes designated as white in the Phase 1 OMRs that were not included in the build plans of Phase 1, Phase 2, or Phase 3 schemes.
- **Phase 2:** The comparator group for Phase 2 is defined as postcodes designated as white in the Phase 2 OMRs that were not included in the build plans of Phase 2 or Phase 3 schemes.
- **Phase 3:** The comparator group for Phase 3 is defined as postcodes with premises that were designated as white in the Phase 3 OMRs, where no premises were included in the build plans of Phase 3 schemes.

Postcodes or premises were defined as being in the build plans of schemes (i.e. members of the treatment group) if they were either marked in the build plans of the scheme as described in the Speed and Coverage Template (SCT) or if the C3 reports indicated the postcode received subsidised coverage. This latter step accounts for small differences that arise between the SCT and the delivery of the scheme. This might occur – for example – if a planned upgrade was not feasible (e.g. for planning reasons), and the suppliers moved on to upgrade a nearby cabinet that was not in the original build plan.

5.3 Matching models

The first approach to assess the whole programme impact was to select a comparison sample of postcodes that did not receive BDUK investment but shared similar observable characteristics to those that did before the programme began. This was achieved by applying a propensity score matching (PSM) approach similar to that described in subsection 4.5 to:

- Compare the characteristics of postcodes that were and were not included in the build plans of local schemes, and predict the likelihood that each postcode was included in a scheme.

- Using these results, postcodes that were not included in the build plans of local schemes – but shared a similar predicted probability of being included those postcodes that were - were considered to be ‘matched’ and formed part of the comparison group.

- Postcodes that did not feature in the build plans of local schemes and did not share a similar likelihood of inclusion within the build plan of a local scheme were dropped from the sample and did not form part of the comparison group.

5.3.1 Control variables

This approach offers an unbiased estimate of the impact of the programme if it is possible to control for all factors that influenced the inclusion of a postcode within the build plan of a Phase 3 scheme. Postcodes were matched on the same vector of control variables described in subsection 4.4.1.

5.3.2 Matching models

The propensity score matching was completed using nearest neighbour techniques in which each postcode within the build plans of funded schemes was matched to the postcode in the comparison sample with the closest propensity score. Common support was imposed by dropping any postcode from the comparison sample that had a propensity score that was higher than the highest – or lower than the lowest – propensity score associated with postcodes included within the build plans of funded schemes. Individual postcodes in the comparison sample were allowed to form a match with multiple postcodes that received BDUK subsidies. The results of the initial probit models associated with a sample of matching models are set out in the appendix[32]. It illustrates:

- The matching models largely confirmed expectations regarding how the observable characteristics of postcodes would influence their inclusion within local schemes. There was a relatively high degree of consistency in the direction and size of the estimated coefficients when information on average download speeds in 2013 were included as a matching variable in comparable models.

- However, the available data did not explain a high share of the variance in the decisions made by tenderers to include postcodes in the build plans of Phase 1, 2 and 3 schemes (15 to 49 percent). Including additional information on average download speeds did increase explanatory power, but only at the margin.

There is a risk that unobserved factors influenced the decision to include postcodes within the scope of local schemes. The degree to which this is consequential will depend on how far those factors are correlated with the outcomes of interest.

An overview of the resultant matched samples is provided below. The matching models reduced the level of mean standardised bias, i.e. the average percentage differences in the characteristics of the treatment and the comparison sample, to between 3.2 and 5.8 percent. The models were not fully effective in eliminating all observable differences between the treatment and comparison samples. In general, the models generated matched samples in which the treatment group typically contained postcodes with longer line lengths to the nearest exchange.

[32] **Draft Note:** Will be added following submission of state aid report

Table 5.1: Comparison of matched samples (whole programme)

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
Mean standardized bias	3.2		5.8		5.3		5.7		4.0		3.5	
Variable	Treated	Control	Treated	Control	Treated	Control	Treated	Control	Treated	Control	Treated	Control
NGA access in 2012	0.18	0.16	0.15	0.14	0.09	0.10	0.26	0.23	0.10	0.10	0.33	0.34
NGA access in 2013	0.22	0.20	0.20	0.20	0.13	0.14	0.33	0.29	0.12	0.12	0.43	0.44
% of postcodes in LA with NGA, 13	0.50	0.51	0.50	0.51	0.45	0.48	0.62	0.60	0.44	0.45	0.64	0.64
% of postcodes in LSOA with NGA, 13	0.28	0.27	0.28	0.29	0.22	0.24	0.40	0.38	0.15	0.15	0.57	0.58
Line Length (m) / Log Line Length	2595.00	2525.80	7.55	7.62	7.34	7.18	7.70	7.73	7.52	7.57	7.25	7.27
Final speed / Log Line Length	9444.20	9710.40	7.44	6.86	8.01	7.79	6.87	7.22	7.34	6.62	9.22	9.14
Premises with EO lines 2013	3.77	3.83	2.64	2.68	2.99	2.95	2.69	2.89	3.41	3.35	4.46	4.39
Delivery points at serving exchange	6762.7	7550.6	6632.0	6791.7	6289.9	7657.5	7526.6	8193.7	3255.7	3497.9	14092.0	14362.0
Delivery points at serving cabinet	256.73	254.55	239.05	207.93	242.56	250.03	226.06	200.20	263.67	252.71	243.03	248.51
Virgin Media availability	0.06	0.06	0.04	0.04	0.04	0.04	0.06	0.08	0.01	0.01	0.17	0.17
Estimated Upgrade Cost (£)	66213	66838	66153	66564	65468	69618	65983	62526	68522	69637	61317	62369
Cost Per Premises Upgraded	281.73	311.85	331.20	380.52	295.46	323.77	374.82	406.49	283.98	368.74	272.74	291.42
Working Age Population	183.51	187.01	185.38	189.97	172.21	169.46	220.24	212.94	183.07	190.63	184.62	183.66
Population Aged 65 and Above	56.82	56.66	56.86	56.45	55.48	51.27	61.13	59.65	60.55	61.33	49.08	49.13
Population Density (log)	6.12	6.11	5.59	5.17	6.06	6.06	5.30	5.12	5.45	5.14	7.54	7.49
Premises Density (log)	5.59	5.58	5.06	4.65	5.56	5.57	4.73	4.58	4.87	4.55	7.08	7.06
Gross Weekly Wages (in LA)	511.31	512.79	511.25	509.46	510.83	509.84	516.29	514.57	514.53	512.03	504.82	502.93
Employment Rate (in LA)	73.12	72.86	73.27	73.03	73.45	73.11	72.94	72.83	73.85	73.72	71.60	71.58
Unemployment Rate (in LA)	6.95	7.00	6.89	6.80	6.80	6.86	7.12	7.13	6.50	6.31	7.91	7.75
Average Download Speeds 2014							9.84	9.53				
Maximum Download Speeds 2014							20.84	20.58				
% of premises with Superfast access 2014							13.64	13.07				
% of premises with NGA access in 2014							0.30	0.27				

Source: Ipsos MORI analysis

5.3.3 Results

Comparisons between the matched treatment and comparison groups from the analyses above were used to estimate the effect of the Superfast Broadband programme on NGA access, maximum available download speeds, the percent of premises with superfast (30Mbps) availability, and average download speeds. It should be noted that Connected Nations provides a measure of the share of premises on a postcode with superfast availability, but comparisons could produce misleading results if the programme had differential effects on postcodes with larger or smaller numbers of premises. To address this difficulty, an estimate of the number of premises with superfast availability on each postcode was derived by combining measures of the share of premises with superfast availability with estimates of the number of delivery points (as modelled by BDUK).

Table 5.1 and 5.2 below provides these results and includes the findings associated with model variants, illustrating the sensitivity of the results to:

- Inclusion of speed outcomes as outcome variables of interest (Models 2b, 3b, 4b and 7b) – as postcodes for which data on these metrics are excluded, this reduces the available sample sizes for the analysis.
- Inclusion of average download speeds in 2013 as a matching variable (Models 2c and 3c) – again, as this was unobserved for a non-trivial number of postcodes, this also reduced the available sample sizes for analysis.

These results present a complex picture of the impacts of the Superfast Broadband programme which vary both with time and the Phase of the programme[33]:

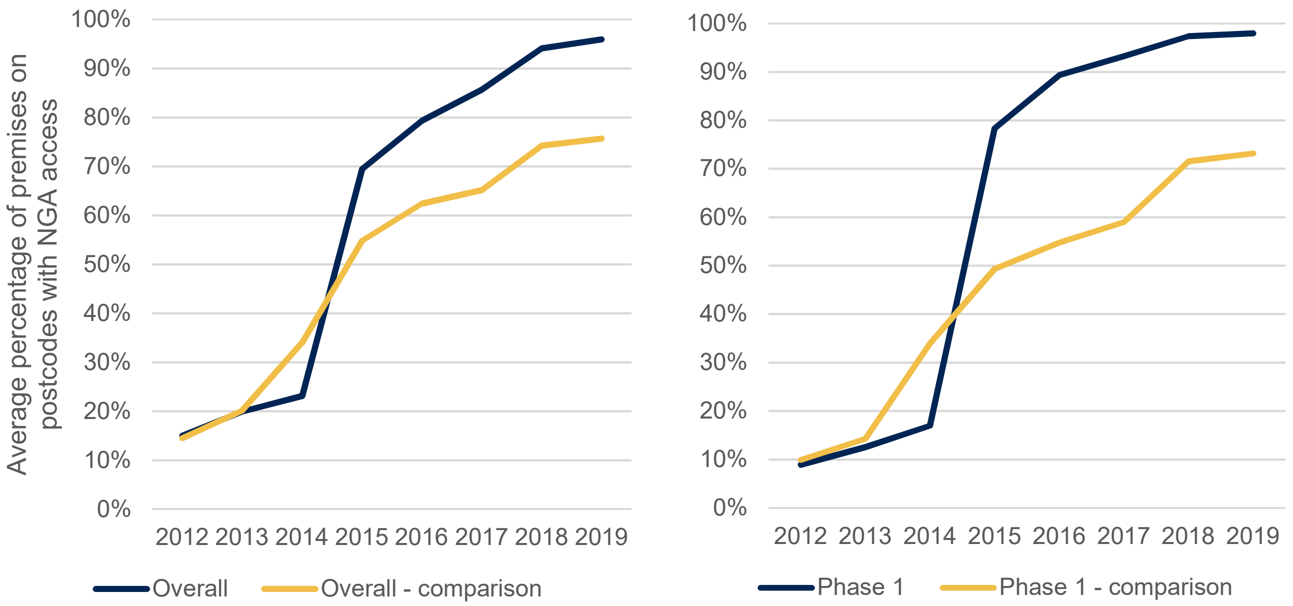
- **Impacts on NGA coverage:** The results indicated that the Superfast Broadband programme increased the share of premises in the programme area with NGA availability by almost 25 percent. The impacts of the programme on NGA coverage appear to have peaked in 2018. This suggests that postcodes that have not benefitted from the programme have started receive commercial deployment of NGA coverage (suggesting that in part, one of the effects of the programme is to accelerate the availability of enhanced infrastructure).
- **Impact on superfast broadband availability:** The impact of the programme on superfast broadband availability continued to rose to 34 percent of premises on the postcodes in the build plans of local schemes by 2019. The effects of the programme on superfast availability were larger than for NGA, and the results do not suggest that these impacts have begun to decay. This would indicate that while some areas benefitting from the programme may have received NGA coverage in the absence of the programme, these technologies would not necessarily have delivered superfast speeds (in common with the findings set out in the preceding section).
- **Phase 1:** The impact of Phase 1 schemes peaked in 2016. Differences between NGA and superfast broadband coverage on postcodes in the build-plans of Phase 1 schemes and the comparison group got smaller in 2018 and 2019. This suggests these earlier schemes had a significant effect in accelerating access to superfast broadband coverage, although some premises would have otherwise benefitted from upgrades at a later point in time.

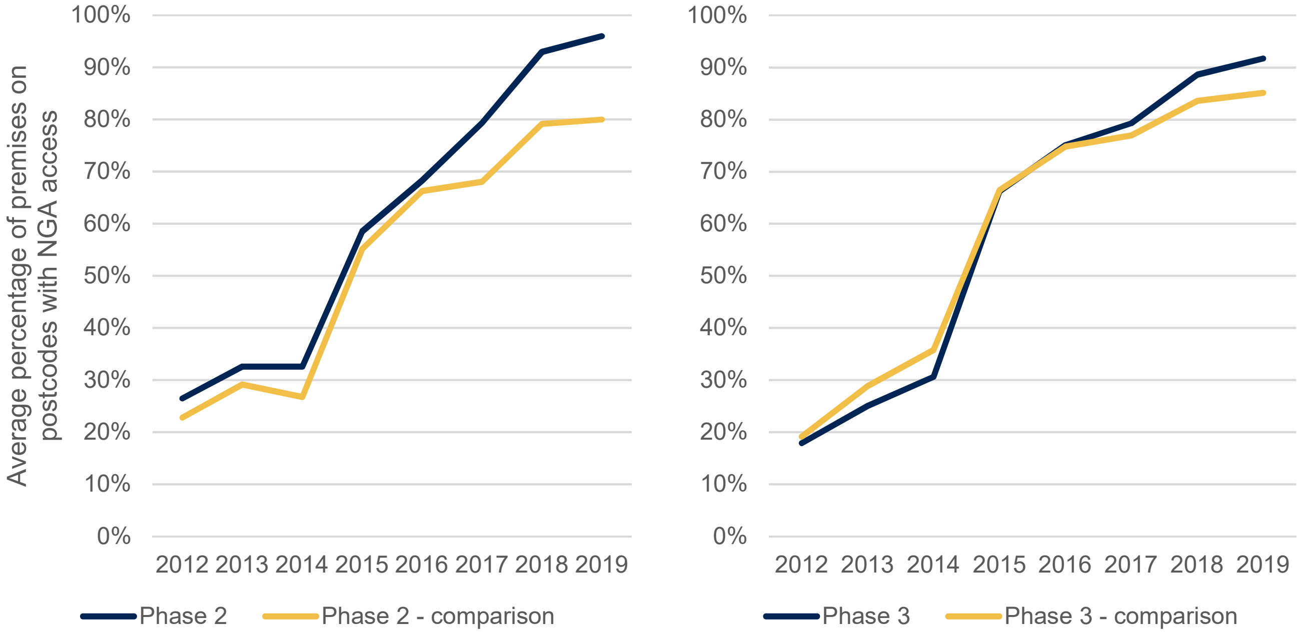
[33] Phase 3 charts below differ from those presented in Section 4 as the matching models used in that analysis incorporated additional years of connectivity data.

- **Take-up:** Using the matching approach, the impact on take-up (as visible in the maximum and average speed of connections) has increased with time, suggesting (as might be expected) that effects on take-up have lagged effects on coverage. More recent editions of Connected Nations include measures of the number of connections taken at superfast speeds. For Phase 2 and Phase 3 analysis, the timing of delivery allows for the analysis to control for baseline take-up levels, with take-up of superfast broadband connections in 2014 used for Phase 2 and take-up in each year from 2014 to 2017 used in the matching approach for Phase 3. The results illustrate the lagged effect with take-up rising slowly over time. There were 3.6 extra connections taken up per postcode delivered to through Phase 2 delivery by 2019.

In the below tables for NGA coverage, the trends for areas within build plans and the comparison areas clearly diverges in 2014 for Phase 1, 2017 for Phase 2 and 2018 for Phase 3. Similar trends are observed for superfast coverage, particularly for Phase 2 and 3 in 2017 and 2018 respectively.

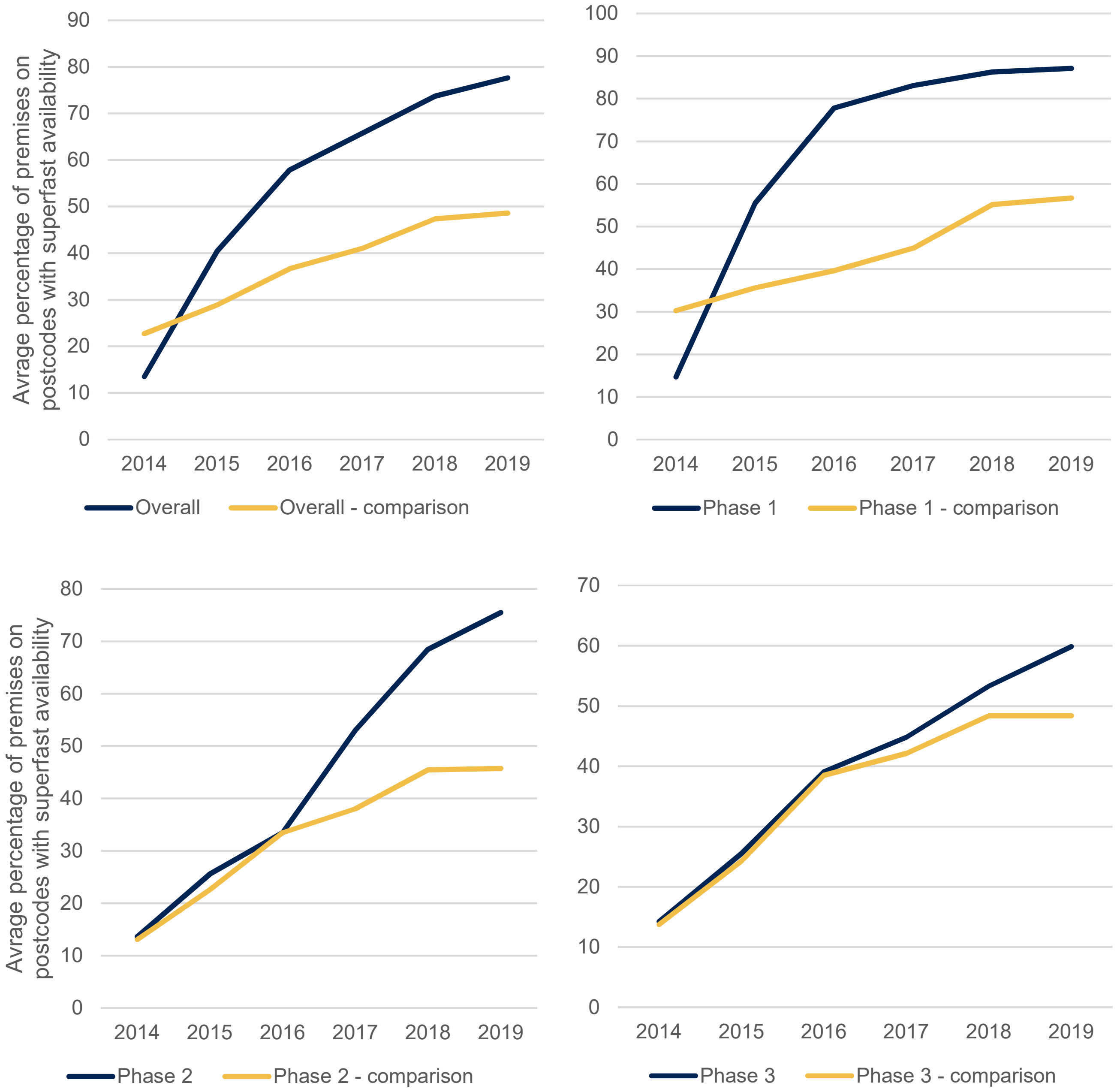
Figure 5.1: Evolution of NGA coverage in upgraded postcodes and comparison postcodes, by Phase





Source: Ipsos MORI analysis; BDUK C3 reports, SCTs & Ofcom Connected Nations

Figure 5.2: Evolution of superfast broadband coverage in upgraded postcodes and comparison postcodes, by Phase



Source: Ipsos MORI analysis; BDUK C3 reports, SCTs & Ofcom Connected Nations

Table 5.2: PSM model results – NGA and superfast broadband availability

	% of postcodes with NGA coverage			Superfast availability as % of premises			Average number of premises with superfast availability		
Effects as of [year]:	**2016**	**2018**	**2019**	**2016**	**2018**	**2019**	**2016**	**2018**	**2019**
Model 2	17.2	23.3	23.6	24.4	31.3	34.1	3.0	4.0	4.3
Model 2b (speed outcomes included)	21.2	24.6	24.2	26.3	32.4	34.6	4.6	5.9	6.3
Model 2c (speeds included as controls)	20.7	24.2	24.1	26.3	32.6	35.1	3.9	5.0	5.3
Phase 1									
Model 3	32.5	27.9	27.4	37.3	34.4	34.4	4.9	4.5	4.5
Model 3b (speed outcomes included)	37.5	32.0	30.9	42.1	38.6	38.2	7.2	6.5	6.5
Model 3c (speeds included as controls)	35.9	29.7	28.8	41.0	36.5	36.3	7.0	6.1	6.1
Phase 2									
Model 4	2.0	17.7	20.8	4.5	27.3	36.1	1.8	4.6	5.9
Model 4b (speed outcomes included)	0.0	17.4	20.3	4.4	27.7	36.1	1.9	6.0	7.6
Phase 3									
Model 7	-	5.0	6.6	-	4.9	8.8	-	1.8	2.4
Model 7b (speed outcomes included)	-	5.2	6.9	-	5.7	9.7	-	1.7	2.4
Urban and rural split									
Model 5 (Rural)	19.8	23.2	22.5	22.7	28.8	30.9	3.2	4.2	4.6
Model 6 (Urban)	9.6	12.3	13.1	11.0	13.9	15.8	1.9	2.8	3.1
Model 1 (all areas as control)	7.5	11.1	10.0	5.4	11.3	12.4	1.3	2.4	2.5

Source: Ipsos MORI analysis; BDUK C3 reports & Ofcom Connected Nations

Table 5.3: PSM model results – Download speeds (maximum and average)

	Max. available download speeds (Mbps)			Average download speeds (Mbps)			Average number of superfast broadband connections		
Effects as of [year]:	**2016**	**2018**	**2019**	**2016**	**2018**	**2019**	**2016**	**2018**	**2019**
Model 2	-	-	-	-	-	-	-	-	-
Model 2b (speed outcomes included)	-0.5	3.3	11.8	-0.9	2.8	9.3	-	-	-
Model 2c (speeds included as controls)	-1.5	2.2	9.4	-1.1	2.5	9.1	-	-	-
Phase 1									
Model 3	-	-	-	-	-	-	-	-	-
Model 3b (speed outcomes included)	4.6	3.7	9.0	0.8	4.7	10.5	-	-	-
Model 3c (speeds included as controls)	-2.5	-5.7	-1.2	-1.5	1.0	7.5	-	-	-
Phase 2									
Model 4	-	-	-	-	-	-	0.3	2.0	3.6
Model 4b (speed outcomes included)	3.0	12.9	16.0	1.1	5.2	9.1	0.3	2.0	3.5
Phase 3									
Model 7	-	-	-	-	-	-	-	0.2	0.3*
Model 7b (speed outcomes included)	-	13.8	18.3	-	5.4	7.5	-	0.2	0.2*
Urban / rural split									
Model 5 (Rural)	-4.1	0.6	3.5	-2.0	2.4	7.4	-	-	-
Model 6 (Urban)	1.8	5.0	8.1	-0.8	2.6	5.4	-	-	-

*Source: Ipsos MORI analysis; BDUK C3 reports & Ofcom Connected Nations; * indicates not statistically significant*

5.3.4 Additionality of subsidised coverage

Aggregating the estimated effects on average number of premises with superfast broadband coverage to estimate the total number of additional premises with superfast broadband coverage by 2019 suggests that between 1.6m and 2.3m additional premises benefitted from superfast broadband coverage that would not have done without the programme by 2019. This implies an overall rate of additionality at between 39 and 57 percent.

Note that the results for Phase 3 in these analyses differ to those presented in Section 4. The difference-in-difference approach used in that section is considered more robust given that it uses a matched sample from which a DiD approach is implemented on whereas the effects visible here are based upon comparisons of the treatment and control means. However, this does illustrate a significant degree of uncertainty with respect to the additionality level of Phase 3 delivery which should be viewed with caution.

Table 5.4: Estimated Additionality – share of premises receiving subsidised coverage that would not have received superfast broadband coverage without the programme (PSM Models)

	Number of Postcodes	Total number of delivery points on postcodes	Estimated effect on the average number of premises with superfast broadband coverage by 2019		Estimated number of additional premises with superfast broadband coverage by 2019		No. of premises receiving subsidised superfast broadband coverage by Sep 2019	No. of premises receiving subsidised coverage by Sep 2019	Estimated Additionality (%)	
			Low	High	Low	High			Low	High
Postcodes in build plans of Phase 1, 2 & 3 schemes	367,091	5,327,795	4.4	6.4	1,615,200	2,349,382	4,149,850	4,298,160	39%	57%
Postcodes in build plans of Phase 1 schemes	291,223	4,297,449	4.4	6.5	1,281,381	1,892,950	3,570,399	3,706,292	36%	53%
Postcodes in build plans of Phase 2 schemes	82,488	1,119,286	5.6	6.9	461,933	569,167	793,956	821,558	58%	72%
Postcodes in build plans of Phase 3 schemes	9,266	108,514	1.7	2.4	15,752	22,238	60,095	79,100	26%	37%

Source: Ipsos MORI analysis; BDUK C3 reports & Ofcom Connected Nations

5.4 Longitudinal panel models

Further modelling was completed to examine the relationship between the number of premises with superfast broadband availability and the number of premises with upgraded connections (at the Output Area level).[34] These analyses were restricted to those areas that were eligible for the programme (i.e. with postcodes or premises identified as white in the OMR). The longitudinal nature of the data allowed the analysis to accommodate for unobserved differences between areas that do not change with time, giving more robust findings than the matching models described above. These results are comparable to the Difference-in-Difference analyses put forward in the State Aid evaluation plan (which envisages the analyses being completed at the premise/postcode level, examining overall changes in coverage between 2016 and 2020 rather than annual variation). This was implemented using the estimation of the following econometric model describing the relationship between the number of premises receiving subsidised superfast coverage through the programme and the outcomes of interest:

$$outcome_{it} = \alpha + \beta X_{i,2013/16} + \gamma C_{it} + \theta t + \alpha^{i} + \alpha^{L} t + \alpha^{T} + \alpha^{L}\alpha^{t} + \varepsilon_{it}$$

This model describes the number of premises with the outcome in area i in period t ($\text{outcome}it$) as a function of a set of observable characteristics of an area before the programme began (Xi,2013/16) and the cumulative number of premises receiving subsidised coverage within the area in the period (Cit). The model also allows for national trends that might influence the outcomes across all areas (t). The model also allows for unobserved differences between areas that do not change over time ($\alpha\ i$), unobserved but time-specific shocks that affect all areas ($\alpha\ T$), unobserved trends at the local authority level ($\alpha\ L\ t$) and unobserved and time-specific shocks at the local authority level ($\alpha\ L\alpha\ t$). The parameter γ gives a direct measure of the additionality associated with the programme, i.e. the proportion of premises receiving subsidised coverage that would not have received NGA/superfast/FTTP coverage in the absence of the programme. To facilitate the estimation of the model, the equation above was specified in first-differences as specified below:

$$\Delta outcome_{it} = \gamma \Delta C_{it} + \theta \Delta t + \alpha^{L} \Delta t + \alpha^{T} + \alpha^{L}\alpha^{T} + \varepsilon_{it}$$

This transformation relates the change in the outcome to the number of premises receiving subsidised coverage within the year. The transformation also results in fixed characteristics of areas being dropping out of the model - including the pre-treatment characteristics of the model – but importantly, differencing in this way means that the results will not be biased because of their omission. However, in some models, these controls were reintroduced to explicitly capture any unobserved trend effects affecting areas with different pre-programme characteristics.

These results could still be biased by unobserved differences between areas that change with time. Given the time frame over which the analysis has been conducted, this is a heightened risk. For example, Openreach's Physical Infrastructure Access (PIA) product has become more accessible during the period of analysis and interviews with suppliers have suggested that this has made some areas commercially viable that previously were not. If this improvement in commercial viability was more significant in areas benefitting from subsidised coverage, then these results could overstate additionality in the longer-term.

5.4.1 Results

The findings of these analyses are presented in the two tables below. In table 5.4:

[34] An Output Area is small area covering around 10-12 postcodes.

- Model 1 presents a simple first difference model produce an estimated increase in NGA coverage of 0.75 premises for each premise receiving subsidised coverage through the programme by 2016, i.e. 77 percent additionality. This declines to 0.71 and 0.70 by 2018 and 2019 respectively.

- Models 2 and 3 exclude those output areas reaching 100 percent NGA coverage and ineligible areas. This reduces the size of the estimated impacts.

- Models 4 and 5 allow for unobserved local authority level trends, time-specific shocks affecting all areas, and time-specific shocks at a local authority level. Adding these further controls further reduces the estimated impacts of the programme (with an implied additionality rates of 60 percent).

- Model 13 uses model 12 but allows for differing effects by Phase. Here, Phase 1 additionality was estimated at 61 percent, Phase 2 at 60 percent and Phase 3 at 19 percent by 2019.

Table 5.5: Longitudinal panel models – estimated impacts

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Areas reaching 100% NGA coverage excluded?	No	Yes	Yes	Yes	Yes	Yes
Eligible areas excluded?	No	No	Yes	Yes	Yes	Yes
Fixed effects	No	No	No	Yes	Yes	Yes
2013 Output Area controls	No	No	No	No	Yes	Yes
Effects up to 2016						
Change in NGA covered premises per premises receiving subsidised coverage	0.75***	0.71***	0.70***	0.62***	0.61***	-
Change in NGA covered premises per premises receiving subsidised coverage under Phase 1	-	-	-	-	-	0.62***
Change in NGA covered premises per premises receiving subsidised coverage under Phase 2	-	-	-	-	-	0.52***
Observations	857,784	292,785	261,688	261,688	250,889	250,889
Adjusted R-Squared	0.24	0.23	0.25	0.36	0.40	0.38
Effects up to 2018						
Change in NGA covered premises per premises receiving subsidised coverage	0.71***	0.69***	0.69***	0.61***	0.60***	-
Change in NGA covered premises per premises receiving subsidised coverage under Phase 1	-	-	-	-	-	0.61***
Change in NGA covered premises per premises receiving subsidised coverage under Phase 2	-	-	-	-	-	0.60***
Change in NGA covered premises per premises receiving subsidised coverage under Phase 3	-	-	-	-	-	0.12***
Observations	1,286,676	350,643	310,041	310,041	297,280	297,280
Adjusted R-Squared	0.24	0.22	0.25	0.36	0.39	0.39
Effects up to 2019						
Change in NGA covered premises per premises receiving subsidised coverage	0.70***	0.69***	0.69***	0.61***	0.60***	-
Change in NGA covered premises per premises receiving subsidised coverage under Phase 1	-	-	-	-	-	0.61***
Change in NGA covered premises per premises receiving subsidised coverage under Phase 2	-	-	-	-	-	0.60***
Change in NGA covered premises per premises receiving subsidised coverage under Phase 3	-	-	-	-	-	0.19***
Observations	1,501,122	365,370	321,421	321,421	308,101	308,101
Adjusted R-Squared	0.24	0.22	0.25	0.37	0.40	0.39

*Source: Ipsos MORI analysis; BDUK C3 reports & Ofcom Connected Nations; *** represents differences significant at 99 percent, ** at 95 percent and * at 90 percent*

5.4.2 Additionality over time

The results above only compare changes in NGA coverage and premises receiving subsidised coverage within the same year. This may provide a misleading representation of impact for the following reasons:

- **Delayed coverage for areas likely to receive enhanced connectivity anyway:** The matching models above pointed to a possible effect whereby the programme may have delayed investment in superfast coverage in those postcodes that would have been likely to receive enhanced that investment anyway. Failing to allow for this possible effect could cause estimates of impact to be overstated.

- **Lagged effects:** Additionally, there may be recording lags in the data (with increases in maximum download speeds visible in the Connected Nations data up to 1 year following the installation of the technology). Failing to allow for these lagged effects would cause estimates of impact to be understated.

- **Acceleration effects**: There is also a possibility that part of the effect of the programme is to accelerate an area's access to faster broadband speeds, rather than enabling the area to access faster speeds on a permanent basis. This would imply higher rates of additionality in the short-term and lower rates of additionality in the longer-term.

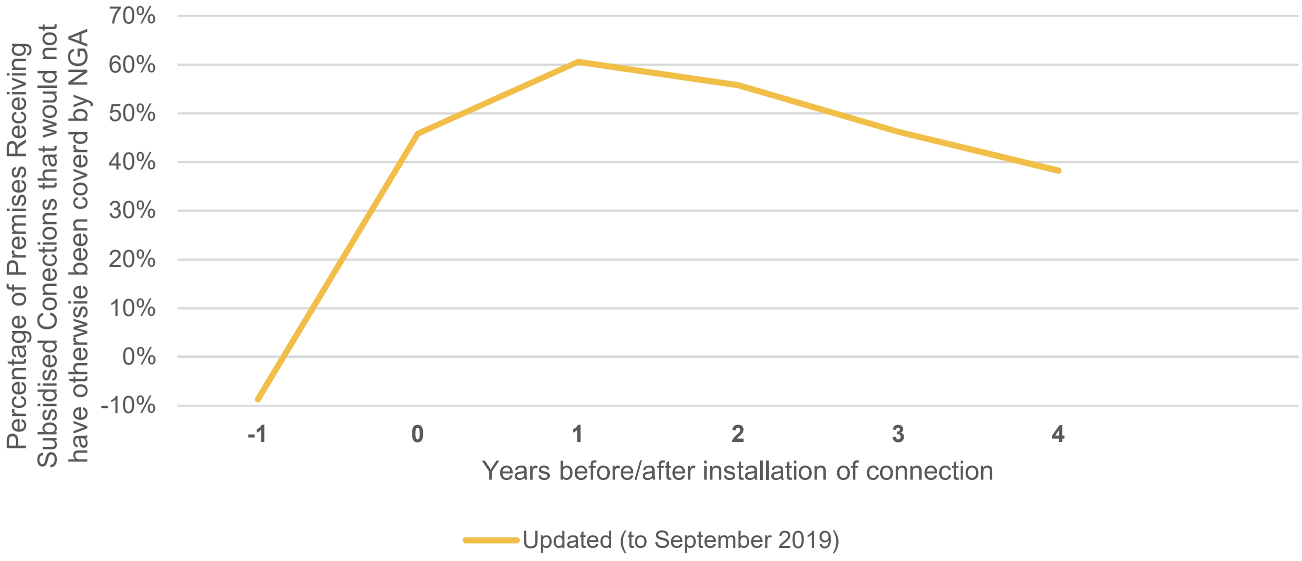
These hypotheses were explored by introducing forward and backward lags of the treatment variable into the model as follows (the panel data only included five years so it was not possible to include more lags within the models to explore longer-term effects):

$$\Delta NGA_{it} = \gamma_1 \Delta C_{it+1} + \gamma_2 \Delta C_{it} + \gamma_3 \Delta C_{it-1} + \gamma_4 \Delta C_{it-2} + \gamma_5 \Delta C_{it-3} + \gamma_6 \Delta C_{it-4} + \theta \Delta t + \alpha^L \Delta t + \alpha^T + \alpha^L \alpha^T + \varepsilon_{it}$$

The results are set out in the table below and suggest that the scheme did have a negative effect on NGA availability in the year before premises received subsidised coverage (equivalent to nine premises per 100 connections). This implies a small degree of initial localised crowding out. However, the estimates suggested that in the year following the delivery of subsidised coverage, 0.57 additional premises received NGA coverage per premises upgraded (57 percent additionality). The results also suggested that 5 percent of premises receiving subsidised connections would have received NGA coverage anyway but two years later. This gives overall additionality of 59 percent over the four-year period, which is consistent with the estimates of the matching models.

The pattern remains consistent across phases in the below. This also allows for the plotting of additionality over time. The results shown in table 5.5 and the figure below imply a slowly decreasing level of additionality over time, up to five years after delivery in the overall results. This implies that the likelihood of an area being upgraded in the absence of the programme increases as time passes, albeit at a slow rate. The analysis illustrates an overall level of additionality after four years of 40 percent, which compares to 60 percent after one year. This is illustrated in the figure below.

Figure 5.3: Estimates of additionality of NGA Coverage over time



Source: Ipsos MORI analysis; BDUK C3 reports & Ofcom Connected Nations

Table 5.6: Estimated Additionality Over Time – Longitudinal Panel Models

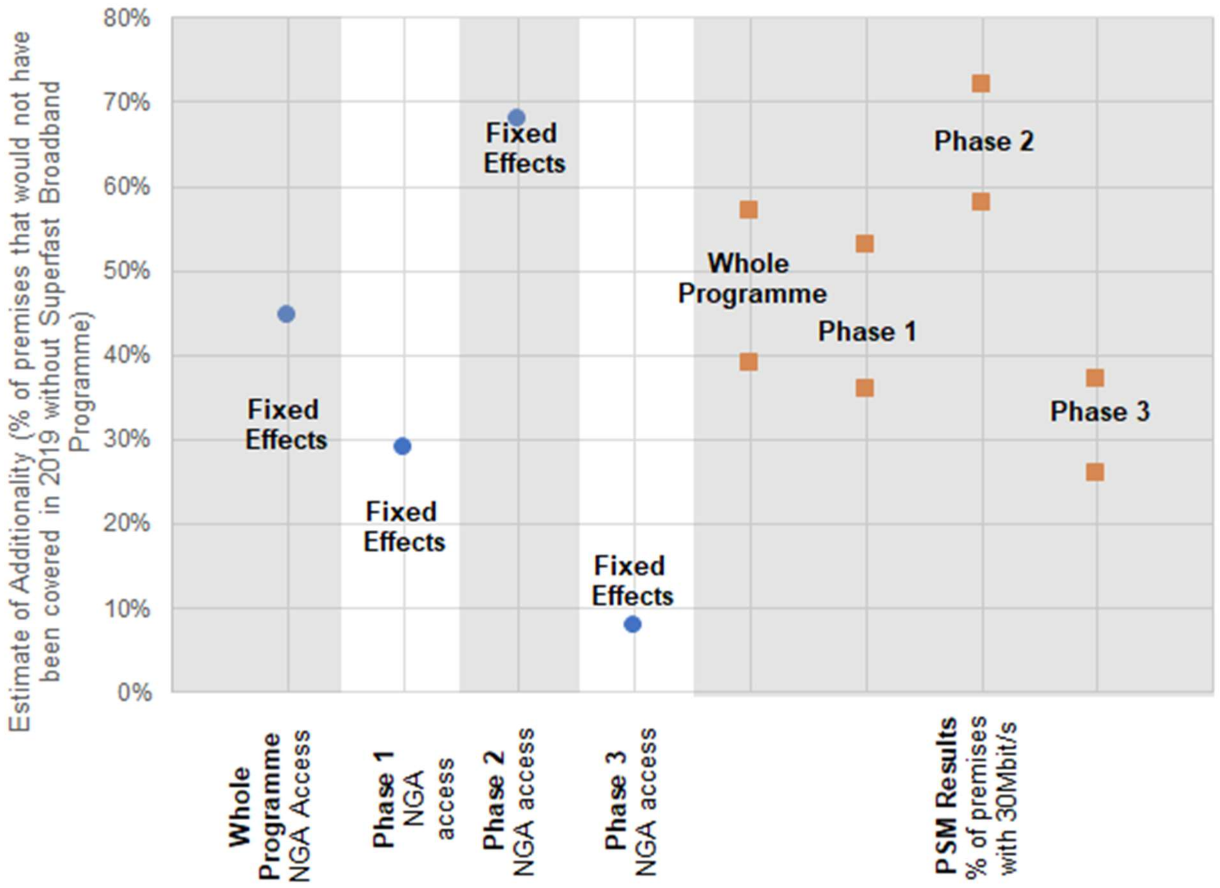
	Overall	Phase 1	Phase 2	Phase 3	Overall
Areas reaching 100% NGA coverage excluded?	Yes	Yes	Yes	Yes	Yes
Eligible areas excluded?	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes
2013 Output Area controls	Yes	Yes	Yes	Yes	Yes
Up to 2019					
Change in NGA covered premises per premises receiving subsidised coverage (T+1)	-0.09***	-0.09***	-0.07***	-0.04*	-0.09***
Change in NGA covered premises per premises receiving subsidised coverage (T)	0.57***	0.57***	0.57***	0.08**	0.55***
Change in NGA covered premises per premises receiving subsidised coverage (T-1)	0.16***	0.16***	0.18***	-	0.15***
Change in NGA covered premises per premises receiving subsidised coverage (T-2)	-0.05***	-0.05***	-0.01	-	-0.05***
Change in NGA covered premises per premises receiving subsidised coverage (T-3)					-0.10***
Change in NGA covered premises per premises receiving subsidised coverage (T-4)					-0.08***
Total effect 2/5 years post delivery	0.59	0.59	0.69	0.04	0.38
Observations	209,182		209,182	79,471	
Adjusted R-Squared	0.45		0.46	0.40	

*Source: Ipsos MORI analysis; BDUK C3 reports & Ofcom Connected Nations; *** represents differences significant at 99 percent, ** at 95 percent and * at 90 percent*

5.4.3 Summary of findings

The figure below summarises the estimates of additionality across the methods implemented above for the whole programme analysis.

Figure 5.4: Summary of additionality estimates across methods



Source: Ipsos MORI analysis; BDUK C3 reports & Ofcom Connected Nations

5.5 Crowding Out

The programme could have negative effects elsewhere if its delivery diverted scarce resources – such as skilled labour or capital – away from areas in which providers planned to install enhanced infrastructure without subsidy. However, positive effects (crowding-in) are also possible if the process of demand and cost recovery supported by the programme encouraged providers to make further or bring forward investments in superfast broadband infrastructure.

The level of crowding in or out was explored by assuming any effects of this nature were likely to occur at the local level. While telecoms operate national supply chains, the delivery of construction activity tends to be by local contractors (motivating this assumption). Additionally, it was assumed that the size of these effects would be linked to the volume of delivery in nearby white postcodes. This was operationalised using the following econometric model (a non-parametric distance-decay model):

$$NGA_{jt} = \alpha + \sum_{k=1}^{5} \gamma_k C_{kt} + \theta t + \alpha_i + \alpha_L t + \alpha_t + \alpha_L \alpha_t + \varepsilon_{it}$$

This model relates the number of premises covered by NGA on grey, black and otherwise ineligible postcodes in output area j in period t (NGA_{jt}) to the cumulative number of premises receiving subsidised coverage within distance bands (k) of increasing distance from area j (C_{kt}). Five distance bands were adopted for the purposes of the analysis at 10km intervals from the centroid point of the relevant LSOA[35] (0 to 10km, 10km to 20km, 20km to 30km, 30km to 40km, and 40km to 50km). The parameter γ_k captures the effect of each premises covered delivered in distance band k in period t on the number of premises on grey, black, and other ineligible postcodes covered by NGA. A positive coefficient is a signal of crowding-in and a negative coefficient is a signal of crowding out. The parameter θt accounts for time trends t the national level.

The model also allows for unobserved differences between areas that do not change over time (α_i), unobserved but time-specific shocks that affect all areas (α_t), unobserved trends at the local authority level ($\alpha^L t$) and unobserved and time-specific shocks at the local authority level ($\alpha_L \alpha_t$). As before, the model was specified in first differences removing the influence of any time invariant factors that might be correlated with the outcome:

$$\Delta NGA_{jt} = \sum_{k=1}^{5} \gamma_k \Delta C_{kt} + \theta \Delta t + \alpha_L t + \alpha_t + \alpha_L \alpha_t + \varepsilon_{it}$$

Any LSOAs without any grey, black, or otherwise ineligible postcodes were removed from the sample. Additionally, if NGA coverage reached 100 percent on all relevant postcodes within the Output Area, subsequent observations were removed from the sample from the following year (as by assumption there can be no crowding in or crowding out effects once 100 percent coverage is achieved).

5.5.1 Results

Overall, the analysis suggested the delivery of subsidised coverage led to a small reduction in NGA coverage in nearby areas in of crowding out in the 0 to 10km distance but also a small degree 10km to 20km and 20 to 30km away in the year of delivery. One year after, the opposite is true for areas 10 to

[35] Distances were calculated at an LSOA rather than a postcodes level to reduce the number of distances between pairs of areas that required calculation to produce the dataset needed for this analysis.

20km away and 20km to 30km. The level of crowding out estimated overall is negligible in these models however.

Table 5.7: Estimated Level of Crowding Out – up to 2019

	Model 26	Model 27	
	No lagged effects	Effect in year t	Effect in year t+1
0 to 10km	-0.0004***	-0.0004***	0.0002
10 to 20km	-0.0001	-0.0002*	0.0002*
20 to 30km	-0.0001*	-0.0003***	0.0004***
30 to 40km	0.0002***	0.0002***	0.0000
40 to 50km	0.0000	0.0000	0.0001
Total effect	-0.0003	-0.0001	
R-squared	0.2620	0.2620	
Observations	101,022	101,022	

*Source: Ipsos MORI analysis; BDUK C3 reports & Ofcom Connected Nations; ***, ** & * represent statistical significance at 99.9, 99 and 95 percent respectively*

6 Cost effectiveness

This final section of the technical appendix sets out a cost-effectiveness analysis of the Superfast Broadband programme using the impacts estimated across the whole programme as presented in section five. The analysis relates the expected net subsidy associated with the programme to the number of additional connections delivered.

6.1 Costs

Data on the costs of delivering the Superfast Broadband programme have been drawn from BDUK monitoring data and the outputs of an extensive modelling exercise. Details of these can be found in Appendix 2.

6.2 Cost-effectiveness of public sector funding

6.2.1 Contracted cost per premises passed

Data on the costs of delivering the Superfast Broadband programme have been drawn from BDUK monitoring data and the outputs of the modelling exercise described in Section 5 of Technical Appendix 2. A total of £1.9bn of public sector funding (in nominal terms[36]) was committed across Phase 1, 2 and 3 contracts with a total of 5.5 million contracted premises passed. This equates to an ex-ante gross cost per premise passed of £342. There was significant variation across the various phases. Phase 1 had the lowest gross public sector cost per premises passed of £266. Phase 3 had the highest public sector cost per premise at over £1,216. This is expected given the proportion of FTTP build expected in Phase 3 delivery which was expected to come at a higher cost.

Table 6.1: Contracted gross public sector cost per premises passed over Phases 1, 2 and 3

	Contracted public sector cost[37] (£m)	Contracted premises passed	Gross public subsidy per gross premises passed (£)
Phase 1	1169,1	4,388,618	266.39
Phase 2	332.6	830,654	400.39
Phase 3	391.9	322,242	1,216.29
Overall	**1893.6**	**5,541,514**	**341.72**

Source: Ipsos MORI analysis; CORA; BDUK

6.2.2 Expected cost per premises passed by March 2019

The table below provides estimates of the current expected public sector cost per premises passed by March 2019 (following the approach outlined in Technical Appendix 3). As highlighted, current expectations of public spending (before implementation and take-up clawback) differs significantly to the contracted costs outlined above (primarily driven by underspend on Phase 1 contracts). The expected gross public spend per premises passed was lower overall at £268. and the expected gross public spend per premises passed fell from £1,216 to just above £497 (primarily due to expected underspend, though note that these projections are highly uncertain at this stage).

Factoring in the likelihood that some of those premises passed to date would otherwise have received coverage through commercial deployments, the table below also includes the estimated number of

[36] The time profile associated with these contracts was not available, so this is presented in nominal terms on an undiscounted basis.
[37] In nominal terms, not in present value terms. Taken from CORA management extract

additional premises passed. This applies estimated additionality over the first three years following delivery (to align with the period covered by the OMR process) of 56 percent. The gross public sector cost (i.e. before clawback) per additional premises passed over three years was £460 (in 2019 prices).

The table below provides estimates of the expected public sector cost per premises passed by March 2017. Expected Phase 3 costs were scaled down to 17 percent of the total to reflect the amount of delivery by March 2019. These costs were calculated in present value terms and in 2019 prices.

Table 6.2: Expected gross public sector cost per gross and additional premises passed over Phases 1, 2 and 3

	Expected public sector cost (£m)	Premises passed to date	Additional premises passed to date	Expected Gross public subsidy per gross premises passed (£)	Expected Gross public subsidy per additional premises passed (£)
Phase 3	25	51,285	28,720	490	880
Overall	**1353**	**5,268,398**	**2,950,303**	**260**	**460**

Source: BDUK, Ipsos MORI analysis

6.2.3 Net public cost per additional premises upgraded over three years

The table below outlines the expected public sector costs net of the clawback mechanisms. This is expected to reduce the net cost per additional premises upgraded from £890 to £790 for Phase 3 contracts (though again, given the early stage of delivery, these estimates are highly uncertain).

Table 6.3: Net public sector cost per additional premises passed over Phases 1, 2 and 3

	Net public sector cost (£m)	Additional premises upgraded to date	Net public subsidy per additional premise upgraded (£)
Phase 1	429.8	2818651.0	152
Phase 2	274.3	500273.0	548
Phase 3	22.6	28720.0	788
Overall	**726.7**	**3353638.0**	**217**

Source: BDUK, Ipsos MORI analysis

6.2.4 Cost per connection

Finally, as highlighted in Section 4, a total of 15,369 connections were made to infrastructure subsidised through Phase 3 of the programme. Combining this with the estimated costs of delivery to this point gives an estimated gross cost per connection of £1,642 before clawback and £1,472 after clawback. However, the findings of the analysis indicated that Phase 3 of the programme had no net effect on the number of superfast connections over the relatively short time-frame for the analysis.

6.3 Benchmarking

Whilst an attempt has been made to compare the costs per connection outlined for the programme above, there remains little evidence on comparable interventions. There are very few studies that have sought to examine the cost-effectiveness of broadband programmes. This may in part be because of a relative lack of public programmes on the same scale as the Superfast Programme and a consequent lack of published evaluative work.

However, a recent study evaluating parts of the Superconnected Cities Programme (SCCP) did include a cost benefit analysis of the Connection Voucher Scheme element of that programme. This made vouchers up to a value of £3,000 available to small to medium sized businesses (SMEs) to put towards upgrading their internet connection. To be granted, the connection would need to provide at least superfast speeds but was technology agnostic. The study found the average cost of subsidised connections through this programme was £1,400, although this also varied substantially by technology type (ranging from £1,100 for FTTC connections to £2,800 for Fixed Wireless/Microwave connections). The cost per installation was estimated at £1,400, though each installation led to a further 4.7 additional connections per postcode. This equated to an estimated cost per additional connection of £290. However, this is not directly comparable to the figures above as it focuses on the cost of connections rather than the cost of coverage.

Annex A: Datasets used in the analysis

This Annex provides an overview of the data available for the analyses reported in this Appendix, highlighting issues relating to comprehensiveness or quality, and any implications for the findings.

Connected Nations

Ofcom's Connection Nations report provided the evidence on the key outcomes of interest for the analysis - including NGA availability, available speeds, and the speeds of connections (which gives an indication of take-up) between 2012 and 2019. The data provided a snapshot of local connectivity in June of each year up to and including the 2016 release. The 2017 release provided a snapshot in May of that year and the 2018 and 2019 releases gave a snapshot for September.

The number of postcodes included in the report has changed from year-to-year, and in compiling the data any postcode with missing data for one or more years was dropped from the analysis. This gave a sample of 1.54m postcodes which excluded any new postcodes that may have emerged as result of new housing or commercial developments on greenfield sites. The following analyses should be reviewed bearing in mind the following limitations of the data:

- **Coverage of suppliers:** The number of suppliers providing data to Ofcom for the Connected Nations output has increased with time. In 2019, the data incorporated information provided by 24 fixed network suppliers covering all such Superfast suppliers with one exception[38] as well as data from Airband, a wireless internet service provider and Superfast supplier. The data also includes returns from 12 other wireless ISPs. The 2017 and 2018 data included information from fewer fixed network suppliers but still included all Superfast suppliers with the above exception. Smaller suppliers were less likely to be included in earlier years of the data. Between 2012 and 2014 only coverage from the major providers (BT, Virgin Media and KCOM) was reported with Sky and TalkTalk added in 2015. In 2016, a further five alt-net providers were added including B4RN, Gigaclear and Hyperoptic.

- **Measures of superfast and FTTP availability:** The Connected Nations data has increased in resolution over time with a greater number of variables included in the dataset in each year. In 2012 and 2013, the dataset only gave a binary measure of whether a postcode has Next Generation Access (NGA)[39] access or not[40]. From 2014 onwards the data described the percentage of premises with NGA and superfast access. It was only possible to construct a consistent measure of superfast availability across the 2012 to 2019 period by converting post 2014 measures of NGA access into a binary measure. This was achieved by assuming a postcode had NGA access if more than 50 percent of the premises on the postcode had NGA access. This measure more closely tracked aggregate changes[41] in NGA access than the available alternatives[42] – but is likely to overstate NGA coverage in earlier years (potentially leading to an understatement of the impact of the programme. NGA access is positively correlated with the availability of superfast broadband, with a Pearson's correlation coefficient of 0.7[43]. However, it is not a strong predictor in some cases, for example where the distance of premises from the serving cabinet is large. As such, a focus on NGA access will

[38] UKB have not been included in the Connected Nations data for any year but delivered the Phase 2 contract in Swindon.

[39] Defined by Ofcom as: New or upgraded access networks that will allow substantial improvements in broadband speeds and quality of service. Can be based on a number of technologies including cable, fixed wireless and mobile. Most often used to refer to networks using fibre optic technology.

[40] The 2012 and 2013 OfCom datasets will have systematically overstated NGA coverage for the analytical purposes of this paper, as a postcode qualified as being passed by NGA if just one premise was enabled with NGA.

[41] I.e. the share of premises with NGA coverage, which is measured directly in the Connected Nations dataset between 2014 and 2016.

[42] Such as assuming a postcode has NGA coverage if at least one premises was covered by NGA.

[43] This was calculated based on the relationship between share of premises with NGA coverage and the share of premises with superfast (30 Mbit/s) coverage at a postcode level, as captured in the 2016 to 2019 Connected Nations datasets.

overstate superfast availability. In addition, NGA access was excluded from the 2017 release and has been imputed using both NGA availability in 2016 and superfast availability in 2017. Where a postcode had NGA availability in 2016 it was assumed this remained the case in 2017 whilst any postcodes that did not have NGA available in 2016 but had more than 50 percent of premises with superfast available in 2017 were also assumed to have NGA available in 2017. Superfast availability itself appears in the data from 2014 onwards, while observations of FTTP coverage are available from 2017.

- **Definition of superfast:** There were differences in the definition of superfast employed by the programme in Phase 1 and Phase 2 (>24Mbps) and the Connected Nations data (>30Mbps). In these cases, analyses will understate the effect of the programme on superfast availability where subsidised coverage has delivered speeds of between 24 and 30 Mbps. The definition of superfast in Phase 3 aligns with Connected Nations.

- **Missing data:** The Connected Nations data describes the average and maximum download speeds of connections. Average and maximum download speeds are missing for a meaningful share of postcodes in early years, particularly 2012 and 2013 but to a lesser extent throughout, due to insufficient numbers of premises or missing data. This is primarily an issue for the long-term assessment of the impacts of the programme. Restricting the sample to postcodes where speed data is available in all years between 2016 and 2019 reduces the sample size to 1.2m postcodes, though data on NGA access is available for all postcodes. Clearly, there are questions as to how far there are systematic differences between those postcodes for which speed data is and is not available, and the analysis has sought to explore the effect of including and excluding these postcodes on the estimated impact of the programme.

- **Truncated data:** Observations of low and high download speeds are truncated in the 2012 and 2013 Connected Nations data. Speeds of less than 4Mbps are recorded as '<4Mbps' and speeds greater than 30MBits/s are recorded as '30Mbps' – and as such cannot be included as a control variable without further reducing the size of the available sample. Again, this limitation is only of relevance to the longer-term assessment of the programme's impacts.

- **Change in methodology to derive the premise base:** In 2019, Ofcom altered the derivation of the premise base used to allocate supplier provided data returns to coverage of postcodes across the UK[44]. The result of this methodological change is that some postcodes saw reported falls in superfast and FTTP coverage between 2018 and 2019. The code used to produce the premise base for the 2019 release is available in the methodology report and was used to provide revised measures of the premises base for 2019 whilst Ofcom provided the code to generate the premise base for all years prior. The percentage of premises with superfast, NGA and FTTP availability in 2019 was multiplied by the 2019 premise base for each postcode to generate the number of premises with such availability in 2019. This was then divided by the 2018 premise base to construct a revised measure of availability for 2019.

ThinkBroadband

ThinkBroadband is an independent organisation which collects information about broadband coverage in the UK. ThinkBroadband made data available on broadband coverage by infrastructure provider by

[44] See https://www.ofcom.org.uk/__data/assets/pdf_file/0021/186411/connected-nations-2019-methodology.pdf

postcode for the years 2012, 2016, and 2020. This enabled the construction of postcode level measures of the number of network providers.

The data covered the estimated footprints of 60 network providers[45] offering broadband coverage (superfast or below). The data also includes the type of technology used to provide these broadband services. This data has been collected in three main ways:

- **Desk research of the Openreach network:** Identifying the location of Openreach cabinets and the postcodes they serve, the technology used in the cabinet and when this was upgraded.

- **Press releases and network provider engagement:** ThinkBroadband staff monitor press releases issued by network providers that state where they have built networks and where they are planning to build networks in the future. Additionally, network providers engage with ThinkBroadband directly, informing them of their footprints of their existing networks and are going to build networks. The information received from network providers and press releases is validated by ThinkBroadband staff, who check that broadband coverage is available from the network provider in the postcodes they claim to cover.

- **Cross reference with speed test data:** Individuals undertaking speed tests on the ThinkBroadband website are asked to provide their Internet Service Provider (ISP). The data generated by the Speed Tests is checked against the coverage data collected by ThinkBroadband. Where a speed test flags that a network provider (through providing access to ISPs) has coverage in an area that the coverage data states the network provider does not, this area is validated. If the network provider does have coverage in the area highlighted in the speed test, this is added to the coverage database.

This data covered a total of 1.7m postcodes in 2020 and 2016 and 1.6m in 2012. These matched in to the majority of postcodes used in the Phase 3 analysis with 99 percent of each cross section successfully linked.

Speed and Coverage Templates

Details of eligible (‘white’) postcodes and the postcodes included in the build plans of local schemes are generally captured within Speed and Coverage Templates (SCTs) that are completed by providers as part of the tendering exercise. BDUK supplied Ipsos MORI with all available SCTs, which covered almost all local schemes that had been contracted under Phase 1, 2 and 3 by September 2019[46]. Postcode level data in Phase 1 and 2 SCTs and premise level data in Phase 3 SCTs were aggregated and matched to the Connected Nations datasets. Any postcodes that did not match were dropped from the analysis. Table 1.1 provides a breakdown of the postcodes available by their status as defined in the SCTs. In summary:

- **White postcodes:** There were 348,480 ‘white’ postcodes eligible for BDUK subsidies (23 percent of postcodes in the UK) under Phase 1 of the programme, 173,014 postcodes eligible for BDUK subsidies under Phase 2 of the programme (11 percent of postcodes in the UK) and 118,460 eligible postcodes in Phase 3 (eight percent of UK postcodes).

- **Postcodes included in build plans:** The build plans associated with local schemes covered 248,521 postcodes (16 percent of postcodes in the UK) in Phase 1, 95,266 postcodes in Phase 2 (6

[45] Data covered suppliers that owned and operated their own networks and did not cover ISPs in this analysis

[46] Two SCTs from Phase 2 and a further three from Phase 3 were not used in the analysis as they did not contain the necessary information and were in different formats.

percent of postcodes in the UK) and 66,926 postcodes in Phase 3 (4 percent of UK postcodes). These figures exclude any postcodes that were included in build plans for non-superfast delivery.

- **Grey or Black Postcodes:** For Phase 1, a total of 524,124 postcodes were deemed as 'grey' or 'black' in the SCT template, and therefore ineligible for BDUK subsidies (around 34 percent of postcodes in the UK). The number of ineligible postcodes rose to 744,233 in Phase 2 (48 percent of the UK) and then fell to just 39,472 for Phase 3.[47]

- **Descoped and ineligible LAs:** A further 227-232,000 postcodes were ineligible for BDUK subsidies because they were 'de-scoped' by the Local Authority or Devolved Administration or were located in Local Authorities deemed outside the scope of the programme by BDUK because commercial deployments were expected to be extensive (or Local Authorities voluntarily declared themselves ineligible). The ineligible local authorities were Birmingham, Bristol, Kingston-Upon-Hull, Manchester and Salford – and the 33 Boroughs of London - while Coventry, Portsmouth and Southampton did not take part. This was equivalent to just under 15 percent of the postcodes in the UK.

- **Postcodes not present in SCT or areas without schemes:** The SCTs prepared by local bodies did not always provide full coverage of the postcodes within their area. This was particularly the case for Phase 3 where SCTs predominantly included just those premises that were eligible for subsidy. Additionally, some local bodies eligible for BDUK subsidies did not come forward with a scheme (e.g. Luton). It is unknown if these postcodes were 'white,' 'grey' or 'black'. This accounted for 19 percent of postcodes in the UK under Phase 1, and 22 percent under Phase 2 and 75 percent in Phase 3. In Phase 3, large numbers of ineligible premises were not included in the SCTs (explaining the high share of postcodes falling in this category).

- **Area excluded from the analysis:** SCT templates were not available for a small number of local areas (Gloucestershire & Herefordshire and North Yorkshire) who contracted their programmes via an OJEU process rather than using the BDUK Framework Agreement in Phase One. Additionally, there was no SCT template available for Wales. No information is available on the postcodes included within the build plan of these schemes or those that were eligible and these areas have been dropped from most analyses provided in this report. Additionally, a prior evaluation scoping study prepared for BDUK recommended the exclusion of Cornwall owing to the contaminating effect of the broadband coverage subsidised through the EU Convergence programme. On this basis, Cornwall has also been excluded in the following analyses[48]. Phase 3 schemes did not cover these areas and no areas were excluded.

[47] Note that for Phase 3, most SCTs only included premises that were eligible for subsidy.

[48] It is understood that a similar issue applies in Northern Ireland with EU funded programmes bringing superfast coverage to towns and villages. However, prior programmes were planned - and to a large extent delivered - before the Superfast Broadband programme. Their effects on coverage would have been captured through the Open Market Review process, enabling these external factors to be controlled for in the analysis.

Table 1.1: Overview of Speed and Coverage Templates, Phase 1, 2 and 3

Status	Phase 1		Phase 2		Phase 3	
	Number	Percentage	Number	Percentage	Number	Percentage
White postcode within build plan defined in SCT	248,521	16.18	95,266	6.2	66,926	4.36
White postcode out of build plan defined in SCT	99,959	6.51	77,748	5.06	51,534	3.35
Grey or Black postcode in SCT	524,124	34.11	744,233	48.44	39,472	2.57
De-scoped postcode or 'ineligible' LA	227,214	14.79	227,450	14.8	231,894	15.09
Postcodes not present in SCT or in areas with no scheme	290,082	18.88	264,371	17.21	1,146,567	74.63
Area excluded from analysis	146,493	9.53	127,325	8.29	-	-
Total	**1,536,393**	100	**1,536,393**	**100.0**	**1,536,393**	**100.0**

Source: SCT templates, Ipsos MORI analysis

C3 reports

Claimed delivery of premises upgraded 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 September 2019 were used to support the analyses reported below and elsewhere in this evaluation. These provided details of 6.3m premises that were claimed to have been upgraded by providers. Not all of these premises would have received coverage subsidised by BDUK, and a number of steps were taken to refine this dataset:

- **Predicted speeds:** Around 608,500 premises (in 101,768 postcodes) were claimed to have been upgraded to an available download speed of less than 24Mbps[49]. This might occur, for example, if the premise was too far from the serving exchange or cabinet, and includes delivery of basic broadband funded by BDUK but is treated as out of scope of the evaluation.

- **Dates**: A further 4,984 premises upgraded were dropped from the dataset because the reported date of the upgrade occurred before the programme began or was not clear (e.g. the quarter quoted was larger than 4). It is assumed that these represent data entry errors, and account for a negligible share of the overall number of premises upgraded.

- **Matching to Connected Nations:** Finally, 33,222 premises upgraded were associated with postcodes that were not present in the Connected Nations dataset. These were also excluded from the analysis as there were no observations of the outcomes of interest.

- **Allocation to delivery years:** Allocation of delivery to specific years was complicated by the changing times across years from which the Connected Nations snapshots were taken (as described above). To address this issue, delivery between July 2016 and April 2017 were assigned to 2017 (a

[49] 30Mbit/s was the threshold applied for Phase 3.

period of 10 months), and delivery between May 2017 and August 2018 were assigned to 2018 (a period of 16 months).

The table overleaf maps the resultant sample of upgraded premises to the status of areas described in Table 1.1. Sixty four percent of claimed delivery under Phase 1 and 91 percent under Phase 2 was reported in postcodes included in the build plans of local schemes defined in the SCT. A large share of this apparent discrepancy for Phase 1 and 2 is accounted for by delivery recorded in those areas that have been excluded from the analysis (20 percent under Phase 1 and one percent under Phase 2).

The data also points to a level of claimed delivery in areas that were outside the build plan:

- **Delivery in other white postcodes:** Just over 400,000 premises upgraded in Phase 1 were claimed on white postcodes outside of the build plan defined in the SCT. This fell to 29,000 for Phase 2 and 868 for Phase 3. Discussions with BDUK suggested that this would occur primarily where the engineers reached a cabinet and found that they could not upgrade, e.g. for technical reasons or if there was a planning constraint. In this case, the engineers may move on to the next eligible postcode. In principle, these changes should have been captured in the SCT via a change request, though in practice the SCTs do not provide a perfect record. Reinvestments also may not have been fully captured in change requests. These postcodes were reallocated to the set of postcodes benefitting from BDUK subsidies.

- **Delivery in ineligible areas:** Only a small fraction of premises upgraded located in ineligible areas, i.e. the grey, black, and de-scoped postcodes or postcodes in ineligible local authorities. Discussions with BDUK suggested that this would primarily occur because the serving cabinets upgraded would simultaneously serve premises on white and ineligible postcodes, and providers would report the full set of premises upgraded. In the analysis, these postcodes were not reallocated to the set of postcodes considered to have benefitted from BDUK investment as suppliers did not receive a subsidy to upgrades these premises.

- **Delivery on postcodes not included in the SCT:** In Phase 3, 88 percent of claimed delivery was on postcodes that included in the build plans of Phase 3 contracts. However, 10 percent of claimed delivery was claimed for premises upgraded on postcodes that were not included in the SCTs. These premises were discounted from the analysis and are suspected to be premises bordering ineligible areas.

Table 1.2: Claimed Number of Premises Upgraded, 2013 to 2019

Status	Phase 1		Phase 2		Phase 3	
	Number of Premises Claimed	Percentage	Number of Premises Claimed	Percentage	Number of Premises Claimed	Percentage
White postcode within build plan defined in SCT	2,949,323	64%	805,211	93%	78,232	88%
White postcode out of build plan defined in SCT	400,744	9%	29,372	3%	868	1%
Grey or Black postcode in SCT	319	0%	22,950	3%	564	1%
De-scoped postcode or 'ineligible' LA	6,104	0%	0	0%	0	0%
Postcodes not present in SCT or in areas with no scheme	350,622	8%	0	0%	8,781	10%
Area excluded from analysis	925,677	20%	12,763	1%	0	0%
Total	**4,632,789**	**100%**	**870,296**	**100%**	**88,445**	**100%**

Source: C3 Reports, Ipsos MORI analysis.

Infrastructure data

BDUK supplied a range of other data describing the pre-programme characteristics of postcodes in the UK. These served as control variables for the analysis. These primarily described the characteristics of local networks in 2013[50] in terms of factors likely to influence the costs of upgrading serving cabinets or the final speeds attained. These variables included:

- Modelled length of the line from the serving exchange to the serving cabinet to the premise;
- Modelled length of the line from the serving cabinet to the premise;
- Modelled share of exchange only lines;
- Modelled number of delivery points at the serving exchange;
- Modelled number of delivery points at the serving cabinet (equalling zero for postcodes served by Exchange Only lines);
- Whether the postcode was within the Virgin Media or K-COM footprint in 2013;
- Number of residential and non-residential delivery points on the postcode in 2013.

Some postcodes were served by more than one cabinet. In these cases, the variables above were calculated as a weighted average across the cabinets serving the postcodes, with the share of delivery points served by each cabinet providing the weights. The available data did not capture all factors likely to influence installation costs, such as topography or local planning constraints.

Area characteristics

A further set of control variables were collected describing the characteristics of the resident population before the programme was delivered. These included measures of the size of the working age population

[50] The modelling has not been updated since 2013 and therefore no more recent data was available to update this.

and population aged 65 plus at the output area level derived from the 2011 Census that were also used to calculate measures of population density. An indicator of whether a postcode was located within rural or urban areas was derived from the ONS Postcode Lookup table. Finally, measures of the economic performance of areas in 2013 were derived from the Annual Survey Hours and Earnings and the Annual Population Survey respectively, including gross weekly earnings, and unemployment and employment rates. The latter were observed at the level of the local authority district.

LFFN and Gigabit Connectivity Voucher Scheme

Finally, BDUK supplied the postcodes associated with premises that had received a Gigabit Connectivity Voucher to control for their possible influence over the outcomes of interest. These entitle recipients to a subsidy towards a gigabit capable connection (typically FTTP) which would lead to similar outcomes as those expected through the Superfast Programme. There were 2,135 vouchers issued in 2018 and 11,901 in 2019. These were spread across 1,018 postcodes in 2018 and 6,102 in 2019. In total 6,833 postcodes benefitted from at least one voucher.

The postcodes within 1km of Wave One Local Full Fibre Networks Programme (LFFN) areas were also matched into the data with FTTP rollout targeted in these areas as part of the LFFN. These encompassed 64,863 postcodes in total in areas of West Sussex, Tameside, across the Pennines (Trans-Pennine Initiative (TPI) areas) and around schools in rural areas benefitting from the Public Sector Building Upgrades scheme. In total, 7,400 postcodes and 106,401 premises delivered to through the Superfast programme were within 1km of FTTP coverage or connections brought forward with support from LFFN. Details of Wave Two and Wave Three schemes were unavailable.

Annex B: First probit progressions – propensity score matching models (Phase 3)

Table 6.4: PSM probit regression outputs

Treatment group	Delivered as of Sep 2019				All in build plans			
Controls included	No speed controls		Speed controls included		No speed controls		Speed controls included	
Variable	Coef	P>z	Coef	P>z	Coef	P>z	Coef	P>z
Number of suppliers in postcode (2012)	-1.36	0.00	-1.36	0.00	-0.70	0.00	-0.01	0.05
Number of suppliers in postcode (2016)	1.18	0.00	1.22	0.00	0.73	0.00	0.02	0.00
Superfast % of premises (2014)	0.00	0.00	0.00	0.07	0.00	0.00	-0.02	0.06
Superfast % of premises (2015)	-0.01	0.00	-0.01	0.00	0.00	0.00	0.00	0.89
Superfast % of premises (2016)	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.07
NGA % or premises (2012)	-0.07	0.02	-0.07	0.19	-0.15	0.00	-0.01	0.08
NGA % or premises (2013)	-0.09	0.01	-0.18	0.00	-0.04	0.05	0.01	0.00
NGA % or premises (2014)	0.48	0.00	0.48	0.00	0.31	0.00	-0.01	0.15
NGA % or premises (2015)	-0.08	0.00	-0.01	0.86	0.08	0.00	0.00	0.11
NGA % or premises (2016)	0.00	0.97	0.08	0.05	-0.01	0.41	-0.01	0.05
% of postcodes in LA with NGA, (2013)	-0.41	0.00	-0.47	0.00	-0.44	0.00	0.00	0.67
% of postcodes in LSOA with NGA, (2013)	0.25	0.00	0.33	0.00	-0.02	0.21	0.00	0.06
Line Length (m)	0.01	0.19	-0.01	0.22	0.00	0.72	0.00	0.00
Final speed	0.01	0.00	0.00	0.83	0.01	0.00	-0.83	0.00
Premises with EO lines 2013	0.00	0.60	0.00	0.84	0.00	0.00	0.83	0.00
Delivery points at serving exchange	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
Delivery points at serving cabinet	0.00	0.00	0.00	0.03	0.00	0.01	0.00	0.00
Virgin Media availability	-1.19	0.00	-1.26	0.02	-0.97	0.00	0.00	0.00

Estimated Upgrade Cost (£)	0.00	0.10	0.00	0.46	0.00	0.00	-0.09	0.00
Cost Per Premises Upgraded	0.00	0.20	0.00	0.06	0.00	0.99	-0.13	0.00
Working Age Population	0.00	0.03	0.00	0.50	0.00	0.00	0.24	0.00
Population Aged 65 and Over	0.00	0.00	0.00	0.04	0.00	0.00	0.12	0.00
(Log) Population Density	0.18	0.00	0.19	0.00	0.07	0.00	0.10	0.00
(Log) Premises Density	-0.12	0.00	-0.16	0.01	-0.03	0.04	-0.47	0.00
Gross Weekly Wages (in LA)	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.29
Employment Rate (in LA)	0.08	0.00	0.08	0.00	0.08	0.00	-0.01	0.06
Unemployment Rate (in LA)	0.06	0.00	0.05	0.00	0.05	0.00	0.01	0.00
Number of premises with superfast available (2014)	0.00	0.17	-0.01	0.08	0.00	0.08	0.00	0.00
Number of premises with superfast available (2015)	0.01	0.04	0.00	0.19	0.00	0.09	0.00	0.00
Number of premises with superfast available (2016)	0.00	0.36	0.00	0.60	0.00	0.93	-0.69	0.00
Number of superfast connections (2016)			-0.02	0.02			0.00	0.39
Number of superfast connections (2015)			0.03	0.05			0.00	0.00
Number of superfast connections (2014)			0.02	0.38			0.00	0.00
Average Download Speeds (2012)			0.02	0.02			0.18	0.00
Maximum Download Speeds (2012)			0.00	0.95			-0.14	0.00
Average Download Speeds (2013)			-0.03	0.01			0.00	0.00
Maximum Download Speeds (2013)			0.02	0.00			0.07	0.00
Average Download Speeds (2014)			-0.03	0.00			0.05	0.00
Maximum Download Speeds (2014)			0.01	0.00			-0.03	0.00
Average Download Speeds (2015)			0.00	0.90			0.00	0.94
Maximum Download Speeds (2015)			0.00	0.67			0.00	0.11
Average Download Speeds (2016)			0.00	0.30			0.00	0.01

Maximum Download Speeds (2016)			0.00	0.00			-3.52	0.00
Average Upload Speeds (2014)			0.01	0.80			0.00	0.91
Average Upload Speeds (2015)			-	-			-	-
Average Upload Speeds (2016)			0.01	0.31			0.02	0.01
Constant	-5.49	0.00	-5.14	0.00	-4.46	0.00	0.00	0.00

Annex C: Control group regression results

Table 6.5: State aid control group approach predictive regression results

	Model 1	Model 2	Model 3	Model 4
Model	Logit	OLS	OLS	OLS
Outcome	NGA availability in 2019	Superfast availability in 2019	FTTP availability in 2019	Number of suppliers in 2020
Number of suppliers in 2012	0.102	3.934***	-7.13***	0.077***
Number of suppliers in 2016	-0.094	-2.141***	7.538***	0.879***
Superfast access in 2014	-0.019***	-0.012***	-0.079***	0*
Superfast access in 2015	-0.014***	0.006**	0.185***	0***
Superfast access in 2016	0.019***	0.546***	-0.14***	0***
NGA access in 2012	0.694***	-0.845***	-1.644***	-0.014***
NGA access in 2013	-0.252***	0.448***	0.692***	0.015***
NGA access in 2014	0.738***	-2.154***	-2.861***	0.009***
NGA access in 2015	1.084***	4.452***	3.074***	-0.016***
NGA access in 2016	3.033***	-19.738***	-3.067***	0.011***
% of postcodes in LA with NGA, 13	0.434***	7.592***	8.957***	0.096***
% of postcodes in LSOA with NGA, 13	-0.231***	-3.032***	2.087***	0.019***
Line Length (m) / Log Line Length	0.032***	-0.925***	-0.08***	0.004***
Final speed / Log Line Length	0.031***	0.435***	0.059***	0.001***
Premises with EO lines 2013	0.002***	0.034***	-0.037***	-0.001***
Delivery points at serving exchange	0**	0***	0***	0***
Delivery points at serving cabinet	0.002*	-0.001***	-0.002***	0***
Virgin Media availability	1.323***	-1.88***	-6.607***	0.018***
Estimated Upgrade Cost (£)	0***	0***	0*	0**
Cost Per Premises Upgraded	0***	0***	0.001***	0***
Working Age Population	0***	0.011***	0.014***	0***
Population Aged 65 and Above	-0.001	0.029***	-0.017***	0***
Population Density (log)	0.049***	-2.932***	-6.231***	-0.019***
Premises Density (log)	0.056	5.602***	6.331***	0.032***
Gross Weekly Wages (in LA)	0.004*	0.024***	-0.007***	0***
Employment Rate (in LA)	0.007***	0.168***	-0.221***	0.004***
Unemployment Rate (in LA)	0.077***	0.56***	-0.493***	0.001***
FTTP availability 2017 / number of premises	0.107***	0.193***	1.745***	0.003***
Superfast availability 2014 / number of premises	0.041***	-0.041***	0.139***	0
Superfast availability 2015 / number of premises	0.013***	0.002	-0.263***	0***
Superfast availability 2016 / number of premises	-0.006***	0.011**	0.044***	0.001***
Constant	-4.105***	4.283***	31.443***	-0.253***

Observations	699,153	699,153	699,153	699,153
R Squared	0.484	0.541	0.306	0.916

*Source: Ipsos MORI analysis; BDUK C3 reports & Ofcom Connected Nations; *** represents differences significant at 99 percent, ** at 95 percent and * at 90 percent*

Annex D: Regression based difference-in-difference tables

Figure 6.1: Regression based DiD results part 1 (treatment postcodes include those upgraded by Sep 2019)

Outcome	Change in NGA			Change in SFB			Change in FTTP			Change in number of suppliers		
Controls included	No Controls	Postcode Controls	All Controls	No Controls	Postcode Controls	All Controls	No Controls	Postcode Controls	All Controls	No Controls	Postcode Controls	All Controls
Treatment (upgraded by Sep 2019)	0.107***	0.0265***	0.0265***	25.21***	10.51***	10.64***	28.69***	23.48***	23.85***	0.202***	0.205***	0.208***
Total GBVS vouchers in postcode			-0.00205			0.606*			-1.047***			-0.00569
Total GBVS vouchers in OA			0.00999***			0.282			1.808***			0.0183***
Total GBVS vouchers in LSOA			-0.00218***			0.178*			0.168**			0.000517
PSBU school within 100m			-0.00619			-9.631*			-3.521			0.175**
PSBU school within 500m			0.0524**			4.778			0.00856			-0.133***
PSBU school within 1000m			-0.00483			-5.174**			-13.02***			-0.0318
Number of suppliers present in 2012		-0.0124***	-0.0126***		-4.747***	-4.730***		-20.64***	-20.55***		0.0870***	0.0877***
Number of suppliers present in 2016		0.0241***	0.0244***		6.893***	6.895***		21.56***	21.53***		-0.123***	-0.124***
Superfast coverage (2014)		0.000154**	0.000156**		-0.0415***	-0.0410***		-0.0551***	-0.0543***		0.000264**	0.000277**
Superfast coverage (2015)		-0.000600***	-0.000596***		0.0202**	0.0202**		0.0141*	0.0135*		-0.000536***	-0.000544***
Superfast coverage (2016)		0.000139***	0.000135**		-0.490***	-0.490***		-0.0662***	-0.0658***		0.000338***	0.000342***
NGA coverage (2012)		-0.00946***	-0.00961***		-1.312***	-1.284***		0.0773	0.192		-0.00982*	-0.00897
NGA coverage (2013)		0.00338	0.00361		0.255	0.315		2.237***	2.303***		0.0269***	0.0278***
NGA coverage (2014)		-0.0297***	-0.0298***		0.0678	-0.00643		-0.635	-0.807		-0.0276***	-0.0295***
NGA coverage (2015)		0.0448***	0.0449***		4.093***	4.158***		1.867***	2.022***		-0.0361***	-0.0343***
NGA coverage (2016)		-0.745***	-0.744***		-18.03***	-17.99***		-1.047**	-1.003**		0.0149**	0.0153**
NGA coverage in LA (2016)		0.0497***	0.0497***		11.83***	11.66***		14.14***	13.68***		0.0531***	0.0496***
NGA coverage in LSOA (2016)		-0.0139***	-0.0141***		-1.935***	-1.979***		0.613	0.535		0.00813	0.00699
Line length (log)		-0.000590	-0.000632		-0.980***	-0.995***		0.0888	0.0607		0.00481***	0.00466***
Line speed (log)		0.00265***	0.00265***		0.456***	0.454***		0.151***	0.150***		0.000663	0.000663
Exchange only lines		6.93e-05	7.25e-05		0.0615***	0.0617***		0.0319**	0.0326***		-0.000812***	-0.000799***
Exchange delivery points		-2.00e-07**	-2.00e-07**		-4.96e-05***	-4.90e-05***		-9.50e-05***	-9.32e-05***		5.56e-07***	5.61e-07***
Cabinet delivery points		2.56e-05***	2.58e-05***		-0.000494	-0.000408		-0.000958	-0.000758		-3.70e-05***	-3.49e-05***

Virgin Media coverage		-0.0118***	-0.0119***		-2.576***	-2.564***		-5.923***	-5.910***		0.0436***	0.0436***
Total cost to upgrade cabinet in 2013		3.17e-07***	3.15e-07***		7.91e-05***	7.91e-05***		2.32e-06	2.24e-06		-1.09e-07	-1.12e-07
Cost per premise to upgrade cabinet in 2013		-2.90e-07	-3.19e-07		0.000380***	0.000375***		0.000728***	0.000725***		6.56e-06***	6.54e-06***
Working age population		3.52e-06	1.65e-06		0.00599***	0.00593***		0.00675***	0.00687***		6.98e-05***	6.99e-05***
Population 66+		8.04e-05***	8.49e-05***		0.0212***	0.0216***		-0.0220***	-0.0221***		-0.000398***	-0.000396***
Population density (log)		-0.00411	-0.00341		-1.906***	-1.810***		-6.413***	-6.228***		-0.0308***	-0.0291***
Premises density (log)		0.0121***	0.0114***		4.601***	4.515***		6.145***	5.995***		0.0326***	0.0312***
Weekly wages		0.000243***	0.000245***		0.0350***	0.0349***		0.0208***	0.0203***		0.000200***	0.000197***
Employment rate		-0.000484**	-0.000525**		-0.0922***	-0.0953***		-0.437***	-0.442***		0.00463***	0.00455***
Unemployment rate		0.00195***	0.00193***		0.0372	0.0484		-0.412***	-0.383***		0.00374***	0.00394***
FTTP premises (2017)		0.000994***	0.000998***		0.106***	0.107***		-0.474***	-0.471***		0.00354***	0.00356***
SFB premises (2014)		-0.000262*	-0.000271*		-0.0443**	-0.0455**		-0.00425	-0.00493		-0.000109	-0.000118
SFB premises (2015)		0.00106***	0.00105***		0.0219	0.0215		0.102***	0.102***		0.000707**	0.000706**
SFB premises (2016)		-0.000959***	-0.000950***		-0.00282	-0.00210		-0.0880***	-0.0883***		-0.000237	-0.000238
Constant	0.111***	0.494***	0.495***	13.79***	19.18***	19.29***	4.775***	27.99***	28.21***	0.0766***	-0.331***	-0.329***
Observations	60,597	56,085	56,085	60,597	56,085	56,085	60,579	56,085	56,085	60,540	56,085	56,085
R-squared	0.011	0.685	0.686	0.057	0.481	0.482	0.138	0.229	0.234	0.034	0.056	0.058

**** represents differences significant at 99 percent, ** at 95 percent and * at 90 percent*

Figure 6.2: Regression based DiD results part 2 (treatment postcodes include all in build plans)

Outcome	Change in NGA			Change in SFB			Change in FTTP			Change in number of suppliers		
Controls included	No Controls	Postcode Controls	All Controls	No Controls	Postcode Controls	All Controls	No Controls	Postcode Controls	All Controls	No Controls	Postcode Controls	All Controls
Treatment (all in build plan)	0.328***	0.0314***	-0.0182***	-0.0180***	6.059***	-3.164***	-3.131***	3.535***	1.571***	1.637***	0.0486***	0.0539***
Total GBVS vouchers in postcode				-0.00273			0.505			-0.570**		
Total GBVS vouchers in OA				0.0120***			0.572**			1.652***		
Total GBVS vouchers in LSOA				-0.00358***			-0.0112			0.102*		
West Sussex LFFN within 500m				-0.0101			-30.75			-13.55		
West Sussex LFFN within 1000m				0.0289			1.579			8.971		
PSBU school within 100m				0.00538			-2.634			-1.321		
PSBU school within 500m				0.0893***			8.125***			-0.511		
PSBU school within 1000m				-0.0636***			-4.354**			-3.337**		
TPI within 100m				-0.0251			-26.37			10.21		
TPI within 500m				0.00504			20.68			0.324		
TPI within 1000m				0.0475			-8.184			-6.590		
Number of suppliers present in 2012			-0.0232***	-0.0232***		-8.595***	-8.606***		-18.60***	-18.62***		0.0312***
Number of suppliers present in 2016			0.0294***	0.0295***		8.996***	9.014***		18.74***	18.78***		-0.0612***
Superfast coverage (2014)			0.000198***	0.000199***		-0.00113	-0.000850		-0.0398***	-0.0394***		-1.00e-05
Superfast coverage (2015)			-0.000442***	-0.000441***		0.0357***	0.0360***		0.0295***	0.0297***		-0.000479***
Superfast coverage (2016)			2.59e-05	2.37e-05		-0.478***	-0.478***		-0.0738***	-0.0740***		0.000104
NGA coverage (2012)			-0.00251	-0.00246		-0.804**	-0.802**		-0.698***	-0.670***		-0.00923**
NGA coverage (2013)			0.00939***	0.00951***		0.653	0.676*		1.328***	1.359***		0.0157***
NGA coverage (2014)			-0.0266***	-0.0267***		-2.427***	-2.443***		0.164	0.122		-0.00388
NGA coverage (2015)			0.0717***	0.0716***		5.525***	5.538***		0.0317	0.0936		-0.0622***
NGA coverage (2016)			-0.717***	-0.717***		-16.92***	-16.88***		-1.216***	-1.173***		0.0179***
NGA coverage in LA (2016)			0.0241***	0.0240***		7.582***	7.534***		8.196***	8.042***		0.0255***
NGA coverage in LSOA (2016)			-0.0292***	-0.0294***		-2.183***	-2.199***		2.333***	2.300***		0.00775
Line length (log)			-0.00149**	-0.00152**		-1.023***	-1.027***		-0.00438	-0.0155		0.00387***
Line speed (log)			0.00195***	0.00195***		0.253***	0.253***		0.0897***	0.0889***		0.00134***
Exchange only lines			0.000255***	0.000259***		0.0505***	0.0508***		-0.0247***	-0.0237***		-0.000758***

Exchange delivery points			-2.25e-07**	-2.19e-07**		-1.50e-05	-1.47e-05		-7.00e-06	-6.16e-06		1.66e-06***
Cabinet delivery points			6.38e-05***	6.42e-05***		0.000530	0.000569		-0.00262***	-0.00250***		-4.87e-05***
Virgin Media coverage			-0.00941***	-0.00924***		-1.777***	-1.761***		-5.436***	-5.419***		0.0423***
Total cost to upgrade cabinet in 2013			4.26e-07***	4.25e-07***		9.06e-05***	9.05e-05***		-7.51e-06**	-7.92e-06**		7.36e-08
Cost per premise to upgrade cabinet in 2013			7.87e-07	7.68e-07		0.000223***	0.000221***		0.000294***	0.000293***		1.49e-06
Working age population			-4.16e-05***	-4.23e-05***		0.0164***	0.0163***		0.0141***	0.0140***		0.000136***
Population 66+			0.000105***	0.000107***		0.0405***	0.0407***		-0.00245	-0.00212		-0.000119***
Population density (log)			0.00284	0.00360		-3.388***	-3.314***		-4.065***	-3.955***		0.00486
Premises density (log)			0.00238	0.00165		6.267***	6.196***		3.978***	3.877***		-0.00137
Weekly wages			0.000139***	0.000139***		0.00924***	0.00925***		0.00252*	0.00239*		0.000328***
Employment rate			0.000435**	0.000422**		0.0428	0.0414		-0.262***	-0.264***		0.00373***
Unemployment rate			0.00358***	0.00358***		0.166***	0.168***		-0.254***	-0.247***		0.000775
FTTP premises (2017)			0.000903***	0.000908***		0.0997***	0.100***		-0.525***	-0.524***		0.00299***
SFB premises (2014)			-0.000223*	-0.000228*		-0.0555***	-0.0566***		0.000665	-0.000182		0.000418*
SFB premises (2015)			0.000498***	0.000500***		-0.0463**	-0.0465**		0.0252	0.0247		0.000430
SFB premises (2016)			-0.000408***	-0.000409***		0.0783***	0.0791***		-0.00836	-0.00760		-0.000353*
Constant	-2.012***	0.111***	0.460***	0.461***	13.79***	21.15***	21.14***	4.775***	25.66***	25.64***	0.0766***	-0.353***
Observations	1,599,664	118,454	109,964	109,964	118,454	109,964	109,964	118,422	109,964	109,964	118,333	109,964
R-squared		0.002	0.609	0.610	0.007	0.358	0.359	0.006	0.082	0.085	0.004	0.028

**** represents differences significant at 99 percent, ** at 95 percent and * at 90 percent*

Annex E: Regression based difference-in-difference tables with matched sample

Figure 6.3: Regression based DiD results with matched sample part 1 (treatment postcodes include those upgraded by Sep 2019)

Outcome	Change in NGA			Change in SFB			Change in FTTP			Change in number of suppliers		
Controls included	No Controls	Postcode Controls	All Controls	No Controls	Postcode Controls	All Controls	No Controls	Postcode Controls	All Controls	No Controls	Postcode Controls	All Controls
Treatment (upgraded by Sep 2019)	0.0508***	0.0329***	0.0323***	16.02***	11.09***	11.17***	26.08***	23.07***	23.43***	0.166***	0.189***	0.194***
Total GBVS vouchers in postcode			-0.0130			0.747			-0.675			0.0218
Total GBVS vouchers in OA			0.0167***			0.179			1.288*			-0.00315
Total GBVS vouchers in LSOA			-0.00401**			0.202			0.428*			0.00451
PSBU school within 100m			-0.0304			-15.58*			-2.579			-0.0490
PSBU school within 500m			0.0627*			5.790			-1.990			-0.110
PSBU school within 1000m			0.00773			-2.148			-10.74***			-0.155***
Number of suppliers present in 2012		-0.0182***	-0.0186***		-5.904***	-5.921***		-20.52***	-20.48***		0.191***	0.191***
Number of suppliers present in 2016		0.0331***	0.0335***		8.846***	8.868***		23.03***	23.02***		-0.177***	-0.178***
Superfast coverage (2014)		-1.15e-05	-1.56e-05		-0.104***	-0.106***		-0.133***	-0.135***		6.42e-05	5.36e-05
Superfast coverage (2015)		-5.05e-05	-3.93e-05		0.0488**	0.0497**		-0.0555**	-0.0556**		-0.00172***	-0.00174***
Superfast coverage (2016)		-0.000258**	-0.000263**		-0.564***	-0.563***		0.0243	0.0256*		0.00206***	0.00209***
NGA coverage (2012)		-0.0350***	-0.0359***		-1.279	-1.266		4.393***	4.706***		-0.00919	-0.00393
NGA coverage (2013)		0.00732	0.00707		-0.421	-0.387		4.821***	4.934***		0.0422**	0.0440**
NGA coverage (2014)		-0.0568***	-0.0561***		1.297	1.331		4.473***	4.264***		-0.0589***	-0.0630***
NGA coverage (2015)		0.0614***	0.0606***		5.527***	5.510***		-0.837	-0.653		-0.0758***	-0.0719***
NGA coverage (2016)		-0.752***	-0.751***		-14.39***	-14.34***		-0.226	-0.228		0.0224	0.0208
NGA coverage in LA (2016)		0.104***	0.107***		25.32***	25.24***		33.48***	32.47***		-0.118***	-0.134***
NGA coverage in LSOA (2016)		-0.00183	-0.00138		-1.048	-1.136		-0.209	-0.400		0.0385*	0.0360*
Line length (log)		-0.00441**	-0.00450**		-1.304***	-1.309***		0.0352	0.0341		0.00402	0.00410
Line speed (log)		0.00143***	0.00140***		0.434***	0.431***		0.256***	0.256***		-0.000577	-0.000529
Exchange only lines		0.000620***	0.000611***		0.187***	0.187***		0.217***	0.221***		-0.00114**	-0.00108**
Exchange delivery points		-2.60e-07	-2.83e-07		-0.000145***	-0.000143***		-0.000580***	-0.000568***		-2.42e-06***	-2.24e-06***
Cabinet delivery points		5.54e-05***	5.60e-05***		0.00134	0.00144		-0.00726***	-0.00715***		-0.000163***	-0.000164***

Virgin Media coverage		-0.00888	-0.00907		-1.792	-1.852		2.047	1.926		0.322***	0.321***
Total cost to upgrade cabinet in 2013		2.59e-07***	2.47e-07***		9.27e-05***	9.15e-05***		5.14e-05***	5.22e-05***		-1.34e-07	-9.34e-08
Cost per premise to upgrade cabinet in 2013		4.01e-06**	3.99e-06**		0.00106***	0.00105***		0.00132***	0.00131***		3.26e-06	2.95e-06
Working age population		1.85e-06	-2.14e-07		-0.00426	-0.00443		0.00337	0.00394		-0.000139**	-0.000131**
Population 66+		0.000127*	0.000136**		-0.00796	-0.00719		-0.0609***	-0.0618***		-0.000599***	-0.000626***
Population density (log)		0.0120	0.0122		1.582	1.691		-9.736***	-9.656***		-0.0468***	-0.0452***
Premises density (log)		-0.00238	-0.00275		1.612	1.513		8.258***	8.249***		0.0198	0.0193
Weekly wages		0.000455***	0.000457***		0.0647***	0.0649***		0.0667***	0.0660***		0.00117***	0.00116***
Employment rate		-0.00183***	-0.00195***		-0.594***	-0.602***		-1.081***	-1.064***		0.00689***	0.00736***
Unemployment rate		-0.000857	-0.00105		-1.166***	-1.166***		-1.303***	-1.246***		0.00234	0.00334
FTTP premises (2017)		0.00122**	0.00121**		0.265***	0.268***		-1.235***	-1.226***		0.00501***	0.00515***
SFB premises (2014)		0.000501	0.000474		0.0222	0.0243		-0.191**	-0.182**		-0.00337***	-0.00321***
SFB premises (2015)		2.30e-06	-6.60e-06		-0.00345	-0.00236		0.356***	0.357***		0.00627***	0.00633***
SFB premises (2016)		-0.000630*	-0.000620*		-0.0472	-0.0508		-0.201***	-0.208***		-0.00180**	-0.00193***
Constant	0.166***	0.488***	0.498***	22.91***	40.34***	40.80***	7.210***	56.11***	54.39***	0.0931***	-0.744***	-0.785***
Observations	14,851	14,851	14,851	14,851	14,851	14,851	14,851	14,851	14,851	14,851	14,851	14,851
R-squared	0.004	0.695	0.695	0.034	0.450	0.451	0.109	0.320	0.323	0.024	0.098	0.101

**** represents differences significant at 99 percent, ** at 95 percent and * at 90 percent*

Figure 6.4: Regression based DiD results with matched sample part 2 (treatment postcodes include all in build plans)

Outcome	Change in NGA			Change in SFB			Change in FTTP			Change in number of suppliers		
Controls included	No Controls	Postcode Controls	All Controls	No Controls	Postcode Controls	All Controls	No Controls	Postcode Controls	All Controls	No Controls	Postcode Controls	All Controls
Treatment (all in build plan)	-0.00708**	-0.0190***	-0.0187***	0.855***	-3.217***	-3.169***	2.398***	1.602***	1.687***	0.0494***	0.0517***	0.0528***
Total GBVS vouchers in postcode			-0.00270			0.548			-0.745**			-0.00197
Total GBVS vouchers in OA			0.0139***			0.638**			1.661***			0.00899**
Total GBVS vouchers in LSOA			-0.00415***			-0.0494			0.0972			0.00825***
West Sussex LFFN within 500m			-0.00955			-30.78			-13.81			-0.0362
West Sussex LFFN within 1000m			0.0328			1.917			8.908			-0.142
PSBU school within 100m			-0.0120			-5.722			-1.693			0.0109
PSBU school within 500m			0.114***			9.794***			-1.281			-0.301***
PSBU school within 1000m			-0.0851***			-4.681**			-2.471			0.179***
TPI within 100m			-0.0272			-26.19			10.71			0.0236
TPI within 500m			0.00947			20.82			0.244			-0.0257
TPI within 1000m			0.0478			-8.222			-6.807			-0.174
Number of suppliers present in 2012		-0.0340***	-0.0340***		-9.927***	-9.936***		-20.44***	-20.46***		0.0368***	0.0364***
Number of suppliers present in 2016		0.0390***	0.0390***		9.950***	9.966***		20.54***	20.58***		-0.0578***	-0.0570***
Superfast coverage (2014)		0.000274***	0.000274***		0.00488	0.00524		-0.0479***	-0.0474***		-0.000216*	-0.000200*
Superfast coverage (2015)		-0.000426***	-0.000425***		0.0381***	0.0384***		0.0343***	0.0347***		-0.000534***	-0.000531***
Superfast coverage (2016)		-1.22e-05	-1.41e-05		-0.483***	-0.484***		-0.0705***	-0.0709***		0.000215***	0.000209**
NGA coverage (2012)		-0.00225	-0.00220		-0.806**	-0.808**		-0.577*	-0.554*		-0.0165***	-0.0163***
NGA coverage (2013)		0.00972***	0.00991***		0.806*	0.835*		1.072***	1.116***		0.0208***	0.0216***
NGA coverage (2014)		-0.0304***	-0.0306***		-2.795***	-2.814***		0.850**	0.807**		-0.00691	-0.00734
NGA coverage (2015)		0.0783***	0.0781***		6.032***	6.043***		-0.533*	-0.473*		-0.0693***	-0.0675***
NGA coverage (2016)		-0.719***	-0.718***		-16.91***	-16.87***		-1.024***	-0.978***		0.0154***	0.0156***
NGA coverage in LA (2016)		0.0240***	0.0236***		8.009***	7.966***		8.387***	8.235***		-0.0208***	-0.0225***
NGA coverage in LSOA (2016)		-0.0318***	-0.0320***		-2.356***	-2.373***		2.945***	2.902***		0.00849	0.00771
Line length (log)		-0.00209***	-0.00214***		-1.106***	-1.110***		-0.0531	-0.0607		0.00455***	0.00450***
Line speed (log)		0.00171***	0.00172***		0.202***	0.202***		0.0899***	0.0904***		0.00139***	0.00137***
Exchange only lines		0.000327***	0.000332***		0.0465***	0.0469***		-0.0318***	-0.0306***		-0.000615***	-0.000594***

Exchange delivery points		-1.54e-07	-1.45e-07		-3.77e-06	-3.53e-06		-2.68e-05**	-2.56e-05**		1.97e-06***	1.97e-06***
Cabinet delivery points		8.32e-05***	8.39e-05***		0.00108	0.00112		-0.00350***	-0.00340***		-4.81e-05***	-4.75e-05***
Virgin Media coverage		-0.00749	-0.00737		-0.693	-0.686		-3.706***	-3.737***		0.0344***	0.0337***
Total cost to upgrade cabinet in 2013		4.66e-07***	4.65e-07***		9.62e-05***	9.60e-05***		-1.67e-06	-2.13e-06		1.28e-07**	1.21e-07*
Cost per premise to upgrade cabinet in 2013		9.12e-07	8.87e-07		0.000197**	0.000195**		0.000315***	0.000314***		7.57e-07	7.73e-07
Working age population		-5.54e-05***	-5.63e-05***		0.0198***	0.0197***		0.0163***	0.0163***		0.000151***	0.000151***
Population 66+		0.000125***	0.000128***		0.0414***	0.0418***		-0.00478*	-0.00447*		-5.00e-05	-4.62e-05
Population density (log)		0.00405	0.00497		-3.486***	-3.401***		-3.825***	-3.721***		0.0163***	0.0169***
Premises density (log)		0.000926	2.88e-05		6.566***	6.483***		3.674***	3.579***		-0.0153***	-0.0158***
Weekly wages		0.000125***	0.000125***		0.00666***	0.00669***		-0.000877	-0.000999		0.000453***	0.000452***
Employment rate		0.000570**	0.000566**		-0.00889	-0.00991		-0.310***	-0.310***		0.00446***	0.00445***
Unemployment rate		0.00391***	0.00390***		0.0993*	0.100*		-0.306***	-0.299***		0.000562	0.000721
FTTP premises (2017)		0.000858***	0.000869***		0.159***	0.160***		-0.797***	-0.795***		0.00248***	0.00249***
SFB premises (2014)		-0.000203	-0.000210		-0.0566**	-0.0581***		0.0149	0.0139		0.000909***	0.000886***
SFB premises (2015)		0.000487***	0.000493***		-0.0550**	-0.0552**		-0.0244	-0.0252		0.000464	0.000440
SFB premises (2016)		-0.000376***	-0.000381***		0.0919***	0.0929***		0.0236*	0.0246*		-0.000540**	-0.000503**
Constant	0.148***	0.456***	0.456***	19.09***	26.00***	25.93***	5.972***	31.26***	31.01***	0.0764***	-0.474***	-0.477***
Observations	87,110	87,110	87,110	87,110	87,110	87,110	87,110	87,110	87,110	87,110	87,110	87,110
R-squared	0.000	0.597	0.597	0.000	0.329	0.329	0.002	0.084	0.087	0.003	0.029	0.033

**** represents differences significant at 99 percent, ** at 95 percent and * at 90 percent*

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State aid evaluation of the UK National Broadband Scheme

Technical Appendix 2 – Modelling of Internal Rates of Return

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Key Terms

Term / acronym	Meaning
FTTP / FTTH	Fibre to the Premises / Fibre to the Home – This refers to an access network structure in which the optical fibre runs from the local exchange to the end user's living or office space.
FTTC	Fibre to the Cabinet - An access network structure in which the optical fibre extends from the exchange to the cabinet. The street cabinet is usually located only a few hundred metres from the subscriber's premises. The remaining part of the access network from the cabinet to the customer is usually copper wire but could use another technology, such as wireless.
Implementation clawback	Subsidies returned to the public sector in the event that build costs are lower than originally contracted.
IRR	Internal rate of return – the discount rate that sets the present value of a cash flow to zero of the lifetime of a project
Network provider	Telecommunications providers which own infrastructure which is used to deliver internet services
PMO costs	Project management office costs
PFM	Project Financial Model – a model of the investment projects costs and revenues used to determine the level of subsidy to be offered
Take-up clawback	Subsidies returned to the public sector in the event that take-up exceeds original expectations.
WACC	Weighted Average Cost of Capital – a measure of the cost of capital faced by network providers.

Summary

This methodological appendix provides modelling of the expected future profitability of contracts awarded to network providers under the 2016 to 2020 UK National Broadband Scheme (known as Phase 3 of the Superfast Broadband programme). As these contracts were at an early stage of delivery at the time of writing, this analysis was informed by comparable analysis of contracts awarded under the 2012 to 2016 UK National Broadband Scheme (known as Phase 1 and 2). Comparisons between Phases have been used to draw inferences in relation to trends in the expected profitability as the programme has evolved.

Key evaluation questions

This analysis addresses the following evaluation questions set out in the State aid evaluation plan:

- Has the aid had a significant incentive effect on the aid beneficiaries?
- Was the subsidy required to deliver commercially sustainable networks?

Background

The motivation for this analysis stems from the results of classical economic theory that suggest the private sector will maximise profits by implementing all projects that generate a rate of return that at least equal their cost of capital. The rationale for the programme is underpinned by an assumption that there are some areas of the UK where investments in superfast broadband infrastructure will not generate a rate of return that exceeds the cost of capital. These investments would not be commercial viable. The programme seeks to provide the minimum subsidy that would be required to make these investments commercially viable (i.e. the subsidy that would equalise the expected returns associated with the investment and the cost of capital faced by the network provider).

However, the public sector cannot perfectly observe the expected costs and revenues associated with potential investments in superfast coverage and network providers have incentives to seek subsidies for investments that would have been commercially viable without public support. These risks are addressed by an Open Market Review process designed to encourage network providers to reveal their investment plans and ensure subsidies are directed towards premises that would not be covered by commercial deployments. Contracts are also designed to protect the public sector from the risk that the subsidy exceeds the minimum needed for the project to go forward (for example, if costs prove less significant than originally expected or if revenues exceed original expectations).

Key findings

- **Commercial viability without subsidy:** Based on projections provided by network providers at the tendering stage, the proposed network build was expected either to generate losses or to deliver positive rates of return that were substantially lower than the cost of capital faced by the network provider. Updating this evidence based on observed costs and take-up suggests that:

  - **Phase 1:** Phase 1 contracts are expected to be substantially more profitable than anticipated at the tendering stage as build costs were systematically overstated and take-up was systematically understated. On average, the portfolio of Phase 1 contracts are projected to deliver an IRR of **[redacted]**, relative to the network providers Weighted Average Cost of Capital of **[redacted]**. Eight of the 28 contracts were expected to deliver a rate of return that exceed the network provider's WACC. This calls into question the strength of the incentive effect in these cases – i.e. the network provider would arguably have had an incentive to proceed with these projects without subsidy.

  - **Phase 2:** Phase 2 contracts were expected to be loss making without subsidy on average (an IRR of **[redacted]** on average). However, 3 of the 31 contracts were expected to deliver rates of return that exceeded the network provider's WACC.

  - **Phase 3:** The expected IRRs associated with Phase 3 projects without subsidy are not significantly higher than those expected at the tendering stage (moving from **[redacted]** per annum loss to positive annual rate of return of **[redacted]**). In all cases, the IRRs associated with the projects were expected to be substantially lower than the WACC of the network provider (**[redacted]**). Arguably, a subsidy would have been needed in all cases to create a sufficient economic incentive to deliver these contracts**.**

- **Effectiveness of contractual mechanisms:** The protections put in place by BDUK to protect the public sector from the risk that it provided more the minimum subsidy needed have proven effective. The contracts have been designed such that network providers are required to return resources to the public sector if build costs are understated or if take-up proves higher than expected (leading to higher levels of profitability):

  - **IRRs:** After the clawback of subsidy, the average IRRs associated with Phase 1, 2 and 3 contracts are expected to fall to **[redacted]**, **[redacted]** and **[redacted]** on average. Few contracts awarded under Phase 2 or 3 are expected to deliver a rate of return that exceeds the network providers' WACC.

  - **Net public spend:** Many contracts awarded under Phase 1 were expected to deliver IRRs that exceeded the network provider's WACC after the application of implementation and take-up clawback. These schemes were largely commercially viable without a subsidy and the clawback mechanisms are expected to return almost all subsidy to the public sector.

- **OMR process:** The OMR process identifies postcodes that where there are no plans to deploy superfast on a commercial basis in the next three years. However, this analysis suggests that the absence of commercial deployment plans does not necessarily imply delivery of infrastructure is not economically viable – commercial deployments may also be constrained by other market failures or the capacity of network providers. As suggested in Technical Appendix 1, the provision of subsidies may also be effective in encouraging network providers to bring forward commercially viable schemes more rapidly than they would have otherwise. The contracting mechanisms have enabled this to take place often at no net cost to the public sector (ignoring the administrative costs associated with the programme).

- **Understatement of take-up:** Network providers have consistently underestimated the level of take-up in their ex-ante projections submitted as part of the tendering process. It is not possible to determine how far network providers took an overly conservative approach during Phase 1 (as no information is available on wider take-up of commercial deployments). Take-up projections in Phases 2 and 3 do appear understated given network providers would have had information on take-up from prior contracts. The understatement of take-up will have fed through to understated revenue projections and rates of return, increasing the level of gap funding required from the public notionally required to make the project economically viable. While the contractual mechanisms have helped contain the risk that network providers earn excess returns, they still have benefitted from a reduction in the risk they faced in making the investment (as while higher than expected take-up clawback reduced the net revenues earned, the higher levels of subsidy awarded provided protection in the event the project was a commercial failure).

- **Opportunity costs:** While the contracts have proven largely effective in containing subsidies to the minimum needed for the project to go forward, the public sector has incurred opportunity costs by tying resources up in the programme. BDUK may wish to consider whether seeking to contain these opportunity costs in future procurements could be justified. The evidence in this analysis indicates that higher levels of competition limit the extent to which network providers can transfer risk to the public sector (as doing so results in less competitive tenders). However, other options could include using the information on the tail end of the distribution of observed take-up rates across Phase 1, 2 and 3 contracts to set a maximum level of subsidy to be offered as part of a given procurement. This may still allow network providers to understate profitability by adjusting revenues via price schedules (though if BDUK are able to monitor revenues earned on connections as well as volumes of customers, this may limit scope to do so).

- **Future competition:** The results of these analysis also do not factor the possibility that the network providers' market share and any excess profits are eroded by the entry of competitors via the open access arrangements required by the programme. This could only be realistically assessed if BDUK were able to monitor revenues earned by network providers alongside customer volumes (as this would help explore issues in relation to both market share and prices).

- **Future analysis:** It should be noted that the analysis of Phase 3 contracts is based on limited evidence on actual build costs and take-up (and assumptions were largely developed based on experiences across Phase 1 and 2 of the programme). This analysis will need to be revisited as part of any future evaluation.

1 Introduction

This methodological appendix provides modelling of the expected future profitability of contracts awarded to network providers under the 2016 to 2020 UK National Broadband Scheme (known as Phase 3 of the Superfast Broadband programme). As these contracts were at an early stage of delivery at the time of writing, this analysis was informed by comparable analysis of contracts awarded under the 2012 to 2016 UK National Broadband Scheme (known as Phase 1 and 2). Comparisons between Phases have been used to draw inferences in relation to trends in the expected profitability as the programme has evolved.

1.1 Key evaluation questions

This analysis addresses the following evaluation questions set out in the State aid evaluation plan:

- Has the aid had a significant incentive effect on the aid beneficiaries?
- Was the subsidy required to deliver commercially sustainable networks?

1.2 Approach

The aim of the analysis is to explore whether public subsidies were needed to provide an incentive to network providers to extend superfast networks to the areas targeted by the programme. The approach adopted in this appendix is informed by the methodology agreed in the State aid evaluation plan agreed between Building Digital UK (BDUK) and the European Commission. This involves comparing the expected rates of return on the investments made to the cost of capital faced by the network provider.

The motivation for this analysis stems from the results of classical economic theory that suggests - in a competitive market with no transaction costs - the private sector will maximise profits by implementing all projects that generate a rate of return that at least equal their cost of capital. The rationale for the programme is underpinned by an assumption that there are some areas of the UK where investments in superfast broadband infrastructure will not generate a rate of return that exceeds the cost of capital. These investments would not be commercial viable, leaving some areas at risk of being excluded from superfast broadband coverage (producing a ‘digital divide’). The programme seeks to provide the minimum subsidy that would be required to make these investments commercially viable (i.e. the subsidy that would equalise the expected returns associated with the investment and the cost of capital faced by the network provider).

However, it is not feasible for the public sector to perfectly observe the expected costs and revenues associated with potential investments in superfast coverage before it awards subsidies. Network providers also have an incentive to seek subsidies for investments that would have been commercially viable in the absence of public support to maximise profitability and minimise risk exposure. The design of the programme anticipates this risk through the implementation of an Open Market Review process designed to encourage network providers to reveal their investment plans and to ensure that subsidies are directed towards premises that would not be covered by commercial deployments. The contracts are also designed to protect the public sector from the risk that the subsidy exceeds the minimum needed for the project to go forward (for example, if costs prove less significant than originally expected or if revenues exceed original expectations).

This section examines the effectiveness of these arrangements by comparing the expected rate of return on the contracts awarded (the Internal Rate of Return[1] or IRR) to the network providers Weighted Average Cost of Capital (WACC)[2]. As highlighted in the State aid evaluation plan, if the actual IRR earned on the investments made exceeds the WACC before the subsidy was awarded, then this would call into question the strength of the incentive effect provided by the subsidies. It should be noted that this may not hold true where there are market failures (e.g. a dominant supplier with market power may not be incentivised to implement an investment project if it earns a marginal rate of return).

1.3 Contract design

1.3.1 Determination of the subsidy provided

Contracts are awarded through the programme by local bodies. BDUK is not party to the contract but enters a Grant Agreement (or Budget Transfer Agreement) with the local bodies when allocating public funds[3]. Under the model, the winning network provider finances, designs, builds, owns, and operates the network and earns profits on the revenues generated by take-up of superfast coverage. This feature of the model aims to allow private providers to leverage existing infrastructure whilst encouraging continuous investment in the network[4].

As highlighted above, the funding is provided through a gap funding model, which seeks to prevent the network operator from bidding for more than the minimum subsidy needed to deliver the project to deliver an IRR that broadly equals the providers cost of capital[5]. The minimum subsidy is determined by the network provider's Project Financial Model (PFM) which is submitted as part of the tendering process. This provides expectations of the:

- Number of premises to receive subsidised coverage under the proposed network build (by type of technology)
- Capital and operational costs associated with the proposed network build
- Share of premises that will take up a superfast connection over time (including churn in customers)
- Average prices to be charged to customers taking up different packages and/or technologies
- Revenues earned from customers taking up superfast services
- Operational and capital costs associated with connecting new customers to the network and providing superfast broadband services on an on-going basis
- Weighted Average Cost of Capital of the network provider

These expectations determine the expected rate of return (the IRR) that would be earned on the proposed network build. The difference between the IRR and the network provider would determine the maximum level of subsidy the network provider could bid for. Subsidies were provided to the winning network provider in instalments following the completion of contractual milestones and for qualifying costs only. Qualifying costs refer to capitalisable expenditure directly attributable to

[1] The discount rate that sets the present value of an income stream to zero.
[2] For the purposes of this analysis, an average comparison between IRR and the network provider WACC has been made. A comparison to the marginal cost of capital would be preferable approach and may therefore produce different results from average rates.
[3] BDUK (2020). *Contracts: Superfast*. An Overview of the Contract for the Superfast Programme.
[4] BDUK (2016). *Funding options for BDUK funded broadband infrastructure*. Accessed at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/548348/2016_NBS_-_State_Aid_Guidance_-_Delivery_and_Funding_Options.pdf on 7 April 2020.
[5] BDUK (2016). *Funding options for BDUK funded broadband infrastructure*. Accessed at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/548348/2016_NBS_-_State_Aid_Guidance_-_Delivery_and_Funding_Options.pdf on 7 April 2020.

delivering the deployed services and incremental to current business[6]. There were some changes in both the items included in the PFM and the qualifying costs over the three phases as set out in Table 1.1.

Table 1.1: Allowable costs by phase

	Costs described in the Project Financial Model			Qualifying costs		
	Phase 1	**Phase 2**	**Phase 3**	**Phase 1**	**Phase 2**	**Phase 3**
Build capex[7]	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**
Build opex (or deployment opex)[8]	**N**	**Y**	**Y**	**N**	**Y**	**Y**
Connection capex[9]	**Y**	**Y**	**Y**	**Y**	**Y**	**N**
Connection opex	**Y**	**Y**	**Y**	**N**	**N**	**N**
Maintenance/incremental opex	**Y**	**Y**	**Y**	**N**	**N**	**N**
PMO costs	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**
Ongoing contractual reporting	Incurred by throughout although it does not form part of the network provider's contribution.					

Source: BDUK

1.3.2 Clawback mechanisms

The design of the tendering process described above will set the IRR equal to the network providers cost of capital if the network provider provides accurate assessment of the expected costs and revenues associated with the network build. The actual IRR earned by the network provider could vary from these expectations if:

- Actual build or operational costs vary against original expectations
- Take up of subsidised coverage is (or the prices charged are) higher or lower expectations – producing differences in the revenues earned

Such differences could arise if network providers made systematic errors in their projections (for example, if demand for superfast coverage expanded more rapidly than the market expected). Network providers could also behave strategically by overstating the anticipated build cost or understating expected future revenues. This would increase the apparent level of public subsidy required for the project to go forward. This would allow the network provider to earn excess returns on the investment (though as this strategy would reduce the competitiveness of the proposed network build, scope to adopt this approach will be limited by the strength of the competition for the contracts). To minimise the risk that public subsidy exceeded the minimum required for the project to go forward, the contracts incorporated two clawback mechanisms:

[6] BDUK (2020). *Value for Money: Superfast. An Overview of Value for Money Analysis on the Superfast Programme*.
[7] Costs incurred to dig up roads, manage projects, install infrastructure
[8] Operating costs incurred during the build phase
[9] Costs related to connecting individual premises to the network, e.g. providing routers, or sending an engineer to the premises[9]

- **Implementation clawback:** Contracts with network providers incorporate an 'implementation clawback' mechanism. If a PFM contains overly pessimistic build cost assumptions, or if unexpected cost savings are made during the deployment phase, the overall network provider's investment remains unaltered, whilst public funding is reduced accordingly[10].

- **Take-up clawback:** To further reduce the risk of overcompensating providers, contracts include a take-up clawback mechanism to recuperate funding in instances where actual revenues and profits have exceeded network operator expectations set out in the bid. If take-up is higher than expected for any type of technology deployed, some of the extra profit made by the network provider is shared with the Local Body up to seven years after the contract closure date. As such, the contracts have been designed to limit excess profits earned in scenarios where take-up exceeds expectations. The enforcement of this contractual mechanism is enabled by on-going monitoring of take-up of superfast connections.

The contracting model, however, does not imply that all the commercial risk is transferred to the network provider. Mechanisms are in place in the contract to allow for errors or incorrect assumptions, which can be amended before specific milestones are achieved[11]. The contracting model also allows providers to transfer risk to the public sector in some scenarios. If providers provide low take-up assumptions, this will increase the assumed level of subsidy required for the project to be commercially viable. This strategy will require the provider to return a higher level of funding to the public sector if the project is a commercial success. However, the network provider will benefit from greater protection from the risk that the project does not lead to the anticipated revenues.

1.4 Methodology

1.4.1 Approach to estimating the expected IRR

The aim of the analysis is to compare the IRRs earned in practice by network providers against their cost of capital. However, this involves several challenges:

- **Data availability:** Network providers have a contractual obligation to provide BDUK with information on the actual costs of the network build and the share of premises upgraded that have been connected. However, network providers are not required to provide information on on-going operational costs or revenues earned (partly due to challenges in attributing operational costs to the infrastructure). As such, it is not possible to observe the profitability of the contracts awarded directly.

- **Time horizons:** The IRR associated with the network build is determined over long time horizons (i.e. fifteen to twenty years depending on the Phase). Due to the early stage of implementation for a large proportion of Phase 3 contracts, information on final build costs are not yet available and there are few quarters of reported information on take-up to provide meaningful comparisons against expectations.

The following general methodology was adopted in light of these constraints:

- **Phase 1 and 2:** A modelling exercise was completed to project the costs, revenues and IRR associated with Phase 1 and 2 contracts. The build costs – and any implementation clawback -

[10] The maximum amount of implementation clawback is equal to the total amount of public funding originally agreed with the network provider. For further information: BDUK (2020). *Value for Money: Superfast. An Overview of Value for Money Analysis on the Superfast Programme.*

[11] BDUK (2020). *Contracts: Superfast. An Overview of the Contract for the Superfast Programme.*

associated with these contracts were either known (where the contract was complete) or revised expectations were available from BDUK where the project was at advanced stages of completion. Observations of take-up were available for an extensive period, though not for the fifteen-year period over which the IRR was originally calculated. A projection of future take-up was developed by projecting past trends forwards. Estimates of revenues, operational costs and take-up clawback were derived by applying assumptions provided by the network provider in their original PFM relation to the average revenue and operational cost per user to this revised take-up projection. These revised estimates of expected costs and revenues were used to provide an update to the expected IRR on the project.

- **Phase 3:** There was limited data available on the costs and take-up of most Phase 3 contracts owing to their comparatively early stage of implementation. Projections of the build costs associated with these contracts were developed by scaling initial expectations in light of any changes in the number of premises to be upgraded. Information on actual take-up was generally insufficient to develop a projection by extrapolating past trends into the future, so an assumption was adopted that take-up would broadly follow patterns observed and projected for Phases 1 and 2.

A comprehensive overview of the methodology is included in the appendix of this report. The following sections provide key details of the measures that have been developed and the information sources used.

1.4.2 Calculating the IRR

The IRR for each project represents the discount rate that makes the net present value (NPV) of a project zero - it is the value of *r* in the following (where *c* is a stream of net cash flows over *t* time periods):

$$NPV = \sum_{t=1}^{T} \frac{C_t}{(1+r)^t} = 0$$

The net cash flow in each period from the point of view of the network provider is equal to:

$$C_t = (S_t - CB_t) + R_t - (BC_t + O_t)$$

Here, $(S_t - CB_t)$ represents the net subsidy received in period *t* (i.e. the subsidy less clawback returned to the public sector). R_t is the revenue earned in period *t.* $(BC_t + O_t)$ represents the costs incurred by the network provider in terms of build costs (BC_t) and operational costs (O_t). The IRR is sensitive to the overall time frame of the investment and the timing of expenses and revenues. It cannot be derived analytically and is typically estimated using iterative methods (in BDUKs PFM it is implemented using the IRR function in Excel). Five types of IRR were considered for each contract (in line with the State aid evaluation plan), defined in the following table.

Table 1.2: Estimated IRRs

IRR number	Description	Overview	Data sources used
IRR 1	The **original IRR before state aid** (baseline).	Estimated by the network provider at the time of bid based on expected build costs, operational costs and revenues. This provides the network providers estimated return on the investment, without subsidy, at the tendering stage.	Expected cash flows are provided in the PFM developed by the network provider (from which the IRR was derived by Ipsos MORI).
IRR 2	The **original IRR after state aid** (estimated by the network provider at the time of bid).	Estimated by the network provider at the time of bid based on expected build costs, operational costs, revenues and the proposed subsidy. This provides the network providers estimated return on the investment, with subsidy, at the tendering stage. The IRR2 would be expected to align approximately with the network provider's WACC.	Expected cash flows with subsidy payments are provided in the PFM and calculated by the network operator and presented in the PFM.
IRR 3	The **updated estimate of IRR before state aid** (modelling exercise based on latest available data and/or evidence-based assumptions).	The estimated rate of return on the project based on actual (or forecast) build costs, and modelled revenues and operational costs (based on actual and projected take-up). Net subsidy payments are set to zero. This gives an estimate of the actual rate of return on the investment, had the project been implemented without a subsidy. contract.	Information on actual build costs are provided in Finance Tracker and/or Investment Reports provided to BDUK by network providers. Forecast build costs are provided by BDUK or estimated based on any variance between the originally contracted and current expected number of premises to be upgraded. Information on actual take-up is taken from C3 reports provided by BDUK. Take-up is projected based on observed trends to provide a future projection for the remainder of the time. Estimates of revenues and operational costs are derived by applying assumptions set out in the PFM with respect to average revenues and operational costs per user/customer.
IRR 4	The updated **estimate of IRR after state-aid and before clawback** (modelling exercise based on latest available data and/or evidence-based assumptions).	This provides the estimated return on investment based on actual build costs, revenues, and operational costs (as above), and after subsidy payments paid by BDUK but before clawback is returned to the public sector.	As for IRR3, including information on actual subsidy payments derived from the Finance Tracker reports provided to BDUK by network providers. Forecast subsidy payments are
IRR 5	The updated estimate of IRR after state-aid and after clawback (modelling exercise based on latest available data and/or evidence-based assumptions).	This provides the estimated return on investment based on actual build costs, revenues, and operational costs (as above), and after subsidy payments paid by BDUK and after clawback is returned to the public sector.	As for IRR4, including information on forecast implementation and take-up clawback. Where contracts are complete, these have been derived from Investment Reports provided by BDUK and updated where there are differences in expectations regarding clawback.

1.4.3 Sources of information

The following sources of information have been used to develop the analysis:

- **Project Financial Models (PFMs):** In all three phases, providers are required to submit a PFM with their bid for contracts. As highlighted above, PFMs provides the network provider's expectations at the point of tendering in relation to:

  - how many premises will be upgraded and when under the proposed scheme
  - the costs associated with delivery broken down by type
  - the level of expected take-up for different types of technologies
  - the revenues assumed to be generated, and
  - on-going operational costs.

  In addition, the network provider is required to provide expectations around cost and price inflation over the timeline, and the level of funding required at each milestone from the Local Body. Providers are asked to provide their discount rate for the project and justify this in relation to their Weighted Average Cost of Capital (WACC)[12]. The network provider uses this information to project cashflows over the project timeline. The period over which cashflows (and the associated IRRs) are considered varies across Phases (20 years for Phase 3 and 15 years for Phases 1 and 2). There are also minor differences in the treatment of subsidy payments (from Phase 2, public subsidies are recognised in the cash flow in the quarter following the claim rather than in the same quarter).

- **Finance Tracker:** Details on the actual costs incurred in the network build are provided by network providers, submitted to local bodies and shared with BDUK, which include quarterly information about milestones achieved, as well as public sector funding and network provider's own investment.

- **Premises passed and connections data**[13]**:** The actual cumulative number of connected premises per quarter is reported in the WSS section of the C3 report provided by the network provider and the total number of premises to be upgraded[14].

- **Monitoring Log:** BDUK's Cora management information database holds records of the delivery of contracts (whether they are closed or still ongoing) as well as the final public subsidy provided to the providers. As most Phase 2 and all Phase 3 contracts are still open the database only contained final public funding figures for (completed) Phase 1 contracts.

- **Investment Fund Reports:** Network providers are required to provide a summary of the investment made, the funding claimed, clawback, and interest payments, which are compiled after contract closure. This marks the end of the contractual payments from the Local Body to the network provider. The reports are only provided for completed contracts.

1.4.4 Scope of analysis

The modelling was completed for those contracts for which the required information was available. The focus varied depending on the Phase of the contract:

- **Phase 1:** The focus of the analysis of Phase 1 was on developing an approach that could be applied to Phase 3 contracts. The modelling was applied to completed projects where there was

[12] UKRN (2018). *Cost of Capital – Annual Update Report. Information Paper*. Accessed at: https://www.ukrn.org.uk/wp-content/uploads/2018/11/2018-UKRN-Annual-WACC-Summary-Update-v2.pdf on 7 April 2020.

[13] Premises passed, and connections data is reported in the C3 report WSS extract sourced from the OpenReach report

[14] Whilst there are generally low levels of FTTP in Phase 1, Phase 3 has considerably more FTTP technology than FTTC

full information on the actual build costs and implementation clawback. At the time of the analysis, 28 of the 45 contracts awarded under Phase 1 were complete.

- **Phase 2 and 3:** As few Phase 2 and 3 contracts had closed at the time of the analysis, the modelling of Phase 2 and 3 contracts was extended to incomplete projects. As highlighted above, information on project delivery (including costs incurred and premises upgraded) is collected through the BDUK Finance Tracker. However, not all network providers were providing these to BDUK at the time of the analysis and information on actual delivery was unavailable for 17 Phase 2 contracts and 16 Phase 3 contracts. As such, the ex-ante projections provided in the PFM could not be updated for these contracts.

- **Recent Phase 3 contracts:** The population of contracts for the analysis was based on those signed by July 2019. A further 15 contracts were agreed between August 2019 and October 2020. These were not included in the analysis as insufficient information was available on the delivery of these project.

Table 1.3 below summarises the number of contracts covered by this analysis across all three phases, (out of 135 contracts).

Table 1.3: Contracts in scope for analysis

	Phase 1	Phase 2	Phase 3
Total number of contracts	45	48	51
Number of contracts in scope	28	31	20
Network providers	▪ BT/Openreach	▪ Airband ▪ BT/Openreach ▪ CallFlow ▪ Gigaclear ▪ UKB	▪ Airband ▪ Gigaclear ▪ Openreach

1.5 Limitations

There are several general limitations associated with the analysis which should be borne in mind when reviewing IRR3 through to IRR5:

- **Take-up:** Estimates of revenues, operational costs and take-up clawback are driven by a projection of future take-up. This projection is based on an extrapolation of past trends and actual take-up may be higher or lower than projected in practice. Deviations from these projections will have complex effects on the IRRs presented in the following sections. For example, while higher take-up than projected would imply higher revenues and higher IRRs, the network provider may need to return a higher share of the subsidy received to the public sector via the take-up clawback mechanism than expected.

- **Modelling of revenues:** The modelling of future revenues is based on the price schedules put forward by the network provider in its PFM submitted as part of the tendering process. The analysis assumes that these prices are both accurate and are constant over the duration of the period. Additionally, the average revenue per user is based on the share of customers taking up FTTC and FTTP technologies assumed by the network provider in its PFM. In practice, prices may vary over time. For example, increased competition may place downward pressure on prices (resulting in lower revenues and lower IRRs than estimated in the following analyses). If demand for more expensive packages is higher than expected, this will result in higher revenues and higher IRRs than estimated. This cannot realistically be addressed in any future iterations of the evaluation unless BDUK were to begin monitoring the revenues earned by network providers on connections made to subsidised infrastructure.

- **Operational costs:** The modelling of operational costs are based on the forecast of operational costs provided by the network provider in its PFM, divided by the forecast number of customers, to provide an estimate of the operational cost per user. If actual operating costs per connection differ from these assumptions – for example, due to technological change – then the IRRs will be higher or lower than presented below.

- **Customer upgrades:** The PFM (and by extension, the updates to these models in light of observed costs and take-up) do not account for any revenues foregone by network providers as a result of any customers upgrading from existing packages. As such, the IRRs presented below will be systematically overstated (and the significance of this issue is unknown).

- **Internal focus:** The IRRs focus on the revenues earned and costs incurred by the network provider with the primary objective of establishing whether the network provider had an economic incentive to deliver the network build without a subsidy. However, it should be noted that there will likely be displacement of customers, revenues and profits from other network providers. While this issue does not affect the IRRs, the rates of return presented will not mirror the social rate of return.

- **Comparability:** The IRRs for Phase 1 and 2 are not strictly comparable to those for Phase 3 as the Project Financial Model developed by the BDUK considers costs and revenues over different time horizons (and the IRRs for Phase 3 will be systematically higher than those presented for Phase 1 and 2). The degree to which these differences are significant will be dependent on how significant the residual value of Phase 1 and 2 schemes will be at the end of 15 years.

2 Analysis of Phase 1 and 2 contracts

This section sets out the modelling of the rates of return earned contracts awarded under the 2012 to 2016 UK National Broadband Scheme (Phase 1 and 2). The scope of this analysis applies to the 28 closed contracts in Phase 1, two closed Phase 2 contracts, and 29 open Phase 2 contracts, **[redacted]**. **[Redacted]**.

For the purposes of the following analysis, it is important to note that most Phase 1 contracts were awarded through a framework agreement with two network providers, under which BT/Openreach were the sole bidder. Phase 2 saw the more widespread use of OJEU processes and contracts were awarded to a more diverse mix of network providers including Airband, CallFlow, Gigaclear, and UKB. As such, comparisons between the IRRs earned on Phase 1 and 2 contracts can also reveal some insights into the behaviour of tenderers under different competitive conditions.

2.1 Internal rates of return at the tendering stage (IRR1 and IRR2)

The expected internal rates of return at the tendering stage are based on the projected cash-flows provided by the network provider in its PFM for each contract. These provide the estimated IRR of the proposed network build without and with the subsidy provided by BDUK. If the gap funding model is effective, subsidies should be allocated to projects that deliver an IRR that is lower than the cost of capital faced by network provider. The subsidy provided should bring the IRR associated with the project in line with its cost of capital.

Table 2.1 summarises the IRRs associated with Phase 1 and 2 contracts pre- and post-subsidy:

- **Commercial viability without subsidy:** On average, the projected IRR associated with the network build was substantially lower than the network provider's WACC **([redacted]**) for both Phase 1 and 2 contracts. In both cases, the proposed network build was expected to be loss making (**[redacted]** and **[redacted]** per annum for Phase 1 and 2 respectively). This also suggests that Phase 2 schemes were expected to be less profitable than Phase 1 schemes. This is to be expected as Phase 2 schemes were intended to target 'harder to reach' areas than Phase 1. However, this also masks differences in the underlying bidding strategy – Phase 2 contracts were prepared the basis of more optimistic higher take-up assumptions than Phase 1 (and had assumptions been rolled over from Phase 1, Phase 2 contracts would have been expected to be less profitable than implied below).

- **Commercial viability with subsidy:** The average IRR 2 (after public funding) across Phase 1 and 2 was estimated at **[redacted]** and **[redacted]** respectively. This is **[redacted]** to **[redacted]** percentage points lower than the cost of capital faced by the network provider (**[redacted]**) and would on the surface suggest that these projects would be unviable even with the public subsidy. This could be explained if the network provider considered future profitability beyond the clawback period (from which all profits made would be retainable) in its calculations, which would have raised long-term returns.

Table 2.1: Internal rates of return for Phases 1 and 2 contracts in scope at tender stage

[Redacted]

2.2 Expected and actual build costs

The qualifying build costs associated with the proposed network build eligible for public funding support were estimated by the network provider to be approximately £341.8m across the Phase 1 portfolio for 28 contracts. The total qualifying build costs associated with the 31 Phase 2 contracts was £358.0m. Information on actual build costs are taken from BDUK's Finance Tracker[15]. Beyond this point, it has been assumed that:

- **Phase 1:** No further build cost will be incurred for Phase 1 contracts, as the networks have been built and the contracts have since closed.

- **Phase 2:** For Phase 2 contracts that are still open, future build costs have been estimated based on reported spend to date and expected future premises to be passed.

Table 2.2 compares actual build costs compared to those expected at the tendering stage:

- **Phase 1:** The build costs associated with Phase 1 contracts were systematically understated (though it should be noted that network providers did have the option of submitting a change request to rescope the project, and this may be partly reflected in the figures below). On average, build costs were **[redacted]**. Other things being equal, this will raise the expected IRR on the investment, though this effect will be offset by the implementation clawback mechanism.

- **Phase 2:** The reverse pattern was observed in Phase 2. Build costs were systematically understated, and on average build costs were expected to be **[redacted]**.

The differences between the two Phases might be explained by differences in their scale and geographical coverage. Phase 1 contracts were larger and it may have been more straightforward to generate scale economies. They were also targeted at areas that were more straightforward to upgrade. However, this may also reflect the effect of competition. While the public sector is insulated from the risk of underspend via the implementation clawback mechanism, if network providers overstate the anticipated build cost they are protected from unforeseen costs (transferring risk to the public sector). This bidding strategy is relatively more feasible where competitive conditions are weak (as such an approach would reduce the competitiveness of the original bid).

[15] Up to Q1 FY13/14 for Phase 1 and Q4 FY16/17 for Phase 2

Table 2.2: Expected and actual build costs, Phase 1 and 2 contracts in scope

[Redacted]

2.3 Take-up, revenues and operational costs

2.3.1 Take-up

The take-up level represents the number of premises connected (i.e. households taking up the superfast services enabled). It is a significant component of the analysis as it influences both the level of revenues earned by providers, operational costs, as well as subsidies to be returned to the public sector via the take-up clawback mechanism.

Figure 2.1 below shows the profile of expected take-up (as a percentage of premises passed) for Phase 1 and 2 contracts, as sourced from each respective PFM. This is compared to actual take-up as monitored by BDUK. The figure illustrates that actual take-up has substantially exceeded expected take-up in both Phases 1 and 2 of the programme:

- **Phase 1:** In the long-run, take-up was predicted to peak at **[redacted]** of the premises passed. In practice, actual take-up exceeded this level in the third year of the contract and continued to increase to almost **[redacted]** by 2019/20.

- **Phase 2:** Expected take-up was predicted by network providers to peak at **[redacted]** for Phase 2 contracts. Given the network providers had learned from Phase 1, some questions could be raised about the credibility of these expectations (i.e. observed take-up on Phase 1 contracts had already broadly reached this level at the time Phase 2 contracts were awarded). In practice, actual take-up of Phase 2 rose more quickly than for Phase 1 contracts and had reached **[redacted]** by 2019/20.

Based on this information, a generalised logistic function has been used to forecast take-up beyond the point of latest available data in both phases, capped at a maximum value of 85%. This is in line with the assumption that the maximum take-up level is around 85% across the UK[16]. The forecast suggests that take-up could reach a peak of **[redacted]** across the Phase 1 portfolio (28 contracts) by the end of the project lifetime (Q4 FY27/28) **[redacted]** by the end of Phase 2 (31 contracts). Overall, the figures indicate that network providers understated future take-up in both Phases and this implies that the IRRs presented in the previous subsection will also be understated (though clearly this will also be influenced by the cost overruns expected for Phase 2).

Figure 2.1: Take-up levels for Phase 1 and 2 contracts (in scope)

[Redacted]

2.3.2 Modelled revenues

Revenues are not reported by the network operator. As such revenues are modelled on two values: reported or modelled take-up (as described above) and the average revenue per user as reported by the network provider in its PFM[17]. On average across the portfolios, the ARPU for FTTC is £22.50 and £23.38 in Phase 1 and 2 respectively. The difference in ARPU for FTTP is much larger, at £50.62 in

[16] Ofcom (2018). *Connected Nations 2018.*Accessed at: https://www.ofcom.org.uk/__data/assets/pdf_file/0020/130736/Connected-Nations-2018-main-report.pdf on 7 April 2020. Page 18.

[17] ARPUs for Phase 1 are calculated based information sourced from Phase 1 PFMs, notably steady-state revenue FTTC rental and steady-state FTTC connected premises.

Phase 1 and £34.50 in Phase 2 (suggesting that price premium associated with FTTP services has come down over the period). The assumed ARPU by contract is illustrated in Table 2.3.

Table 2.3: Calculated ARPUs (£s)

[Redacted]

These figures were combined with the take-up projections described above to provide an estimate of the revenues earned by network providers under initial assumptions put forward in the PFM, and how these may differ in light of observed levels of take-up:

- **Phase 1:** Up until quarter 3 2019/20, network provider take-up predictions underestimated take-up by a factor of **[redacted]** on average across the portfolio in Phase 1. Using these average revenue per user assumptions, network providers would be expected to have earned **[redacted]** in revenues (**[redacted]** more than the **[redacted]** expected under the original take-up projection). Over the 15 years covered by PFM, revenues across the Phase 1 contracts in scope are estimated at **[redacted]** (**[redacted]** expected under the original take-up projection).

- **Phase 2:** For Phase 2, network providers underestimated take-up levels by a factor of **[redacted]**. The total modelled revenue for Phase 2 contracts is forecast at **[redacted]** over the 15-year assessment period, approximately **[redacted]** than predicted at the baseline.

The higher than expected revenues earned on Phase 1 and 2 contracts will place upward pressure on the IRRs earned by network providers. However, it should be noted that much of these revenues are recognised many years after the initial investment cost and their present value will be substantially lower than the nominal values presented below.

Table 2.4: Expected and forecast revenues, Phase 1 and 2 contracts

[Redacted]

2.3.3 Operational costs

Operating costs (i.e. costs associated with providing broadband services) are not reported by the network provider. The only source of information on operating costs is the operating expenditure projections provided by the network provider in the PFMs. These projections were combined with the projections of take-up provided in the PFM, to provide an estimate of the operational cost per connection. This result was then applied to the updated projection of take-up described above to estimate the additional operational costs that would be incurred under higher levels of demand. It should be noted that this imposes an assumption of constant returns to scale (i.e. there are no scale economies associated with a larger number of customers). It also assumes that these costs are both accurate and do not change with time.

The original projections of operating costs are compared to revised estimates based on the updated take-up projection in the table below. As take-up was higher than anticipated, operating costs are also expected to exceed original expectations (with offsetting effects on the IRRs earned).

Table 2.5: Expected and forecast operating costs, Phase 1 and 2 contracts

[Redacted]

2.4 Internal rates of return before clawback (IRR3 and IRR4)

The above estimates of the actual and forecast costs and revenues were used to estimate the expected IRR for each contract in light of the observed evidence. The estimates are set out in the table below. The figures show:

- **Viability of projects without subsidy (IRR3):** The data indicates that on average, Phase 1 and 2 contracts would not have delivered a rate of return that exceeded the network provider's WACC (**[redacted]**). As such, in general terms, network providers would not have had an incentive to make these investments without public support. However, projects were more profitable than expected at the tendering stage, delivering substantially higher rates of return than the expectations set out in the PFM (IRR1 in Table 2.1):
    - This was particularly the case for Phase 1, where the IRRs were driven up both by higher than expected take-up and lower than expected build costs. The overall portfolio was expected to deliver an IRR of **[redacted]** (approaching the IRR with subsidy expected of **[redacted]** expected at the tendering stage), and 8 of the 28 contracts were expected to deliver a rate of return that exceed the network provider's WACC. This calls into question the strength of the incentive effect in these cases – i.e. the network provider would arguably have had an incentive to proceed with these projects without subsidy.
    - Phase 2 contracts were expected to be loss making without subsidy on average (an IRR of **[redacted]** on average). However, 3 of the 31 contracts were expected to deliver rates of return that exceeded the network provider's WACC.
- **IRR with subsidies (IRR4):** Once the subsidies provided by the public sector are factored in, network providers could be expected to earn internal rates of return that substantially exceed their WACC in many cases. The average IRR with subsidy payments (but before clawback) based on actual and/or expected costs and take-up rose to **[redacted]** for Phase 1 and **[redacted]** for Phase 2. These excess returns are driven largely by the conservative projections of take-up put forward by network providers (and in Phase 1, lower than anticipated build costs).

Table 2.6: Internal rates of return for Phases 1 and 2 contracts based on actual and forecast costs and take-up, before clawback

[Redacted]

2.5 Clawback

As highlighted in Section 1, to reduce risk that suppliers earn excess returns, two types of clawback mechanisms are used ex-post to retrieve excess public funding:

- **Implementation clawback:** if suppliers underestimate build cost assumptions, or if unexpected cost savings are made during the deployment phase, the overall supplier's investment remains unaltered, whilst public funding is reduced accordingly. As such all underspend is recouped.
- **Take-up clawback:** Where final take-up is higher than expected for any type of technology deployed, a portion of the extra profit made by the supplier is shared with the local body up to seven years after the contract closure date.

There is an additional capping mechanism in place for network provider protection, whereby take-up clawback is capped to the level of the Local Body's net fund (where the net investment fund is defined as total public funding net of capital underspend). Estimates of underspend and take-up clawback are based on a combination of BDUK projections prepared on the closure of the contract (as set out in the Investment Report). For incomplete contracts, clawback modelling is based on expected take-up, the Project Unit Margin (PUM) and Project Investment Ratio (PIR) as determined by the network provider in the PFM, and the Gainshare Investment Ratio (GIR) set at 85% as determined by discussions with BDUK (see appendix for more detail on these terms).

The results indicate that the clawback mechanisms are expected to return substantial levels of funding to the public sector. For example, while £280m of public funding was awarded to the Phase 1 contracts in the scope of this analysis, the net cost is expected to fall to £38m (primarily due to take-up clawback). 10 of the 28 contracts were delivered at close to no net subsidy. For Phase 2, the £331m public funding awarded to these contracts is expected to fall to £186m once clawback is received.

Table 2.7: Underspend and take-up clawback across subset of Phase 1 portfolio (28 contracts)

[Redacted]

2.6 Internal Rates of Return after clawback (IRR5)

The following table provides the estimated IRR once clawback has been accounted for (and compares this to IRR4):

- **Phase 1:** The expected IRR associated with Phase 1 schemes after clawback is estimated at **[redacted]** on average. This exceeds the WACC of the network provider (**[redacted]**) and reflects the likelihood that a share of the investments would have been commercially viable in the absence of a subsidy. It should be noted that the clawback mechanisms, in many cases, are expected to recover almost all the subsidy awarded to the network provider. The evidence from the Technical Appendix 1 (Reducing the Digital Divide) also suggests that the subsidies encouraged network providers to bring forward coverage more rapidly. As such, Phase 1 may have helped accelerate superfast availability in many areas with limited public expenditure (beyond the opportunity cost of tying resources up in the programme).

- **Phase 2:** On average, the clawback mechanisms reduced the expected IRR of Phase 2 contracts from **[redacted]** to **[redacted]**. Most schemes funded under Phase 2 were not expected to be commercially viable without a subsidy. Assuming these projects will have a residual value at the end of the timescale for this analysis, it indicates that the clawback mechanisms are effective in containing the level of subsidies at the minimum level needed to create an economic incentive for network provider to proceed with the project.

Table 2.8: Internal rates of return for Phases 1 and 2 contracts based on actual and forecast costs and take-up, before clawback

[Redacted]

3 Phase 3 analysis

This section sets out the results of applying the modelling approaches described in the preceding section to Phase 3 contracts awarded under the 2016 to 2020 UK National Broadband Scheme. This analysis covers 20 of the 51 contracts that had been awarded at the time of writing. The 31 contracts not covered by this analysis were excluded either because information on actual delivery costs had not been supplied to BDUK by the network provider at the time of the analysis, or because the contracts were awarded after September 2019 (and little progress had been made with delivery). These issues are described in more depth in Section 1.

3.1 Methodological issues

Phase 3 contracts were at a relatively early stage of delivery. By September 2019, around 17 percent of the contracted premises to be upgraded had been delivered. This creates some additional challenges and uncertainties in relation to developing a projection of the likely profitability of the contracts subject to the analysis:

- **Delivery costs:** Many contracts had not completed a meaningful share of their delivery and updated forecasts of final delivery costs were not available – although the number of premises upgraded and costs incurred to date were known. An assumption was adopted that the network provider would deliver the remaining premises to be upgraded at the unit cost per premises graded estimated in the PFM at the tendering stage. This was applied to current forecasts of the number of the premises to be upgraded (capturing any changes made to the scale of the contracts that had been agreed with the Local Body). However, this assumes that delivery costs will align with original expectations. It also assumes that the delivery costs are uniform over the delivery of the contract – and to the degree that suppliers prioritised areas that were easier to upgrade, this could lead to an understatement of the costs associated with these contracts (an overstatement of the associated IRRs).

- **Take-up:** There was insufficient information to extrapolate future take-up based on past trends (most contracts had one or two quarters of reported take-up). An assumption was adopted that growth in take-up would mirror patterns observed in Phases 1 and 2. If take-up proves higher (or lower) than observed on past contrasts, this will lead to an understatement (overstatement) of the associated IRRs.

- **Time horizon:** It should be noted that the PFMs for Phase 3 contracts considered the costs and revenues over 20 years (rather than 15 years in Phase 1 and 2). As such, the IRRs estimated in the following section are not directly comparable with those set out in the preceding section.

In light of the above, the estimates of the IRRs associated with Phase 3 contracts should be treated as indicative. Greater certainty can be provided in any future evaluation, as there will be more information available on actual delivery costs and take-up.

3.2 Internal rates of return at the tendering stage (IRR1 and IRR 2)

The following table provides the IRRs for Phase 3 contracts at the tendering stage, with and without public subsidies. The table also includes the IRRs associated with 13 contracts that were out of scope because the network provider did not provide Finance Tracker information (but a PFM was available). The table shows:

- **Commercial viability without subsidy:** On average, Phase 3 contracts were expected to be loss making without a subsidy (delivering a IRR of **[redacted]**). There was substantial variation at the individual contract level, although no project was expected to deliver an IRR that exceeded the network provider's WACC. The expected profitability of investments proposed by network providers facing a higher cost of capital were broadly in line with those put forward by the dominant supplier which faced a lower cost of capital (a weighted average of **[redacted]** and **[redacted]** respectively). It should be noted that the dominant supplier will have a competitive advantage in bidding for contracts awarded under a gap funding model, as the level of subsidy required to make the project economically viable will be lower.

- **Commercial viability with subsidy:** The expected IRR associated with the contracts with subsidies averaged **[redacted]** per annum. This was lower than the average network providers WACC (**[redacted]** on average). **[Redacted]** expected an average IRR of **[redacted]** annum (**[redacted]** below its WACC). The IRRs associated with contracts awarded to **[redacted]** were slightly higher (at **[redacted]**) but some **[redacted]** below their average WACC (**[redacted]**). As highlighted in the preceding section, it is possible that the network providers saw residual value in the network build at the end of project lifetime. However, this also suggests that the greater competition for Phase 3 contracts have led some network providers to commit to potentially loss making investments (from an economic point of view), and greater risk transfer from the public to the private sector.

- **Comparison with Phase 1 and 2:** The expected profitability of Phase 3 contracts without subsidy was expected to be higher than those associated with Phase 1 and 2 contracts, meaning that they would require a lower level of public support to make them economically viable. This appears counter-intuitive as Phase 3 contracts were targeted at harder to reach areas. As illustrated below, this was driven primarily by the more optimistic take-up assumptions adopted by network providers in tenders. This could also be driven by the higher levels of competition involved, which may have limited scope for network providers to use less optimistic take-up assumptions to transfer risk to the public sector.

Table 3.1: Internal rates of return expected at the tendering stage[18]

[Redacted]

3.3 Expected and actual build costs

At the tendering stage, the expected costs associated with the network build (for the contracts in the scope of this analysis) were estimated by network providers to be approximately £169m. Based on information on actual costs to date:

- **Costs to date:** Network providers had incurred costs of £101m in delivering the network build based on information available at the time of writing.

- **Forecast future costs:** Across the portfolio, the future costs associated with the network build were expected to be £66m.

- **Expected versus forecast:** At the portfolio level, the forecast costs are broadly in line with expected costs and as such have little effect on the IRRs presented below. While there is variation at the contract level, this variance is primarily driven by differences in the contracted

[18] Possibility for all contracts to be placed into an annex if preferred.

number of premises to be upgraded and any changes that have subsequently been agreed with the local body. The results do not factor in any possible differences in the expected and actual efficiency of the network build, and to the degree that these are significant, the estimated IRRs presented below will be overstated or understated. As such, this will need to be revisited in any future evaluation.

Table 3.2: Expected build costs, actual build costs and forecast build costs

[Redacted]

3.4 Take-up, revenues and operational costs

3.4.1 Take-up

Figure 3.1 below shows the profile of average take-up (as a percentage of premises passed) for Phase 3 contracts:

- **Expected take-up:** On average, network providers expected take-up to reach just over **[redacted]** in the long-term. As highlighted above, this is higher than assumed for Phase 1 and 2 contracts, and has increased the expected IRRs on Phase 3 contracts. However, there are questions around the plausibility of these assumptions given that take-up on Phase 1 and 2 contracts had already exceeded this value at the time many of these contracts were awarded.

- **Actual take-up:** There was limited data available on actual take-up (shown in a solid orange line in the following figure). Take-up did lag expectations, but this is primarily driven by delays in delivery of the scheme rather than lower than expected demand for superfast services. However, as the associated revenues will be realised at later stages than originally expected, these delays will have the effect of reducing the IRR associated with the investments.

- **Projected take-up:** As highlighted above, owing to the limited data available on the take-up, it has been assumed that future take-up patterns will mirror the growth in demand observed for Phase 1 and 2 contracts (the dashed curve is based on the average of Phase 1 and 2). This is a source of additional uncertainty (particularly as most delivery is FTTP rather than FTTC) and will require revisiting in any future evaluation.

Figure 3.1: Expected and modelled take-up levels for Phase 3 contracts in scope

[Redacted]

The average take-up curve for Phase 1 and 2 suggests that overall take-up for FTTC/P technologies across Phase 3 contracts have predicted higher rates of take-up than observed on Phase 1 and 2 contracts. The forecast suggests that take-up could reach a peak of **[redacted]** premises connected across the Phase 3 portfolio by the end of the project lifetime (20 year period).

3.4.2 Modelled revenues

Revenues were modelled in the same way as for Phase 1 and Phase 2. The table below gives the average revenue per user for Phase 3 contracts by FTTC and FTTP technologies. Average revenues per user for FTTC broadly align with those assumed for Phase 1 and 2 contracts. However, average revenues per user for FTTP (at £43.20) lay somewhere between average prices for Phase 1 (£50.62) and Phase 2 (£34.50). It is unclear what is driving these differences, although it should be noted that the PFMs for Phase 3 allowed for revenues driven by FTTP enabled Fibre Voice Access products which were not explicitly accounted for in Phase 1 and 2.

Table 3.3: Phase 3 ARPUs (average revenue per quarter)

[Redacted]

As with Phase 1 and 2, these estimates of the average revenue per user were applied to the projection of take-up to provide an updated projection of future revenues. Figure 3.2 below presents the modelled revenue against the network provider prediction at the baseline. Total revenue across the Phase 3 portfolio is estimated to be in the region of **[redacted]** at the end of 20 years, around **[redacted]** higher than expected in the PFM (**[redacted]**). The figure also highlights the effect of delays in the early years of the contract. While revenues are expected to exceed expectations, this is not expected to occur until the seventh year following the commencement of the contract (with cumulative revenues exceeding expectations in the eleventh year).

Figure 3.2: Baseline revenue projections against modelled revenue for Phase 3 contracts (in scope)

[Redacted]

3.4.3 Operating costs

Similarly, Figure 3.3 below presents the modelled operating costs. Modelled operating costs in Phase 3 include network and wholesale connection opex, deployment closure costs, ongoing contractual reporting, wholesale cessation costs and wholesale migration costs. The analysis suggests that the level of operating costs is forecast to exceed predictions by **[redacted],** in line with higher than predicted take-up.

Figure 3.3: Baseline operating cost projections against modelled revenue for Phase 3 contracts (in scope)

[Redacted]

3.5 Internal rates of return before clawback (IRR3 and IRR4)

The following table summarises the IRRs for Phase 3 contracts with and without subsidy, based on the updated revenue and cost projections set out in the preceding sections:

- **Commercial viability without subsidy:** Although projected take-up is higher than assumed by network providers at the tendering stage, the IRR associated with the projects without subsidy are not significantly higher (moving from **[redacted]** per annum loss to positive annual rate of return of **[redacted]**). This can be explained by the delays early in the contract, resulting in revenues being recognised later than originally expected. In all cases, the IRRs associated with the projects were expected to be substantially lower than WACC of the network provider (**[redacted]**). Arguably, a subsidy would have been needed in all cases to create a sufficient economic incentive to deliver the scheme.

- **Commercial viability with subsidy:** The provision of subsidies increases the average IRR associated with the contracts to **[redacted]**. This exceeds the network providers WACC and as with the other Phases, in 12 of the 20 cases the network provider would be expected to earn excess returns without the application of implementation and take-up clawback. However, it should be noted that the size of these excess returns is substantially smaller (on average) than those associated with Phase 1 and 2 contracts. Again, this provides a signal that the more competitive environment for Phase 3 contracts may have limited scope for network providers to transfer risk to the public sector.

Table 3.4: Internal rates of return based on forecast build costs, revenues and operational costs, before clawback[19]

[Redacted]

3.6 Clawback

Estimates of clawback have been developed on the basis of predicted underspend associated with the network build and predicted take-up levels, and are substantially more uncertain than for Phase 1 and 2 contracts. However, the modelling shows that the Phase 3 contracts could be expected to generate **[redacted]** of implementation clawback. Additionally, fewer contracts are expected to trigger take-up clawback (with **[redacted]** of take-up clawback expected across the portfolio). This is again explained by the delays associated with the delivery of Phase 3 contracts – while take-up is projected to exceed original expectations, this is not expected to occur until relatively late on in the lifetime of the project (often beyond the final review point that takes place seven years into the contract).

Table 3.5: Modelled implementation and take-up clawback

[Redacted]

3.7 Internal rates of return after clawback (IRR5)

The following table shows the expected IRRs after the application of clawback. Overall, the analysis suggests that the clawback mechanism may prove effective in limiting any excess returns that might be earned by network providers. Across the portfolio, the clawback mechanisms are expected to reduce the IRR associated with the contracts (on average) to **[redacted]** – broadly in line with ex-ante expectations (IRR2, **[redacted]**). Additionally, at the individual contract level, only one is expected to deliver a rate of return that exceeds the WACC of the network provider.

Table 3.6: Internal rates of return for Phase 3 based on forecast costs and take-up, after clawback

[Redacted]

[19] Possibility for all contracts to be placed into an annex if preferred.

Appendix - Methodology

3.8 Internal Rate of Return (IRR)

The internal rate of return (IRR) is the rate of return that brings the net present value of all inflows and outflows to zero (i.e. the rate of return on the project). If the IRR of the project exceeds the cost of capital (i.e. the cost to the company of obtaining money in order to undertake that project) then the project will increase the wealth of the shareholders and, in broad terms, should be undertaken.

The internal rate of return is calculated using Excel's IRR formula, to mirror the calculations of network operators within the PFM. The IRR function syntax has a *value* argument which is required. This is an array or reference to cells that contain the values for which to calculate the IRR i.e. annual cashflows. The IRR uses the order of values to interpret the order of cash flows.

3.9 Take-up

Take-up (i.e. number of premises connected) is derived from a combination of actual and predicted information and is analysed separately for FTTC and FTTP.

3.9.1 Phase 1 approach

Actual data on take-up is available up to and including Q3 FY19/20 from C3 reports[20]. From Q4 FY19/20 and to the end of the 15-year contract period forecast take-up figures have been used.

The following generalised logistic function has been used to forecast take-up:

$$y(t) = A + \frac{K - A}{(1 + Q \cdot e^{-g \cdot t})^{\frac{1}{v}}}$$

The function is thus bounded between a lower asymptote (A) and an upper asymptote (K), whilst g is the growth rate, t the inflection point, and v is positive and influences the inflection point and the shape of the curve. In the model, the function takes the following specification:

$$take - up = \frac{0.85}{(1 + 1.4 \cdot e^{-g \cdot t})^{\frac{1}{v}}}$$

The function is thus only positive ($A = 0$) as take-up cannot be negative, and takes a maximum value of 85% take-up as its upper bound ($K = 0.85$). This, in line with the assumption that average take-up level is around 85% across the UK[21], ensures that combined take-up of FTTC and FTTP does not exceed 85% of all passed premises. In order to match the data as closely as possible, the parameters of the function g and v (with $v \neq 0$), as well as Q, were adjusted iteratively to ensure that the function matched the actual take-up trend in the final few quarters of observed data.

The generalised logistic function is applied to FTTC and total FTTC and FTTP take-up. Given the small number of premises taking-up FTTP broadband, the function does not appear suitable to

[20] C3 reports are standard schedules that include information on take-up quarterly from the first M2 milestone.

[21] Ofcom (2018). *Connected Nations 2018.*Accessed at: https://www.ofcom.org.uk/__data/assets/pdf_file/0020/130736/Connected-Nations-2018-main-report.pdf on 7 April 2020. Page 18.

estimate future take-up levels for FTTP[22]. For FTTP take-up, a logarithmic regression in the following form is used to determine the parameters for predicted take-up by quarter (t):

$$y(t) = \alpha \cdot \ln(t) + \beta$$

In one case, for instance, the logistic function led to an overestimation of take-up in the early quarters and an underestimation in slightly later periods before the actual and the forecast trends converge in the last quarters for which take-up is observed.

3.9.2 Phase 2 approach

Actual data on take-up for Phase 2 is available up to and including Q1 FY20/21 from C3 reports. Take-up after Q4 FY19/20 and to the end of the 15-year timeline was forecasted using the same logistic function approach in Phase 1.

For contracts in Phase 2, the take-up forecast is based on the latest **[redacted]** (ORMP) figure from C3 reports (Q1 20/21).

3.9.3 Phase 3 approach

Data on actual connections for Phase 3 contracts is limited due to the relatively recent start of the contracts (in general roll-out began after FY17/18).

The treatment of take-up in Phase 3 is therefore based on actual take-up data from C3 reports until Q1 FY20/21 (on average four quarters of information across the contracts) and subsequently follows the average take-up from Phase 1 and 2. In this case, the percentage take-up is applied to the ORMP figure derived from the contracts' Speed & Coverage Template (SCT).

The timeline considered in Phase 3 is 20 years as per the contracting mechanism, note that this is a longer assessment period than contracts in Phases 1 and 2 (each 15 years).

3.10 Revenue

Revenue figures are not provided by network operators. The calculation of revenue is informed by actual and predicted levels of take-up (premises connected). Revenue is split into recurring and non-recurring revenue as per the PFM and is calculated separately both for FTTC and FTTP.

3.10.1 Phase 1 approach

Recurring revenue

Recurring revenue (wholesale revenue[23]) is calculated for FTTC and FTTP as follows:

*Recurring revenue = Take-up * ARPU * revenue inflation (deflation) assumption*

Two methodologies have been applied to determine ARPUs for FTTC and FTTP:

[22] On average, the function led to an overestimation of 860,322 premises connected in each quarter of Phase 1 and 295,380 premises connected in each quarter of Phase 2.

[23] Wholesale prices are defined as the prices that the network operator can charge other communications providers to gain access to telecoms services (i.e. the technology rolled out). The provision of wholesale access is required by contract in compliance with State Aid rules. For further information: Ofcom (2020): *Next Generation Access Glossary*. Accessed at: https://www.ofcom.org.uk/__data/assets/pdf_file/0013/63220/nga_glossary.pdf on 3 August 2020.

- **Phase 1 ARPUs:** As ARPUs are not indicated in the Phase 1 PFMs, these have been calculated using the steady-state rental revenue divided by the number of connected premises at steady-state, from which a price per connected unit at steady-state is derived;
- **Phase 3 ARPUs:** Where contracts for the same local body were awarded to **[redacted]** also in Phase 3, ARPUs from Phase 3 PFMs were applied to connections. If a Phase 3 contract for a local body had not been awarded to **[redacted]**, a similar **[redacted]** Phase 3 contract was used to derive ARPUs[24].

The revenue inflation (deflation) assumption is assumed by the network operator as constant throughout the period and equal to 1.

Non-recurring revenue

The following types of non-recurring revenue have been considered both for FTTC and FTTP churned volumes:

- **Installation:** the installation price included in PFMs and customer growth net of churn based on actual figures until Q3 FY19/20 and predicted take-up afterwards:

*Installation revenue = (connections + net customer growth) * installation price * revenue inflation (deflation) assumption*

- **Cease:** relating to the predicted termination of contracts:

*Cessation revenue = cease volumes * service cessation cost * revenue inflation (deflation) assumption*

- **CP:CP:** migration costs
- Migration revenue = CP:CP volumes * service migration cost * revenue inflation (deflation) assumption

All cost figures for installation, cessation, and migration have been derived from Phase 3 PFMs or a comparator where an equivalent contract in Phase 3 was not available.

3.10.2 Phase 2 approach

Similar to Phase 1, revenue in Phase 2 is split into recurring revenue and non-recurring revenue. Calculations follow the same methodology applied to Phase 1 contracts.

3.10.3 Phase 3 approach

Phase 3 revenue calculations, both for recurring and non-recurring revenues, are entirely based on Phase 3 PFM assumptions, but follow the same methodology applied in the case of Phase 1 and Phase 2.

3.11 Premises passed

Premises passed values are used in the analysis to determine take-up and future build capex where contracts remain open.

[24] Geography and ORMPs were generally considered to find a Phase 3 equivalent of a Phase 1 contract.

3.11.1 Phase 1 approach

All Phase 1 contracts in scope of the analysis are closed contracts. It was therefore not a requirement to estimate premises passed.

3.11.2 Phase 2 approach

The majority of Phase 2 contracts (29 out of 31) were open at the time of this analysis[25]. The forecast premises passed figure in this case has been sourced from the latest C3 report (Q1 FY19/20).

3.11.3 Phase 3 approach

All 20 Phase 3 contracts covered by the analysis were open at the time of this analysis. The forecast premises passed figure in this case has been derived from the contracts' SCT build plans.

3.12 Opex

Opex (i.e. the operating expenditure connected to the roll-out and functioning of the service) is not provided by network operators. It has been calculated based on data from the PFMs and the actual and forecast take-up data.

3.12.1 Phase 1 approach

In Phase 1, opex was calculated for **connection opex** and **maintenance opex**.

The unit opex cost was calculated based on PFM data for FTTC and FTTP as follows:

average unit opex = opex / solution volumes

Which was applied to the number of connections to determine **connection opex:**

*connection opex = number of connections * average opex unit cost * opex inflation (deflation) assumption*

Maintenance opex is based on a BDUK assumption of a maintenance opex cost of £18.60 (network operator phase 3 assumption) a year for both FTTC and FTTP.

*maintenance unit opex cost = number of connections * quarterly maintenance opex cost (£4.65) * opex inflation (deflation) assumption*

Inflation is assumed to be constant and equal to 1 throughout the period[26].

3.12.2 Phase 2 approach

There are three components to opex in Phase 2: **connection opex**, **deployment opex**, and **incremental opex**, applied to both FTTC and FTTP connections.

The unit cost for opex is determined using the same approach as Phase 1 per quarter for both FTTC/P:

Unit opex cost =total opex (from start of take-up) / number of connections

[25] The only two closed contracts in the sample were CORN201 and SGLO201.
[26] This assumption is included in Phase 3 PFMs.

Connection opex

The approach to calculating connection opex follows the same methodology as in Phase 1. An addition to the contracting mechanism in Phase 2 is the inclusion of deployment opex.

Deployment opex

Compared to Phase 1, in Phase 2 deployment opex is a qualifying cost as it is directly attributable to build activities, although it is not capitalisable. It includes elements such as ineffective engineers' time and costs related to a service centre, but overall it makes up a small proportion of the build cost[27].

Thus, deployment opex was updated by firstly calculating average deployment opex. From the PFM, the measure of average deployment opex across the period was used alongside the expected number of premises passed to find the average opex deployment cost for each contract as follows:

average deployment opex unit cost = deployment opex / total number of premises passed

The actual and predicted number of premises passed by quarter, introduced in Section 3.11, was then used to obtain a measure of deployment opex throughout the project timeline as follows:

*deployment opex = actual and predicted premises passed * average deployment unit cost*

Inflation is assumed to be constant and equal to 1 throughout the period[28].

3.12.3 Phase 3 approach

Opex is presented differently in Phase 3 contracts, structuring it into "build vs in-life costs" as opposed to operating and capital expenditure. The modelling replicates the network operators' calculations in the PFM, updated for revised connections.

Component	**Type**	**Calculation**
Network opex	FTTC & FTTP	*(FTTC + FTTP premises connected) * unit opex cost per connection * opex inflation (deflation) assumption*
GEA connection	FTTC & FTTP	*Churned volumes + net customer growth (net of churn) * opex unit cost * opex inflation (deflation) assumption*

[27] BDUK information.
[28] This assumption is included in Phase 3 PFMs.

GEA cease	FTTC & FTTP	*(FTTC + FTTP churned volume cessation) * opex unit cost per ceased FTTC/FTTP connection * opex inflation (deflation) assumption*
CP:CP	FTTC & FTTP	*(CP:CP FTTC + FTTP churned volumes) * opex unit cost per CP:CP transfer FTTC/FTTP connection * opex inflation (deflation) assumption*

Two additional costs set out in the PFM, deployment closure costs and ongoing contractual reporting, could not be updated due to the lack of actual information on network volumes; thus, data from the PFM (i.e. the network operators' forecast) has been used for the modelling.

3.13 Capex

Capex is analysed as **build capex** (relative to the premises that have been passed) and **connection capex** (for premises that have been connected to broadband). Actual capex information is provided in the Finance Trackers by network operators to BDUK.

3.13.1 Phase 1 approach

Build capex

The total cost of passing premises is based on the number of premises passed by quarter divided by the build capex for both FTTC and FTTP.

The average build capex is obtained by dividing the total cost of passing premises over the 15-year contract period by the number of premises passed at steady-state, both for FTTC and FTTP. Build capex becomes zero after the end of the deployment period.

As all Phase 1 contracts are closed, updated cashflow calculations utilise actual build capex as reported in the Finance Tracker.

Connection capex

Similarly, the total cost of connecting premises with FTTC or FTTP is given by the total connection cost divided by the number of premises connected at steady-state.

For FTTC and FTTP, connection capex is estimated as:

*connection capex = net customer growth * average connection capex * capex inflation (deflation) assumption*

Net customer growth is calculated as in the case of non-recurring revenue and is net of churn.

3.13.2 Phase 2 approach

Build capex

As the majority of Phase 2 contracts have not completed deployment, there is a requirement to model future build capex associated with future premises passed. A unit cost of build capex using baseline network operator predictions and total predicted build capex was calculated (in the same way as Phase 1) to support the estimate of future build expenditure.

The components to produce this estimate are set out below:

Value	Source	
Total predicted premises	PFM	network operator prediction
Total predicted cost	PFM	network operator prediction
Build capex unit cost	Calculation	Predicted premises / Predicted cost
Total spend to date	Finance tracker	Reported data
Assumed premises passed to date	BDUK modelling	
Revised build capex unit cost	Calculation	Spend to date / assumed premises passed to date
Remaining expected premises passed	Calculation based on BDUK modelling	Total assumed premises passed – assumed premises passed to date
Assumed remaining spend	Calculation	Revised build capex unit cost * remaining expected premises passed

Connection capex

For Phase 2 contracts connection capex is an allowable cost and is therefore reported in the Finance Tracker by network operators. Beyond the latest available quarter, it has been estimated for future periods for both FTTC/P:

*connection capex = net customer growth * average connection capex * capex inflation (deflation) assumption*

Net customer growth is calculated as in the case of non-recurring revenue and is net of churn.

3.13.3 Phase 3 approach

As Phase 3 contracts have not completed deployment, there is a requirement to model future build capex associated with future premises passed. A unit cost of build capex using baseline network operator predictions and total predicted build capex was calculated (in the same way as Phase 1) to support the estimate of future build expenditure.

The components to produce this estimate are set out below:

Value	Source	
Total predicted premises	PFM	network operator prediction
Total predicted cost	PFM	network operator prediction

Build capex unit cost	Calculation	Using above
Total spend to date	Finance tracker	Reported data
Total predicted premises	SCT	
Revised assumed total spend	Calculation	Total predicted premises * build capex unit cost
Assumed remaining spend	Calculation	Revised assumed total spend - total spend to date

Another element of build capex included in the Phase 3 calculations is non-PMO build capex, replicating this from the PFMs.

Connection capex

The approach to calculating connection capex follows the same methodology as applied in Phase 2.

3.14 Capital clawback

Capital clawback is triggered where the network operators' prediction of build capex exceeds actual expenditure.

3.14.1 Phase 1 approach

Capital clawback for Phase 1 contracts was sourced from the contract summary in the IFGR files provided by BDUK. As closed contracts, values for capital clawback did not require forecasting.

3.14.2 Phases 2 and 3 approach

For Phases 2 and 3, capital clawback has been estimated as follows:

Component	**Source**
Build capex to date	Finance Tracker
Future build capex	Calculation as per 1.5.1 above
Total revised estimate of build capex	Calculation – sum of lines above
Baseline build estimate	PFM
Overspend or underspend prediction	Comparing revised estimate and baseline estimate, where underspend triggers clawback

3.15 Take-up clawback

3.15.1 Phase 1 approach

In Phase 1, IFGR files were used as a source of information for take-up clawback. The IFGR forms include information on the following to calculate take-up clawback:

- **Project Unit Margin (PUM):** The Project Unit Margin (PUM) is the modelled average profit per customer over the term of the contract.
- **Project Investment Ratio (PIR):** The Project Investment Ratio is the proportion of OIR.
- **Outturn Investment Ratio (OIR):** cost invested by the supplier at the end of the build.
- **Gainshare Investment Ratio (GIR).** The maximum of the PIR and OIR.

The maximum of the PIR and OIR is used to determine the GIR. The triggers of clawback (i.e. the exposure to clawback) is determined by review points set by BDUK and is calculated as:

*take-up clawback = net additional take-up[29] * PUM * (1 – GIR)*

The take-up reinvestment amount is calculated as:

take-up reinvestment amount = exposure to claw-back – any take-up clawback amounts already paid back to the LB

3.15.2 Phase 2 and 3 approach

Clawback calculations for the two Phase 2 closed contracts (CORN201 and SGLO201) follow the same methodology applied to Phase 1 contracts (above).

Clawback for open Phase 2 and 3 contracts is forecast based on data included in the PFM and additional management information shared by BDUK.

The components required, and respective sources, are set out below:

Component	**Source**
Actual and forecast connections	C3 report and modelling forecast
Variance in connections	Difference between C3 report/modelling forecast and PFM information
PUM	PFM
PIR	PFM
OIR	[BDUK modelling for Phase 2] Not included for Phase 3
GIR	Maximum of PIR and OIR (always OIR)
Interim review proportion	85% for all contracts with a few minor exceptions where it's 50%
Take-up review points	Phase 2 review points sourced from BDUK. Phase 3 review points are annually from contract start date as per BDUK guidance.

[29] Net additional take-up represents the difference between actual take-up and PFM take-up. For further information, please refer to *Schedule 5.1 Milestone Payments and Claims Procedure* of any Phase 1 contracts.

3.16 Cash flow

The previously determined revenue, opex, and capex have been used to calculate cashflow throughout the project timeline. The structure of the cashflow is consistent across all three phases.

Cashflow item	Description
Revenue	Calculations based on calculated ARPUs or Phase 3 ARPUs
Opex	Calculation
EBITDA	Revenue – Opex
Build Capex	Actual figures from the Finance Tracker have been used up to and including (Phase 1 Q4 FY16/17; Phase 2 up to Q3 FY19/20; Phase 3 up to Q4 FY19/20), which is the point of steady-state for passed premises. After this, it is modelled for open contracts or assumed that no further build costs are incurred for completed contracts.
Connection capex	Calculation
Total capex	Sum of build and connection capex
Cashflow **pre funding**	EBITDA - Capex
Public funding	Actual figures from Finance Trackers up to and including (Phase 1 Q4 FY16/17; Phase 2 up to Q3 FY19/20; Phase 3 up to Q4 FY19/20). If differences exist between BDUK records of paid public funding, the difference is added in the last quarter recorded in the Finance Tracker.
Adjusted cashflow **post funding**	Cashflow pre funding + public funding
Capital Clawback	Sourced from IFGR files for closed contracts, modelled for open contracts.
Take-up Clawback	Sourced from IFGR files for closed contracts, modelled for open contracts.
Interest on capital	Sourced from IFGR files for closed contracts, not modelled for open contracts.
Interest on clawback (gainshare)	Sourced from IFGR files for closed contracts, not modelled for open contracts.
Clawback capping	Where take-up clawback is above net funding (Total public funding – capital clawback – interest on capital), it triggers a capping of the clawback.
Total clawback	Sum of capital clawback, take-up clawback, interest and capping

Adjusted cashflow **post clawback**	Cashflow post funding – clawback
Baseline IRR **pre-funding**	Baseline IRR before state aid - estimated by the network operator at the time of bid
Baseline IRR **post-funding**	Baseline IRR post state aid – estimated by the network operator at the time of bid
Updated IRR **(pre-funding pre-clawback)**	Modelled IRR before state aid and clawback
Updated IRR **(pre-clawback)**	Modelled IRR post state aid but before clawback
Updated IRR **(post-clawback)**	Modelled IRR post state aid post clawback

3.17 Assumptions

The results of the financial analysis are largely dependent on a number of assumptions. Table 3.7 below sets out a RAG rating for all assumptions applied in the analysis and the respective assumed degree of sensitivity for the IRR results. The level of assumed take-up and the capping of 85% in particular are significantly influential on the IRR results. This capping was deemed appropriate through discussions with BDUK and with reference to Ofcom's Connected Nations 2018 report indicating average take-up of 85% across the UK. No time factor has been applied to decrease the assumed 15% of premises which do not take-up superfast broadband over time. Scenario analysis could be undertaken to understand the degree to which the IRRs are underestimated as a result of this capping. Other external factors, such as the COVID-19 pandemic, have not been taken into account quantitatively but it can be assumed that the delivery and take-up profile have been disrupted as a result, which may have a suppressing effect on the IRRs.

Table 3.7: RAG rate assumptions

Component	Phase	Required for	Source	Quality of assumption RAG rating	Influence on analysis
Steady-state FTTC connected premises	1,2,3	Revenue calculation	PFM		High
Steady-state FTTP connected premises	1,2,3	Revenue calculation	PFM		High
Steady-state revenue FTTP rental	1,2,3	Revenue calculation	PFM		High
FTTC ARPU (£)	1 and 2	Revenue calculation	Calculation (Steady-state revenue FTTC rental/Steady-state FTTC connected premises, source: PFM)		High
FTTP ARPU (£)	1 and 2	Revenue calculation	Calculation (Steady-state revenue FTTP rental/Steady-state FTTP connected premises, source: PFM)		High
FTTC ARPU (£) Phase 3	3	Revenue calculation	Phase 3 PFM		High
FTTP ARPU (£) Phase 3	3	Revenue calculation	Phase 3 PFM		High
FTTC Installation price	1,2,3	Revenue calculation	Phase 3 PFM		Medium
FTTP Installation price	1,2,3	Revenue calculation	Phase 3 PFM		Medium
CP-CP GEA Migration same product/premise	1,2,3	Revenue calculation	Phase 3 PFM		Medium
Service cessation (any product variant)	1,2,3	Revenue calculation	Phase 3 PFM		Medium
Quarterly maintenance cost	1 and 2	Operating expenditure	BDUK provided assumption (£18.60 per customer per annum Phase 3 network operator prediction)		Medium
FTTC opex average unit cost	1 and 2	Operating expenditure	Calculation (FTTC opex cost/FTTC solutions volumes, source: PFM)		High

FTTP opex average unit cost	1 and 2	Operating expenditure	Calculation (FTTP opex cost/FTTP solutions volumes, source: PFM)		High
Deployment opex	2	Operating expenditure	Calculation (Deployment opex cost/premises passed within deployment phase, source: PFM)		Low
Deployment closure cost	3	Operating expenditure	Phase 3 PFM (directly sourced; not updated)		Low
Contractual reporting	3	Operating expenditure	Phase 3 PFM (directly sourced; not updated)		Low
Network operating cost	3	Operating expenditure	Calculation (total FTTP and FTTC connections*unit operating cost source: PFM)		High
FTTC connection (wholesale)	3	Operating expenditure	Calculation (FTTC churned volumes + FTTC net customer growth) * wholesale opex cost per quarter per connection source: in life cost book PFM)		High
FTTP connection (wholesale)	3	Operating expenditure	Calculation (FTTP churned volumes + FTTP net customer growth) * wholesale opex cost per quarter per connection source: in life cost book PFM)		High
FTTC & FTTP CP: CP migration	3	Operating expenditure	Calculation (FTTC and FTTP migration churned volumes * wholesale migration cost per quarter per connection source: in life cost book PFM)		Medium
GEA (FTTC) Cease	3	Operating expenditure	Calculation (FTTC cease churned volumes*wholesale cessation cost per quarter per connection source: in life cost book PFM)		Medium
GEA (FTTP) Cease	3	Operating expenditure	Calculation (FTTP cease churned volumes*wholesale cessation cost per quarter per connection source: in life cost book PFM)		Medium
FTTC build unit cost	1,2,3	Capital expenditure, implementation clawback	Calculation (FTTC total cost/max FTTC premises passed, source: PFM)		High
FTTC connection unit cost	1,2	Capital expenditure	Calculation (FTTC connection capex/max FTTC premises connected, source: PFM)		Medium
FTTC connection unit cost	3	Capital expenditure	In life cost book PFM (unit capex cost FTTC)		Medium
FTTP build unit cost	1,2,3	Capital expenditure, implementation clawback	Calculation (FTTP total cost/max FTTP premises passed, source: PFM)		High
FTTP connection unit cost	1,2,3	Capital expenditure	Calculation (FTTP connection capex/max FTTP premises connected, source: PFM)		Medium
FTTP connection unit cost	3	Capital expenditure	In life cost book PFM (unit capex cost FTTP)		Medium
Premises passed profile	2,3	Capital expenditure, implementation clawback	BDUK modelled forecasts		High
Total predicted premises passed per contract	3	Capital expenditure, implementation clawback	Speed and coverage templates		High

Total predicted premises passed per contract	2	Capital expenditure, implementation clawback	BDUK modelled forecasts		High
Take-up	1,2	Take-up, revenue, operating costs, implementation clawback, take-up clawback	Logistic function using subset of reported take-up capped at 85%		High
Take-up	3	Take-up, revenue, operating costs, implementation clawback, take-up clawback	Average take-up curve for Phase 1 and 2 (FTTC and FTTP combined) capped at 85%		High

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December 2020

State aid evaluation of the UK National Broadband Scheme

Technical Appendix 3 – Economic and Social Impacts

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Key Findings

This Technical Appendix provides quantitative estimates of the economic and social impacts of subsidised broadband coverage delivered through the Superfast Broadband Programme between 2012 and 2019. The analysis is based on econometric analysis of a variety of administrative and secondary datasets providing longitudinal data at a small area level. This analysis provides estimates of the local impact of the Superfast Broadband Programme on the areas where the programme has provided subsidised coverage.

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

Key definitions

- **Outcomes:** Outcomes are social or economic measures that could be affected by the programme (e.g. jobs, turnover, life satisfaction). Outcomes are measured at the local level.

- **Impacts:** Impacts are the effects on the outcome that are attributable to the programme over and above what would have occurred in the absence of the programme. Impacts occur over a longer time period. Impacts are measured at the local level.

- **Benefits:** A measurable improvement of a positive outcome (as perceived a by one or more stakeholders), which contributes towards one or more organisational objectives. Benefits are measured at a national level, net of displacement.

Impacts on businesses

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

- **Jobs:** Subsidised coverage led to the creation or retention of 17,600 jobs in the areas benefitting from the programme by 2018 (compared to 7,400 by 2016[1]).

- **Turnover:** Subsidised coverage also increased in the annual turnover of firms located in these areas by £1.9bn by the end of 2018 (compared to £1.8bn by the end of 2016).

- **Additional turnover from efficiency gains:** The total increase in the annual turnover of firms driven by increases in the productivity of local firms was estimated at £845m by the end of 2018[2]. As time has passed, the programme's effects on local employment have strengthened relative to its effects on turnover growth. This tendency has reduced the increase in annual turnover from efficiency gains from £1.4bn at the end of 2016.

- **Relocations and new firm formation:** These local economic impacts were partly driven by an increase in the number of firms located in the area. Subsidised coverage increased the number of firms located in areas benefitting from the programme by 0.5 percent. The relocation of firms to areas

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

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

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

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

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

Impacts on workers

The analysis undertaken found a positive impact on the hourly wage of workers in the Output Area of around 0.7 percent per worker following the first upgrade (although there was no effect on hours worked). This provides further confidence that the effects on turnover per worker can be treated as a productivity gain.

Consumer value and well-being

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

Impacts on the public sector

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

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

- **Number of patients**: Subsidised coverage increased the number of patients registered with GPs by 3.2 to 5.9 percent on average between 2013 and 2019.

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

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

- **Primary School income:** Total incomes were estimated to rise by 1.7 percent largely due to increases in self-generating income (this could be explained if superfast connectivity has enabled schools to make more efficient use of leisure facilities and/or has attracted higher income residents to the area).

- **Primary school resources:** The programme had an impact on ICT, teaching expenditure and the number of teachers, with these decreasing by 17.7 percent, increasing by 8.2 percent and 2.0 percent respectively. However, these findings were not robust to the addition of further controls and as such the findings are inconclusive.

- **Primary school pupil numbers and composition:** The programme had a positive effect on overall pupil numbers (which would be consistent with the findings set out above for GP surgeries), though these results are not robust to unobserved local authority trends or time specific shocks affecting all schools. The programme also led to reductions in the share of pupils eligible for Free School Meals (FSM) or with Special Educational Needs (SEN) (of 2.8 and 4.6 percentage points respectively), and a slight increase in the share of pupils with English as an Additional Language (EAL).

Benefit to cost ratio

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

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

Summary of estimated local and national impacts

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

Source: Ipsos MORI analysis

Using the estimates of the net benefits of the programme on businesses and households and the cost of the programme, the estimated Benefit to Cost Ratio (BCR) associated with the programme **in the short-term is between £2.7 and £3.8 per £1 of net lifetime public sector costs**. This exceeds the hurdle rate of return normally applied in the appraisal of public sector programmes and suggests that the programme has already delivered a strong rate of return. In **the long-term (allowing for future economic benefits i.e. 2019-2030), the BCR is estimated to rise to between £3.5 and £5.0 per £1 of net public sector spending.**

[4] Impacts net of local displacement and crowding out

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

1 Introduction

This Technical Appendix provides quantitative estimates of the economic and social impacts of subsidised broadband coverage delivered through the Superfast Broadband Programme between 2012 and 2019. The analysis is based on econometric analysis of a variety of administrative and secondary datasets providing longitudinal data at a small area level and below (including micro data).

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

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

1.1 Key definitions

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

1.2 Aims and objectives

The Superfast Broadband Programme aims to provide gap funding to network providers to extend superfast broadband services to rural areas that would not otherwise benefit from commercial deployments. The aim of this Appendix is to provide a quantitative assessment of the economic and social impacts and benefits of the programme between 2012 and 2019. The paper seeks to address the following core questions defined by BDUK in its overall evaluation plan for the Superfast Broadband Programme:

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

The analysis also seeks to address questions defined in the common methodology for State aid evaluation[6] relating to the indirect impacts of the intervention (namely – has the scheme had spill-over effects on other firms or geographical regions?). This Appendix considers the impacts of the programme in four key areas

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

– its effects on businesses and the performance of local economies, workers, households and the performance of public services (linked to the BDUK Benefits Realisation Framework below).

Table 1.1: Coverage of the BDUK Benefits Realisation Framework

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

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

1.3 Methodology

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

Estimates of the causal effects of subsidised coverage have been derived from econometric models comparing those areas benefitting from the programme in earlier years (a pipeline approach) to those benefitting later. This approach will provide robust estimates of the impacts of the programme if there are no systematic differences between areas benefitting at different stages that are correlated with the outcomes of interest. Further details of the rationale for this approach are set out in Section 3.

1.4 Key issues

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

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

- **Additionality:** The findings in this paper focus on the economic and social impacts of subsidised coverage. As the analysis compares areas that did and did not have superfast coverage, the estimates should be robust to issues of technological substitution (e.g. using mobile data services in place of fixed lines). They do not account for the possibility that subsidised coverage could have come forward in the absence of the programme (i.e. if network providers would have extended their networks without public funding). This aspect of additionality also needs to be addressed to provide estimates of the net (rather than gross) benefits of the programme – and is explored in Technical Appendix 1 (Reducing the Digital Divide), which provides estimates of the share of subsidised coverage that would not have come forward in the absence of programme. Results from these parallel analyses are incorporated in the cost-benefit analysis presented in the final chapter, where the focus is on the net costs and the benefits of the programme at a national level are presented.

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

- **Population dynamics:** Some of the outcomes of interest – for example the impacts of superfast broadband on residents' experiences of public services – could plausibly be driven by changes in the composition, or growth of, the resident population. While this could plausibly be explored using the small area data taken from the regular Office for National Statistics (ONS) Census of Population, these take place every ten years. The next Census is due to take place in 2021 and not available at the time of writing. For some outcomes explored, there are some questions as to how far the outcomes of interest are a direct or indirect consequence of superfast connectivity (e.g. expansions in GP patient registers could be explained by the possible effect of enhanced connectivity in opening new channels to the resident population or by its effects in making the area more attractive to new residents – causing local populations to grow).

- **COVID-19 pandemic:** The data deployed in this analysis ran up to mid-2019 and therefore does not allow for an analysis of the impacts of the programme in relation to COVID-19. It is likely that the programme enabled benefits such as remote working, the delivery of public services (e.g. GP consultations) on-line and increased local resilience through supporting social distancing arrangements. These benefits will be considered in a future assessment of the programme, as part of the final round of evaluation.

- **Future trading relationship with the EU:** There are a number of uncertainties in relation to the UK's future trading relationship with the EU which could impact the long-term benefits of the programme. At this stage, any forecasting of these costs and benefits would be highly speculative and therefore has not been attempted as part of this analysis. Impacts of the programme in relation to EU exit will be explored in a future analysis of the programme.

1.5 Structure of this report

The remainder of this report is structured as follows:

- Section 2 provides an overall analytical framework for the study – describing the anticipated causal processes.

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

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

- Section 5 provides an analysis of the impact of the programme on workers.
- Section 6 provides an analysis of the impact of the programme on households.
- Section 7 provides an analysis of the impact of the programme on the performance of public sector services.
- Section 8 provides a cost-benefit analysis of the programme.

2 Analytical framework

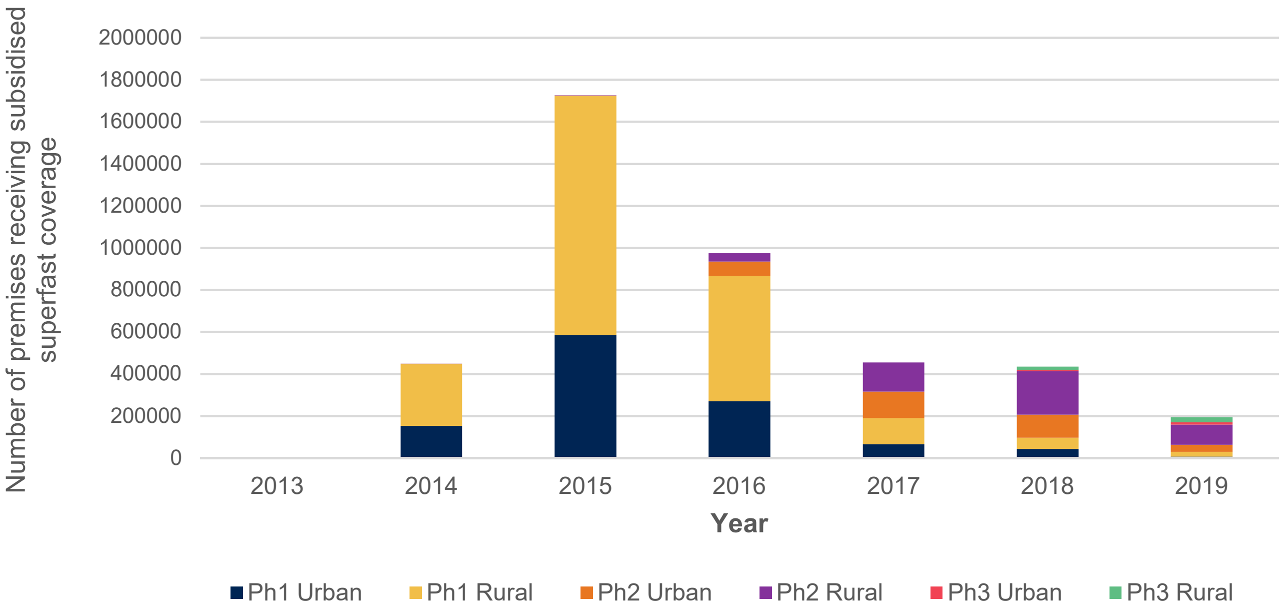
This section provides an overarching analytical framework for the assessment of the economic and social benefits of the Superfast Broadband Programme. This section provides a theoretical outline explaining how the anticipated outputs of the programme (i.e. increased availability of superfast broadband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

2.1 Superfast Broadband Programme

The Superfast Broadband Programme aims to provide gap funding to network providers to extend superfast broadband services to rural areas that would not otherwise benefit from commercial deployments. The figure below provides an overview of the number of premises receiving subsidised coverage between 2013 and 2019, under Phase 1, 2 and 3 of the programme.

Figure 2.1: Number of premises receiving superfast (30Mbps[7]) coverage subsidised by BDUK, Phase 1, Phase 2, and Phase 3 SCTs are available, 2013 to September 2019[8]

Panel B: Delivery of all contracts



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

2.2 Impacts on businesses and local economic performance

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

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

[7] 24MBits for Phase 1 and Phase 2

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

to obtain faster connectivity through leased lines or by relocating to areas where faster speeds were already available. This creates an expectation that the primary users of the superfast coverage made available will be Small and Medium-sized Enterprises (SMEs) making use of asymmetric subscriber lines – rather than large firms with the scale needed to make leased lines commercially viable or digitally intensive firms where faster and more reliable connectivity is central to the underlying business model. The shift in emphasis from FTTC to FTTP technology in the latter phase of the programme may alter these incentives – making faster speeds (and symmetric connections) available may increase the number and types of firms that could potentially benefit from the programme.

- **Usage:** Faster and more reliable connectivity can potentially enable several productivity or growth enhancing investments. A recent review[9] of the impacts of ultrafast network deployment highlights several potential business applications of faster connectivity:

  - **Access to new markets:** On-line channels to market are becoming an increasing important source of revenues to businesses in the UK, rising to £688bn in 201810 from £375bn in 2009. A 2010 Government review highlighted that the use of ICT and broadband can enable small businesses to access to new markets[11]. A 2016 review of the impact of fibre connectivity on SMEs in the South West of England, provides numerous examples of how superfast connectivity has reduced barriers to entering export markets[12].

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

  - **Internet of things**: The internet of things describes products, applications and services that are driven by devices that collect data from sensors and communicate with each other through local or wide area networks. This creates opportunities to realise efficiencies through automation and analytics by enabling more rapid and effective decision making13. One example is the energy efficiency savings that are possible using smart meters to manage energy and heat consumption in industrial contexts. Again, as these applications are data intensive, higher capacity networks are needed to enable their implementation.

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

- **Productivity gains:** Numerous studies have shown that faster broadband stimulates productivity growth. Adoption of superfast broadband could raise the productivity of local firms in several different

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

ways. As noted, these improvements may take time to arise and complementary business investments may be required to take advantage of higher speeds.

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

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

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

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

- **Crowding out:** Additionally, expansion of demand may also place upward pressure on local wages and prices, potentially encouraging other firms locally to reduce their output (crowding out)[14]. The Superfast Broadband Programme may also crowd out private investment in superfast broadband in infrastructure – this possibility is explored in Technical Appendix 1.

- **Sorting effects:** The programme may also result in local economic benefits via the spatial reallocation of economic activity. Several studies[15] have illustrated that the availability of broadband makes economic activities viable in less central locations, with the employment impacts associated with the availability and adoption of broadband often found to be stronger in rural or less central locations than in metropolitan urban areas:

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

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

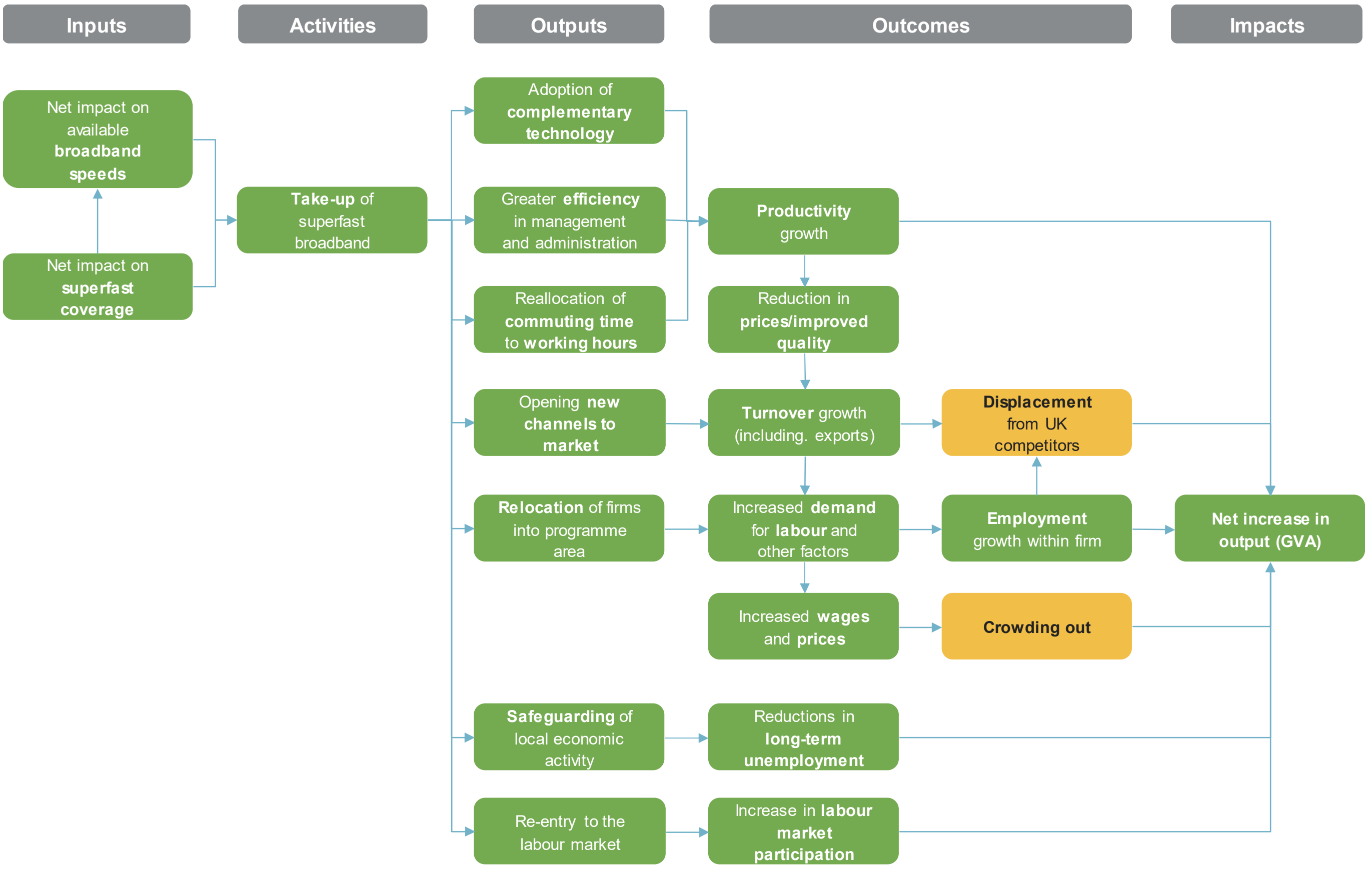
  - **Crowding out:** The attraction of firms from other areas also has the potential to place upward pressure on local prices, encouraging lower productivity firms to reduce their output or relocate

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

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

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

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



2.3 Impacts on workers

The programme may also have the following effects on workers:

- **Teleworking:** Faster connectivity also has the potential to transform the nature of work by enabling efficient remote working. While this also relies on residential upgrades, a range of studies have estimated that increased teleworking can produce productivity gains – both reducing working hours lost to commuting delays and by improving work-family balance and job satisfaction. However, research does not always suggest that teleworking has positive benefits. For example, a 2018 review of teleworking in the public sector indicated that public servants experienced negative effects from teleworking – including greater professional isolation and less organisational commitment on the days they worked entirely from home[16]. Similar findings were also obtained in a study of US federal Government workers[17]. As the COVID-19 pandemic has resulted in a substantial expansion in teleworking as workers have been asked to work from home where possible, past studies may not be a good guide to the future effects of the programme on worker productivity.

[16] De Vries et al (2018) The Benefits of Teleworking in the Public Sector: Reality or Rhetoric?
[17] Caillier (2012) The Impact of Teleworking in a US Federal Government Agency

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

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

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

- **Safeguarding of economic activity in previously low connectivity areas:** Improved broadband infrastructure may help some areas retain economic activity that would have otherwise been lost to other high connectivity areas (though there will be offsetting effects for the areas that would have otherwise benefitted). While many workers may be able to adjust to such local economic shocks by

[18] Though note that the programme has been designed to equalise the IRR on the project with the suppliers Weighted Average Cost of Capital, so in principle, suppliers will not earn excess profits on their investments.

[19] Wages could also rise if the programme stimulates demand for workers with locally scarce skills (creating wage inflation) or if firms choose to share any productivity benefits with workers, for the purposes of retention.

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

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

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

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

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 problems could produce local issues of long-term unemployment[24] and permanent losses of output (i.e. hysteresis effects) as these workers would not be redeployed elsewhere in the economy – costs that could be averted by subsidised coverage.

2.4 Impacts on households

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

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

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

- **Social interaction:** Faster broadband may also open new modes of communication between residents. While use of email and social media may not be dependent on higher bandwidths (and can be straightforwardly used via mobile telecommunications networks), the COVID-19 pandemic has popularised the use of video conferencing (previously used for remote meetings in a business context) as a mode of interpersonal communication. This technology requires greater bandwidths and subsidised coverage has the potential to improve well-being by supporting more extensive social interactions within and beyond the communities in which residents live (potentially reducing social isolation for some).

- **Social costs:** Greater on-line social interaction may not always be positive. There is evidence that for some groups, greater use of social media is associated with lower levels of self-esteem. Internet

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

addiction (i.e. compulsive desire to use the internet) has also been an area of recent clinical investigation – and has been found to be associated with depression and self-esteem. The direction of causality is unclear – i.e. internet addiction may be a symptom of underlying emotional disorders, rather than a cause – but it should be at least acknowledged that improved broadband connectivity has the potential to produce negative subjective well-being effects in some users[25].

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

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

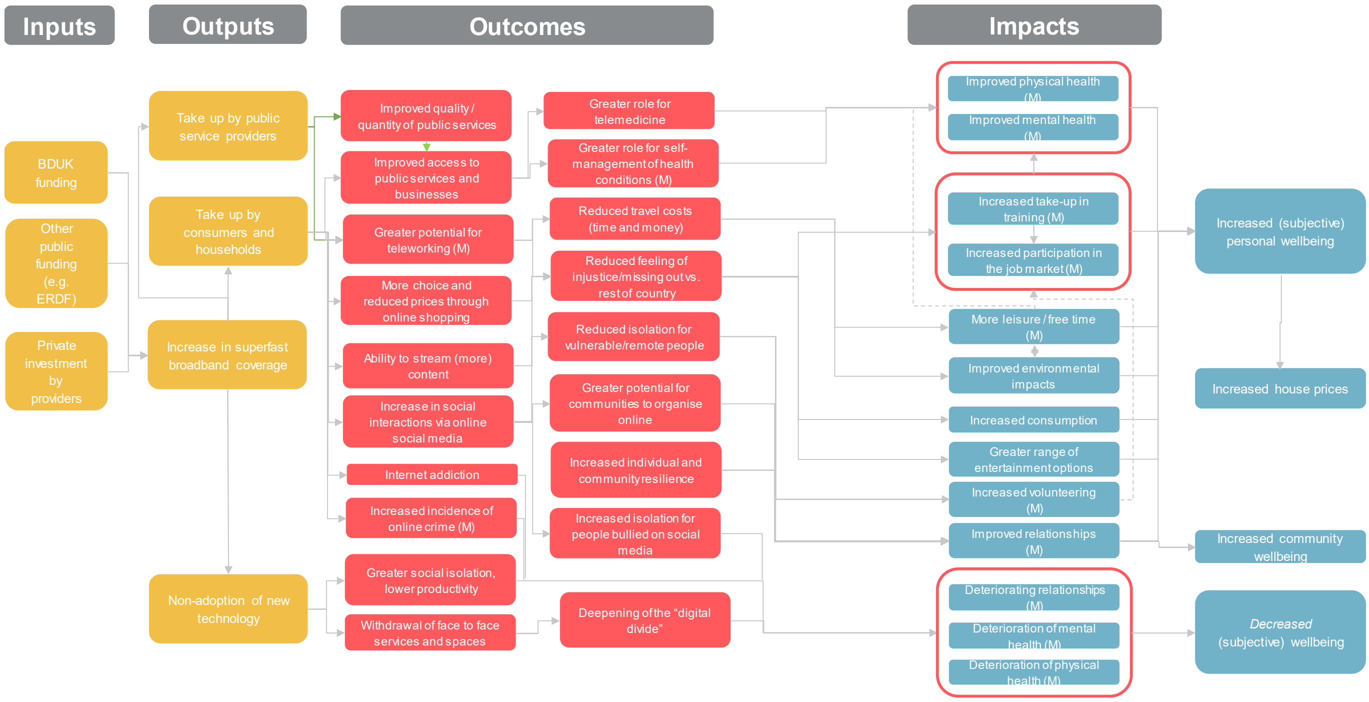
- **Rural population growth:** Migration of population to rural areas could also lead to pressures on local housing markets. This could also have a negative impact on the well-being of residents for example, if it increases equilibrium rents or stimulates house building activity on previously undeveloped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

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

[25] Pantic (2014) Online Social Networking and Mental Health, Cyberpsychology, Behaviour and Social Networking

[26] Natarajan et al (2020) Civil Society Perspectives on Inequality: Focus Group Research Finding, Submission to UK2070 Commission.

Figure 2.3: Household impacts of superfast broadband



2.5 Impacts on public sector service delivery

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

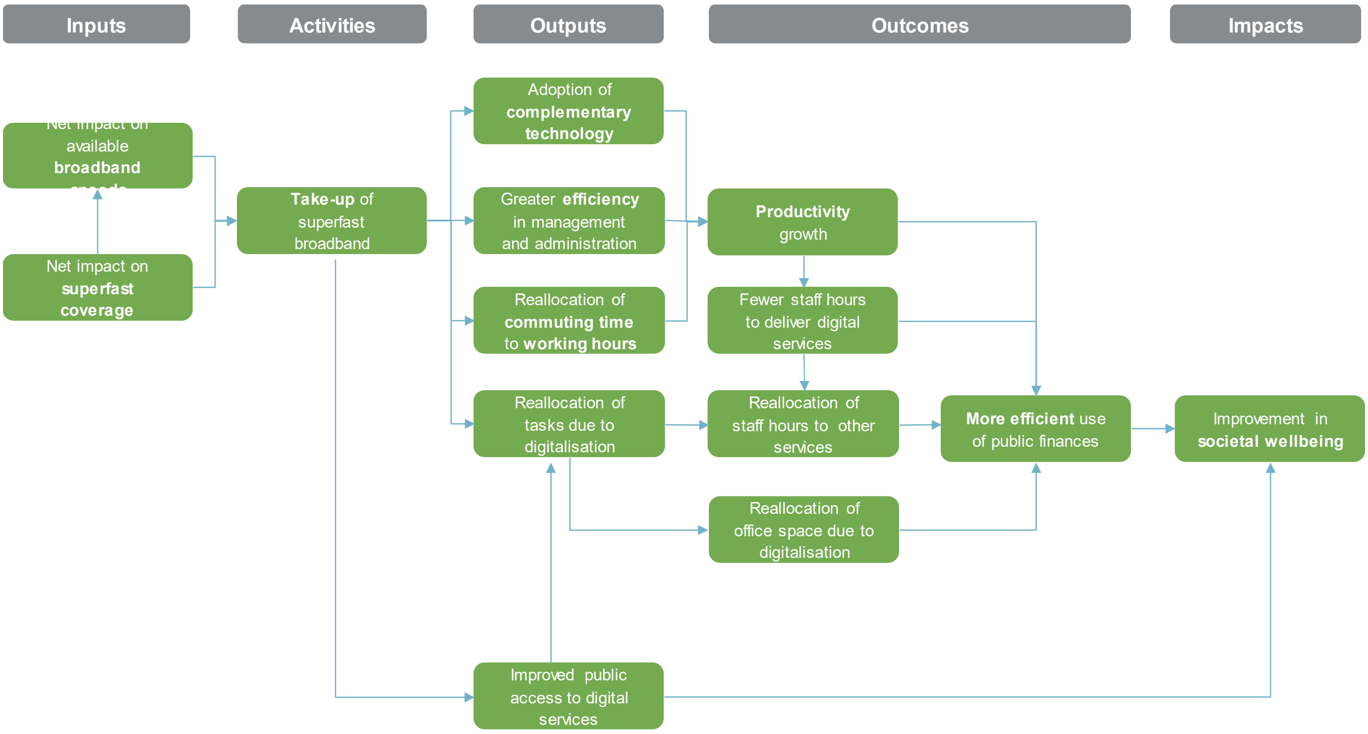
- **Direct efficiency gains:** Subsidised coverage may allow public sector organisations to benefit from the faster broadband connectivity. This will potentially allow these organisations to realise efficiency gains from the adoption of similar technologies to those described above in relation to the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

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

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

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

Figure 2.4: Public service delivery impacts of superfast broadband



3 Methodological framework

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

3.1 Counterfactual

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

- **Reverse causality:** Reverse causality is typically a central challenge in the evaluation of the impacts of infrastructure projects. Areas often benefit from enhanced infrastructure investment because they are expected to grow in the future. Comparing areas that do and do not benefit from enhanced infrastructure tends to overstate the effects of investment, as those areas receiving the investment would be expected to grow more rapidly anyway. This problem is perhaps less acute in the case of the Superfast Broadband Programme as it was designed to address inclusion objectives (i.e. enabling areas of the UK to obtain superfast broadband services that were being delivered on a commercial basis to denser urban areas) rather than to address specific spatial development priorities. However, several Local Bodies have used the tendering process to align the delivery of the programme with local economic development priorities and reverse causality problems are likely present in at least some areas benefitting from the programme.

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

3.2 Pipeline design

The issues identified above were handled by exploiting the long timeframes over which the programme was delivered. This enables comparisons to be made between those areas that benefitted from the programme first to those that received the intervention later. In this set up, areas receiving subsidised coverage at later stages act as a comparison group for those that receive the intervention earlier. In this design, comparisons are restricted to areas that eventually received the intervention. As such, comparisons should be robust to problems caused by systematic differences between areas that do and do not benefit from subsidised broadband coverage.

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

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

This model links the outcome of interest for area *i* in period t (y_{it}) to whether the area has benefitted from subsidised coverage in period t (T_{it}). The coefficient β captures the effect of subsidised coverage on the outcomes. Models also generally included a vector of time varying control variables describing other characteristics of the areas that may also influence the outcome of interest (X_{it}). Econometric models were also developed to allow for unobserved but time invariant characteristics of the areas of interest that could bias results (α^i) as well as unobserved but time specific shocks (α^t) affecting all areas[27].

3.3 Limitations

There are some methodological limitations to this approach:

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

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

  - **Order of upgrades:** The network provider selects the order in which postcodes benefit from subsidised upgrades. If they adopt a profit maximising strategy, it would be anticipated that they would deliver to the profitable postcodes first. Evidence from Technical Appendix 1 suggests that in Phases 1 and 2, network providers tended to prioritise postcodes with higher demand density. However, in Phase 3, network providers appeared to prioritise lower density areas where competitors were less likely to have a presence nearby. If higher demand density is positively correlated with underlying economic performance or other outcomes of interest, then this could lead to an overstatement of the impacts of the programme.

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

  Attempts to mitigate these issues have been made by controlling for the observed characteristics of the areas benefitting from the programme as well as unobserved characteristics that do not change with time. However, there may be time varying but unobserved characteristics of the areas

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

benefitting from the programme that have not been controlled for in the analysis. As such, the design does not involve quasi-random allocation between the treatment and comparison groups and the results should be considered to attain Level III on the Maryland Scale.

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

3.4 Validity of the pipeline design

In order for the pipeline design to produce unbiased estimates of the programme impact, there must not be any systematic differences between areas receiving investment earlier and those receiving investment later that are also correlated with the outcomes of interest. For example, if subsidised broadband is rolled out to areas experiencing higher productivity growth first, then this will overstate the impact of the programme. The suitability of the pipeline approach for use throughout the analysis utilising this approach in this paper was tested by comparing the characteristics of the areas receiving upgrades at various times. Significant differences in the key characteristics of these areas would weaken the pipeline approach and would support a hypothesis that the choice of areas to be delivered to over time was systematic and not random.

The postcodes first receiving subsidised coverage in each year between 2013 and 2018 were first of all compared using the Business Structure Database (BSD). This allows for the comparison of these areas in terms of their economic performance (see subsection 4.1.1 for more detail on the BSD). This did not identify many differences between the areas upgraded at different times in terms of the sizes and sectors of local firms. The average turnover generated in output areas upgraded in 2016 was, however, lower than the average across areas upgraded in other years.

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

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

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

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

Table 3.2: Characteristics of employees working in areas receiving coverage in each year between 2013 and 2018

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

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

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

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

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

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

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

Table 3.4: Characteristics of schools in areas receiving coverage in the year before upgrade, 2013 to 2018

	Year before postcode was upgraded				
	2013	2014	2015	2016	2017
Number of pupils	196.28	172.80*	181.16	185.00	267.07*
Percentage of pupils with EAL	3.26	2.97	5.36*	5.10*	7.16*
Percentage of pupils with FSM	10.61	9.07*	8.89*	8.68*	18.72*
Percentage of SEN pupils	4.38	3.53*	6.98*	7.72*	12.03*

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

4 Impacts on businesses

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

4.1 Data

The following analyses made use of the following datasets.

4.1.1 Business Structure Database

The Business Structure Database is an annual snapshot of the Interdepartmental Business Register (IDBR). The database contains longitudinal observations of employment and turnover at an enterprise and workplace[28] level and was accessed through the Office for National Statistics (ONS) Secure Research Service (SRS).

The data also provides the industry sector and the Output Area associated with each workplace, enabling tracking of relocations and the opening of new locations. The underlying data on employment and turnover are assembled from PAYE and VAT returns or from Annual Business Survey or Business Register of Employment Survey[29] returns if the firm is included in the sample. These arrive with different lags and are recorded as and when data arrives. Known issues with the data include the fact that some records are thought to be up to two years out of date, and some caution is urged by ONS in using the BSD in evaluating policy interventions over short time horizons[30]. Annual cross sections from 2012 to 2018 were used for the following analyses (at the time of writing, the 2019 BSD was not available).

The BSD incorporates 'live' local units. Between 2012 and 2018, a total of 5,354,635 unique live local units were present with the number present in each yearly cross section in the table below. All other local units were removed from the cross sections where a death date was present.

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

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

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

Year	Number of live local units
2012	2,759,355
2013	2,772,002
2014	2,883,556
2015	2,974,482
2016	3,077,227
2017	3,201,395
2018	3,216,459

Source: Business Structure Database

The BSD research data consists of annual cross-sections at the enterprise and local unit level (i.e. one enterprise may have multiple local units if it operates from more than one site). Employment is observed at the level of local units, while turnover is recorded at the level of the overall enterprise. To provide local measures, turnover was apportioned to each local unit based on their share of employment in the overall enterprise. This implicitly assumes that all local units are equally productive and could have a distortionary effect on findings if the provision of subsidised broadband coverage alters relative productivity of local units (i.e. if the productivity of local units benefitting from subsidised coverage increases in response to the upgrade, then this effect will be diluted by the apportionment process). Measures of turnover were deflated using the HM Treasury GDP deflator and expressed in 2019 prices[31].

The most granular geographical identifier of individual local units was the Output Area[32] (the postcodes of local units were withdrawn in 2019). The BSD dataset was aggregated to the Output Area giving measures of the total employment and turnover of firms located in the Output Area, the total number of live local units active in the area. Measures of turnover per worker were calculated by dividing through the total turnover of firms located in the Output Area with the total employment. The final panel dataset comprised 509,166 observations across 72,738 Output Areas. In addition, two further panel datasets were generated focused on subgroups of the firms of interest:

- **Spatially stable:** Local units which remain situated in the same output area between 2012 and 2018. These local units were identified by comparing the output area for each local unit across each cross section. Where these areas remained the same across the period, the local unit was marked as 'spatially stable'. The interest in this group of firms was motivated by the possibility that local economic impacts were driven by firms relocating to areas benefitting from subsidised coverage, implying a corresponding loss of economic activity elsewhere (displacement). Focusing the analysis solely on those firms that did not relocate provides greater confidence that the productivity gains associated with the programme represent improvements in efficiency rather than improvements in local productivity driven by the relocation of more productive firms to the relevant areas. Of the 5,354,635 unique local units covered by the BSD, 4,605,693 (86 percent) were marked as spatially stable. 1,175,328 (22 percent) were both spatially stable (i.e. did not move location) and present in each cross section between 2012 and 2018 (new start-ups established or business closing since 2012 would not appear in this latter figure).

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

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

- **Single site:** Enterprises that operate from one site. These were identified through analysis of the total number of live units falling under each enterprise reference. Where this equalled one, the local unit was marked as a single site. The interest in these firms was as a way to provide a cross-check against the process of apportioning turnover across local units. Therefore ensuring that the apportioning process did not result in misleading results. However, it should also be noted that single site firms are not representative of the overall business population and will typically be smaller operations. Of the 5,354,635 unique local units covered by the BSD, 4,581,023 (86 percent) were marked as single site.

The use of data at the Output Area has some advantages over an analysis configured at the postcode level. As the observations cover all economic activity in an area, findings implicitly account for any displacement or crowding out effects at the local level. However, as it was not possible to identify whether specific firms had benefitted from subsidised coverage brought forward by the programme, a replication exercise was completed to explore the comparability of results generated in a prior study[33] using postcode level data. These analyses used data from the BSD between 2012 and 2016 but involved equivalent data processing steps. The table below provides a comparison between the estimated impacts on turnover, employment and turnover per worker based on postcode and Output Area data for the equivalent period[34].

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

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

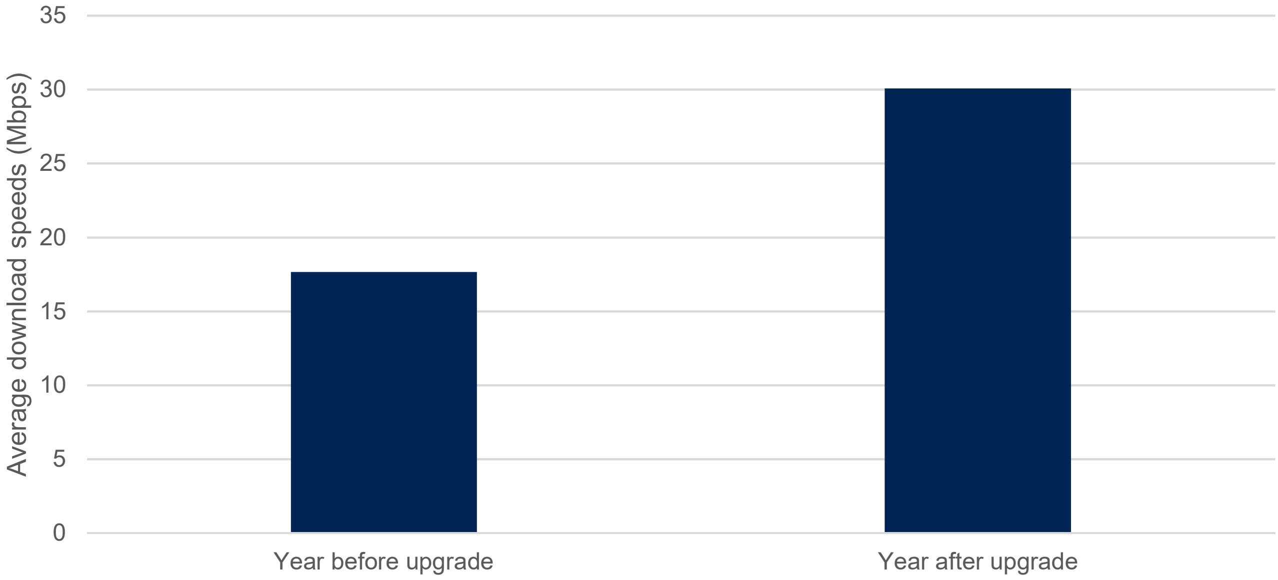
	Employment	Turnover	Turnover per worker	Number of firms
Postcode level	0.8%***	1.2%***	0.3%*	0.3%***
Output Area level	0.3%***	1.2%***	0.9%***	0.4%***

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

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

[33] Economic and Public Value of the Superfast Broadband Programme. (2018). DCMS. Available at: https://www.gov.uk/government/publications/evaluation-of-the-economic-impact-and-public-value-of-the-superfast-broadband-programme
[34] These models were implemented using the econometric specification specified in section 4.3.1 (configured at a postcode and Output Area level respectively).

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



Source: Ofcom Connected Nations; Ipsos MORI analysis

4.1.2 Valuation Office Agency

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

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

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

4.1.3 C3 reports

Claimed delivery of superfast coverage was taken from the C3 reports provided to BDUK by contractors. An aggregated dataset was produced by BDUK and supplied to Ipsos MORI. The C3 report captures the address of each premise the contractor claimed they had upgraded, and provides predicted download and upload speeds. C3 reports to end of quarter 4 2018/19 were used to support the analyses reported below, providing details of some 6.1m[35] premises that were claimed by providers. As the focus of the analysis was on the impact of subsidised coverage on economic performance, all claimed delivery was retained for the purposes of analysis - delivery of sub-superfast coverage and coverage delivered in grey, black, and ineligible areas were included. The C3 reports covered a total of 450,059 postcodes in the UK (27.7 percent of the 1,625,197 postcodes in the UK[36]). These were spread over 72,739 Output Areas.

4.2 Overview

Figures 4.1 and 4.2 provide an overview of trends in economic activity in the programme areas between 2012 and 2018 (using data from the BSD). These show that the employment, turnover and turnover per worker of firms located in areas receiving subsidised coverage grew over the period covered by the analysis. However, there were differences in the economic density of areas benefitting from Phase 1 of the programme and those benefitting in Phases 2 and 3. Areas benefitting from Phase 1 contracts were associated with lower levels of employment and turnover (and were apparently less productive) than areas covered by later contracts. This would be consistent with a greater focus on residential suburban zones in Phase 1 as opposed to rural town centres (with denser clusters of businesses). As most areas benefitting from the programme (81 percent) received coverage under Phase 1, these areas dominate whole programme averages. This has possible implications for the pipeline approach to the degree that areas with greater and lower business density have seen divergent growth paths over the course of the period.

Data from the VOA suggested that the average rateable value per square metre was lower on postcodes in build plans of schemes funded than across England and Wales in 2010 (at £876 vs £1,124[37]). This indicates that the willingness to pay to obtain floorspace in the programme area was lower amongst businesses, suggestive of lower productivity advantages attached to the location (although these simple averages do not account for differences in the mix of retail, warehousing, commercial and industrial floorspace). Postcodes in the build plans of funded schemes saw average rateable values per square metre rise from £876 to £1208 (38 percent) between 2010 and 2017, slightly more rapidly but not dissimilar to the rise observed for England and Wales overall at 32 percent (from £1,124 to £1,489)[38].

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

[36] As covered in the 2018 Ofcom Connected Nations data

[37] In 2019 prices.

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

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

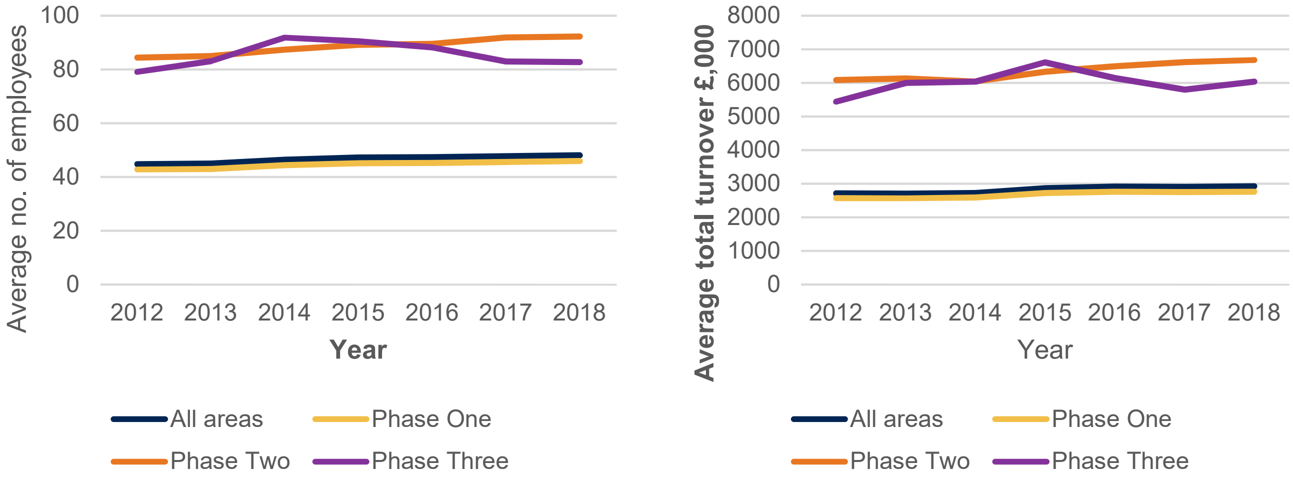
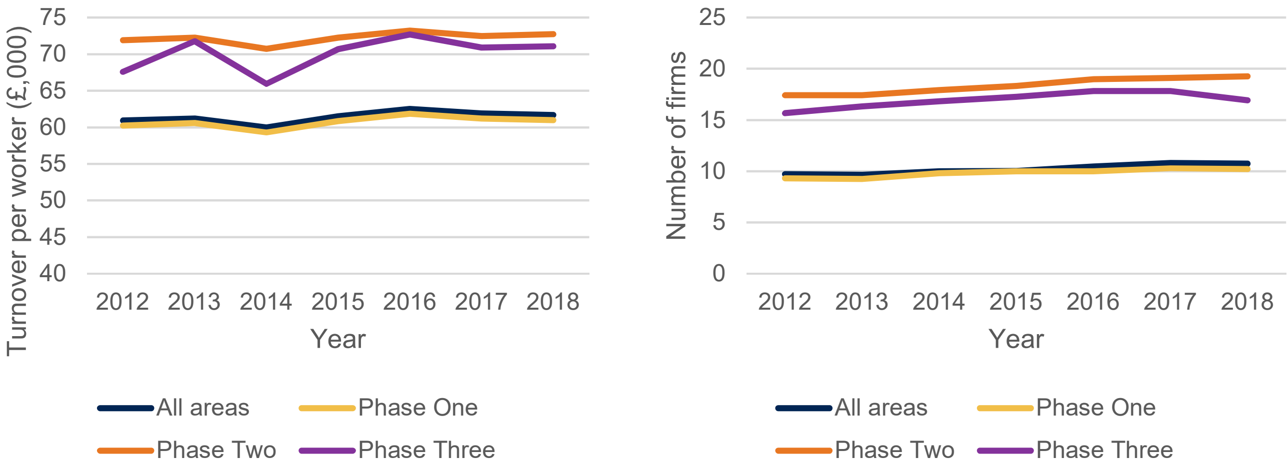


Figure 4.3: Average turnover per worker and average number of firms per output area, output areas benefitting from subsidised coverage (2019 prices)



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

4.3 Results

4.3.1 Business Structure Database

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

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

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

The models also controlled for general trends at the national level (t) and allows for differential trends across different sectors of the economy and businesses of different employment size bands ($X_{i,t=2012}t$). Here, $X_{i,t=2012}$ represents the share of employment in each sector and size-band in 2012, which was interacted with time to capture unobserved trends affecting different sectors and sizes of firms that would determine growth in the Output Area. The model also controls for any time invariant unobserved differences between output areas (αi). To mitigate the risk of possible biases driven by unobserved differences between areas benefitting from the programme and areas that were not, the sample was restricted to the 72,739 Output Areas that received subsidised coverage at some point between 2012 and 2019 (i.e. including areas that had not yet benefitted from subsidised upgrades).

Local economic impacts

The table below provides estimates of the overall effects of the Superfast Broadband Programme on employment, turnover and turnover per worker of firms located in Output Areas benefitting from subsidised coverage. The econometric models provided an estimate of the percentage effect on total employment, turnover, turnover per worker, and the number of firms in the area per premises upgraded (the first row of Table 4.3). The implied effect at the Output Area level was estimated by multiplying these results by the average number of premises upgraded per Output Area by 2018.

The results indicated that the programme has had a positive impact on the employment and turnover of firms located in Output Areas benefitting from subsidised coverage. The effect on turnover (1.0 percent) was larger than the effect on employment (0.6 percent), implying that the productivity of local firms rose in response to subsidised coverage (0.4 percent, using turnover per worker as a proxy variable). Finally, the number of firms located in the area increased – suggesting that the programme encouraged firms to relocate to areas benefitting from enhanced coverage.

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

Outcome	Employment	Turnover	Turnover per Worker	Number of firms
Estimated effect per premises upgraded, areas upgraded by March 2018 (%)	0.000067***	0.000120***	0.000053***	0.000061***
Implied effect at the Output Area level (%)	0.555***	0.992***	0.436***	0.504***
No. of observations	509,166	509,166	509,166	509,166
R-squared	0.286	0.607	0.620	0.285
Estimated effect at the Output Area level (12-16, %)	0.293***	1.121***	0.920***	0.430***

Source: Ipsos MORI analysis. The outcome variables were expressed in the form of natural logarithms and the coefficients can be interpreted as the marginal percentage effect of subsidised coverage on the outcome of interest. All models were estimated with fixed effects, allowing for unobserved trends at the national level, and at the sector and size-band (based on the Output Areas share of employment by sector). Effects were aggregated to the level of OA by multiplying the estimated effect per premises by the average number of subsidised upgrades in areas benefitting by March 2018 (82.7).

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

Persistence of impacts over time

The results above suggest that the impact of the programme has varied with time. The estimated effect of the programme on turnover per worker has apparently got smaller with time. This could be explained if the impact of subsidised coverage decays with time (i.e. the effect of enhanced infrastructure on competitiveness is temporary rather than permanent). There may also be diminishing marginal returns as the programme expands - firms located in areas benefitting from the programme at later stages may be less able to exploit enhanced connectivity. These issues were explored by examining the relative impact of subsidised coverage under Phases 1, 2 and 3 of the programme[39].

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

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

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

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

*Source: Ipsos MORI analysis. '***', '**', and '*' indicate whether the estimated coefficient was significant at the 99, 95 and 90 percent level of confidence. All models were estimated with fixed effects, allowing for unobserved trends at the national level, and at the sector and size-band (based on the Output Areas share of employment by sector). The periods covered by each Phase are provided in parentheses in the first column – note that these do account for delivery in 2019 and future years.*

As highlighted below, there were no statistically significant differences in the profile of firms (by sector or size-band) benefitting from subsidised coverage in different years that would provide an obvious explanation for these differences. The findings above could be explained if firms take time to realise the benefits of enhanced connectivity. A large share of the premises upgraded under Phase 2 were delivered in 2017 and 2018 (see Figure 2.1). Very little in the way of delivery of Phase 3 contracts was complete by March 2018. This was probed further focusing solely on areas that had benefitted from the programme by March 2016, and estimating the impact of subsidised coverage to each year between 2014 and 2018. The results are summarised in the following figure (Figure 4.4).

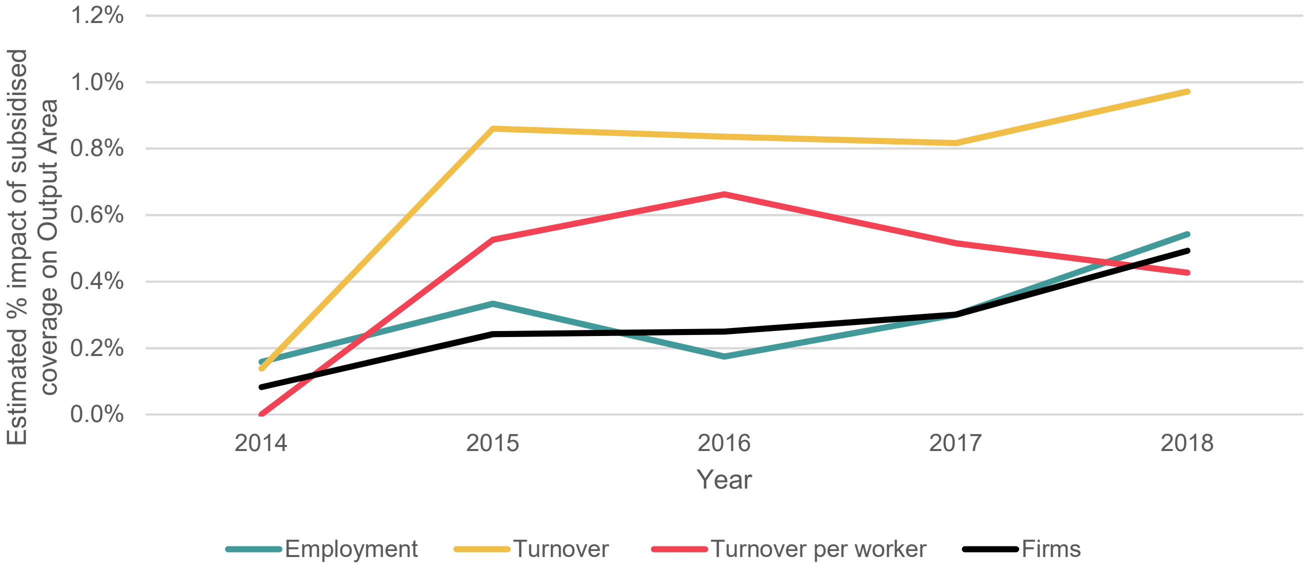
The findings show:

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

- **Relocations:** The impact of subsidised coverage on the number of firms located in the areas benefitting appears to strengthen with time. This indicates enhanced broadband infrastructure is an important component of local competitiveness and the ability of areas to attract external investment.

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

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



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

Spatially stable firms

The results above capture the overall effect of the programme on the Output Areas benefitting from the programme. While these findings implicitly account for displacement and crowding out at the local level, they do not represent net economic impacts at the national level and as such cannot be included in a cost benefit analysis. As noted, a share of the local effect is driven by incoming firms and there will be corresponding losses in economic activity elsewhere. To obtain clearer estimates of the economic impacts of the programme, a set of analyses were completed focusing on firms that did not change location between 2012 and 2018.

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

- **Overall impacts:** Across all areas upgraded by March 2018, subsidised coverage increased the average employment of spatially stable firms by 0.45 percent and their turnover by 0.64 percent. There was no statistically significant effect on turnover per worker.

- **Impacts on areas receiving subsidised coverage by end of March 2016:** The programme did however, lead to productivity impacts on those areas that had benefitted from subsidised coverage by the end of March 2016. By the end of 2018, subsidised coverage increased the employment of spatially stable firms by 0.17 percent and their turnover by 0.88 percent. The impact on turnover per worker was estimated 0.71 percent.

- **Persistence of impacts:** Equivalent results to the end of March 2016 are provided in the final panel (4 rows) of the following table. Comparisons between the effects of the programme to 2016 and 2018 shows a similar pattern to that suggested above. It appears that subsidised coverage leads to an initial impact on turnover, which is followed by an expansion in employment. This erodes the initial productivity gain, and in this case the estimated rate of decay in the estimated effect on turnover per worker was 12.8 percent per annum.

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

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

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

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

Single site firms

As highlighted in subsection 4.1, the analyses set out above could potentially be distorted by multi-plant firms owing to the need to apportion turnover measures across individual sites. This was examined further by restricting the analysis to firms with a single site. As highlighted in the table below, the estimated effects of the programme on firms with a single site did not differ in a significant way to those estimated across all firms. This suggests that the presence of multi-plant firms in the sample of firms does not materially influence the results.

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

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

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

Impacts by technology type and speed

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

- **Technology type:** FTTC was the dominant technology type used in the delivery of the programme and the estimated impacts of FTTC coverage broadly aligned with overall impacts of the programme. The findings also indicated that both FTTP and wireless solutions had the potential to deliver larger impacts (though while the estimated coefficients were generally larger than for FTTC, few estimates were statistically significant). The use of both technologies was limited, however, by March 2018 and it is arguably too early to judge the relative effectiveness of these competing solutions.

- **Diminishing returns to speed:** The findings suggested that there were diminishing returns to the predicted speed of the connection available. The effects of moving to speeds below 24Mbps[40] were estimated to be between 2.5 and 3 times larger than the impacts of superfast connectivity (on employment, turnover and turnover per worker). This indicates the absence of basic broadband being a more potentially severe impediment for businesses and releasing businesses from this constraint can have significant economic impacts. The findings did not indicate that ultrafast connectivity (download speeds exceeding 80Mbps) had statistically significant impacts on employment, turnover or turnover per worker. However, this is connected to the findings relating to FTTP. As stated above, it is likely too early to explore the long-term economic impacts of making faster speeds available (and in the context of growing demand for bandwidth, the full impacts of the faster speeds will not be observed in the short-term).

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

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

Table 4.7: Estimated impact of subsidised coverage on local employment, turnover and turnover per worker per premises upgraded, by technology type and predicted speed (2012 to 2018)

Outcome	Employment	Turnover	Turnover per worker	Number of firms
Effects by type of technology				
FTTC	0.000065***	0.000118***	0.000054***	0.000061***
FTTP	0.000144*	0.000154	0.000010	0.000041
Wireless	0.000540**	0.000680**	0.000141	0.000429***
Effects by predicted speed of connection				
Basic (<24Mbps)	0.000182***	0.000305***	0.000123***	-0.000020
Superfast (>24Mbit to 80Mbps)	0.000054***	0.000100***	0.000047***	0.000070***
Ultrafast (>80Mbps)	0.000143*	0.000152	0.000008	0.000041

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

Impacts by urban and rural areas

The analysis was also completed for urban and rural areas separately[41]. The table below provides the estimated impacts for urban and rural areas. The findings suggest that the estimated magnitude effects (per premises upgraded) on employment and turnover was larger in urban areas than in rural areas. However, there were no statistically significant differences in terms of the estimated effect on turnover per worker and the number of firms located in the Output Area.

It should be noted that the economic density of rural Output Areas benefitting from the programme was higher than urban areas (i.e. at 48.4 jobs per rural Output Area in comparison to 39.4 jobs per urban Output Area). This indicates that urban areas benefitting from the programme tended to be in more residential suburban zones. As such, this indicates that rural delivery of the programme will have raised the productivity more workers on average, leading to larger economic impacts in absolute terms than delivery in urban zones.

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

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

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

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

Total local economic impacts

The table below aggregates the estimates of the overall economic impacts of the Superfast Broadband Programme over the number of areas benefitting from the programme by applying the estimated effects to the average total employment and turnover of firms located in the Output Area in 2012. The results indicated that by 2018, the subsidised coverage led to the following estimated local impacts (these should not be interpreted as the net economic impacts at the national level):

- **Jobs:** The number of workers employed in Output Areas benefitting from the programme increased by 17,600 jobs due to the subsidised coverage (compared to 7,400 by 2016[42]). This accounts for any offsetting and localised displacement or crowding out effects – e.g. if firms benefitting from subsidised coverage claim market share from competitors in the neighbourhood, then the associated impact on jobs will be captured in Output Area totals.

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

- **Additional turnover from efficiency gains:** The total increase in the annual turnover of firms driven by apparent efficiency gains was estimated at £845m by the end of 2018[43]. This compares to £1.4bn at the end of 2016.

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

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

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

Source: Ipsos MORI analysis

4.3.2 Commercial rental values (Valuation Office Agency)

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

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

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

To probe this issue, the following analysis examines the effects on commercial rents as inferred from changes in rateable value between 2010 and 2017. Productivity effects can be inferred indirectly from changes in the rental value of commercial space, and land values. The amount businesses are willing to pay to move to new premises would be expected to be equal to the benefit they expect to gain from access to facilities offered by the property. If enhanced connectivity leads to higher commercial rents, this should provide an indirect measure of the increased profitability that can be obtained by firms by relocating to the property. In this respect, an increase in rateable value (the VOA's estimate of the rental value of the property) can be viewed as a measure of the productivity gain expected by a new tenant (in line with DCLG's appraisal guidance[44]) – though this will likely factor in the timeline over which the productivity gain is expected to persist.

Econometric model

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

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

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

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

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

Results

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

[44] The DCLG Appraisal Guide. (2016). DCLG. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/576427/161129_Appraisal_Guidance.pdf

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

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

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

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

5 Impacts on workers

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

5.1 Data

The following analyses made use of the following datasets.

5.1.1 Annual Survey of Hours and Earnings

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

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

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

A total of 27,024 Output Areas benefitting from subsidised coverage between 2012 and 2018 were linked to at least one local unit containing a sampled employee between these years. A total of 89,031 workers were associated with firms located in subsidised areas providing a total of 435,217 annual observations of wages and pay.

5.1.2 Claimant Count

Experimental data on the claimant count was taken from NOMIS[45]. This captures the number of people claiming Jobseeker's Allowance plus those who claim Universal Credit and who are required to seek work and be available for work[46]. This has replaced the number of people claiming Jobseeker's Allowance as the headline indicator of the number of people claiming benefits principally for the reason of being unemployed. Data between 2013 and 2019 was downloaded at the LSOA level for England and Wales and the Data Zone level for Scotland (being the smallest census geography areas available). There were a total of 41,729 areas with claimant count data available.

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

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

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

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

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

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

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

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

5.1.3 C3 Reports

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

5.2 Results

5.2.1 Wage impacts

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

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

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

The models also controlled for general trends at the national level (t) and allow for differential trends across different sectors of the economy and businesses of different employment size bands ($X_{i,t=2012}t$). Here, $X_{i,t=2012}$ represents the share of employment in each sector and size-band fixed in 2012. The model also controls for any time invariant unobserved differences between output areas (αi). To mitigate against the risk possible of biases driven by unobserved differences between individuals in areas benefitting from the programme and those in areas that did not, the sample was restricted to those individuals employed in Output Areas that received subsidised coverage at some point between 2012 and 2019.

Overall effects

The table below provides estimates of the overall effects of the Superfast Broadband Programme on both hourly earnings and total hours worked for individuals employed by firms located in Output Areas benefitting from subsidised coverage. The results found a positive impact on the hourly wage of workers in the OA of around 0.7 percent per worker following the first upgrade (although there was no effect on hours worked). This provides further confidence that the effects on turnover per worker can be treated as a productivity gain. However, it should be noted that these effects were not statistically significant in models that were restricted to individuals whose wages were observed in each year between in 2013 and 2018 (though it is important to note that the restrictions placed on this model reduced the sample size substantially to just over 6,020 observations).

Table 5.1: Impact of subsidised coverage on hourly earnings and total hours worked, 2013 to 2018

Outcome	Model 9	Model 11
Fixed effects	Yes	Yes
National time trends	Yes	No
Individual and occupation time trends	Yes	Yes
Firm/individual controls	Yes	Yes
Model specification	OLS	OLS
Individuals present in all periods	No	Yes
Average impact following the first premises upgraded		
Hourly wage (£, ln)	0.00738***	0.00342
Total hours worked (hrs, ln)	0.000725	-0.00418*
Number of observations	432,681 – 432,771	6,020
Adjusted R-squared	0.209-0.357	0.258-0.274

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

Effects by occupation

Isolating effects by occupation showed varying impacts depending across occupations:

- **Professional occupations:** For professional occupations (such as scientists, health professionals, teaching professionals and business, media and service professionals), the estimated effect of subsidised coverage on hourly earnings was shown to be similar to those found overall at 0.7 percent. Subsidised coverage was also estimated to have led to a decrease in the number of hours worked of 0.8 percent.

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

- **Sales and customer service:** The largest increase in wages was found for sales and customer service workers at a 1.1 percent increase, however in this case no corresponding reduction in hours was observed.

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

Table 5.2: Impact of subsidised coverage on hourly earnings and total hours worked by occupation group (SOC10), 2013 to 2018

Outcome	Hourly wage (£, ln)	Total hours worked (hrs, ln)
Fixed effects	Yes	Yes
National time trends	Yes	No
Individual and occupation time trends	Yes	Yes
Firm/individual controls	Yes	Yes
Model specification	OLS	OLS
Individuals present in all periods	No	Yes
Effects per premises upgraded		
Managers and senior officials	9.88e-05	-0.00430*
Professional	0.00726***	-0.00862***
Associate professional and technical	-0.00109	-0.00115
Administrative and secretarial	0.00414	-0.000233
Skilled trades	0.00594*	-0.00604**
Personal service	0.00400	-0.00276
Sales and customer service	0.0116***	-0.000389
Process, plant and machine operatives	-0.00164	-0.00651**
Elementary	0.00816***	0.00333
Number of observations	34,154 – 63,465	35,155 – 63,477
Adjusted R-squared	0.128-0.238	0.127 – 0.309

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

5.2.2 Unemployment impacts

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

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

Here, the number of claimants in area i in period t (Y_{it}), is determined by its exposure to BDUK subsidies (T_{it}) and the characteristics of the area in 2013 (X_i,2013). The parameter β provides an estimate of the impact of subsidised coverage on the number of claimants. As the characteristics of areas could have been influenced by the programme, only pre-programme characteristics are controlled for to avoid possible issues with endogeneity that could cause estimates of impact to be biased.

Overall effects

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

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

- Model 3 and 4 expand upon models 1 and 2 by restricting the sample to only those areas that had received subsidised coverage by 2019. Here, there was a reduction of between 0.4 and 1.1 claimants per LSOA upgraded.

- Model 5 uses a fixed effects specification with no controls aside from a dummy for universal credit and finds much higher effects. These are tempered by the introduction of time fixed effects in Model 6 and then travel to work area level trends on top in Model 7. The most robust model (Model 7) implies a reduction of 0.6 claimants on average per LSOA upgraded.

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

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

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

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

Dose response models

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

Refining this approach, the table below uses alternative treatment variables defined as the cumulative proportion of postcodes in an LSOA upgraded (Model 8) and the overall number of premises upgraded within the LSOA (Model 9). Both these take the form of a difference-in-differences specification and are, in principle, robust to time invariant differences between LSOAs.

The results of model 8 below indicated that for every 10,000 premises upgraded, the number of unemployed claimants fell by 32 over subsequent years[47]. The results with the cumulative percentage of postcodes in the LSOA/Data Zone receiving subsidised coverage as the treatment also indicated that for every percentage point increase in postcodes of the area upgraded there were 0.28 fewer claimants. This

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

would equate to 2.8 fewer claimants per 10 percent additional coverage of the postcodes within an LSOA/Data Zone.

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

Outcome	Model 8	Model 9
Areas controls (2013)	Yes	Yes
Time FE	Yes	Yes
Area level trends	Yes	Yes
Areas included	Treated only	Treated only
Model specification	FE	FE
Treatment variable	Cumulative % of postcodes receiving subsidised coverage	Number of premises upgraded
Claimant count (number)	-0.2785***	-0.00321***
Number of observations	151,858	152,481
Adjusted R-squared	0.437	0.434

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

Residential vs non-residential effects

An adapted version of model 9 above was reapplied to explore the potential for differences in the magnitude of the effect on the claimant count based upon the degree to which premises upgraded in LSOAs were residential or non-residential. This found:

- **Residential upgrades:** Residential upgrades were associated with reductions in the number of claimants. This equated to an estimated 31 fewer claimants per 10,000 residential premises upgraded.
- **Non-residential upgrades:** In comparison, the results suggested that effects from non-residential upgrades were larger at 301 fewer claimants per 10,000 non-residential premises upgraded. This would support the hypothesis that productivity gains are largely driven by commercial use of superfast broadband connectivity.

Table 5.5: Impact of subsidised coverage on the claimant count, residential vs non-residential effects, 2013 to 2019

Outcome	Model 10	
Areas controls (2013)	Yes	
Areas included	Treated only	
Unobserved area effects	Yes	
Unobserved area trends	Yes	
Model specification	FE	
Treatment variable	Number of premises upgraded	
	Residential coefficient	Non-residential coefficient
Claimant count (number)	-0.00309***	-0.0305***
Number of observations	61,542	
Adjusted R-squared	0.418	

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

6 Impacts on households

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

6.1 Key issues

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

- **Direct effects on well-being:** The direct effect of making superfast broadband infrastructure available can be expected to arise from consumption of superfast broadband services. This will include consumption for leisure purposes but also potentially for working purposes (i.e. by enabling teleworking). While this will involve benefits for the consumer (e.g. in the form of increased choice or leisure time) it will also involve costs. The consumer will incur costs in the form of additional spending on broadband services. However, there may be other costs – for example, those relocating on the expectation that they will be able to commute less often may also be faced with longer commutes. As such, it is important to focus on the net impacts of making superfast broadband infrastructure available (i.e. the well-being indicator should measure the consumers' surplus[48]).

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

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

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

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

  - Greater superfast coverage could also lead to negative indirect impacts on some groups if it accelerates the digitalisation of public and private services. If greater take-up superfast

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

broadband makes it efficient for services to be moved online, the closure of physical service delivery points will have negative impacts on those without access (or the skills) to access those services online. Closure of services may also have negative effects on the vibrancy of town centres, which may also have offsetting effects on the well-being of residents.

- **Observability of well-being:** Finally, the welfare or utility of individuals cannot be directly quantified or monetised in the same way as the economic impacts described in the preceding section. As such, alternative approaches are needed to estimate the value of benefits to the consumer. Two strategies are adopted in the following sections. Firstly, a revealed preference approach is adopted in which the impact of superfast broadband coverage on house prices is explored (on the basis that the benefits arising from superfast broadband consumption will be capitalised into house prices). A second approach based on stated preferences is adopted, using measures of subjective well-being collected through surveys.

6.2 Impacts on house prices

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

6.2.1 Data

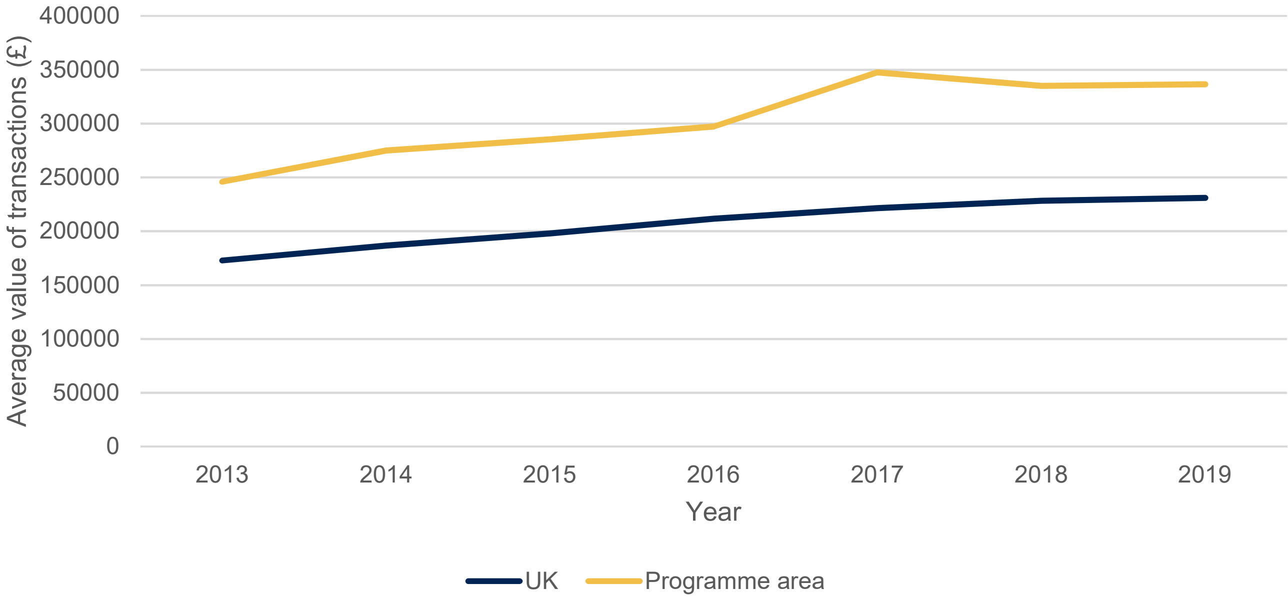
The primary dataset used for the analysis was the transaction level data on houses sold compiled by HM Land Registry. This provides a variety of data on individual housing transactions, including:

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

This data was linked to both the C3 reports and the build plans defined in the Speed and Coverage Templates to identify properties sold on postcodes that benefitted from subsidised upgrades. This process identified 1,186,131 homes sold on postcodes that benefitted from subsidised coverage at some point between 2013 and 2019, and a further 213,963 homes sold on postcodes defined in the build plans for contracts awarded through the programme but which have not been upgraded yet. Around 586,510 (49 percent) of these transactions took place before the postcode was upgraded. Information on the start date of the relevant contract was also appended to the data to provide a proxy for the announcement date of the scheme (to test for anticipation effects).

The figure below provides an overview of changes in (unweighted) average house prices between 2012 and 2019 in areas covered by the build plans of contracts awarded through the programme and the UK overall. House prices in the programme area increased quickly over the period (rising by 37 percent over the period), mirroring national trends.

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



Source: Land Registry HPI, SCTs, Ipsos MORI analysis

On average, the prices of houses sold in the programme area were 46 percent higher than those sold nationally (£303,251 versus £207,146). This does not account for differences in the types of houses traded, and there were also differences in the composition of characteristics of houses sold in the programme area when compared to the national average, as illustrated in the table below. Given these differences in composition, Figure 6.1 should not be taken to imply that the areas benefitting from the programme are necessarily characterised by higher levels of wealth. For example, between 2013 and 2019, detached house sales in build areas were sold for an average of £356,980 compared to £379,959 for such houses sold across England and Wales in the same period. The same pattern is evident across each of the home types presented below with the average price paid over the period for those in target areas of each type being lower than the equivalent national average.

Table 6.1: Distribution of houses sold by type, programme areas and UK, 2012 to 2019 (percentage of transactions)

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

Source: Land Registry, SCTs, Ipsos MORI analysis

The dataset was enriched with a further set of controls derived from the DfT Journey Time Statistics (previously Accessibility Statistics) between 2012 and 2017[50]. These provided LSOA estimates of the average journey times (by road, public transport, and walking and cycling) to a variety of amenities that may also influence house prices. These amenities included centres of employment, education, healthcare

[49] Taken from the March 2020 Price Paid Data update. See: https://www.gov.uk/government/news/march-2020-price-paid-data
[50] The publication of 2018 journey time statistics (due in August 2020) was cancelled due to the COVID-19 pandemic.

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

6.2.2 Econometric model

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

$$y_{it} = \alpha + \beta T_{it} + \gamma P_{it} + \delta X_{it} + \alpha_i + \alpha_t + \varepsilon_{it}$$

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

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

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

6.2.3 Results

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

This indicates that buyers were willing to pay a premium to obtain homes that had been upgraded. These estimates also compare to results from a previous study estimating the per household benefit of upgrading rural areas of the UK to FTTC of £3,145 (based on an analysis of the impact of upgrading local exchanges to ADSL during the 2000 to 2010 period)[51]. It should be noted, however, that there are several challenges in interpreting the increase in house prices attributable to the programme as a measure of social welfare:

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

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

- **Expectations:** There are also questions as to how consumers form expectations regarding the likely future availability of superfast broadband and build this into their willingness to pay for houses. In principle, if households have perfect information on the deployment plans of network providers, the estimated effects of the programme show what households are willing to pay for a housing with superfast broadband coverage over and above housing that will be upgraded in later years. If this is the case, then the results can be understood as the short-term gain associated with having access to superfast broadband services more rapidly. However, it is also possible that households are short-sighted or have imperfect information – in which case the price premium would represent the value attached to gaining access to superfast broadband coverage forever. Such an interpretation would increase the plausibility observed of the result, though this perhaps does not seem realistic given broader Government commitments to extend broadband coverage on a universal basis in the near to medium-term.

- **Broadband vs other factors:** As illustrated in Section 4, superfast broadband coverage appears to have induced firms to relocate to areas benefitting from the programme. As such, the change in house prices may not just reflect the value of the technology to users, but may also be driven up by the need for employees to relocate to avoid episodes of unemployment or lengthy commutes. These advantages will be permanent and provide a reasonable explanation for the apparent effect on willingness to pay. However, these other features of the property will be of relatively little importance for those that are not employed by the relocating firms. This substantially limits how far such a measure can be extrapolated across the broader population benefitting from subsidised coverage.

- **Functioning of housing markets:** As a final point, the operation of the housing market may not operate perfectly as it relies in part on the role of agents in the transaction process. Agents may seek to exploit broadband availability as a marketing feature to drive up prices (in which case, the price premium may not reflect improvements in underlying welfare).

- **Migration:** Finally, to the degree that changes in house prices are driven by migration (rather than by the broadband coverage itself), there may be corresponding falls in house prices in other areas (so these values may not represent net effects).

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

Outcome	Model 9	Model 10	Model 11	Model 12
Fixed effects	Yes	Yes	Yes	Yes
Unobserved national trends	No	Yes	No	No
Time fixed effects	No	No	Yes	No
Controls for journey times to local amenities	No	No	No	Yes
Model specification	OLS	OLS	OLS	OLS
Effects per premises upgraded (postcode level results)				
Average price of houses sold (£, log)	0.148***	0.0116***	0.0056***	0.0065***
Number of observations	836,606	836,606	836,606	836,606
Adjusted R-squared[52]	0.06 (0.828)	0.09 (0.832)	0.09 (0.879)	0.07 (0.879)
Effects applying from scheme announcement date (postcode level results)				
Average price of houses sold (£, log)	0.164***	0.0224***	0.0160***	0.0074***
Number of observations	836,606	836,606	836,606	836,606
Adjusted R-squared	0.05 (0.82)	0.09 (0.83)	0.09 (0.83)	0.06 (0.88)

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

6.3 Subjective well-being

The second strand of this analysis (led by Simetrica-Jacobs) examined the effect of subsidised coverage on the subjective well-being of residents of properties that benefited from the programme. This updated research completed as part of a prior evaluation of the programme[53], which combined BDUK and Ofcom Connected Nations data on programme rollout and connection speeds with two nationally representative UK household surveys that include individuals' assessments of their subjective well-being.

6.3.1 Data

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

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

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

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

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

A second set of analysis was completed using the Understanding Society dataset[54] spanning the years 2009 to 2019. It tracks households and individuals over time, and provided 182,172 longitudinal observations (129,035 before the upgrade and 53,137 after the upgrade). Geographical identification of households is less precise, with only the Lower Layer Super Output Area (LSOA) available. Life satisfaction is measured on a 1-7 scale in Understanding Society as opposed to a 0-10 scale in the APS. This variable was transformed linearly to map them to the 0-10 APS scale, for ease of comparison.

6.3.2 Econometric model

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

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

This model linked the self-reported well-being of individuals in period *t* (y_{it}) to a binary measure of whether the premises had been upgraded in period *t* (taking the value of 1 after the first premises and 0 otherwise - represented by T_{it}). A vector of individual controls (X_t) was included to control for a set of individual characteristics known to influence well-being. These controls included factors such as age, gender, marital status, ethnicity, level of education, home ownership, number of children, urbanisation, smoking behaviour, and region. Critically, the models also controlled for incomes, employment status and receipt of benefits to ensure that the results focused on impacts on well-being over and above those driven by the employment effects of the programme (as the preceding chapter illustrated, workers benefitted from the programme through higher wages and shorter working hours for some groups).

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

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

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

6.3.3 Overall results

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

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

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

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

- **Population sorting:** As highlighted above, almost 0.6m residential properties in the programme area were sold after the subsidised coverage was brought forward. This equates to almost 14 percent of the total number of residential premises upgraded by 2019 (estimated at 4.3m). This implies there has been a degree of churn in the resident population, and the findings on well-being may be driven by changes in the composition of residents induced by the programme that may offset any positive well-being effects associated with consumption of superfast broadband. For example, residents of urban areas tend to rate their well-being less highly than rural populations and if there is migration from urban to rural areas, this could reduce the well-being of the overall resident population if these tendencies do not change rapidly following migration.

- **Effects of population growth:** As the following chapter shows, population growth in the programme area appears to have placed pressure on public services, reducing overall satisfaction (at least in relation to primary care services). This type of pressure may have adversely affected the well-being of existing residents. As flagged elsewhere, changes in population may also have adverse consequences for social and community cohesion.

- **COVID-19**: The findings predate the COVID-19 pandemic and it is likely that the effects of the programme on well-being will differ substantially from those presented below, given the role connectivity has played in supporting resilience to the social distancing measures introduced to contain the outbreak.

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

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

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

6.3.4 Well-being impacts by age group

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

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

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

Measure of treatment	Aged 18 to 35		Aged 36 to 64		Aged 65+	
	Effects to 2019	Effects to 2016	Effects to 2019	Effects to 2016	Effects to 2019	Effects to 2016
Upgraded	0.05***	0.08***	-0.05***	-0.03**	0.04**	0.001
Median speed	0.002***	0.003**	-0.002***	-0.006***	0.002***	0.002***
NGA	0.05***	0.05**	-0.07***	-0.06***	0.02*	-0.004
Upgraded	0.095*	0.017	0.109**	0.044	0.133**	0.158***
Median speed	0.0072***	0.0025*	0.0020	0.00097	0.0017	0.003**
NGA	0.075*	0.056	0.003	0.005	0.044	0.116***

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

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

7 Impact on public services

This section examines the impact of the Superfast Broadband Programme on the performance of public services in two areas: primary care services and education. The analyses that follow draw on the GP Patient Survey published by NHS England, and data on school expenditure and performance published by the Department for Education. The available data only permitted a partial exploration of the effects of the programme on healthcare and education services, and the findings set out in this section should be considered preliminary (i.e. identifying issues for further exploration through primary research).

7.1 General practice

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

7.1.1 Background

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

Data available at the time of writing suggested use of video consultations was low[56]. The GP Patient Survey (GPPS) has included a question on video consultations since 2018. Less than one percent of appointments in that year were via video call. No increase was visible in the 2019 data with video consultations still accounting for less than one percent of all appointments offered to respondents on the last appointment. The available data is, however, dated in that it predates the COVID-19 pandemic and use of remote consultations has expanded substantially since March 2020[57].

Commitments have though been made in the NHS England Long Term Plan to a ‘digital first’ primary care system by 2023/24 and giving patients a right to video consultations by April 2021. Higher capacity networks will typically be needed to implement these plans. Online video consultations are estimated to require up 350Kbps per consultation[58], placing considerable additional pressure on local Wi-Fi networks that will be simultaneously used to access and update medical records or action scanned documents. This presents a possible constraint with 40 percent of NHS organisations estimated to be using lower capacity copper lines in April 2019[59], and has proven an inhibiting factor in pilot programmes rolling out video consultations[60]. The Government announced in 2019 that it would support all NHS organisations in obtaining full fibre connectivity to help realise these goals, though clearly the improved broadband infrastructure brought forward under the Superfast Broadband Programme has the potential to address some of the constraints faced.

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

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

58 iplato (2020) Video consultation technical requirements.

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

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

The claimed benefits of video consultations have tended to focus on enhanced time efficiency for GPs and greater convenience for patients. The available evidence on this is mixed. A 2017 study[61] exploring the use of online consultations in 36 GP surgeries found that online video consultations took longer than face-to-face appointments and cost slightly more to deliver (£36 per appointment versus £33)[62]. There is also evidence that greater convenience can induce greater demand. For example, an evaluation of the Babylon GP at Hand service[63] found that patients registering increased their demand for primary care appointments, raising questions about the size of the potential cost savings attached to 'digital first' working practices. A recent review of the potential impacts of online consultation services also highlighted evidence that GPs often regarded these services as adding to, rather than reducing, their workloads (with a reasonable share, 38 percent, of online consultations leading to a face-to-face consultation)[64].

Research has also suggested that users have positive experiences of online video consultations compared to telephone consultations[65] although there are questions as to the degree to which they are preferred to face-to-face consultations and whether they are suitable for discussing all types of patient concerns (e.g. issues of sexual health). Video consultations were particularly helpful for working people and people with mobility or mental health problems and considered superior to telephone consultations in providing visual cues and reassurance, building rapport, and improving communication.

7.1.2 Data

A complete list of general practices was acquired using GP practice data made available through NHS Digital[66]. The data available included details of the number of patients registered at GPs as well as the scale and composition of the local workforce at GP surgeries. Details of the premises upgraded through the Superfast Broadband Programme (via the C3 reports) were linked to this database to identify how many GP surgeries had benefitted from enhanced coverage.

This process identified a total of 2,907 GP surgeries that had benefitted from subsidised broadband coverage between 2013 and 2019. Figure 7.1 provides an illustration of the improvement in available speeds associated with these upgrades, with median available download and upload speeds rising from 14.7Mbps to 43.2Mbps and from 1.2Mbps to 8.6Mbps respectively.

Additional longitudinal data on patients' experience of GP services was obtained by data-linking. Unique reference numbers contained within the GP practice data was matched to GP Patient Survey (GPPS) data[67]. The GPPS is an annual postal survey of people registered with a GP, and collects patients' views of their experiences of primary care. The survey began in 2007, however the questionnaire has changed on several occasions since then. The most recent set of questions were developed for the 2018 survey and many variables are not directly comparable with previous years. The focus was on the period 2016 to 2019 to ensure that the variables used in the analysis were consistent over the period of analysis.

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61 Edwards et al (2017) Use of a primary care online consultation system, by whom, when and why: evaluation of a pilot observational study in 36 general practices in South West England.

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

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

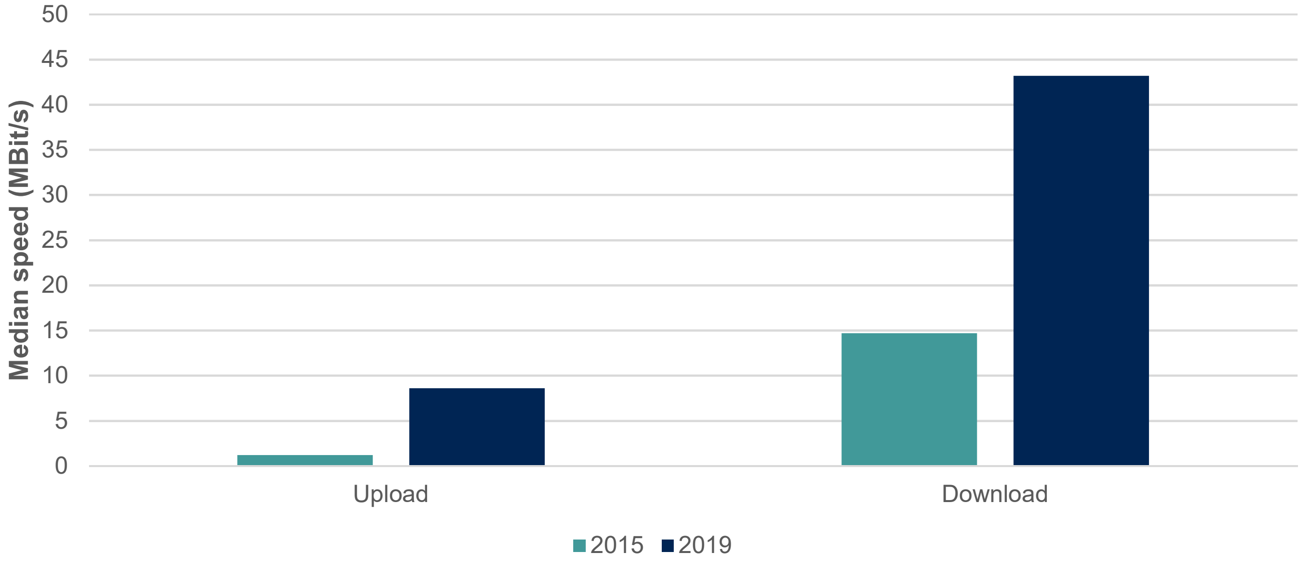
64 Marshall et al (2018) Online consultation in general practice, submission to BMJ Analysis (draft).

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

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

67 https://www.gp-patient.co.uk/

Figure 7.1: Increase in median upload and download speeds for postcodes with GP practices[68]



Source: Ofcom Connected Nations, C3 reports, Ipsos MORI analysis

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

Table 7.1: Outcomes for General Practice

Outcome	Metric (2016-2019)	Source
Number of GPs	In FTE	NHS Digital Workforce data
Number of nursing staff	In FTE	NHS Digital Workforce data
Number of non-clinical staff	In FTE	NHS Digital Workforce data
Register size	Number of registered patients	NHS Digital Practice data[69]
Awareness/Use of ability to book appointment online	Proportion of patients aware of/using online appointment booking services (%)	GPPS
Awareness/Use of ability to order repeat prescription online	Proportion of patients aware of/using online repeat prescription ordering (%)	GPPS
Awareness/Use of ability to view medical records online	Proportion of patients aware of/accessing online medical records (%)	GPPS
Satisfaction with the amount of time afforded them by GP	Proportion of patients satisfied with amount of time for their last appointment (%)	GPPS
Ability to see preferred GP	Proportion of patients able to see preferred GP most or all of the time (%)	GPPS
Satisfaction with available appointments	Proportion of patients satisfied with availability of appointments last time they enquired (%)	GPPS
Overall satisfaction	Proportion of patients describing their overall experience as fairly or very good (%)	GPPS

Source: NHS Digital, GP Patient Survey

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

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

7.1.3 Econometric model

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

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

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

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

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

7.1.4 Impacts on awareness and usage of digital services

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

- **Awareness:** Awareness of the availability of on-line services to book appointments, order repeat prescriptions and review medical records online rose by 7, 5 and 6 percentage points respectively in response to the provision of subsidised coverage.
- **Usage:** Usage of these services increased between 2 and 4 percent. Implied take-up of opportunities to order repeat prescriptions was highest (at around 66 percent of those newly aware of the availability of these services).

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

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

Table 7.2: Impact of subsidised coverage on awareness and usage of on-line primary care services, 2016 to 2019 (% of registered patients)

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

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

7.1.5 Patient satisfaction

There are four measures of patient experience that have been consistently tracked by the GP Patient Survey[71] over the period of interest - satisfaction with the process of booking an appointment, the share of patients that felt that GPs gave them enough time, the share that were regularly able to see their preferred GP, and their overall satisfaction[72]. The findings gave mixed results in terms of the impact of enhanced broadband connectivity on these measures:

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

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

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

72 Satisfaction was measured as the proportion of respondents fairly or very satisfied with their overall experience of their last appointment.

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

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

Table 7.3: Impact of subsidised coverage on access, continuity of care and satisfaction with GP services, 2016 to 2019 (% of registered patients)

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

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

7.1.6 GP resources

The data also supported an investigation of the impacts of the Superfast Broadband Programme on the supply and demand for primary care services (over a more extensive period, from 2012 to 2019). This included the number of patients registered with the GPs concerned (giving a measure of demand), and clinical and non-clinical staff employed by the GP surgery (giving a measure of supply). The findings indicated:

- **Number of patients:** Subsidised coverage increased the number of patients registered with GPs by 3.2 to 5.9 percent on average.

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

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

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

consistent with the findings above on access to GP appointments and continuity of care. These types of issue have also highlighted as explanatory factors for the general declines in public satisfaction with primary care services observed since 2009[74], though it should be noted that access and continuity of care were not highlighted as major drivers of patient satisfaction in past studies[75].

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

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

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

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

Outcome	Model 6	Model 7	Model 8 (effects on other GP surgeries within 20km)
Fixed effects	Yes	Yes	Yes
Time specific shocks	No	Yes	Yes
Model specification	OLS	OLS	OLS
Number of patients registered with the GP (log)	0.0593***	0.0323***	0.0700***
Number of GPs (FTEs, log)	0.0101	0.0091	.
Number of nursing staff (FTEs, log)	0.0529**	0.0541***	.
Number of non-clinical staff (FTEs, log)	0.0744***	0.0544***	.
Number of GPs	1,406 – 1,527	1,486 – 1,504	6,050
Number of observations	5,603 – 5,827	5,603 – 5,827	23,018
Adjusted R-squared[76]	0.02 – 0.03 (0.91 – 0.95)	0.02 - 0.04 (0.91 – 0.95)	0.05 (0.97)

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

7.2 Primary and secondary education

Substantial attention has been given in recent decades to the potential of information and communication technologies (ICTs) to transform education by enriching educational content. A US study commissioned

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

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

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

in 2010 highlighted the potential for broadband enabled technologies to improve learning outcomes by enriching educational content, enabling more interactive and innovative modes of learning, providing more individualised education targeted at refining specific skills, and supporting the delivery of administrative efficiencies (e.g. by enabling cloud computing)[77].

Empirical studies investigating the impact of broadband on educational outcomes have, however, produced mixed findings. While early studies tended to show a positive impact of broadband availability and access to other ICTs on attainment, later studies adopting more rigorous designs have not always reproduced these results. For example, a UK study exploring the impact of the availability of enhanced broadband coverage in the home found no effect on attainment[78]. While no UK study appears to have explored the impacts of broadband in the school, a 2011 study of Portuguese schools receiving connection subsidies found that enhanced connectivity had a negative impact on learning outcomes[79]. This contrasts substantially with results of an evaluation of a 2008 Brazilian initiative to bring broadband to urban elementary and middle schools, which suggested that participation in the programme had positive impacts on Portuguese and maths exam scores.

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

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

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

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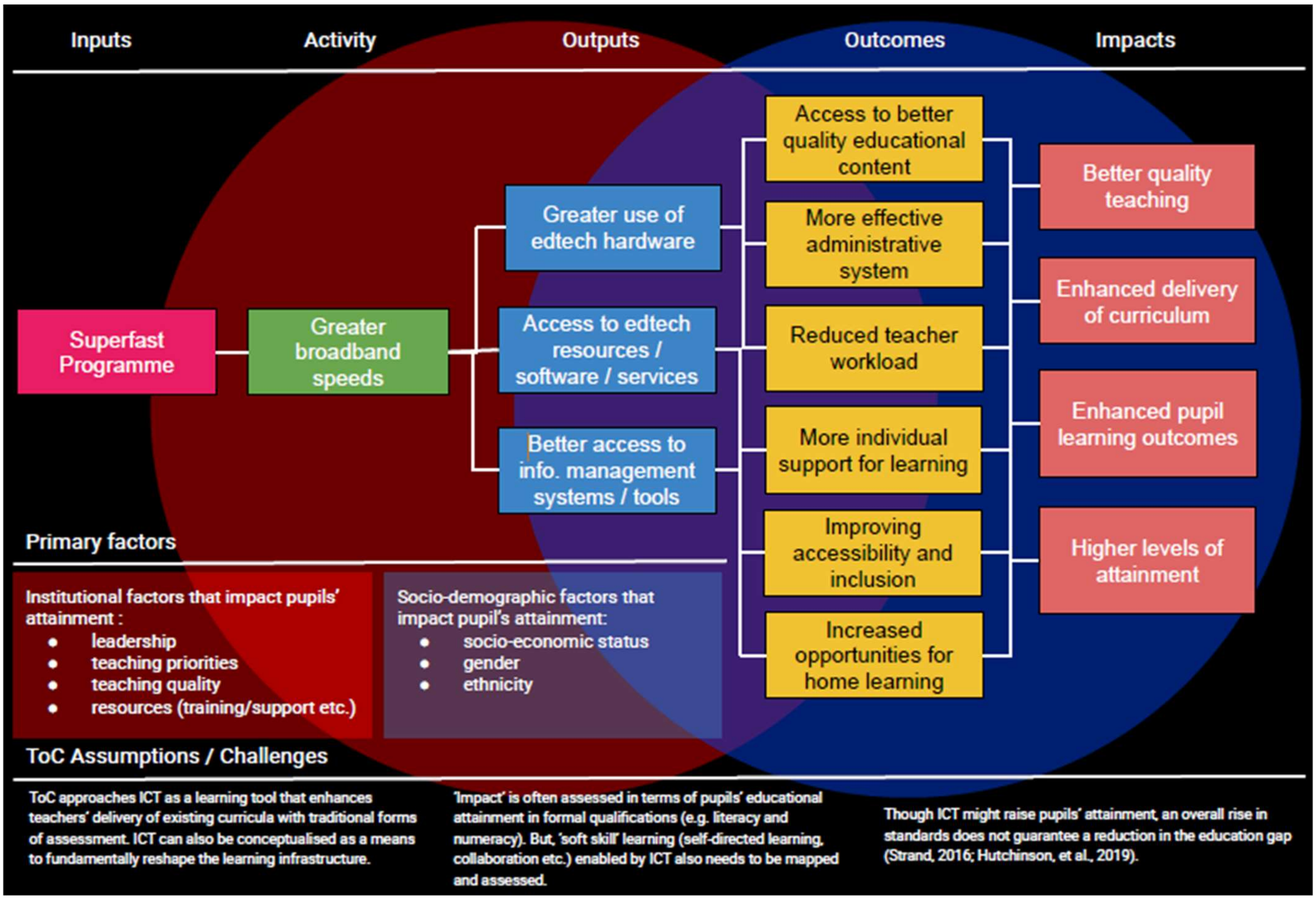
[77] US Chamber of Commerce (2010) The Impact of Broadband on Education

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

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

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



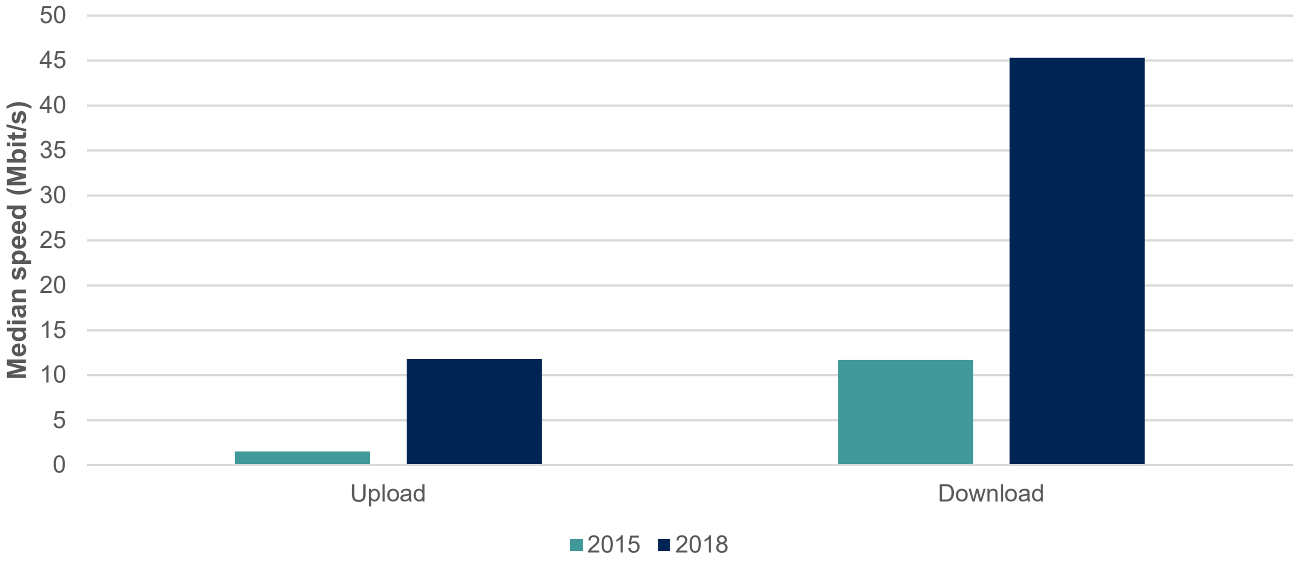
Source: BDUK, Benefits Realisation and Evaluation Team 2020

7.2.2 Data

Data on schools is publicly available from the Department for Education's (DfE) 'find and compare schools' webpage[80]. Details of the premises upgraded through the Superfast Broadband Programme were also linked to DfE databases of primary and secondary schools and academies to identify the educational institutions that benefitted from enhanced coverage. This process identified a total of 3,735 primary schools, 184 secondary schools and 1,815 academies that benefitted from subsidised broadband coverage between 2013 and 2018. The figure below provides an illustration of the improvement in available speeds associated with these with these upgrades, with median maximum available download and upload speeds rising from 11.7Mbps to 45.3Mbps and from 1.5Mbps to 11.8Mbps respectively.

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

Figure 7.3: Increase in median upload and download speeds, primary and secondary schools and academies located on postcodes benefitting from subsidised coverage, 2015 to 2018



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

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

- **Expenditures incurred by schools:** Including expenditure on ICT, to explore the hypothesis set out in Section 2 that enhanced connectivity would enable public services to realise administrative efficiencies through adoption of cloud computing.
- **Resources available to school:** Including income (from DfE grants and self-generated sources) and the scale of the workforce (teachers and teaching assistants).
- **Demand:** As inferred from pupil headcount, which would capture any indirect effects of superfast connectivity via population growth (or possibly changes in the composition of local populations – e.g. older residents being replaced by younger residents with children).
- **Attainment and absence:** Data was available to explore the impact of subsidised coverage on school performance measures. It should be noted that analysis of these measures would conflate several effects. While this may capture the impact of broadband enabled improvements in teaching, it is important to note that these outcomes will also be influenced by any changes in the composition of the pupil population induced by subsidised coverage in the local area (as well as any behavioural changes induced by take-up of superfast services by the resident population). Whilst data was available for pupil attainment and absence, the experimental approaches to this analysis only explored intermediate outcomes initially, meaning that these outcomes were not assessed. Longer-term impacts on attainment are planned to be explored through later research into the public sector impacts of the Superfast programme.

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

- **Free School Meals (FSM)**: The proportion of pupils eligible for free school meals. This reflects the prosperity of the area in which the school is located (although not all pupils eligible for free school meals will take this up). Eligibility for free school meals is also linked to attainment and absence rates and will also influence school income through the DfE grant funding formula.

- **English as a second language (EAL):** The proportion of children for whom English is not a first language reflects the ethnic population of the local areas which may again be correlated with attainment outcomes. Schools are also awarded additional funding for the number of pupils with English as a second language.

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

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

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

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

7.2.3 Econometric models

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

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

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

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

7.2.4 Impacts on ICT spending and other school resources

The table below sets out the estimated effect of subsidised coverage on ICT spending and other school resources. Simple fixed effects models (without controls) found significant effects on all outcomes including ICT spend, teaching spend and the number of teachers, with these decreasing by 17.7 percent and increasing by 8.2 percent and 2.0 percent respectively. However, these findings were not robust the addition of further controls and as such the findings are inconclusive.

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

Outcome	Model 1	Model 2	Model 3	Model 4	Model 5
Fixed effects	Yes	Yes	Yes	Yes	Yes
LAD trends	No	Yes	No	Yes	Yes
Time FE	No	No	Yes	Yes	Yes
Controls for FSM, EAL and SEN	No	No	No	Yes	Yes
Controls for number of pupils	No	No	No	No	Yes
Model specification	FE	FE	FE	FE	FE
ICT expenditure (£s, log)	-0.177***	0.00526	0.00751	-0.00115	-0.0267
Expenditure on teaching (£s, log)	0.0819***	0.000360	-0.00420	-0.00624*	-0.00323
Number of teachers (FTE, log)	0.0200***	-0.00123	-0.00638	-0.00540	-0.000305
Number of observations	16,485 to 18,081				
Adjusted R-squared	0.006 to 0.209				

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

In terms of income, basic fixed effects models find significant increases in total income as well as income from grants and self-generated income. The findings are broadly stable to the addition of controls for unobserved trends at the local authority level – with findings suggesting the total incomes rose by 1.7 percent largely due to increases in self-generating income (this could be explained if superfast connectivity has enabled schools to make more efficient use of leisure facilities and/or has attracted higher income residents to the area).

Table 7.6: Impact of subsidised coverage on school income, 2014 to 2019

Outcome	Model 1	Model 2	Model 3	Model 4
Fixed effects	Yes	Yes	Yes	Yes
LAD trends	No	Yes	No	Yes
Time FE	No	No	Yes	Yes
Controls for FSM, EAL and SEN	No	No	No	Yes
Model specification	FE	FE	FE	FE
Total income (£s, log)	0.112***	0.0168***	0.000343	-0.00134
Self-generated (£s, log)	0.106***	0.0174***	-0.000401	-0.00232
Grant funding (£s, log)	0.267***	0.00873	0.0216	0.0270*
Number of observations	20,274 to 21,870			
Adjusted R-squared	0.049 to 0.439			

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

7.2.5 Impacts on number of pupils and pupil composition

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

In terms of the composition of pupils, more robust models controlling for local authority trends indicated that the programme led to reductions in the share of pupils eligible for FSM or SEN (of 2.8 and 4.6 percentage points respectively), and a slight increase in the share of pupils with English as an additional language (EAL). Again, this would support hypotheses set out elsewhere that the programme has worked to alter the composition of rural populations, though these results are not confirmed by models that allow for time specific shocks affecting all schools.

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

Outcome	Model 10	Model 11	Model 12
Fixed effects	Yes	Yes	Yes
LAD trends	No	Yes	No
Time FE	No	No	Yes
Model specification	FE	FE	FE
Number of pupils (log)	0.0320***	0.00219	-0.00392
% of pupils eligible for FSM	0.775***	-2.885***	-0.0863
% of pupils with EAL	0.548***	0.100**	-0.0426
% of pupils with SEN	-1.272***	-4.591***	-0.376
Number of observations		24,162 to 25,616	
Adjusted R-squared		0.003 to 0.383	

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

8 Cost Benefit Analysis

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

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

8.1 Costs

BDUK monitoring data gave details of 144 contracts that had been signed as part of the Superfast Broadband Programme across Phase 1, 2 and 3 of the programme. The gross value of the public funding associated with these contracts was £1.9bn at the point of award (in nominal terms), providing funding for the capital costs associated with upgrading network infrastructure in the programme area. However, the clawback mechanisms integrated in the contracts required beneficiaries to return resources to the public sector in the event the delivery cost of the project was lower than expected (implementation clawback) or if the project was more profitable than expected (take-up clawback).

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

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

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

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

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

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

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

Source: BDUK, Ipsos MORI analysis

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

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

Table 8.2: Expected net public sector costs (£m, 2019 prices) of delivery to March 2019

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

Source: BDUK, Ipsos MORI analysis

8.2 Additionality

As highlighted in Section 3, the results set out in the preceding section explore the impacts of subsidised coverage. However, the results do not factor in the likelihood that much of this coverage may well have been brought forward through commercial deployments in the absence of the programme. As noted, estimates of the additionality of the coverage funded through the programme are taken from Technical Appendix 1, which examined the share of the premises involved that would not have been upgraded in the absence of the programme (and how this evolved with time). These findings suggested that:

- **Evolution over time:** The level of additionality is estimated to peak in the year after the premises was upgraded at 61 percent. Additionality decayed between the second and fourth year following the upgrade at a rate of 14 percent per annum (to 38 percent in the fourth year). These patterns were broadly stable over Phase 1, 2 and 3 of the programme. This is consistent with a view that the programme substantially accelerated the deployment of superfast connectivity. However, in the absence of the programme, rising demand and take-up as well as regulatory innovation would have led to greater commercial viability over time. This would have induced commercial deployments in many areas in the longer-term in the absence of the programme.

- **Projected additionality:** A high to low range for the future additionality of the programme was developed on the following basis:

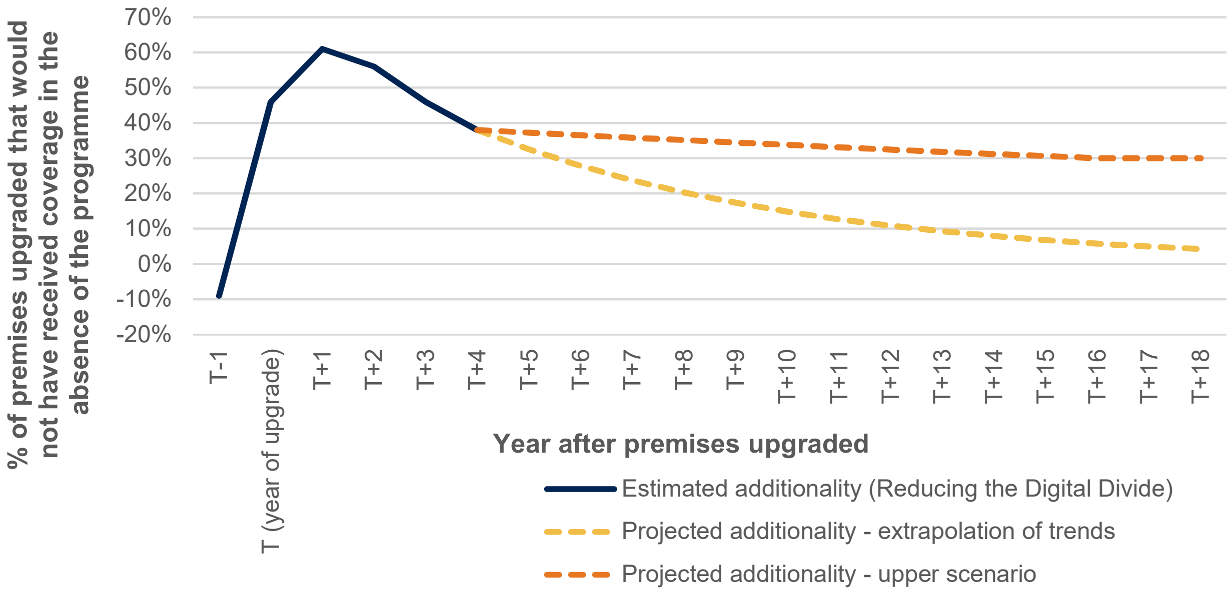
  - **Extrapolation of trends:** A lower bound scenario was developed by extrapolating the trends implied by the results over the duration of the appraisal period. This implied a higher rate of decay (14 percent per annum) and the rate of additionality fell to 4 percent over 14 years. This would capture scenarios in which unforeseen technological innovations enable the hardest to reach premises to be served profitably.

  - **Future telecoms infrastructure review:** A projection of past trends may produce an overly pessimistic view of future additionality. The Future Telecoms Infrastructure Review was prepared on the basis that the final 10 percent of premises (3m of 30.5m in the UK) would never receive commercial investment in full fibre connectivity. This assumption was used to explore the sensitivity of results to a more optimistic view of additionality in the long-run as follows. In 2019, Ofcom's Connected Nations report suggests that 95 percent of premises received superfast coverage. This is equivalent to 29m premises and implies that around 1.5m of the 'last 10 percent' received superfast coverage by 2019. By 2019, 5.3m premises had received subsidised coverage – implying that just under 30 percent would never receive commercial deployments. In this scenario, this share is treated as a notional limit for additionality and the rate of additionality is assumed to decay from 38 percent to 30 percent over 14 years (a rate of decay of 2.0 percent per annum). As this assumption is based on the viability of FTTP rather than FTTC infrastructure, this scenario will likely overstate the long-run additionality associated with the investments (and has been developed primarily to probe the stability of the core findings to alternative assumptions).

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

The figure below displays the assumed additionality profile over time.

Figure 8.1: Additionality profile over time



Source: Ipsos MORI analysis

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

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

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

Source: BDUK, Ipsos MORI analysis

8.3 Economic and social benefits

8.3.1 Productivity gains

In line with the HM Treasury Green Book, it is assumed that the local economic impact of the programme will largely be neutralised by offsetting effects elsewhere in the economy (displacement). While businesses located in areas receiving subsidised coverage have expanded their sales, this will have come at the expense of loss of market share for competing firms (who may be located locally or elsewhere in the UK).

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

As such – and in line with the principles of the HM Treasury Green Book - only the effects of the programme in terms of raising productivity are considered to qualify as economic benefits at the national level. The evaluation provided a range of results to indicate that the programme has supported improvements in productivity – including raising the turnover of per worker and wages of employees of firms located in areas benefiting from subsidised coverage. The effect of the programme was also visible in commercial rental values – which rose by 1.8 percent in response to the upgrade.

GVA based measure of economic benefits

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

- **Short-term impact on turnover per premises upgraded:** The short-term impact of the programme on the turnover per worker of spatially stable firms was estimated at 0.01 percent per premises upgraded in the Output Area (based on results covering the 2016 to 2018 period). The average turnover per worker of spatially stable firms benefitting from the programme was approximately

£106,000. This implies that turnover per worker rose by just under £12 for each premise upgraded across spatially stable units. The average level of employment amongst spatially stable firms in Output Areas supported by the programme was almost 37 employees per output area. This gives a total effect on turnover driven by apparent efficiency gains of £450 per premises upgraded (per annum).

- **Short-term impact on GVA per premises upgraded.** It was assumed that firms did not change the shares of labour and other inputs used in production in response to the subsidised coverage, and the effect on turnover per worker can be interpreted as an improvement in productivity. Applying the average GVA as a percentage of turnover across the UK as whole over the 2008 to 2018 period (31 percent)[81], this gives an effect on GVA per premises upgraded of £140 (per annum).

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

These results were applied to the profile of additional premises upgraded set out in the subsection 8.2. Summary results covering the 2011/12 to 2018/19 period (benefits to date) and the 2011/12 to 2029/30 period (including projected benefits) are set out in the table below. The present value of GVA benefits (with a baseline of 2012/13) are estimated at £1.1bn by 2018/19 and between £1.6bn and £1.8bn by 2029/30.

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

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

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

Source: Ipsos MORI analysis

8.3.2 Unemployment impacts

The results of the evaluation suggested that for every 10,000 premises upgraded there was a corresponding on-going reduction in the number of unemployed claimants of 32.1 claimants. The extent to which these effects might be understood as net economic benefits will be linked to how far the

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

programme drew individuals out of (or helped them avoid) extended periods of involuntary worklessness in which they were not productively deployed (rather than short-term episodes of unemployment[82]).

The data available did not permit an analysis of the effects of the programme on long-term unemployment directly as claimant counts at the local level do not provide information on the duration of claims. However, a prior evaluation (using different data series[83]) suggested that for every individual taken out of unemployment by the programme, 0.29 individuals were taken out of long-term employment. Assuming this applies to the results obtained in this study, it is estimated that for every 10,000 premises upgraded, the number of long-term claimants fell by 9.2.

Assuming the effects on long-term unemployment represent the effect of the programme on the overall productive capacity of the economy, and valuing the output produced by those individuals at £15,480 per annum[84], it is estimated that these effects could have led to an additional £125m in national economic output (GVA) by 2019 (in present value terms). This effect is estimated to rise to between £237m to £306m in the longer-term (though to the extent this is driven by relocation of economic activity, there may have been corresponding increases in long-term unemployment elsewhere).

Table 8.5: Additional GVA resulting from productivity gains (£m, 2019 prices)

Period	Undiscounted (£m)	Discounted (£m)
GVA from the reduction in long-term unemployment 2011/12 to 2018/19 (£m)	144.5 – 144.9	124.9 – 125.2
GVA from the reduction in long-term unemployment 2011/12 to 2029/30 (£m)	303.5 – 409.9	237.1 – 305.9

Source: BDUK, Ipsos MORI analysis

8.3.3 Social benefits

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

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

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

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

[84] It is assumed that the productivity of the average worker avoiding long-term unemployment due to the programme is lower than the national average, and here we have assumed that workers would gross annual pay at the 25th percentile of all workers (based on the 2017 Annual Survey of Hours and Earnings).

- **Valuation:** To reach an estimate of the welfare gains, the implied house price premium of £1,700 to £3,500 was applied to the number of houses sold in the programme area after the premises was upgraded (813,500). This gave a gross value of the price uplift of £1.4bn to £2.9bn.

- **Expectations:** An assumption was applied that consumers had reasonably formed expectations regarding the likelihood that homes would receive superfast coverage in the future. As such, the impact of the programme on house prices is interpreted as the present value of the total welfare gains associated with having access to superfast coverage immediately (and possibly other relevant features of the home, such as proximity to newly relocated employers) as opposed to coverage at some uncertain point in time in the future.

- **Additionality:** Flowing from this, the gross value of the price uplift was adjusted in light of the short-term additionality (an average of 54 percent up to two years following the upgrade) to reflect the possibility that the premises would have otherwise received subsidised coverage in the absence of the programme at the time of purchase. However, the value of the price uplift was not adjusted further in the long-term as it was assumed that the possibility that the property would have received superfast coverage in the future was factored into willingness to pay. As such, the present value of welfare benefits to 2019 and to 2030 are equivalent (and estimated at £741m to £1.5bn).

- **Net effects:** As highlighted in Section 6, to the extent that house prices were driven by migration induced by the programme, these may not represent net benefits as there may be offsetting effects elsewhere. Additionally, there is a possibility that the house price uplift may linked to the programme's effects in attracting additional economic activity to the area (in which case, there may be an element of double counting with the economic benefits).

The following table provides a summary of the results.

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

	Low house price premium (0. 56%)	High price premium (1.16%)
Welfare impacts confined to households purchasing homes		
Land value uplift (£m, present value)	741.9	1,536.8

Source: BDUK, Ipsos MORI analysis

8.4 Benefit to Cost Ratios

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

- **Benefits from 2012 to 2019:** The short-term BCR (based on benefits to date) is estimated at between £2.7 and £3.8 per £1 of net lifetime public sector costs. This exceeds the hurdle rate of return normally applied in the appraisal of public sector programmes and suggests that the programme has already delivered a strong rate of return.

- **Benefits from 2012 to 2030:** In the long-run (allowing for future economic benefits), the BCR is estimated to rise to £3.5 to £5.0 per £1 of net public sector spending.

- **Sensitivity:** It should also be noted that investment in the programme can also be justified on the long-term economic benefits alone. Excluding the welfare effects inferred from house prices (which are less certain), the BCR is estimated to range from £2.5 (low future additionality) to £2.8 (high future additionality). The narrow nature of this range indicates that the benefit to cost ratio is not heavily dependent on the assumptions made regarding future additionality. It should also be noted that the economic benefits are likely to be understated, given the conservative approach adopted to assess the supply side impacts.

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

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

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

Source: BDUK, Ipsos MORI analysis

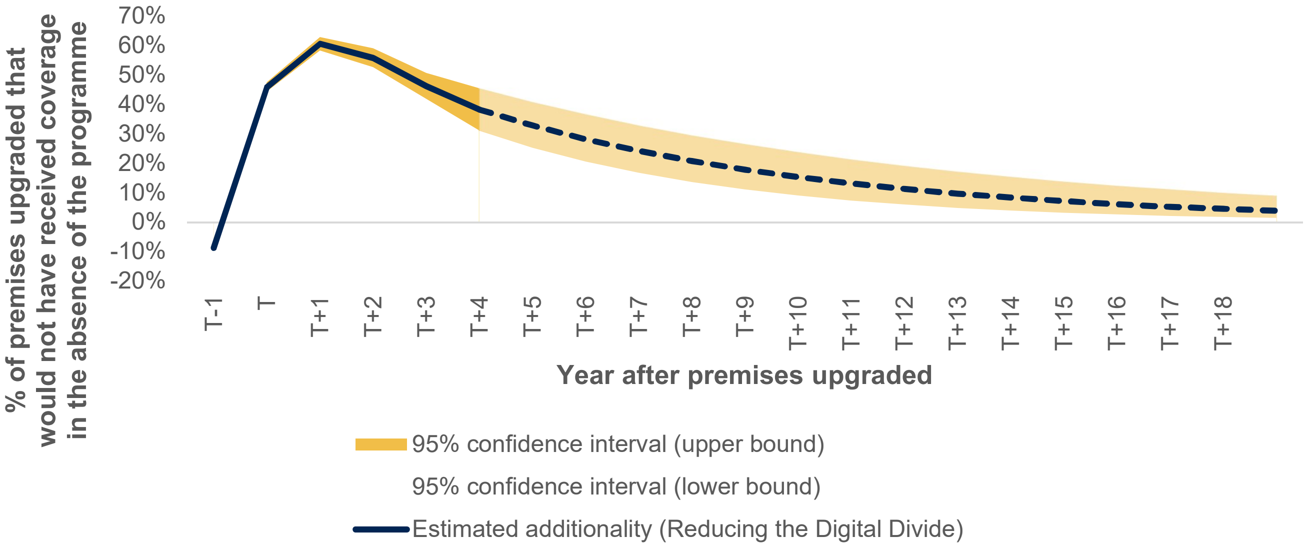
8.5 Margin of error

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

8.5.1 Additionality

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

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



Source: Ipsos MORI analysis

8.5.2 Productivity, unemployment and house prices

The table below provides the 95 percent confidence interval for key parameters driving the estimates of benefits (i.e. the estimated impacts on turnover per worker, unemployment, and house prices). The standard errors associated with some estimates (e.g. turnover per worker and higher bound estimates of impacts on house prices) were not meaningfully different from zero (and were reported as zero in the software used to implement these models).

Table 8.8: 95 percent confidence interval – effects on turnover per worker, unemployment and house prices

	Central estimate	95 percent confidence interval (lower bound)	95 percent confidence interval (upper bound)
Turnover per worker (to 2016)	0.00011	0.00011	0.00011
Turnover per worker (to 2018)	0.00009	0.00009	0.00009
Unemployment	-0.00321	-0.00359	-0.00283
House prices (low premium)	0.00560	0.00246	0.00874
House prices (high premium)	0.01160	0.01160	0.01160

Source: BDUK, Ipsos MORI analysis

8.5.3 Benefit to Cost Ratios

The table below illustrates the margin of error around the most conservative estimates set out in Table 8.6 (i.e. those associated with lower additionality and low house price premium effects). The findings indicate that at the lower bound, the costs of the programme remain justified by the benefits and the social rates of return continue to exceed the hurdle rate of return typically applied in the appraisal of public sector programmes.

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

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

Source: BDUK, Ipsos MORI analysis

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Initial market analysis paper

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1 State aid market analysis

This document presents the early findings from the Superfast Broadband market analysis research. This research involved an analysis of datasets provided by ThinkBroadband to provide evidence to answer State Aid Questions four and five from the State Aid evaluation plan, namely:

- Has the aid had a material effect on the market position of the direct beneficiaries? And
- Is there evidence of changes to parameters of competition arising from the aid?

1.1 Key terms and acronyms

Table 1.1: Key terms and acronyms

Term / acronym	Meaning
NGA	**Next Generation Access** – This refers to new or upgraded access networks that will allow substantial improvements in broadband speeds. This includes Fibre to the Cabinet, Fibre to the Premises (Fibre to the Home), Wireless and Cable broadband connections.
FTTP / FTTH	**Fibre to the Premises / Fibre to the Home** – This refers to an access network structure in which the optical fibre runs from the local exchange to the end user's living or office space.
FTTC	**Fibre to the Cabinet** - An access network structure in which the optical fibre extends from the exchange to the cabinet. The street cabinet is usually located only a few hundred metres from the subscriber's premises. The remaining part of the access network from the cabinet to the customer is usually copper wire but could use another technology, such as wireless.
Cable	Telecommunications infrastructure which utilises cable networks, such as Data Over Cable Service Interface Specification (DOCSIS-3) networks.
Wireless	High-speed internet access where connections use radio signals rather than cables.
ADSL	**Asymmetric Digital Subscriber Line** - A technology used for sending data quickly over a conventional copper telephone line. It is used in current internet services with download speeds up to 24Mbit/s.
ISP	Internet Service Provider – An organisation which provides households / businesses access to the internet. ISPs do not always own the infrastructure used to provide services, and can utilise the infrastructure owned by network providers to provide services.

Network provider	Telecommunications providers which own infrastructure which is used to deliver internet services
LLU	**Local Loop Unbundling** - When communication providers can gain access to the network by placing their own equipment at the exchange. The communication providers then gain control of the line from the local exchange to the customer and the backhaul runs from the local exchange to their core network

.

2 Has the aid had a material effect on the market position of the direct beneficiaries?

The National Broadband Scheme evaluation plan described question 4 of the State Aid evaluation plan as:

"For each supplier awarded a contract under the scheme, the evaluators will compare the supplier's market share of all active (i.e. connected) NGA lines within the relevant county/unitary local authority areas (i.e. those areas in which the supplier was subsidised) at end June 2020 versus end June 2016."

"For each supplier awarded a contract under the scheme, the evaluators will also compare the supplier's market share of all active NGA lines within the UK at end June 2020 versus end June 2016."

2.1 Key findings

The key findings presented here are based on an analysis of the ThinkBroadband speed test dataset. As such, the findings should be viewed the following caveats:

- The speed test data does not collect information for every customers' take-up, or even a random sample of customers (it only collects data for customers that undertake a speed test on the website), and therefore may be subject to some reporting bias;[1]
- Not all ISPs providing connections in a local area may be included in the dataset as customers may not have completed a speed test.

The key findings from the analysis are:

- **The market share of the UK market (share of broadband connections) of the Superfast Broadband Programme beneficiaries has not changed substantially between 2012 and 2020.** At a UK level, the Superfast Broadband programme does not seem to have had a substantial impact on the market position of the programme beneficiaries. The market share for Openreach was high in 2012 (representing 71 percent of connections in 2012, including Sky and TalkTalk connections) and this remains the case in 2020 (75 percent) – although there has been a slight decrease in the market share of Openreach (excluding Sky and TalkTalk) between 2016 and 2020. The four other network providers that have received support represent 0.3 percent of the UK total broadband market.
  - A similar pattern is seen in the NGA market, with Openreach having a market share of over two thirds of the NGA broadband market in 2020, and the other beneficiaries having a market share of around 0.4 percent.
- **The market share of beneficiaries in broadband market in the areas the Superfast Broadband Programme has delivered to has not changed substantially between 2012 and 2020**. At an overall programme level (all areas the Superfast Programme has delivered to combined), the

[1] Despite the potential for reporting bias, we do not believe that any bias in the dataset will affect the conclusions of the research, as the reporting bias should be similar in all areas of the UK.

Superfast Broadband programme again seems to have had little impact on the market share of programme beneficiaries. The market share for Openreach has remained fairly constant between 2016 and 2020, and above the UK average in the areas supported by the Superfast Broadband programme (90 percent compared to the UK average of 75 percent nationally in 2020). The market share of the other beneficiaries has increased in the treatment areas, but these providers still represent under one percent of the market in the Superfast Broadband programme areas in 2020.

- **The market share of beneficiaries at a contract level (in the individual areas Superfast Broadband Programme contracts have been delivered) have changed substantially between 2012 and 2020. In the local areas where projects have been delivered, the beneficiary delivering the contract has seen an increase in their market share.** At a more local level, the programme does seem to have had impact on the market share of the programme beneficiaries. In the areas where Openreach were awarded contracts, they have maintained their market share of around 90 percent of connections. However, in the areas where Gigaclear or wireless providers have been awarded contracts, the market share for Openreach has fallen – though they are still have the largest market share – to closer to 70 percent of the market. In areas where Gigaclear have delivered contracts, they have an estimated market share of 25 percent (compared to 0.2 percent nationally); and wireless / satellite providers have a market share of six percent in the areas they have delivered contracts in (compared to 0.1 percent nationally). This suggests that at a very local level the Superfast Broadband programme has had an effect on the telecommunications market.

2.2 Methodological approach

There are five network providers which have been awarded contracts through the Superfast Broadband Programme. These are:

- Openreach
- Gigaclear
- Callflow
- Airband
- UK Broadband / Relish.

The first stage of the analysis to provide evidence of each providers market share was to identify the ISPs which utilised each network providers infrastructure. This information was collected from a web search of the ISPs' websites, the Openreach website (which lists ISPs which utilise their wholesale products) and the ThinkBroadband website. A complete list of ISPs included in the dataset and the network providers they have been mapped to is included in the Annex.

There is no methodology set out in the evaluation plan for how to undertake the analysis of market share. The analytical approach described below has been used to provide evidence to answer the state aid evaluation question.

- **Analysis of all broadband provision.** The market share of the take-up of broadband connections for the five network providers to benefit from the Superfast Broadband programme as a percentage of the whole broadband market has been analysed and presented. This has been included because of the relatively small number of observations among some groups for the analysis. This analysis includes:

- **The UK broadband market**, assessing the market share of programme beneficiaries.
- **The areas where the Superfast Broadband programme has delivered to**, assessing the market share of programme beneficiaries.
- **Comparator area[2] analysis,** assessing the market share of programme beneficiaries in areas the Phase of the programme did not operate in.
- **The individual contract areas that the programme has operated in**, assessing the market share of programme beneficiaries in these areas.[3]

▪ **Analysis of NGA provision.** The market share of the take-up of broadband connections for the five network providers to benefit from the Superfast Broadband programme as a percentage of NGA connections taken up has been analysed and presented. This includes:

- **The UK broadband market**, assessing the market share of programme beneficiaries.
- **The areas where the Superfast Broadband programme has delivered to**, assessing the market share of programme beneficiaries.
- **Comparator area[4] analysis,** assessing the market share of programme beneficiaries in areas the Phase of the programme did not operate in.

The individual contract areas that the programme has operated in, assessing the market share of programme beneficiaries in these areas. To undertake this analysis, the ThinkBroadband speed test data was used as a proxy measure of take-up of connections. The speed test data does not collect information for every customers take-up, or even a random sample of customers (it only collects data for customers that undertake a speed test on the website), and therefore may be subject to some reporting bias. Additionally, not all ISPs providing connections in a local area may be included in the dataset as customers may not have completed a speed test. However, when the data has been compared to actual take-up measures at a regional and UK level, the speed test data does provide an accurate approximation of take-up. Therefore (and in the absence of other data) the speed test data has been used for this analysis.

The speed test data was matched to the Superfast Broadband programme Management Information (C3 reports from February 2020 and SCTs) to identify the areas which each Superfast Broadband contract has been delivered, and to identify comparator areas for the Superfast Broadband delivery areas (postcodes which were identified as white in the SCTs but were not included in the build plans, and had not been built to). This matching was undertaken using the postcode entry in the datasets.

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[2] Comparator areas were selected as postcodes that were identified as white in the Open Market Review for each phase of the Superfast Broadband programme, but that were not included in build plans or delivered to in that phase of the programme. It is possible that postcodes included in the comparator area for Phase 1 have been delivered to subsequently in Phase 2 or Phase 3 of the programme (and likewise for comparator postcodes for Phase 2 have been subsequently delivered to in Phase 3 of the programme)

[3] Due to small sample sizes, Airband and UK Broadband / Relish contract areas have been combined into a “Wireless”

[4] Comparator areas were selected as postcodes that were identified as white in the Open Market Review for each phase of the Superfast Broadband programme, but that were not included in build plans or delivered to in that phase of the programme. It is possible that postcodes included in the comparator area for Phase 1 have been delivered to subsequently in Phase 2 or Phase 3 of the programme (and likewise for comparator postcodes for Phase 2 have been subsequently delivered to in Phase 3 of the programme)

The market shares have been calculated for three points in time – 2012 (the start of the Superfast Broadband programme), 2016 (when the current State aid decision was introduced) and 2020 (the most recent data available).

2.3 All broadband provision

2.3.1 UK market share

The market share for network providers has been estimated by the proportion of speed tests completed for ISPs which were mapped to the network provider (see Annex 1). At a UK level, connections supplied through the Openreach network dominate the market – with around 40 percent of take-up in all years being made through the Openreach network. This percentage increases if the Sky and TalkTalk networks are included as being provided through the Openreach network (as these networks do utilise the Openreach network) to between 71 percent (2012) and 78 percent (2016) of take-up.

The other suppliers awarded Superfast Broadband contracts represent a very small proportion of the broadband market – cumulatively less than one percent of the total broadband market in 2020 (see table below).

At a UK level, there has not been a large increase in the market share of the programme beneficiaries – in fact between 2016 and 2020, there has been a decrease in the market share of the beneficiaries, driven by a decrease of the market share for Openreach (including Sky and TalkTalk).

Table 2.1: Market share of the total broadband market for Superfast Broadband beneficiaries

Network provider	2012	2016	2020
Openreach	42.82%	38.61%	39.64%
Openreach (plus Sky and TalkTalk)	*71.10%*	*78.08%*	*75.16%*
Airband	0.00%	0.01%	0.09%
Gigaclear	0.00%	0.08%	0.18%
Callflow	0.00%	0.02%	0.02%
UK Broadband / Relish	*0.00%*	*0.00%*	*0.01%*
Total programme participants	71.10%	78.26%	75.52%
Virgin Media	*27.66%*	*19.86%*	*17.10%*

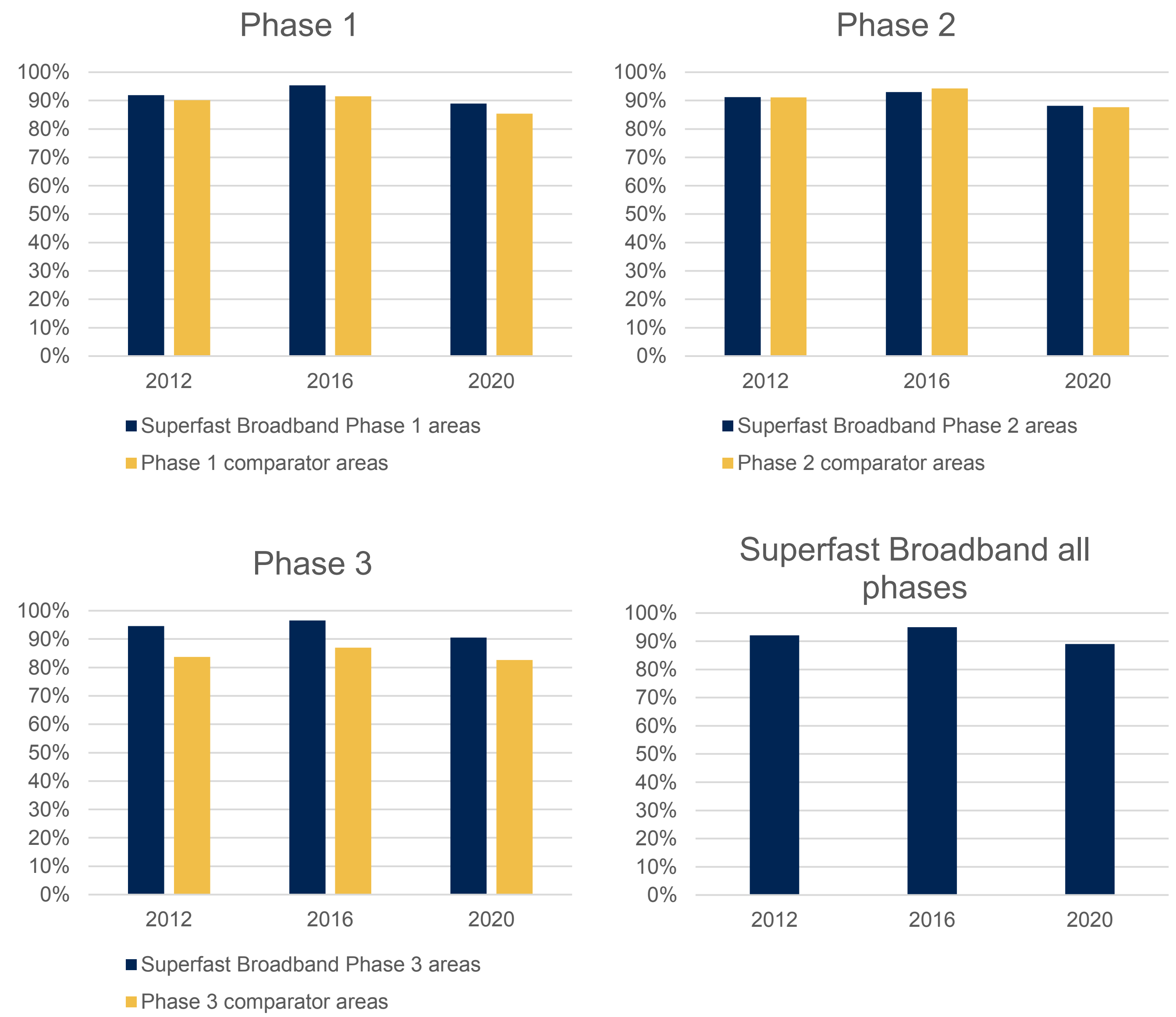
Source: ThinkBroadband data

2.3.2 Superfast Broadband programme delivery and comparator area market share

The market share of the total broadband market for the network providers in the areas that the Superfast Broadband programme has been and is currently operating was analysed using the same approach. The market share for Openreach in these areas remained fairly static between 2012 and 2020, at around 90 percent of all connections (including Sky and TalkTalk), which is higher than the UK average (between 70 and 80 percent).

The Openreach market share was generally slightly lower in the comparator areas in all years than in the Superfast Broadband delivery areas (Phase 2 in 2016 being the exception), but the market share for Openreach remained fairly steady in the comparator areas (between 85 percent and 95 percent in Phases 1 and 2, and between 82 and 87 percent in Phase 3 comparator areas), and higher than the UK average (see figure below).

Figure 2.1: Market share for Openreach (including Sky and TalkTalk) in Superfast Broadband treatment and comparator areas

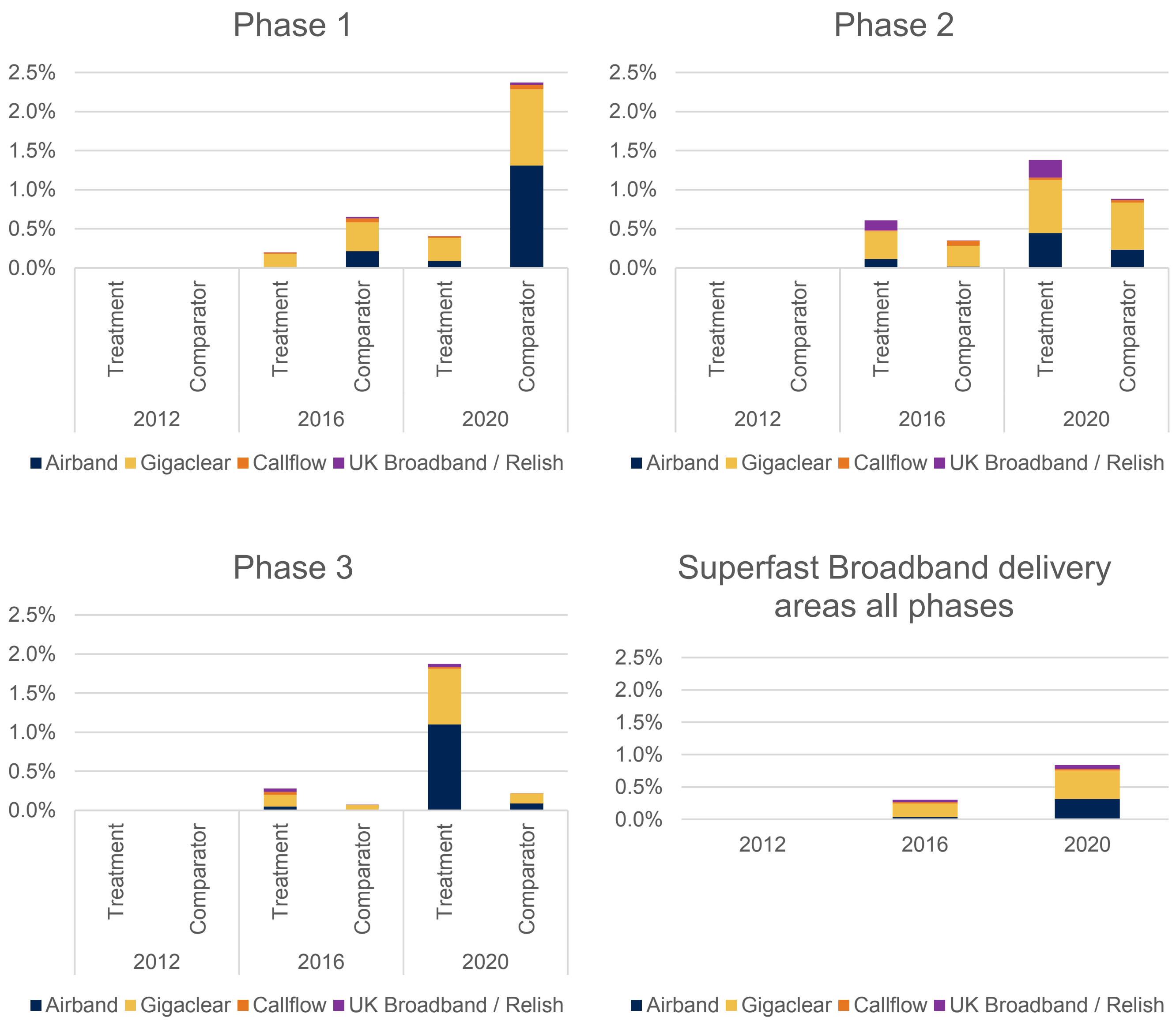


Source: ThinkBroadband data

The market share for all broadband connections for all other network providers awarded contracts through the Superfast Broadband programme is presented in the figure below. This shows that the market share for these network providers has grown to 0.8 percent of connections in 2020 in the Superfast Broadband areas. This is larger than the 0.3 percent market share these network providers hold nationally. However, these network providers hold an even larger market share of 1.2 percent in the comparator areas for the programme, driven by Airband and Gigaclear market share in these areas and the comparator areas for Phase 1 of the programme.[5] This is also still a very small proportion of the total broadband market.

[5] This is most likely because the comparator areas for Phase 1 project areas include areas which were included in Phase 2 and Phase 3 of the project ,of which many areas have now been delivered to by the programme. As some Phase 2 and Phase 3 contracts have been delivered by beneficiaries other than Openreach, their market share in these areas will increase.

Figure 2.2: Market share of total broadband market for all other Superfast Broadband programme beneficiaries in Superfast Broadband and comparator areas



Source: ThinkBroadband data

NOTE: Please be aware of scale of the charts when comparing to Figure 2.1

2.3.3 Superfast Broadband delivery contract areas

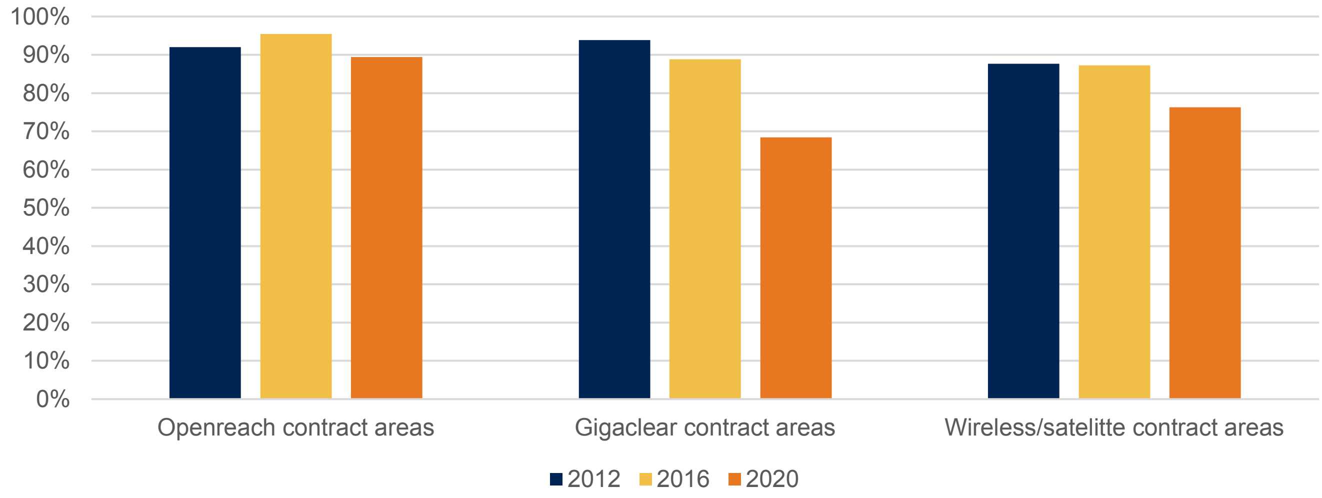
The analysis of the market share at the delivery contract area has been aggregated to the network provider contracted to deliver the local project. This is because of small sample sizes available at specific contract areas. More details of the sample sizes in each project area is provided in the Annex.

This analysis shows that there are differences in the local telecommunications market depending on which beneficiary was selected to deliver the project. In areas where Openreach deliver the local project, the market share of Openreach remains relatively steady, with over half of the take-up through ISPs using the Openreach network (and around 90 percent if Sky and TalkTalk take-up is included). This is illustrated in Figure 2.3 below.

However, in areas where Gigaclear deliver the local project, the market share of Openreach falls from over two thirds in 2012 and 2016 (and 90 percent including sky and TalkTalk take-up) to just over half (and just over two thirds including Sky and TalkTalk). The market share for Gigaclear increases from zero in 2012 to seven percent in 2016, to 25 percent in these areas by 2020. In the areas where Openreach or wireless providers have delivered contracts, Gigaclear has a market share of zero (see Figure 2.4).

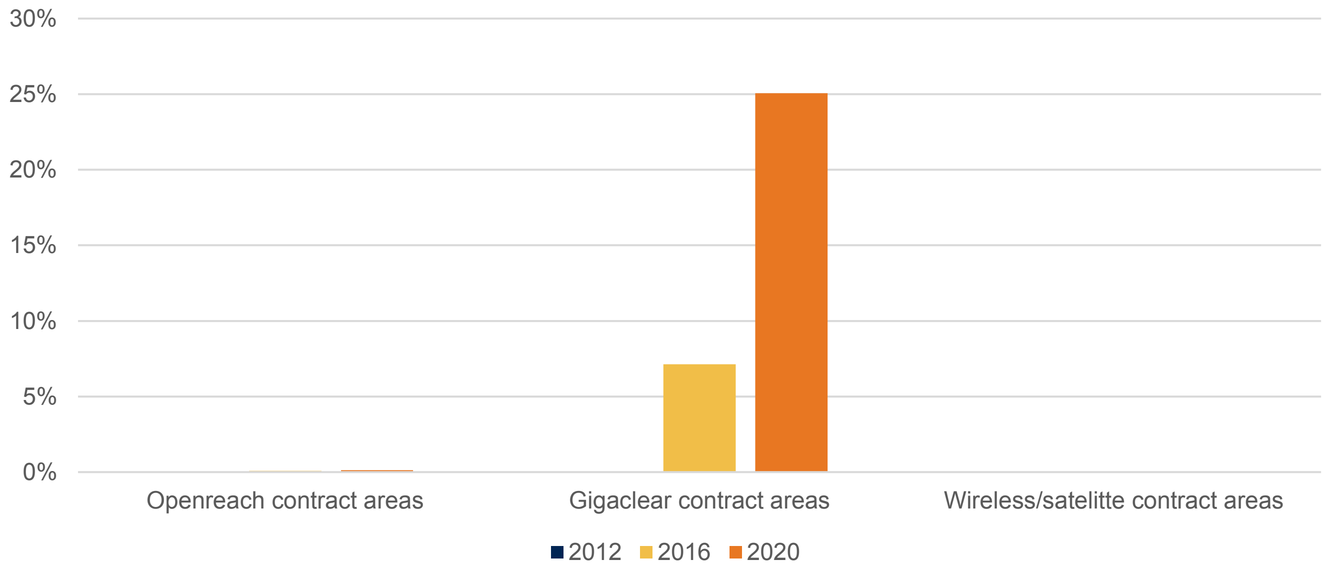
This pattern is repeated for areas where wireless providers have been contracted to deliver Superfast Broadband projects (see Figure 2.5). The market share for Openreach declines from 2012 to 2016 and 2020, with a larger market share taken by the wireless providers, up to six percent in 2020. In areas where Openreach or Gigaclear have delivered projects, the market share of the wireless providers is close to zero (see figures below).

Figure 2.3: Openreach market share



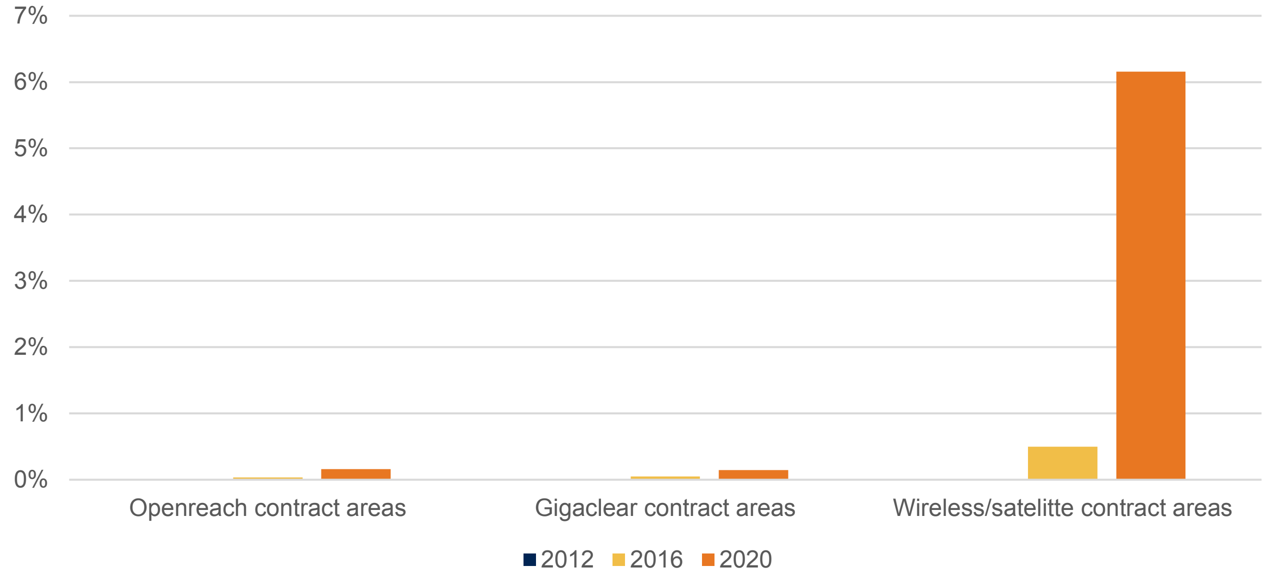
Source: ThinkBroadband data

Figure 2.4: Gigaclear market share



Source: ThinkBroadband data

Figure 2.5: Wireless/satellite provider market share



Source: ThinkBroadband data

2.4 NGA market

The market share of all NGA connections (FTTC, FTTP, cable, wireless and satellite connections) for network providers has been estimated by the proportion of speed tests completed for ISPs which were mapped to the network provider that utilised these technologies. This analysis therefore excludes all speed tests for ADSL, wifi and leased lines. This reduces the sample sizes the analysis is based upon, and particularly in 2012 the sample sizes are very small, therefore the results for 2012 should be viewed with caution.

2.4.1 UK market share

At a UK level, as with the total broadband market, NGA connections supplied through the Openreach network dominate the market, though to a lesser degree than the broadband market as a whole. In 2012 under a quarter of NGA connections were supplied by Openreach[6], and although this has risen to 37 percent by 2020. This percentage increases if the Sky and TalkTalk networks are included with Openreach (as these networks do utilise the Openreach network) to around a third of NGA connections in 2012 and around two thirds in 2020. This suggests that Openreach is more dominant in the ADSL broadband market than in the NGA broadband market (as their market share of the total broadband market is higher than their market share for the NGA market), and that between 2012 and 2016 Sky and TalkTalk were successful in recruiting new customers to NGA connections / converting existing customers to NGA connections than other providers using the Openreach network.

The other suppliers awarded Superfast Broadband contracts represent a very small proportion of the NGA broadband market – cumulatively less than one percent of the market in 2020 (see table below). At a UK level, there has not been a large increase in the market share of the programme beneficiaries – in fact

[6] It should be noted that in 2012 the majority of broadband connections were provided through ADSL, therefore the small market share of Openreach in the NGA market is being driven by the smaller total population of NGA connections in 2012 than in subsequent years.

between 2016 and 2020, there has been a decrease in the market share of the beneficiaries, driven by a decrease of the market share for Openreach.[7]

Table 2.2: Market share of the broadband market for Superfast Broadband beneficiaries

Network provider	2012	2016	2020
Openreach	23.84%	35.46%	36.97%
Openreach (plus Sky and TalkTalk)	*30.27%*	*60.46%*	*67.23%*
Airband	0.00%	0.12%	0.12%
Gigaclear	0.00%	0.15%	0.25%
Callflow	0.00%	0.02%	0.02%
UK Broadband / Relish	0.00%	0.00%	0.02%
Total programme participants	30.27%	60.76%	67.63%
Virgin Media	*69.42%*	*36.90%*	*23.30%*

Source: ThinkBroadband data

2.4.2 Superfast Broadband delivery and comparator area market share

The analysis of the NGA market share of the network providers in the areas that the Superfast Broadband programme has and is currently operating shows that the NGA market share for Openreach in these areas remained fairly constant between 2012 and 2020, at around 90 percent of all connections (including Sky and TalkTalk), which is higher than the UK average (30 percent in 2012 and 67 percent in 2020). The Openreach market share was slightly higher than in the treatment areas for Phases 1 and 3, although in Phase 2 the market share of NGA take-up for Openreach was higher in the comparator areas. However, in all Phases and areas the market share of NGA take-up for Openreach remained fairly steady between 2016 and 2020, and higher than the UK average (see figure below).

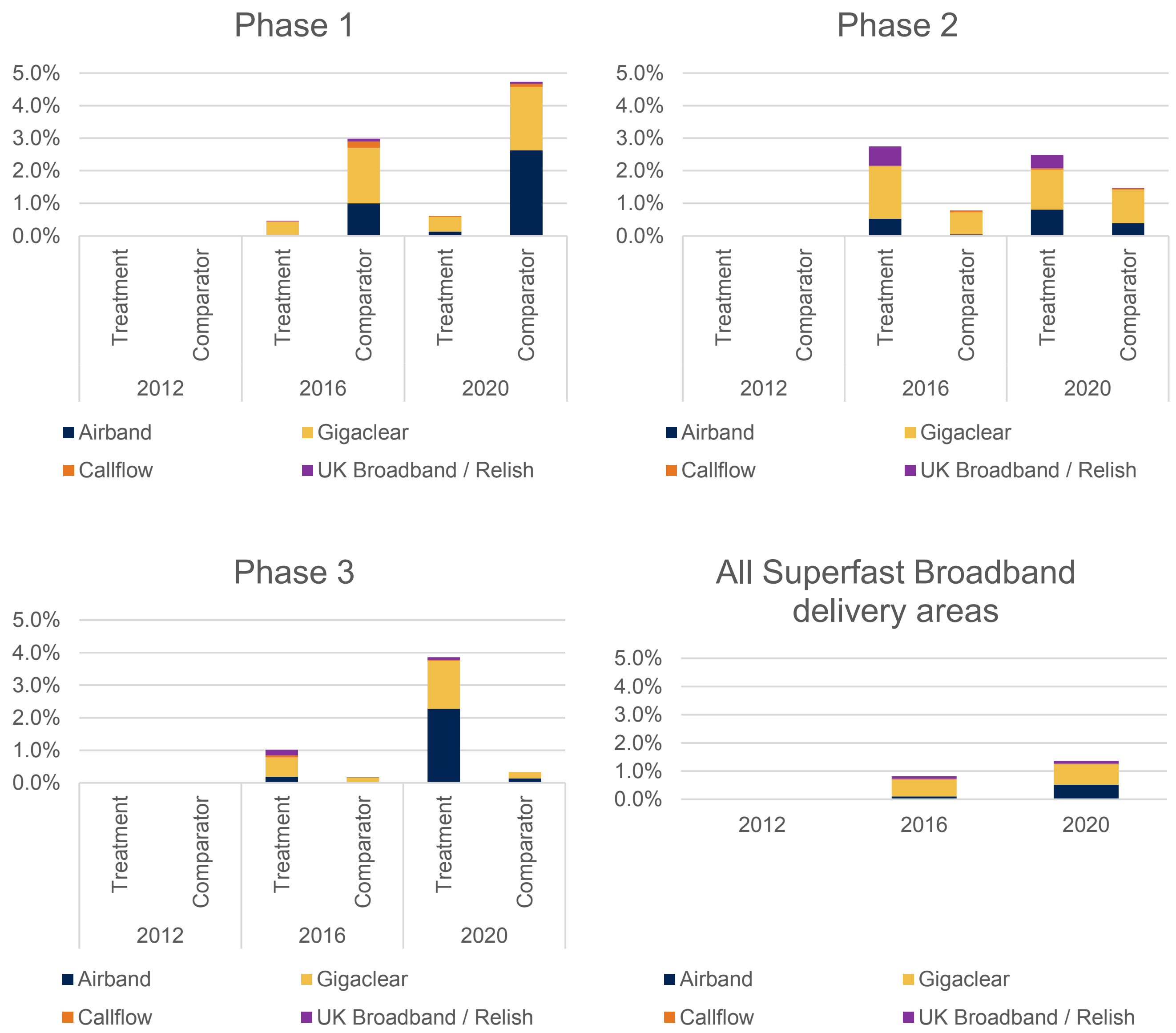
[7] There has been an increase in the market share of the programme beneficiaries other than Openreach between 2016 and 2020 – but given the small market share these beneficiaries have of the total NGA market this increase has little impact on the overall market share of the programme beneficiaries.

Figure 2.6: Market share of NGA broadband market for Openreach in Superfast Broadband treatment and comparator areas

Source: ThinkBroadband data

The market share for NGA connections for all other beneficiaries is presented in the figure below. This shows that the market share for these network providers has grown to 1.4 percent of connections in 2020 in the Superfast Broadband areas. This is larger than the 0.4 percent market share these network providers hold nationally. By phase, the beneficiaries (other than Openreach) have the largest market share of NGA connections in Phase 3 contract areas with nearly four percent of the market share (driven by Airband and Gigaclear market share). This is unsurprising, as the beneficiaries (other than Openreach) did not deliver any contracts in Phase 1 of the programme, therefore would not be expected to have a large market share in Phase 1 areas.

Figure 2.7: Market share of NGA broadband market for all other Superfast Broadband programme beneficiaries in Superfast Broadband and comparator areas



Source: ThinkBroadband data

NOTE: Please be aware of scale of the charts when comparing to Figure 2.6

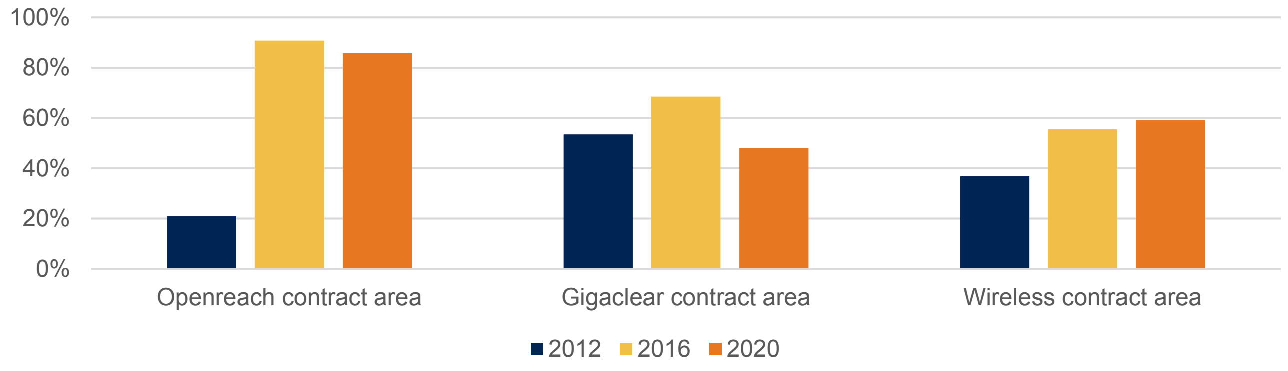
2.4.3 Superfast Broadband project level analysis

When examining the market share by the network provider contracted to an area, it can be observed that there are differences in the local telecommunications market. In areas where Openreach deliver contracts, the market share of Openreach remains relatively steady between 2016 and 2020, with over half of the connections through ISPs using the Openreach network (and around 90 percent when Sky and TalkTalk customers are included). This is illustrated in Figure 2.8 below.

However, in areas where Gigaclear are contracted, the market share of the NGA broadband market of Openreach falls from over two thirds in 2016 (and 90 percent including Sky and TalkTalk) to just over half (and just over two thirds including Sky and TalkTalk). The market share for Gigaclear increases from zero in 2012 to 24 percent in 2016, to 43 percent in these areas by 2020. In the areas where Openreach have delivered contracts, Gigaclear's market share is zero (see Figure 2.9 below).

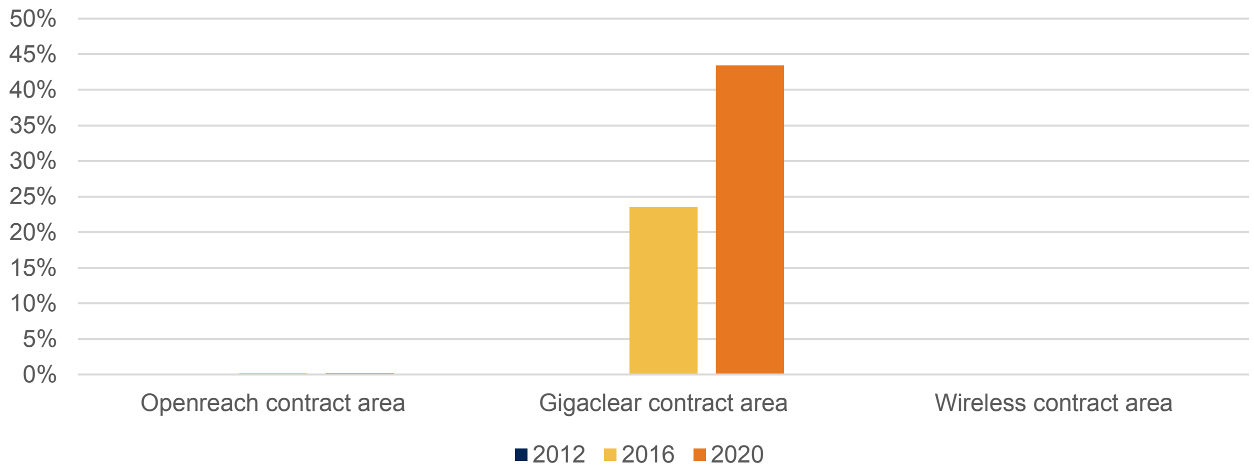
This pattern is repeated for areas where wireless providers have been contracted to deliver Superfast Broadband contracts. The market share for Openreach is relatively stable between 2016 and 2020, and Gigaclear's market share remains close to zero for both years. However, the market share of NGA connections for the wireless providers is 11 percent in areas where they have delivered the Superfast Broadband contracts, and is close to zero in all other Superfast Broadband delivery areas. This is illustrated in the Figure 2.10 below.

Figure 2.8: Openreach market share



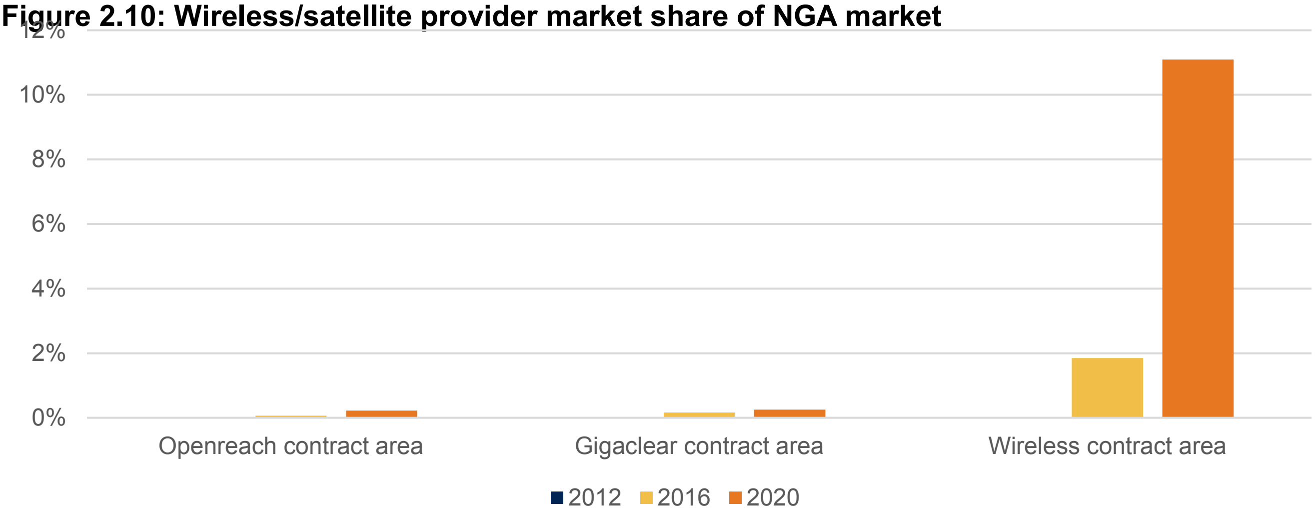
Source: ThinkBroadband data

Figure 2.9: Gigaclear market share



Source: ThinkBroadband data

Figure 2.10: Wireless/satellite provider market share of NGA market



Source: ThinkBroadband data

3 Is there evidence of changes to parameters of competition arising from the aid?

The National Broadband Scheme evaluation plan described question 4 of the State Aid evaluation plan as:

For each local body involved in the scheme, the evaluators will compare the June 2020 versus June 2016 situations at a UK and local level in terms of:

- NGA take-up as a share of all broadband take-up
- market share (of take-up) for each NGA technology (FTTC, FTTP, Cable, fixed wireless)
- number of infrastructure providers offering NGA services
- number of unique operators making use of the open access made available under the 2016 NBS.

3.1 Key findings

The key findings presented here are based on an analysis of the ThinkBroadband speed test and coverage datasets. As such, the findings should be viewed the following caveats:

- The speed test data does not collect information for every customers' take-up, or even a random sample of customers (it only collects data for customers that undertake a speed test on the website), and therefore may be subject to some reporting bias. For example, customers' with slower internet connections (for example using ADSL technology) may be more likely to undertake a speed test as they are dissatisfied with their speed;
- Not all ISPs providing connections in a local area may be included in the dataset as customers may not have completed a speed test;
- There are weaknesses in the coverage dataset, particularly relating to the Virgin Media footprint.

The key findings are:

- **NGA take up has increased in the UK between 2012 and 2020.** The share of NGA broadband take-up as a proportion of total broadband take-up in the UK has increased markedly since 2012. The take-up of NGA connections represented less than half of all broadband connections in 2012, but that this has grown to over 70 percent of internet connections in 2020.A similar pattern is seen in Superfast Broadband Programme areas, with the share of NGA connections increasing from around 10 percent in 2012 to over 60 percent in 2020.
- **There is little difference in the change in technologies used for broadband connections at a UK level and in Superfast Broadband Programme delivery areas, which suggests the programme has had little impact on the technologies used by consumers.** At a UK level, the Superfast Broadband programme does not seem to have had a substantial impact on the technologies that are used to provide broadband connections to households and businesses. The

same trends in the type of technology used to provide broadband connections is observed nationally, in Superfast Broadband delivery areas and in comparator areas. This is namely that there has been a steep decrease in the market share of ADSL connections, and a steep increase in NGA connections. There are some differences in the proportion of each type of NGA solution between the UK pattern and those in Superfast Broadband delivery and comparator areas – but this can be attributed to the starting position (namely the market share of cable technology). The dominant NGA technology in all areas is FTTC connections.

  - **There are differences between the technologies being used by customers in the Superfast Broadband areas depending on which network provider is delivering the contract**. In Openreach contract areas, FTTC connections represented nearly 60 percent of all broadband connections in 2020, with FTTP connections representing under five percent of connections and wireless under one percent of connections. However, in areas where Gigaclear delivered the contract, FTTC, although still the largest share by technology, represented 28 percent of broadband connections and FTTP connections 27 percent of the market (with wireless connections under one percent of the market). Finally, in areas where wireless providers delivered the Superfast Broadband contract, FTTC was again the most prevalent NGA technology (32 percent of connections) but wireless connections had a larger market share than in areas where Openreach or Gigaclear delivered the contract (14 percent of take-up). This suggests that at the local level, the Superfast Broadband programme (and in particular the supplier selected to deliver the project) has had some impact on the type of technology used in the area.

- **There has been a large increase in the number of network providers operating in the UK between 2012 and 2020. This increase is also observed in Superfast Broadband Programme areas, although most network providers only cover a small proportion of postcodes in the Programme areas.** The number of network providers operating nationally, in Superfast Broadband delivery and comparator areas has grown from 2012 to 2020, with the largest increase being between 2016 and 2020. It should be noted that although the number of network providers operating in Superfast Broadband areas has increased over time, the majority of network providers operating in these areas provide services to only a small proportion of postcodes in the delivery area. The increase in network providers nationally, and within Superfast Broadband delivery areas suggests that the programme is not preventing new network providers from entering the UK broadband market (and particularly the NGA market).

- **There has been a large increase in the number of Internet Service Providers operating in the UK and in Superfast Broadband Programme areas between 2012 and 2020.** The number of ISPs providing services in the UK has also increased over time, with 155 providing broadband connections nationally in 2020 compared to 126 in 2016 and 39 in 2012. This increase has been mirrored in Superfast Broadband delivery areas cumulatively, with 145 ISPs providing connections in Superfast Broadband delivery areas in 2020, compared to 111 in 2016 and 36 in 2012. The average number of ISPs operating in Superfast Broadband contract areas has also increased, from just over 12 in 2012 to around 28 in 2020.

  - There are some noticeable differences in the average number of ISPs in project areas by phase and by the network provider that delivered the contract. There are more ISPs operating in Phase 1 contract areas than in Phase 2 and Phase 3 areas – as would be expected as the areas are generally larger and the projects have been completed, meaning ISPs have had more opportunity to utilise the networks built by the project.

- Additionally, there are more ISPs operating in areas where Openreach delivered the Superfast Broadband project than in areas where Gigaclear or a wireless provider have delivered projects. This could be related to the size of the areas and the timing of the projects (all Gigaclear and wireless provision is in Phase 2 and Phase 3 of the programme) – but could also indicate that more ISPs utilise the networks built by Openreach than those built by alternative network providers.

3.2 Methodological approach

The analytical approach described below has been used to provide evidence to answer the state aid evaluation question.

- **Analysis of broadband take-up by technology**. The market share of seven different types of broadband connection has been calculated. These are:
  - FTTP
  - FTTC
  - GFast
  - Cable
  - Fixed wireless / satellite connections
  - ADSL
  - Other connections (leased line and wifi connections).[8]
- The market share by type of technology has been calculated at three points in time (2012, 2016 and 2020) and at four geographic levels, namely:
  - nationally (for the whole of the UK);
  - for all areas where the Superfast Broadband programme has been delivered (combined);
  - for comparator areas to the Superfast Broadband programme (as specified in section 2); and
  - at an individual contract level.
- The number of network providers operating in the areas that the Superfast Broadband programme has been calculated using the ThinkBroadband coverage dataset. The number of network providers offering services has also been calculated for comparator areas to the Superfast Broadband delivery areas, to explore if there are any differences between the areas the programme has delivered to and other comparable areas.
- The number of ISPs operating in an area has been estimated using the Speed Test data. The number of ISPs operating has been estimated at a UK, Superfast Broadband treatment area, comparator area and individual contract level for 2012, 2016 and 2020. It should be noted that the speed test data does not include all ISPs offering services in an area, or the number of ISPs with customers in each area. It measures the number of ISPs where customers have completed speed tests. Therefore, there could be inaccuracies in this data. Additionally, there are a number of contracts with low numbers of speed tests completed, therefore the analysis for these areas lacks robustness.

[8] Mobile internet connections were excluded from the analysis

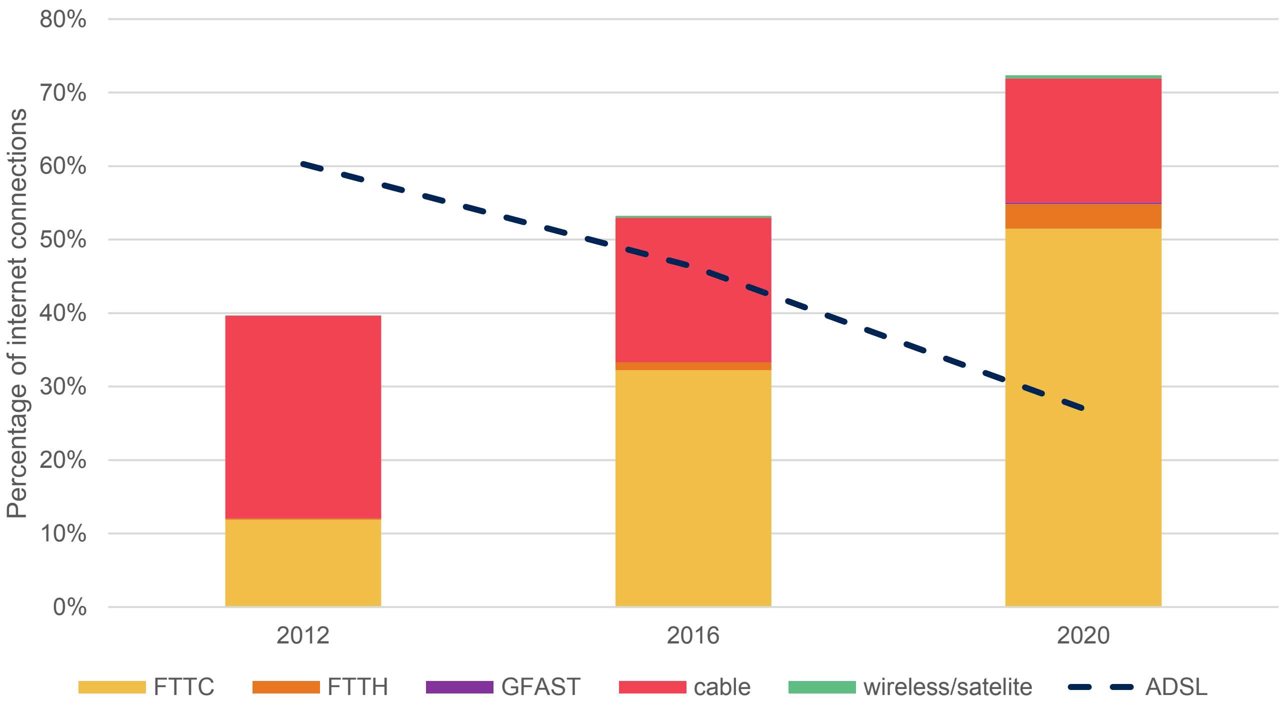
3.3 Results

3.3.1 Broadband take-up by technology

UK analysis

At a UK level, the share of NGA broadband take-up as a proportion of total broadband take-up has increased markedly since 2012. The figure below shows that take-up of NGA connections represented less than half of all broadband connections in 2012, but that this has grown to over 70 percent of internet connections in 2020. FTTC connections represent the largest proportion of NGA connections in both 2016 and 2020 (around a third of all broadband connections in 2016 and just over a half in 2020) – with cable connections representing the next highest proportion of NGA connections (just under 20 percent of all connections in both 2016 and 2020). FTTP and wireless connections represent under five percent of the broadband market in 2020 and under two percent in 2016.

Figure 3.1: Market share of broadband take-up for NGA and ADSL connections

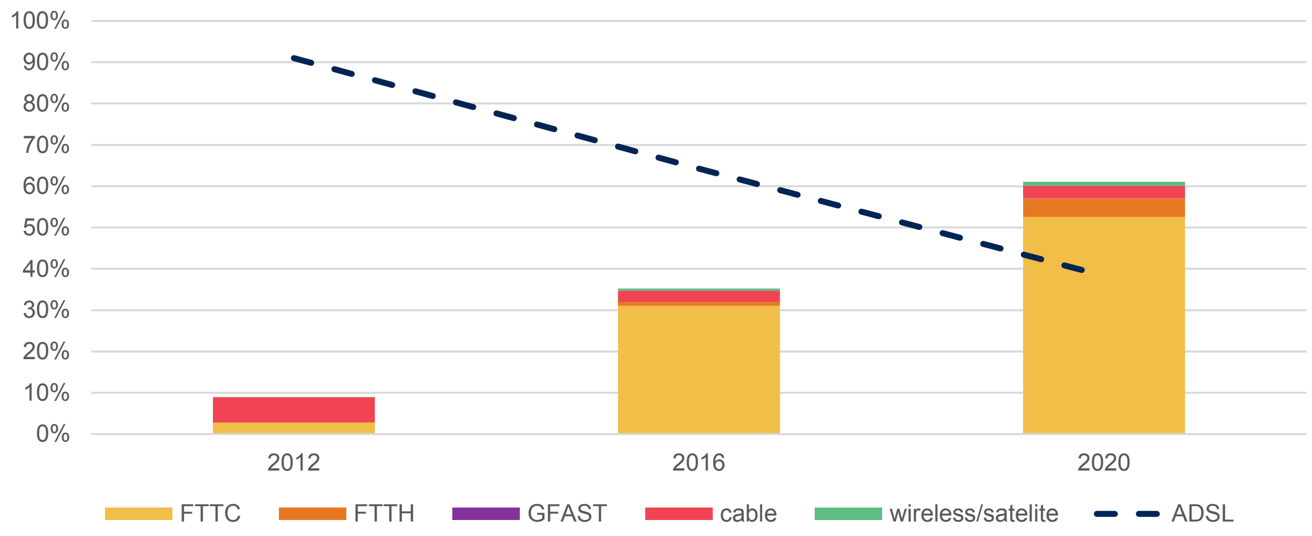


Source: ThinkBroadband data

Superfast Broadband delivery and comparator area analysis

A similar pattern can be seen in the areas where the Superfast Broadband programme has operated. There has been a steep decline in the market share of ADSL connections, and an increase in the market share of NGA connections (see figure below). The market share of NGA connections in the Superfast Broadband areas is below the UK average (at just over 60 percent of the broadband market compared to over 70 percent nationally in 2020). This is to be expected, as some areas have only recently had NGA connections made available to them, which would limit the opportunity of households and businesses to take up these connections. As with the UK pattern, FTTC is the dominant technology for NGA connections, representing around one third of total broadband connections in 2016 and over half of broadband connections in 2020. However, cable connections are a lot less prevalent in Superfast Broadband delivery areas (under three percent of total broadband connections in both 2016 and 2020). FTTP and wireless connections are slightly more prevalent in Superfast Broadband delivery areas than nationally, representing 5.5 percent of connections in the delivery areas in 2020.

Figure 3.2: Market share of broadband take-up for NGA and ADSL connections in Superfast Broadband delivery areas



Source: ThinkBroadband

This analysis was undertaken separately for the delivery areas and comparators for Phases 1, 2 and 3 of the Superfast Broadband programme, and compared to comparator areas for each phase. This, unsurprisingly, found that the largest decrease in ADSL take-up between 2012 and 2016 was in Phase 1 delivery areas, with a smaller increase in Phase 2 delivery areas (as would be expected as not all Phase 2 delivery had been completed by 2016). More surprisingly, there was a reported increase in NGA take up in Phase 3 delivery areas between 2012 and 2016 – despite no Phase 3 roll out having taken place, and this increase was larger than for Phase 2 areas (see Table below). The increase in Phase 3 seems to be driven by increases in reported FTTC connections. However, these areas would have been marked as 'white' postcodes in the Phase 3 OMR process in 2016. This suggests there may have been some inaccuracies in the OMR process for Phase 3 contracts (if the speed test technology has been reported accurately).

The overall change in NGA take-up is higher in the Phase 1 treatment area than in the relevant comparator area between 2012 and 2020, whereas for Phase 2 and Phase 3 the changes in take-up are comparable between the treatment and comparator groups. In Phase 2, the change in NGA take-up in the treatment area increases at a faster rate between 2016 and 2020 than in the comparator group, which as expected suggests that the increase in take-up followed the network build in these areas.

Table 3.1: Change in ADSL connections and NGA connections taken up in Superfast Broadband treatment areas and comparator areas, 2012 to 2020

Area	Change in ADSL take-up		Change in NGA take-up	
	2012-2016	2016-2020	2012-2016	2016-2020
Treatment area – Phase 1 contracts	-33.7p.p.	-24.9p.p.	33.3p.p.	24.7p.p.
Treatment area – Phase 2 contracts	-11.1p.p.	-33.4p.p.	10.5p.p.	33.1p.p.
Treatment area – Phase 3 contracts	-17.8p.p.	-21.6p.p.	17.5p.p.	21.5p.p.
Comparator area – Phase 1 contracts	*-7.9p.p.*	*-28.0p.p.*	*7.3p.p.*	*27.8p.p.*
Comparator area – Phase 2 contracts	*-25.6p.p.*	*-19.8p.p.*	*25.0p.p.*	*19.6p.p.*

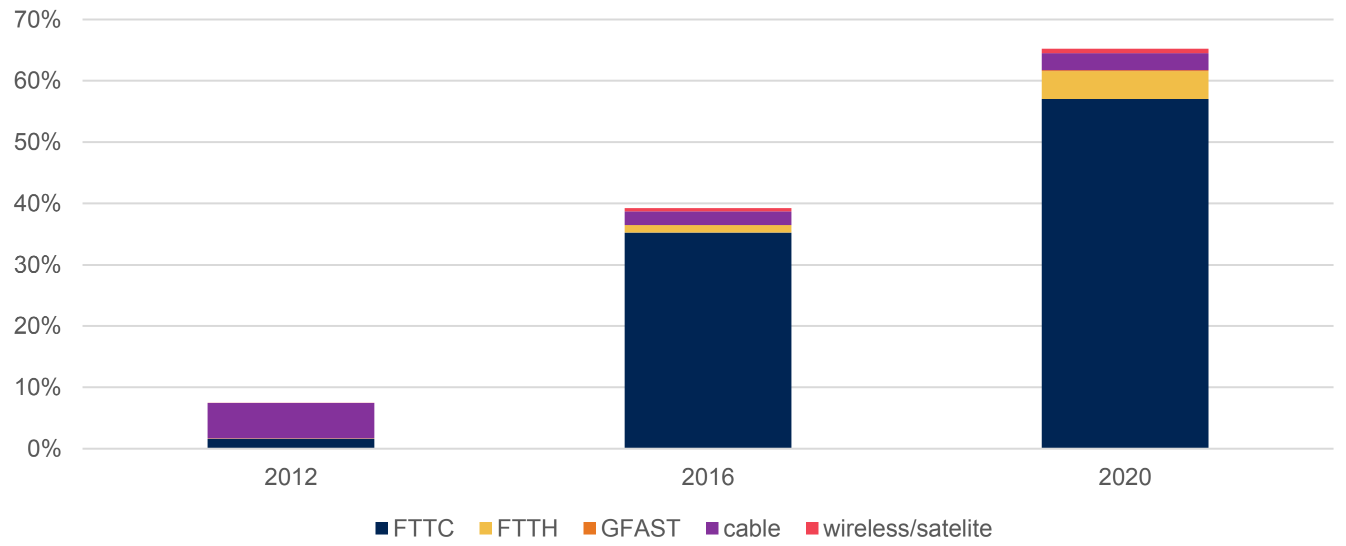
Comparator area – Phase 3 contracts	*-15.8p.p.*	*-21.9p.p.*	*15.4p.p.*	*21.5p.p.*

Source: ThinkBroadband

Superfast broadband programme delivery contract area analysis

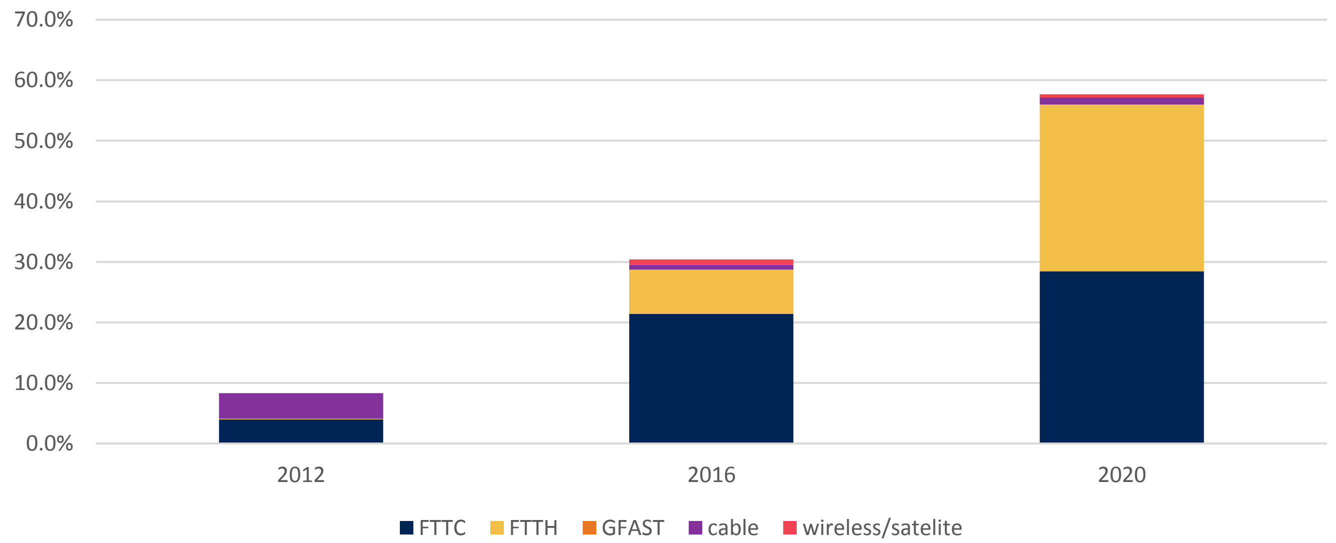
The treatment areas have also been analysed by the beneficiary delivering the contract in the area. This presents some interesting, but not unexpected results regarding the market share of different technologies in contract areas. For areas where contracts have been delivered by Openreach, the majority of NGA take-up is using FTTC technology. While this is also the case for areas where contracts have been delivered by Gigaclear, Airband and UK Broadband, the degree to which FTTC dominates NGA take up is less noticeable. This indicates that the supplier selected to deliver Superfast Broadband contracts influences the type of NGA taken up in those areas (see Figures below).

Figure 3.3: NGA technology type market share in Superfast Broadband areas with contract delivery from Openreach



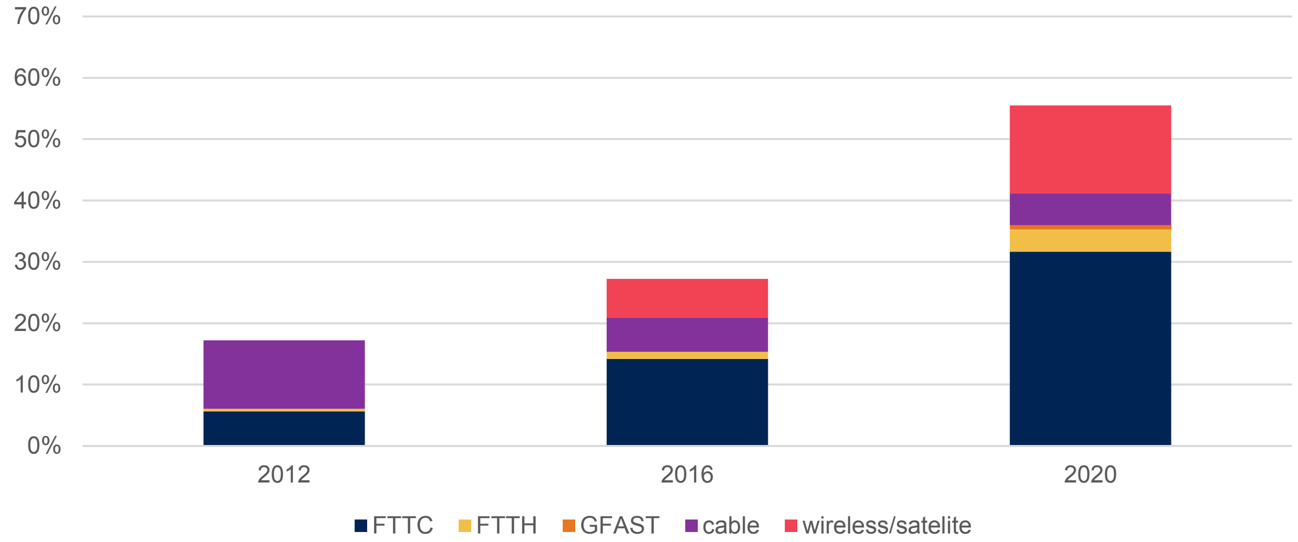
Source: ThinkBroadband

Figure 3.4: NGA technology type market share in Superfast Broadband areas with contract delivery from Gigaclear



Source: ThinkBroadband

NGA technology type market share in Superfast Broadband areas with contract delivery from Wireless providers



Source: ThinkBroadband

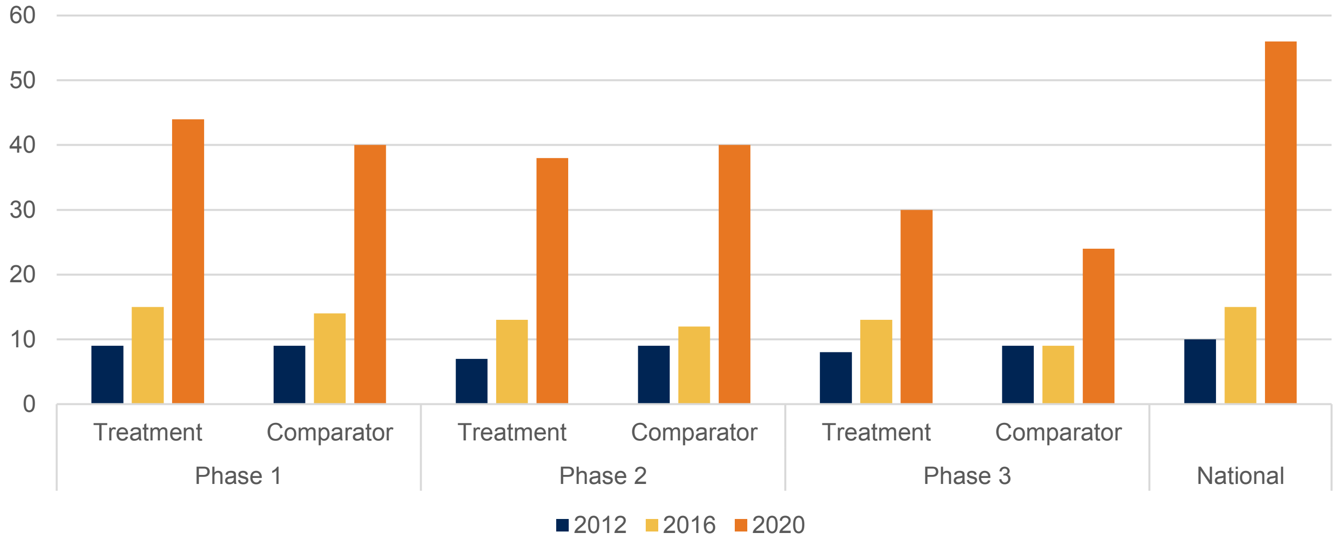
3.3.2 Number of Network providers

Superfast Broadband delivery and comparator areas

The number of network providers operating in the Superfast Broadband contract areas has increased from 2012 to 2020. This pattern is observed for all phases of the Superfast Broadband programme – but the number of network providers operating in Phase 1 contract areas is higher than those operating in Phase 2 and Phase 3 contract areas (44 network providers in Phase 1 areas in 2020 compared to 38 in Phase 2 and 30 in Phase 3 areas). This is not surprising, as the Phase 1 contract areas were generally larger (in terms of postcodes and premises) than Phase 2 and Phase 3 contract areas, and more economically viable – therefore would be more commercially attractive to network providers.

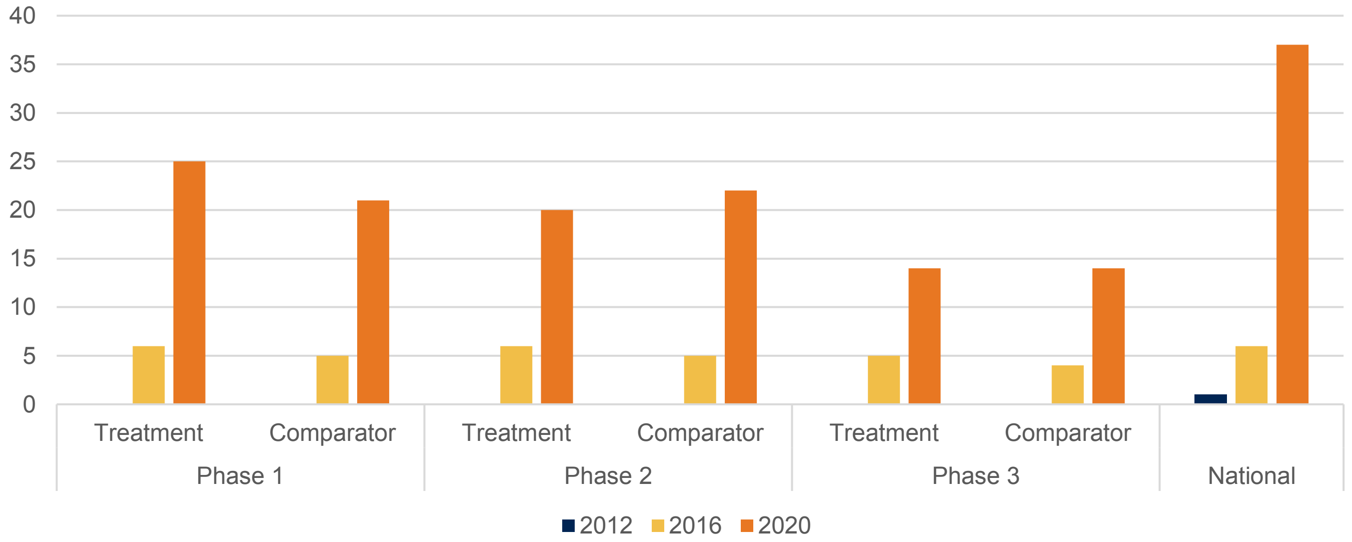
This pattern is matched in the comparator areas for the Superfast Broadband treatment areas and nationally – there has been an increase from ten network providers in 2012 to 55 in 2020 nationally – with most of the increase in network providers being between 2016 and 2020. In 2012, only one network provider which operated in the UK did not have presence in the Superfast Broadband area, and in 2016 all network providers operating nationally had a presence in the Superfast Broadband delivery area. However, by 2020, with the large number of new network providers, there were 12 network providers which operated within the UK but did not provide services to Superfast Broadband areas.

Figure 3.5: Total number of network providers in Superfast Broadband treatment and comparator areas



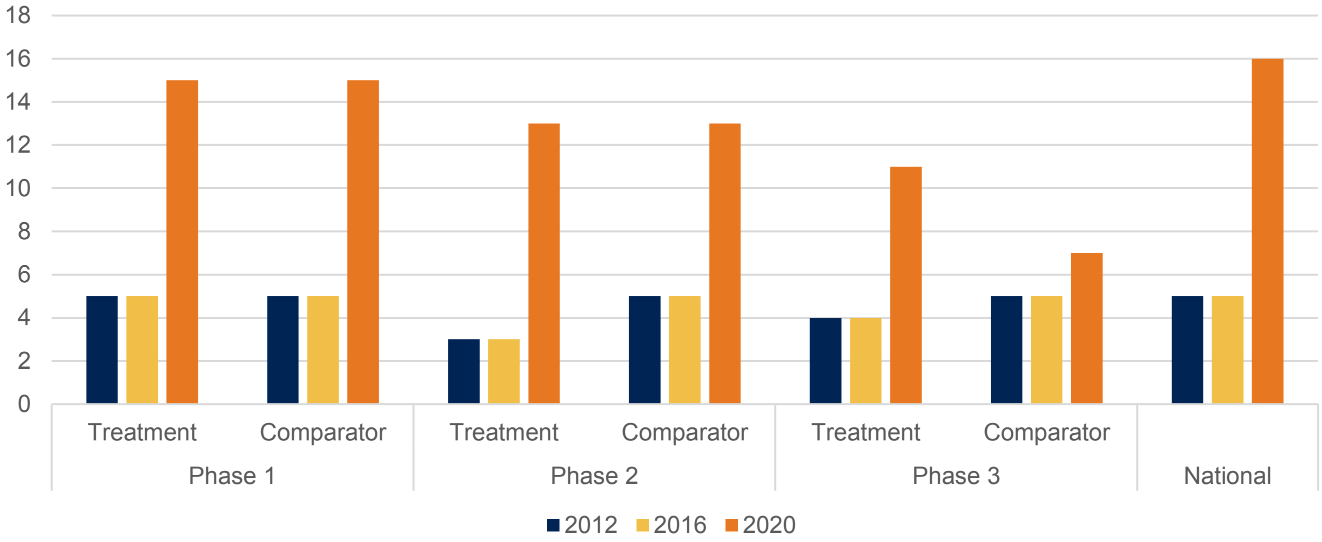
Source: ThinkBroadband

Figure 3.6: Total number of FTTP network providers in Superfast Broadband treatment and comparator areas



Source: ThinkBroadband

Figure 3.7: Total number of wireless broadband suppliers in Superfast Broadband treatment and comparator areas



Source: ThinkBroadband

Although there were a large number of network providers with services in Superfast Broadband delivery areas, most tended to provide services to only a small number of postcodes within the area. Those network providers without a Superfast Broadband contract had a maximum coverage of nine percent of the delivery areas in Phase 1 contracts, 12 percent in Phase 2 contracts and three percent in Phase 3 contracts (all Virgin Media), and below three percent for all other providers in all phases (with the highest levels of coverage among wireless providers.

Table 3.2: Percentage of postcodes covered by selected network providers in Superfast Broadband delivery areas, 2020

	Phase 1	Phase 2	Phase 3
Virgin_cable	9.28%	12.11%	3.62%
Vfast wireless	2.68%	0.74%	0.00%
Kijoma wireless	1.39%	1.06%	0.51%
Boundless wireless	0.71%	0.96%	0.50%
Solway comms wireless	1.41%	0.74%	0.16%
Greenco wireless	0.83%	1.72%	0.00%
Truespeed wireless	0.21%	0.00%	0.72%
Gigafast FTTP	0.22%	0.08%	0.22%
Hyperoptic FTTP	0.14%	0.11%	0.04%
Glide FTTP	0.11%	0.31%	0.37%

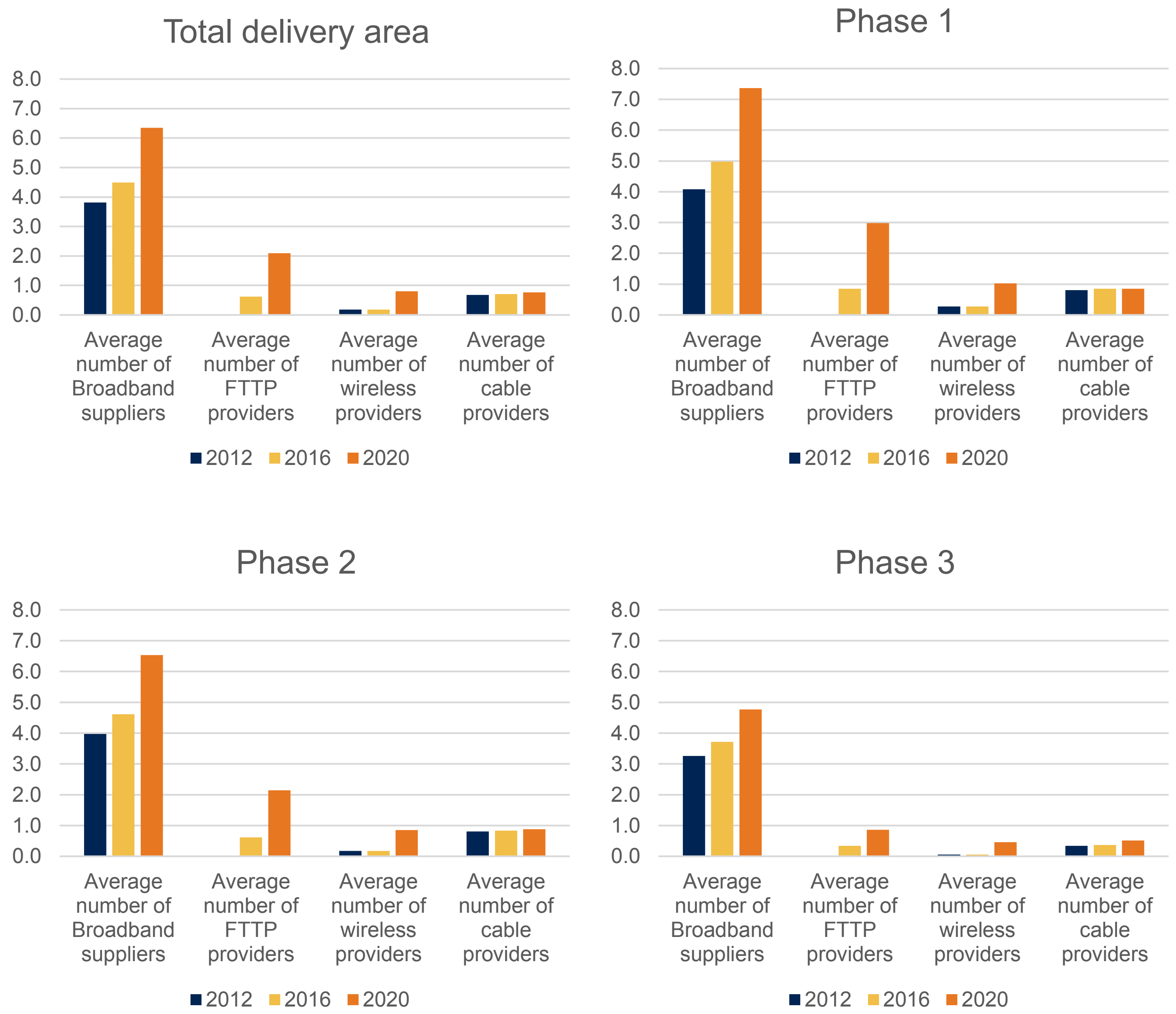
Source: ThinkBroadband data

Superfast Broadband programme delivery contract level analysis

When looking at a project level, the average number of network providers operating in a project area has risen from under four per contract area in 2012 to over six per project area in 2020. There has also been an increase in network providers for each type of technology (except for cable), although there are still a small number of FTTP and wireless providers operating in each contract area.

Examining the average number of network providers operating in a project area by Phase of the Superfast Broadband programme, the average number of network providers is highest in Phase 1 of the programme. This is not surprising, as these areas are larger than the areas in Phase 2 and Phase 3, but in all phases the pattern remains the same – there is an increase in the average number of network providers for total broadband providers, FTTP and wireless providers.

Figure 3.8: Average number of network providers by project area, and by phase of delivery



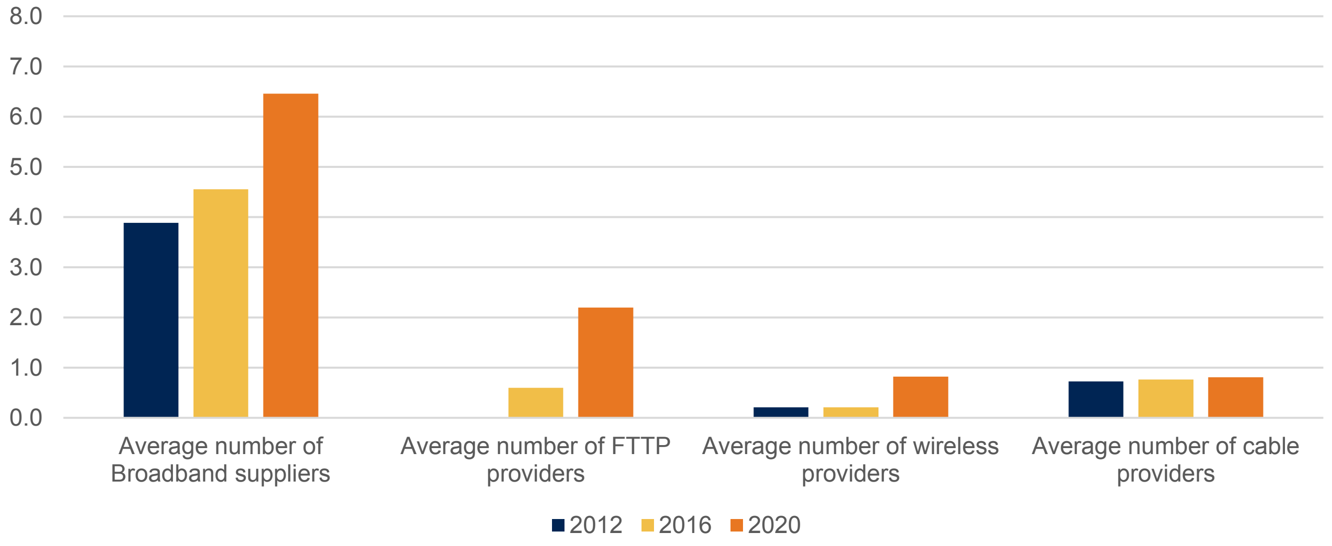
Source: ThinkBroadband data

The Superfast Broadband delivery contracts were again divided up by the supplier delivering the local project, and the areas aggregated by supplier. This showed that in areas where Openreach were responsible for delivering the Superfast Broadband project, there was a slightly higher average number of network providers operating than in areas where Gigaclear or the wireless providers delivered the contracts. This is not surprising, as Openreach contracts (particularly Phase 1 contracts) were delivered over larger geographic areas and in the most economically viable areas. This is the case for both 2016 and 2020.

In areas where the contract is delivered by Gigaclear the average number of FTTP network providers in each contract area was just over one. This suggests that in most Gigaclear contract areas, Gigaclear are the sole FTTP network provider operating. This again is unsurprising, given that the delivery areas were selected for the projects did not have existing NGA coverage and many of the projects are not yet completed.

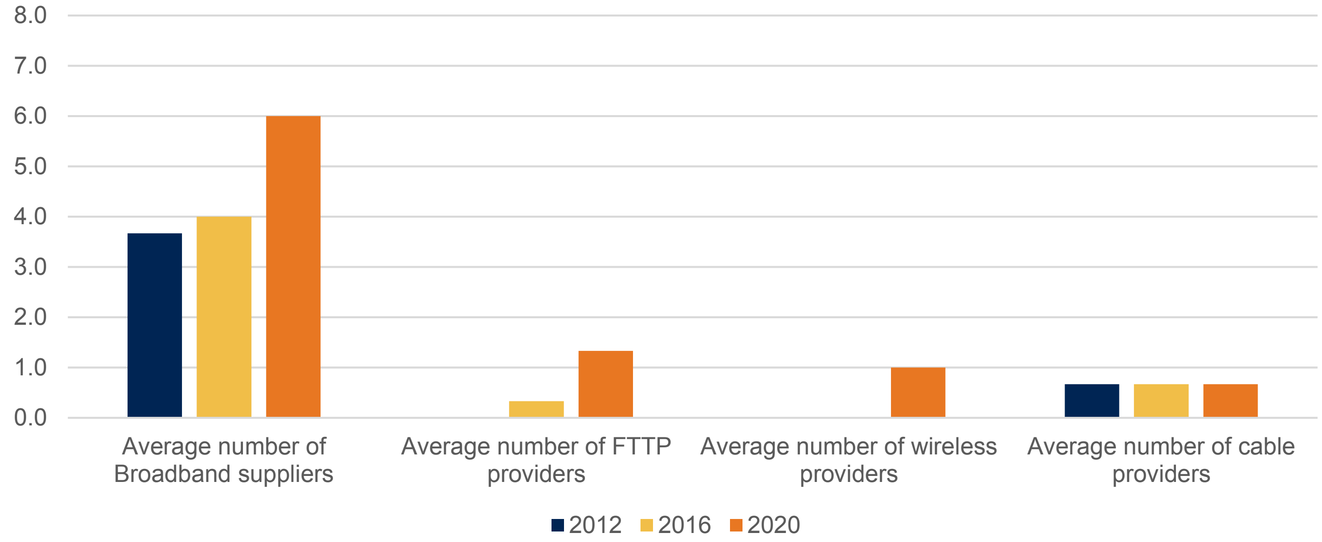
A similar pattern is seen for the wireless network providers – in the Superfast Broadband contract areas there is on average around one wireless network provider (the fact that there is less than one could be due to some of the areas still being in delivery). There are also only a small number of FTTP or cable providers operating in the project areas – suggesting there is limited competition for the Superfast Broadband contract provider.

Figure 3.9: Average number of network providers in Openreach contract areas



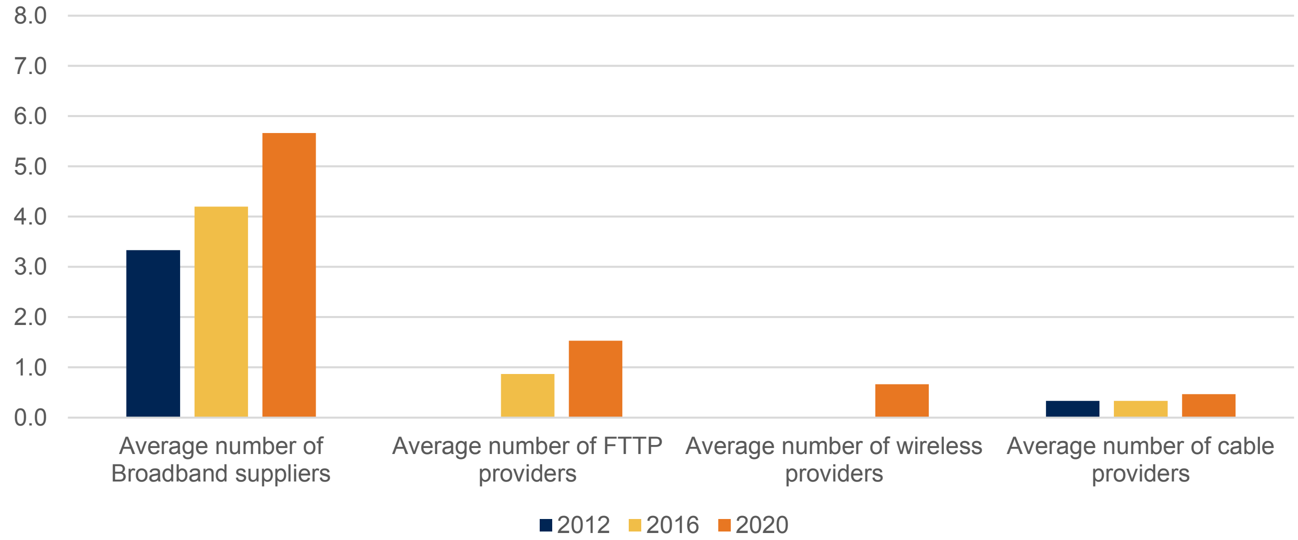
Source: ThinkBroadband

Figure 3.10: Average number of network providers in Gigaclear contract areas



Source: ThinkBroadband

Figure 3.11: Average number of network providers in Wireless contract areas



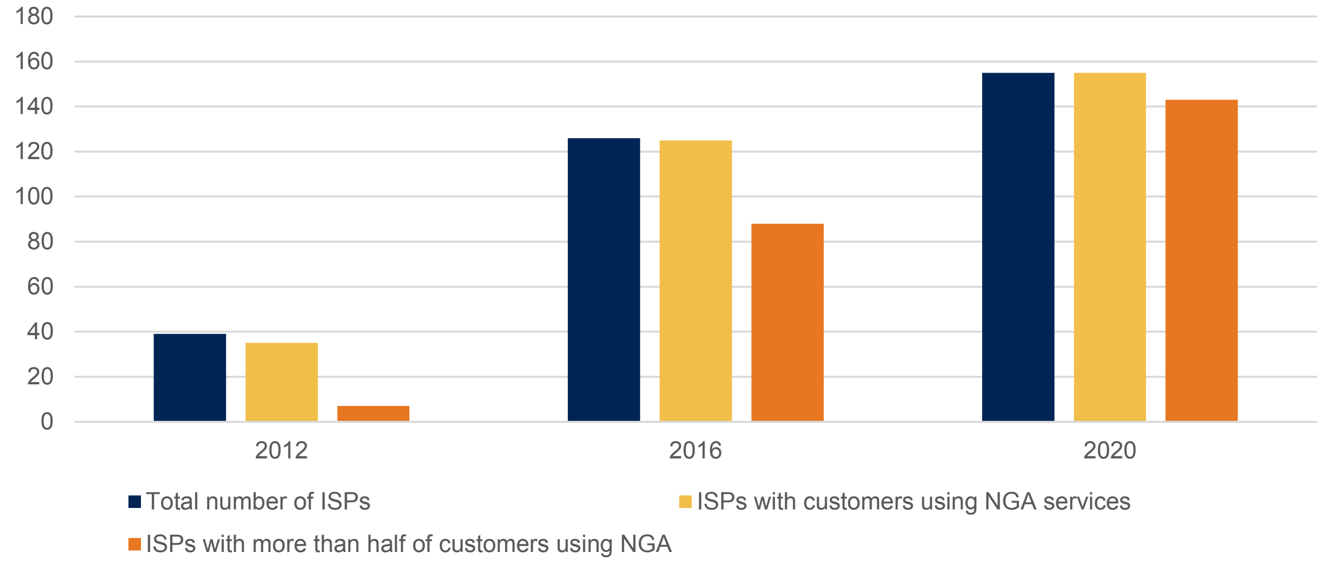
Source: ThinkBroadband

3.3.3 Number of ISPs

UK analysis

The number of ISPs with customers in the UK (proxied as the number of ISPs where customers have completed a Speed Test on the ThinkBroadband website) has increased over time. In 2020, over 150 ISPs had customers in the UK (see figure below). A small number of ISPs which had customers in 2012 and 2016 did not have customers in 2020 (six in total, of which one had customers in 2012 and 2016, three had customers in 2012 but not in 2016 or 2020, and two had customers only in 2016). This shows that there has been a lot of new entrants into the ISP broadband market over this period. In 2012, only a small proportion of ISPs had customers using NGA services – by 2020 this had grown to nearly all ISPs – and by 2020 over 90 percent of ISPs had the majority of their customer base on NGA connections.

Figure 3.12: Total number of ISPs and ISPs with customers using NGA services

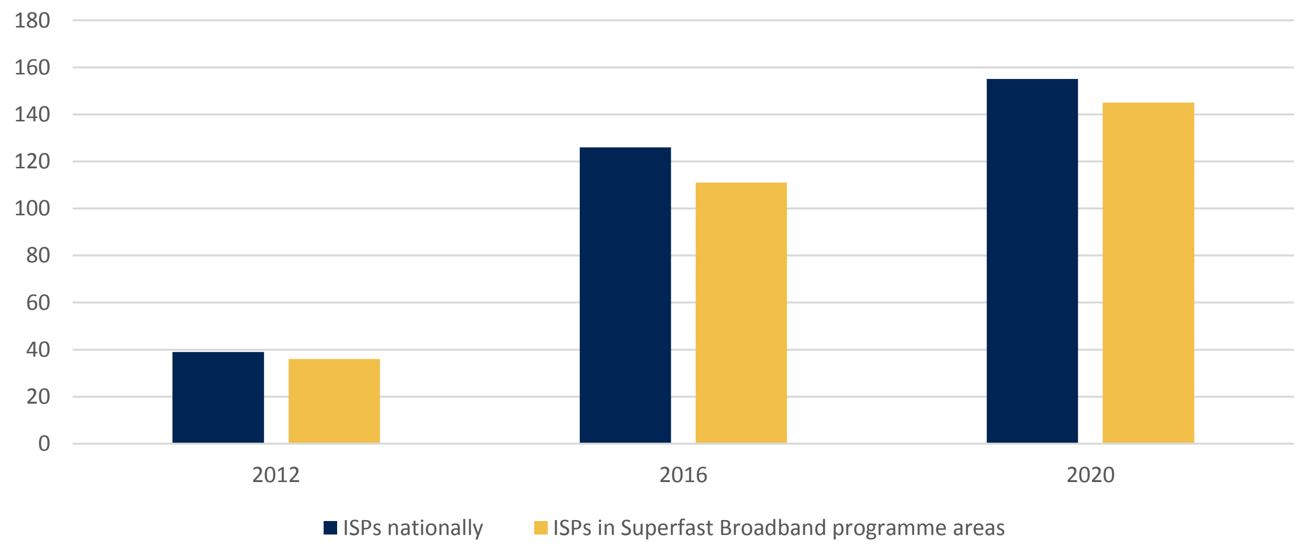


Source: ThinkBroadband

Superfast Broadband delivery areas

A similar pattern to that seen nationally is observed in the Superfast Broadband delivery areas. There has been a large increase in the number of ISPs with customers between 2012 and 2020. A similar (although slightly less) number of ISPs have customers in Superfast Broadband delivery areas than nationally (see Figure below).

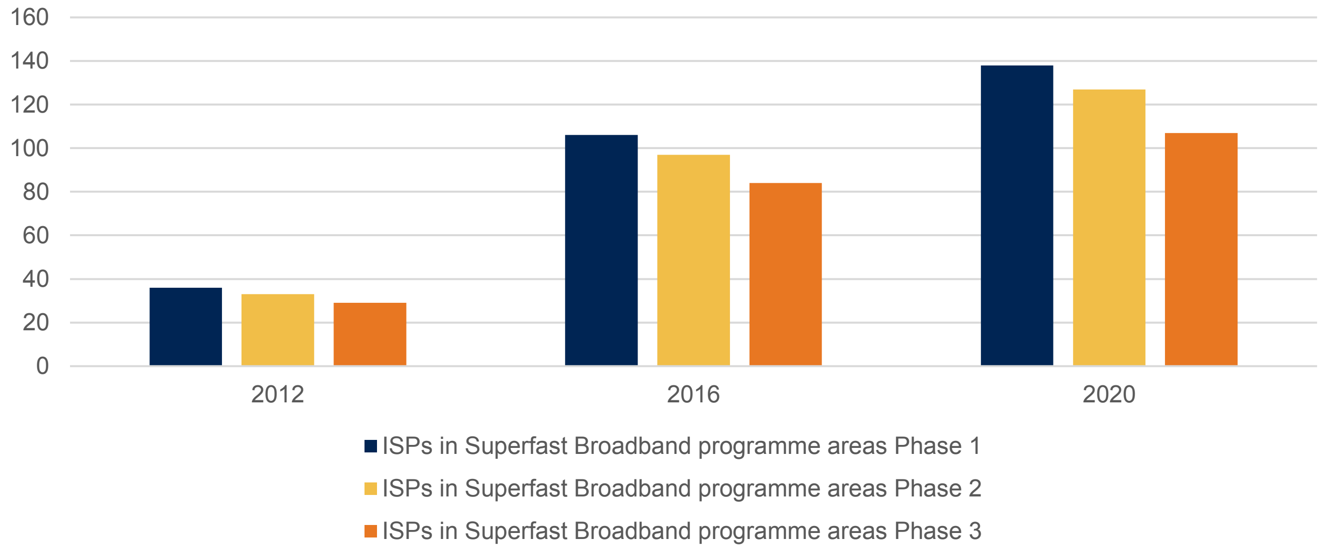
Figure 3.13: Number of ISPs with customers in Superfast Broadband treatment areas



Source: ThinkBroadband data

When comparing between phases, it can be seen that there are a higher number of ISPs with customers in Phase 1 contract areas than Phase 2 and Phase 3. This would be expected, as Phase 1 contracts were delivered larger contracts covering a higher number of premises and in more economically viable areas, therefore there are more customers for different ISPs to access. Additionally, these contracts were completed at an earlier stage, meaning there has been more time for ISPs to utilise the networks built by the Superfast Broadband programme.

Figure 3.14: ISPs with customers in Superfast Broadband delivery areas by Phase of delivery



Source: ThinkBroadband data

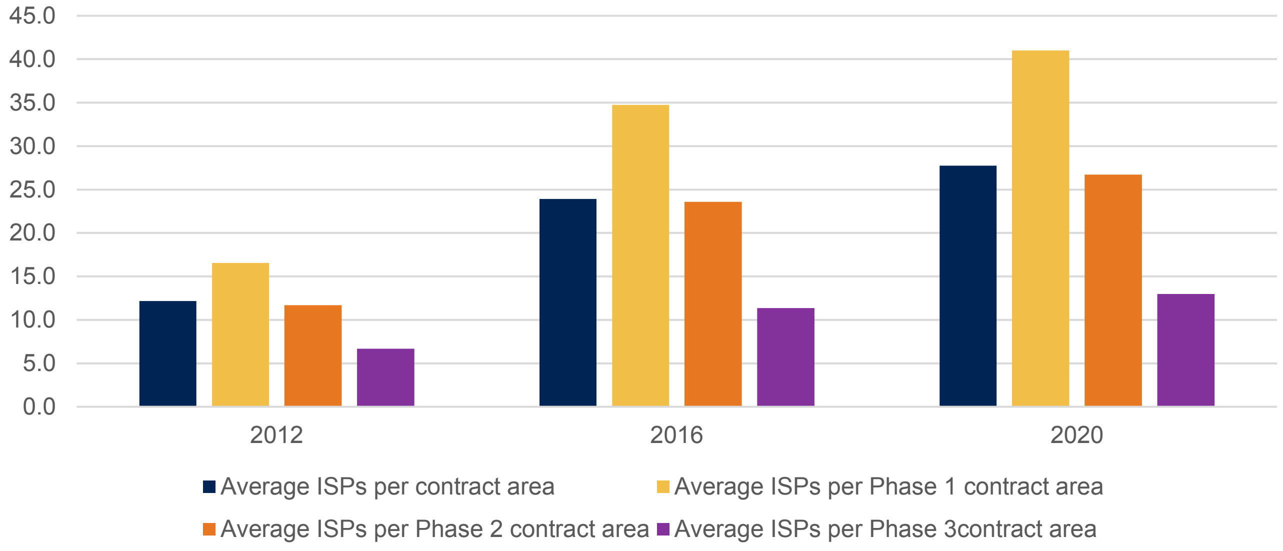
Superfast Broadband Programme delivery contract area analysis

The analysis of the number of ISPs operating in each project area has been aggregated to the network provider contracted to delivery the local project and the phase of the programme the project falls into. This is because of small sample sizes available at specific contract areas. More details of the sample sizes in each project area is provided in the Annex.

The figure below shows that the average number of ISPs servicing customers in Superfast Broadband contract areas has grown since 2012, in line with the patterns seen in the sections above. The average number of ISPs providing services in Superfast Broadband delivery areas has increased from just over 12 in 2012 to nearly 28 in 2020. Most of this increase in provision was between 2012 and 2016, with smaller increases between 2016 and 2020.

However, there are noticeable differences between the number of ISPs servicing customers in the different phases of the programme. There are more ISPs providing services in Phase 1 areas than in Phase 2 and Phase 3 areas. Additionally, the change between 2016 and 2020 for Phase 2 and Phase 3 project areas is small (an increase of 3.1 average ISPs in Phase 2 areas and 1.6 ISPs in Phase 3 areas) compared to the change for Phase 1 contract areas (an increase of 6.3 ISPs). As stated earlier, this would be expected, as Phase 1 contracts were delivered larger contracts covering a higher number of premises in more economically viable areas, therefore there are more customers for different ISPs to access. Additionally, these contracts were completed at an earlier stage, meaning there has been more time for ISPs to utilise the networks built by the Superfast Broadband programme.

Figure 3.15: Average ISPs per contract area by phase

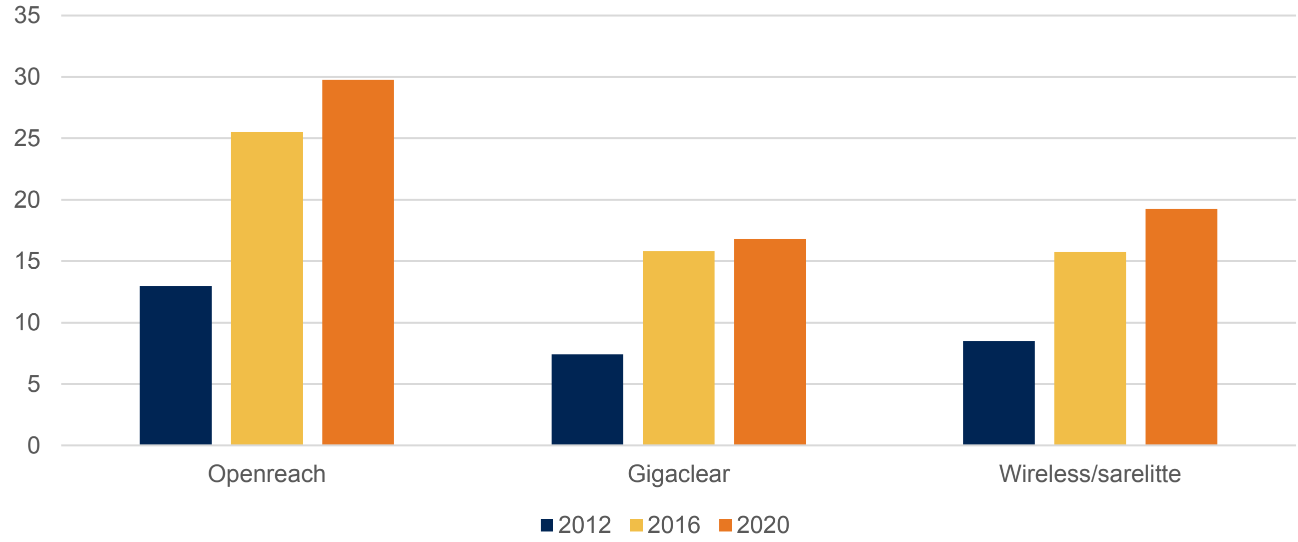


Source: ThinkBroadband

There are noticeable differences between the number of ISPs servicing customers in areas that Openreach delivered projects in and areas where Gigaclear and wireless providers delivered contracts in. There are more ISPs providing services in areas Openreach have delivered in (29.8 ISPs in 2020) than in areas where Gigaclear or wireless providers have delivered contracts in (16.8 ISPs for Gigaclear areas and 19.3 in areas wireless providers deliver contracts in). This pattern is the same in all years. For each area, there has been an increase in the number of ISPs with customers between 2012 and 2016, and 2016 and 2020, although the increase is smaller between 2016 and 2020 – particularly in areas where Gigaclear are delivering contracts.

The larger number of ISPs in Openreach contract areas should be expected, as Openreach contract areas (particularly Phase 1 contract areas) were delivered larger contracts covering a higher number of premises, therefore there are more customers for different ISPs to access. Additionally, these contracts were completed at an earlier stage, meaning there has been more time for ISPs to utilise the networks built by the Superfast Broadband programme. Finally, the technology used to deliver contracts in Phase 2 and Phase 3 contract areas (particularly by Gigaclear) is more advanced (using FTTP connections as standard rather than FTTC connections which Openreach have used in many of their contracts). This means that alternative network providers would not have a technology comparative advantage over the programme beneficiary in areas that Gigaclear have delivered to, but they might have this advantage in Openreach areas.

Figure 3.16: Average ISPs per project area by network provider contracted to deliver contract



Source: ThinkBroadband data

4 Discussion of data used

4.1 Data used

The original state aid evaluation plan agreed with the EU Commission stated that Ofcom Connected Nations data at premise level would be used for this analysis. Due to the commercial sensitive nature of this data, it has not been possible to access it for the purposes of the evaluation. BDUK explored alternative sources, including obtaining the data from network providers. BDUK managed to collect data directly from a large number of suppliers including some programme beneficiaries. However, the dataset from network providers is incomplete and was deemed insufficient for the evaluation. In order to fulfil the requirements of the State Aid evaluation plan, BDUK decided to purchase a dataset from ThinkBroadband.

ThinkBroadband is an independent organisation which collects information and data about internet coverage in the UK. It also runs an online ‘speed test’ function, where individuals can provide a limited amount of data about their broadband package and test the connection speed that they receive. ThinkBroadband have made available two sources of data to be used in this evaluation. These are data which provide data on broadband coverage by supplier (stating which suppliers offer broadband services to all postcodes in the UK) and data which presents the number of speed tests undertaken.

Both of these datasets have been used for the market analysis. The data is described in more detail below.

4.1.1 ThinkBroadband coverage data

This data includes which postcodes 60 network providers offered broadband coverage to, in 2020, 2016 and 2012. The data includes providers of all broadband services, including ADSL and all NGA services (FTTC, FTTH, cable, wireless and satellite services). The data includes the type of technology used to provide these broadband services, the name of the supplier and the connection speeds available to households. This data has been collected in three main ways:

- **Desk research of the Openreach network:** Identifying the location of Openreach cabinets and the postcodes they serve, the technology used in the cabinet and when this has been upgraded.
- **Press releases and network provider engagement:** ThinkBroadband staff monitor press releases made by network providers, which state where they have built networks and where they are planning to build networks in the future. Additionally, network providers engage with ThinkBroadband directly, telling them where they have existing networks and are going to build networks. The information received from network providers and press releases is validated by ThinkBroadband staff, who check that broadband coverage is available from the network provider in the postcodes they claim to cover.
- **Cross reference with speed test data** (see below): The data generated by the Speed Tests is checked against the coverage data collected by ThinkBroadband. Where a speed test flags that a network provider (through providing access to ISPs) has coverage in an area that the coverage data states the network provider does not, this area is validated. If the network provider does have coverage in the area highlighted in the speed test, this is added to the coverage database.

4.1.2 Speed test data

ThinkBroadband offer an online speed test service to individuals visiting their website. In order to complete a speed test, individuals are asked to provide details about their postcode and their Internet Service Provider (ISP). The speed test then collects data to estimate the upload and download speeds the individual is able to receive from their supplier. From the information collected ThinkBroadband can also identify the technology that the individual is using for the speed test.

The speed test data includes the following fields:

- Postcode – the postcode of the individual completing the speed test (self-reported)
- Internet Service Provider – the ISP the individual provides (self-reported), which is cross checked against ThinkBroadband internal data (to ensure that the stated provided does offer services to that postcode)
- Download speed – the average download speed for individuals at the postcode (using a specific supplier and technology type) – data collected from the speed test
- Upload speed - the average upload speed for individuals at the postcode (using a specific supplier and technology type) – data collected from the speed test
- Technology – the technology of the internet connection used for the speed test
- Number of speed tests – the number of speed tests completed in a postcode (for each ISP and technology type). The number of speed tests for a postcode, ISP and technology type is capped at 30 speed tests per year.

Data was provided for 302,400 speed tests in 2012, 3.9 million speed tests in 2016 and 2.5 million speed tests in 2020.[9, 10, 11]

4.2 Data validation

A comprehensive data validation exercise was undertaken by the research team, to test the accuracy of the data provided by ThinkBroadband. This data validation exercise included an internal validity check of the ThinkBroadband data, to check that the coverage dataset listed at least one network provider to all postcodes where broadband services were available, using other publicly available datasets to check the validity of coverage data, comparing the ThinkBroadband coverage data to coverage data provided to BDUK by network providers (as discussed in the section above), and comparing the ThinkBroadband coverage and speed test databases to identify any differences between the datasets.

4.2.1 Internal consistency of ThinkBroadband coverage data

The first step of the validation was to check for any remaining postcodes where no providers were listed as providing coverage. This meant:

- Identifying any postcodes which had technology “unknown” and had no other provider listed:

9 This is the equivalent of 1 percent of premises in 2012, 14 percent in 2016 and 9 percent in 2020. This shows that the sample of speed tests is low for 2012 and relatively large for 2016 and 2020.

10 This does not include speed tests for “mobile” internet connections – which have been excluded from the data set.

11 There are substantially fewer speed tests in 2012 than in 2016 and 2020. In 2012, there were fewer options for consumers in the broadband market (and broadband was less important than in subsequent years) therefore fewer consumers undertook speed tests on the ThinkBroadband website. In 2020, there has been an increase in competition in the speed test market, meaning there are slightly fewer tests completed than in 2016.

  - 837 postcodes were identified in 2020. Of these, 674 are thought to be PO boxes / banks (non-geographical postcodes). A further 89 postcodes were identified as being in Hull, and therefore being covered by Kcom. **This left a total of 74 postcodes to be checked.**
  - 6,222 postcodes were identified in 2016. Of these, 897 are thought to be PO boxes / banks. (non-geographical postcodes). A further 5,180 postcodes were identified as being in Hull, and therefore being covered by Kcom. **This left a total of 145 postcodes to be checked.**
  - 8,918 postcodes were identified in 2012. Of these, 488 are thought to be PO boxes / banks. (non-geographical postcodes). A further 8,283 postcodes were identified as being in Hull, and therefore being covered by Kcom. **This left a total of 147 postcodes to be checked.**
- Some of these postcodes were the same postcodes in different years. This means that there were a total of 201 postcodes to be investigated (See Tab 1 of the excel sheet).

We examined the technology listed for cabinets to check that there was “no backward step” – i.e. technology becoming less advanced as time passed (for example being listed as FTTC in 2012, and then listed as ADSL in 2016). We found no cases of this.

4.2.2 External consistency of ThinkBroadband coverage data

National Statistics Postcode Lookup (NSPL)

We compared the postcodes listed in the ThinkBroadband dataset with the NSPL dataset. This showed that all the postcodes listed in the ThinkBroadband data (except for three) were matched into the NSPL data. Therefore there were no concerns that there were inaccuracies in the postcodes used.

Connected Nations

We have explored the coverage speeds listed for postcodes in the ThinkBroadband data to identify which postcodes can be considered as receiving Superfast Broadband coverage. This was then compared to the level of coverage listed in the Connected Nations data for 2019 and 2016 (this data is not available for 2012). However, in Connected Nations, the Superfast Broadband connections are listed as a percentage of households that can receive connections at this speed, whereas in ThinkBroadband it is a binary measure. Therefore, the following assumptions have been made:

- In ThinkBroadband, if the postcode is listed as having a connection speed of above 24 Mbps, it has been assigned a binary value of 1, meaning that the postcode has Superfast Broadband coverage.
- In the Connected Nations data, if the postcode is listed as having more than half of premises with Superfast Broadband coverage (50 percent or higher), the postcode is assigned a binary value of 1, meaning that the postcode has Superfast Broadband coverage.
- When these two values were compared for the 2016 data, 56,592 postcodes were identified that had differences between the ThinkBroadband data and the Connected Nations data. However, where ThinkBroadband have said that the technology in the cabinet is FTTC, we have stripped these postcodes out of the comparison,[12] and the postcodes where suppliers other than those using the Openreach network were also removed. This left 32,389 postcodes to be examined.

[12] These postcodes were striped out in order to focus on the postcodes that ThinkBroadband were potentially overclaiming FTTC coverage. Additionally, we have removed all postcodes in Hull, due to the unknown nature of the technology in the cabinet

- The same process was followed for 2020 (although this was comparing 2020 ThinkBroadband data with 2019 Connected Nations data). This yielded 36,691 postcodes in the first instance, but with the same approach to stripping out postcodes as described above left 5,812 postcodes to be examined.

A total of 2,630 postcodes showed differences between the ThinkBroadband data in 2020 and 2016 – therefore there were a total of 35,571 postcodes where there were mismatches between the Connect Nations dataset and the ThinkBroadband dataset (under two percent of all postcodes), suggesting that the mismatches are a small proportion of all postcodes.

Network provider data

Five network providers that are included in the ThinkBroadband coverage data responded to a request by BDUK to provide information about the postcodes and premises they provide coverage to. These suppliers were:

- Callflow
- Community Fibre
- Gigaclear
- OFNL
- Virgin Media[13]

The postcodes that these suppliers stated they provided coverage to was compared to the postcodes ThinkBroadband listed they supplied to. When these were compared, there were a small number of differences. These were that the suppliers claimed they had network provision to postcodes where ThinkBroadband did not list them as covering the postcode. The absolute number of postcodes for all the network providers was considered to be small, except for Virgin Media, where there was a large number of postcodes that did not match (although the proportion of postcodes that were mismatched). The fact that there were mismatches was raised with ThinkBroadband, who acknowledged that there were inaccuracies in their Virgin Media dataset. This fact has been noted in the State Aid report. The number of postcodes where this happened are presented in the table below:

Table 4.1: Differences between self-reported Network Provider coverage and stated ThinkBroadband coverage

[Redacted]

4.2.3 ThinkBroadband Coverage and Speed Test data set validation

The speed test data provided by ThinkBroadband was also compared with the ThinkBroadband coverage dataset, to check that suppliers stated they provided coverage in all the areas in which they had speed tests reported in. This was checked for the largest ISPs and network providers. These ISPs and network providers are listed in the table below:

Table 4.2: Network providers and Internet Service Providers included in validation exercise

Network providers	Internet Service Providers
Openreach (wholesale)	▪ AOL

[13] Quickline also submitted a response, but are not included in the ThinkBroadband dataset

	▪ BT ▪ Daisy Wholesale ▪ Eclipse Internet ▪ EE ▪ IDNet ▪ M247 ▪ Plusnet ▪ Zen internet
Sky llu	▪ Sky
TalkTalk llu	▪ TalkTalk ▪ Post Office
Virgin Media	▪ Virgin Media
Hyperoptic	▪ Hyperoptic
Gigaclear	▪ Gigaclear

- **Speed tests submitted by consumers where stated ISP did not match the 2020 coverage dataset:** There were **26,007** postcodes in 2020 where a speed test for an ISP was not matched by coverage from the relevant network provider. This is out of 695,968 postcodes where a speed test was registered in the 2020 dataset (3.7 percent of all postcodes in the dataset and 1.4 percent of all postcodes in the NSPL).
  - It could be assumed that where there is no Sky or TalkTalk LLU coverage that the ISP providers utilise Openreach wholesale products. If this is the case, the number of postcodes where there is a mismatch between the ISP and network providers falls to **12,582** (1.8 percent of postcodes in the dataset and 0.7 percent of all postcodes in the NSPL).
- **Speed tests submitted by consumers where stated ISP did not match the 2016 coverage dataset:** In 2016, there were **77,173** postcodes where a speed test for an ISP was not matched by coverage from the relevant network provider. This is out of 849,185 postcodes where a speed test was registered in the 2020 dataset (9.1 percent of all postcodes in the dataset and 4.1 percent of all postcodes in the NSPL).
  - Again, if it is assumed that where there is no Sky or TalkTalk LLU coverage the ISP providers utilise Openreach wholesale products, the number of postcodes falls to **56,423** (6.6 percent of all postcodes in the dataset and 3.0 percent of all postcodes in the NSPL).
- **Speed tests submitted by consumers where stated ISP did not match the 2012 coverage dataset:** In 2012, there were **21,048** postcodes where a speed test for an ISP was not matched by coverage from the relevant network provider. This is out of 307,458 postcodes where a speed test was registered in the 2020 dataset (6.8 percent of all postcodes in the dataset and 1.1 percent of all postcodes in the NSPL).
  - Again, if it is assumed that where there is no Sky or TalkTalk LLU coverage the ISP providers utilise Openreach wholesale products, the number of postcodes falls to **17,025** (5.5 percent of all postcodes and 0.9 percent of all postcodes in the NSPL).

The number of postcodes with mismatches by ISP and network provider, and therefore requiring further investigation, is presented in the table below. Note some postcodes have mismatches for multiple network providers, therefore the sum of the network provider totals does not equal the overall total for the year. As can be seen, the largest number of mismatches are for the Virgin Media network. However, by the proportion of the total number of speed tests, the Hyperoptic network has the largest share of mismatches. The absolute number of mismatches has been assessed as tolerable. This issue was raised with ThinkBroadband, who stated that there are inaccuracies in their network coverage dataset for Virgin Media, and that the speed test data is likely to be accurate.

Table 4.3: Number of mismatches by network provider and year (and percentage of the total number of speed tests for network provider this represents)

Network provider	2012	2016	2020
Openreach (wholesale)	130 (0.0%)	882 (0.2%)	802 (0.2%)
Sky llu	1,485 (3.8%)	14,386 (4.2%)	11,009 (4.7%)
If exclude postcodes with wbc coverage	*8 (0.0%)*	*148 (0.0%)*	*502 (0.2%)*
TalkTalk llu	2,568 (6.5%)	8,008 (3.4%)	3,383 (2.3%)
If exclude postcodes with wbc coverage	*14 (0.0%)*	*130 (0.1%)*	*233 (0.2%)*
Virgin Media	16,870 (21.8%)	54,910 (23.5%)	10,962 (6.6%)
Hyperoptic	5 (62.5%)	498 (33.7%)	424 (16.3%)
Gigaclear	0 (-)	29 (3.9%)	99 (7.5%)
Total	**21,048 (6.8%)**	**77,173 (9.1%)**	**26,007 (3.7%)**
Total if excludes TalkTalk and Sky postcodes where wbc available	*17,025 (5.5%)*	*56,423 (6.6%)*	*12,582 (1.8%)*

Source: ThinkBroadband data

4.2.4 Summary and implications

As is highlighted above, a number of inconsistencies and gaps in the data have been identified in the data validation exercise. These were reported back to ThinkBroadband. ThinkBroadband provided some reasons as to why there may be differences between the datasets. These included:

- Sky and TalkTalk both offering some services in areas where they do not have LLU networks by utilising Openreach wholesale products,
- Potential lags in the footprint datasets of network providers – ThinkBroadband aim to update the network footprints within ten weeks of new networks being rolled out, but there may be some issues due to this lag; and
- There is a known difficulty with the Virgin Media data, both in terms of customers claiming they have Virgin Media coverage in areas where there is none and the accuracy of the Virgin Media coverage dataset. ThinkBroadband attempt to rectify these issues on an ongoing basis, but are less confident in their Virgin Media data than for all other network providers / ISPs. Therefore, this caveat should be acknowledged when looking at analysis of the Virgin Media data.

The findings in this paper present the analysis using the existing ThinkBroadband datasets. ThinkBroadband have not recommended any changes to the original dataset, but the caveats above should be considered when looking at the findings of the research. Despite these caveats, the ThinkBroadband data was considered the most appropriate and robust data source available to answer the research questions. These caveats are:

- Speed test data is self-reported by customers that complete a speed test online. Therefore, there is potential bias in the sample, and the data may not include all ISPs that provide connections in a particular area (if customers from an ISP do not complete a speed test). However, at a large geographic level (regions) the speed test data has been found to be an accurate approximation of the take-up by ISPs.[14]
- Speed tests can be completed multiple times by the same IP address, up to 30 times. Therefore, the speed test data could be bias by the same customer completing multiple speed tests and being counted as multiple individual entries.
- The sample sizes for completed speed tests was not sufficient to undertake an analysis for all Superfast Broadband contract areas. Therefore, contract areas delivered by the same programme beneficiaries have been combined to improve the robustness of the findings when examining the local impacts of the programme.
- There are known weaknesses in the network provider coverage, particularly for Virgin Media. These weaknesses relate to under 10 percent of the Virgin Media footprint.

[14] Despite the potential for reporting bias, we do not believe that any bias in the dataset will affect the conclusions of the research, as the reporting bias should be similar in all areas of the UK.

Annexes

Annex 1

This annex presents the list of network providers included in the ThinkBroadband dataset, and the mapping of ISPs to network providers.

Table 4.4: Network providers included in ThinkBroadband dataset

Network providers in ThinkBroadband			
Airband (including Airband_wireless and Airband_FTTP)	fibre_nest_persimmon_fttp	kcom_lightstream_fttp	tove_valley_fttp
aylesbury_vale_fttp	FibreFirst_FTTP	kijoma_wireless	trooli_fttp
b4rn_fttp	fullfibreltd_fttp	lothian_wireless	truespeed_fttp
balquhidder_fttp	gigaclear_fttp	ofnl_ifnl_fttp	vfast_wireless
blackfibre_fttp	gigafast_fttp	Openreach (including Openreach WBC and Openreach FTTP)	virair_wireless
boundless_wirelss	glide_fttp	purefibre_fttp	Virgin (including virgin_rfog_fttp, virgin_gig1_gigabit_1000_50, virgin_cable)
box_broadband_fttp	gnetwork_fttp	raveningham_residents_fttp	vision_fibre_fttp
Callflow	grain_connect_fttp	reeth_wireless	voneus_wireless
Cityfibre (including Cityfibre and Gigler)	greenco_wireless	Relish (including Relish_fibre, Relish_wireless and Relish_swindon_wireless)	Wessex (including Wessex_fibre and Wessex_wireless)
colchester_fttp	hampshire_broadband_fttp	ridgehill_residents_fttp	Wight (including Wight_ftttp, Wight_wireless and Wight_cable)
Community Fibre FTTP	hereford_cic_fttp	ruralcomms_wirelss	zoom_wireless
County Broadband (including County Broadband Wireless and County Broadband FTTP)	hiwifi_wireless	sky_llu	zzoomm_fttp
ecom_fttp	hyperoptic_fttp	solway_comms_wireless	
f4rn_fttp	internetty_fttp	spectrum_internet_wireless	
factco_fttp	its_fttp	talktalk_llu	

Table 4.5: ISP to network provider mapping

ISP	Network provider	ISP	Network provider	ISP	Network provider
186k	Openreach	**AAISP**	Openreach	**AB Internet**	Openreach
Ai Networks	Openreach	**Air Broadband**	OFNL / Gigaclear	**Airband**	Airband
Amatis Networks	Openreach	**AOL**	Openreach	**AQL**	Openreach
Ask4	Ask4	**Avanti Satellite Broadband**	Avanti	**Avonline**	Openreach
Aylesbury Vale Broadband	Aylesbury Vale	**B4RN**	B4RN	**Beeline Broadband**	Beeline
Bentley Walker Satellite Broad	Bentley	**bigblu**	bigblu	**Boundless Communications**	Boundless
Box Broadband	Pure	**Bridge Fibre**	Openreach	**BT**	Openreach
BT Business Broadband	Openreach	**BT WiFi**	Openreach	**Buckminster Broadband**	Openreach
Cable and Wireless	Vodafone	**CableCom Networking**	Openreach	**Call Flow Solutions**	Callflow
Cerberus Networks	Openreach	**CityFibre**	Cityfibre	**Claranet SOHO**	Openreach
CloudScape	Openreach	**Commsworld**	Openreach	**Community Fibre**	Community Fibre
connexin	Openreach	**CORETX(C4L)**	Openreach	**Cotswold Wireless**	Cotswold
County Broadband	County Broadband	**Daisy Wholesale**	Openreach	**Datanet**	Openreach
Demon Internet	Vodafone	**Dragon WiFi**	Dragon	**Dyfed Superfast**	Openreach
Eclipse Internet	Openreach	**Ecom**	Ecom	**EE**	Openreach
Elite	Openreach	**Entanet**	Cityfibre	**Evolving Networks**	Openreach
Exa Networks	Openreach	**Exascale**	Fluiddata	**exponential-e**	Openreach
Fast	Openreach	**FastNet**	Openreach	**Fibre for Rural Nottinghamshir**	B4rn
Fibre Nest	Openreach	**FidoNet**	Openreach	**Fluidata**	Openreach
FluidOne	Openreach	**G Network**	G Network	**Gamma**	Openreach
GCI (Edge Telecoms)	Openreach	**Gigabeam**	Gigabeam	**Gigaclear**	Gigaclear
Giganet	Openreach	**Glide Business**	Glide	**Goscomb Technologies**	Openreach
Gradwell	Openreach	**Green Co**	Openreach	**HighNet**	Openreach
HiWiFi	HiWifi	**Hotchilli Internet**	Openreach	**hSO**	Openreach
Hyperoptic	Hyperoptic	**I Love Broadband**	Sky	**ICUK**	Openreach
IDNet	Openreach	**ineedbroadband**	Fullfibreco	**Internet For Business**	Openreach
InTouch Systems	Intouch	**IP River**	TalkTalk	**its Technology**	Openreach
Jersey Telecom	Jersey	**Juice Broadband**	Juice	**KCOM**	KCOM
Keycom	Keycom	**Kijoma Broadband**	Kijoma	**LonsdaleNET**	Lonsdale
Lothian Broadband	Openreach	**Luminet (Urban Wimax)**	Luminet	**M247**	Openreach
Merula Limited	Openreach	**Michaelston-y-Fedw Internet CI**	Michaelston-y-Fedw Internet CI	**O2**	Openreach
O2 Wifi	Openreach	**Oakford Technology**	Openreach	**Optimity**	optimity
Orbital Net	Openreach	**Origin Broadband**	Openreach	**Pembs Wifi**	Openreach
Pine Media	Pine	**Plusnet**	Openreach	**Post Office**	talktalk
Pure Broadband	Pure	**PureFibre (Also Derwenthorpe +**	Pure	**Quickline**	Quickline
Redcentric	Openreach	**Relish**	Relish	**Resqnet Wireless Broadband**	Resqnet
RM Broadband	Openreach	**Satellite Internet**	Openreach	**Scotnet**	Openreach
SeeTheLight(IFNL)	OFNL	**SES Satellite Broadband**	SES	**Sky**	Sky

ISP	Network provider	ISP	Network provider	ISP	Network provider
Sky Corporate	Sky	**Solway Communications**	Solway	**Spectrum Internet**	Spectrum
Spitfire	Openreach	**Stream Networks**	Openreach	**Structured Communications Ltd**	Openreach
Sure	Openreach	**SW Internet**	SW	**SWS Broadband**	Openreach
TalkTalk	TalkTalk	**TalkTalk Business**	TalkTalk	**Technological**	Openreach
Telcom Networks	Openreach	**Tesco Broadband**	TalkTalk	**The Cloud**	Openreach
Timico	Openreach	**toob**	Toob	**Total Web Solutions Ltd**	Openreach
Tove Valley Broadband	Tove	**Truespeed Communications**	Truespeed	**Trunk Networks**	Openreach
UK Broadband	UKB/Relish	**uno Communications**	Openreach	**Userve (Unitron Systems)**	Userve
vaioni	Openreach	**Velocity1**	Openreach	**Vfast Internet**	Openreach
Virgin Media	Virgin	**Virgin Media Business**	Virgin	**VISPA**	Openreach
Vivaciti	Openreach	**Vodafone Broadband**	Vodafone	**Voipfone**	Openreach
Voneus	Voneus	**W3Z Wireless Broadband**	W3Z	**Watchfront**	Openreach
Waveney Internet	Openreach	**webmate**	Openreach	**Wessex Internet**	Wessex
wifinity	wifinity	**Wight Fibre**	Wight fibre	**Wild West Net**	Wild West Net
wildcard networks	Wildcard	**WiSpire**	WiSpire	**Zen Internet**	Openreach
Zoom Internet	zoom	**Zzoomm**	Zzoomm		

Annex 2 – Sample sizes by contract area

Area	Contract ID	Beneficiary	Phase	Speed tests - total			Speed tests - NGA		
				2012	2016	2020	2012	2016	2020
Suffolk	SUFF101	Openreach	1	1,269	17,988	12,071	62	6,947	7,288
Suffolk	SUFF201	Openreach	2	485	8,936	6,941	19	1,543	3,458
Suffolk	SUFF202	Openreach	3	-	-	-	-	-	-
Bedford & Milton Keynes	BEDS101	Openreach	1	519	7,191	4,299	49	3,344	2,830
Bedford & Milton Keynes	BEDS201	Openreach	2	256	3,340	2,777	33	513	1,619
Bedford & Milton Keynes	BEDS202	Openreach	3	2	8	3	0	2	0
Bedford & Milton Keynes	BEDS203	Openreach	3	1	10	8	0	0	0
Berkshire	BERK101	Openreach	1	261	3,144	1,810	27	1,647	1,297
Berkshire	BERK201	Gigaclear	2	237	3,337	2,041	18	1,177	1,133
Berkshire	BERK202	Callflow	2	-	-	-	-	-	-
Berkshire	BERK203	Gigaclear	3	13	132	123	1	44	63
Berkshire	BERK204	Openreach	3	63	527	631	7	141	282
Bucks & Herts	BUCK101	Openreach	1	847	10,709	6,847	77	5,555	4,719
Bucks & Herts	BUCK201	Openreach	2	578	8,160	7,054	52	1,043	3,274
Cambridgeshire	CAMB101	Openreach	1	965	20,532	13,642	84	9,846	9,053
Cambridgeshire	CAMB101a	Openreach	2	-	-	-	-	-	-
Cambridgeshire	CAMB202	Openreach	3	-	-	-	-	-	-
Cheshire	CHES101	Openreach	1	1,150	14,165	9,198	96	6,170	5,732
Cheshire	CHES201	Openreach	2	192	4,026	3,215	13	689	1,039
Cumbria	CMBR101	Openreach	1	1,378	21,241	12,705	37	8,958	8,535
Cumbria	CMBR201	Openreach	2	129	2,516	1,727	1	250	858
Derbyshire	DRBY101	Openreach	1	1,083	17,805	10,880	69	7,589	7,053
Derbyshire	DRBY201	Openreach	2	216	3,658	2,566	24	537	1,001
Devon & Somerset	DEVO101	Openreach	1	4,197	73,065	42,252	154	28,234	25,301
Devon & Somerset	DEVO201	Airband	2	-	-	-	-	-	-
Devon & Somerset	DEVO205	Airband	3	95	1,767	1,771	2	392	855
Devon & Somerset	DEVO101a	Openreach	1	-	-	-	-	-	-
Dorset	DORS101	Openreach	1	1,097	17,020	10,930	87	8,078	7,505
Dorset	DORS201	Openreach	2	69	908	725	2	167	304
Dorset	DORS202	Openreach	3	37	525	570	1	63	175
Durham	DURH101	Openreach	1	1,104	18,322	10,304	99	8,642	7,199
Durham	DURH201	Openreach	2						
Durham	DURH202	Openreach	2	231	3,512	2,303	34	632	1,383
East Riding (Yorkshire)	EYRK101	Openreach	1	552	8,585	5,278	18	4,020	3,667
East Riding (Yorkshire)	EYRK201	Openreach	2	97	2,412	1,584	3	655	792
East Riding (Yorkshire)	EYRK202	Openreach	3	84	1,407	1,171	10	266	442
East Sussex	ESUS101	Openreach	1	816	11,530	7,382	35	4,715	4,398
East Sussex	ESUS201	Openreach	2	120	1,577	1,118	4	212	454
East Sussex	ESUS202	Openreach	3	0	240	210	5	90	123
Essex	ESSX101	Openreach	1	840	12,487	8,119	67	5,966	5,711
Essex	ESSX201	Openreach	2	856	10,926	9,032	51	1,614	5,112
Essex	ESSX202	Gigaclear	2	32	649	338	0	137	165
Essex	ESSX203	Gigaclear	3	16	266	166	1	97	82
Essex	ESSX204	Gigaclear	3	17	403	315	3	70	158
Essex	ESSX205	Openreach	3	44	1,248	965	4	342	404

Essex	ESSX206	Openreach	3	53	622	744	2	133	296
Essex	ESSX207	Gigaclear	3	-	-	-	-	-	-
Essex	ESSX208	Openreach	3	0	29	22	0	18	15
Essex	ESSX209	Openreach	3	0	132	105	3	27	33
Essex	ESSX210	Openreach	3	-	-	-	-	-	-
Essex	ESSX211	Openreach	3	-	-	-	-	-	-
Essex	ESSX212	Openreach	3	-	-	-	-	-	-
Greater Manchester	MANC101	Openreach	1	414	6,207	3,598	64	2,827	2,608
Greater Manchester	MANC101a	Openreach	2	-	-	-	-	-	-
Hampshire	HAMP101	Openreach	1	770	14,281	10,119	44	6,242	6,360
Hampshire	HAMP201	Openreach	2	364	10,630	8,033	49	2,046	3,914
Herefordshire & Gloucestershire	HERE101	Openreach	1	1,460	26,049	15,021	50	9,018	8,426
Herefordshire & Gloucestershire	HERE201	Gigaclear	2	116	2,383	1,139	4	734	667
Herefordshire & Gloucestershire	HERE202	Gigaclear	3	-	-	-	-	-	-
Herefordshire & Gloucestershire	HERE204	Gigaclear	3	120	2,516	1,554	14	631	898
Herefordshire & Gloucestershire	HERE205	Gigaclear	3	56	992	674	12	268	365
Herefordshire & Gloucestershire	HERE206	Gigaclear	3	42	1,366	735	4	358	432
Herefordshire & Gloucestershire	HERE203	Openreach	3	44	684	398	8	153	217
Herefordshire & Gloucestershire	HERE207	Openreach	3	19	340	199	4	83	93
Herefordshire & Gloucestershire	HERE208	Airband	3	-	-	-	-	-	-
Highlands & Islands	HIGH101	Openreach	1	1,138	34,981	21,504	19	10,948	11,683
Isle of Wight	IOFW101	Openreach	1	57	3,035	2,152	0	1,278	1,178
Kent	KENT101	Openreach	1	1,925	25,332	16,789	130	11,073	10,363
Kent	KENT201	Openreach	2						
Kent	KENT202	Openreach	2	234	4,107	2,683	6	601	1,422
Lancashire	LANC101	Openreach	1	1,322	24,219	15,598	72	10,520	10,143
Lancashire	LANC201	Openreach	2	78	1,812	1,088	6	343	532
Leicestershire	LEIC101	Openreach	1	1,322	24,219	15,598	72	10,520	10,143
Leicestershire	LEIC201	Openreach	2	78	1,812	1,088	6	343	532
Leicestershire	LEIC202	Openreach	3	-	-	-	-	-	-
Lincolnshire	LINC101	Openreach	1	1,744	33,284	20,674	75	14,290	12,712
Lincolnshire	LINC201	Openreach	2	150	3,602	2,380	9	370	952
Merseyside	MERS101	Openreach	1	446	7,674	4,169	97	3,862	2,937
Newcastle	NCST101	Openreach	1	94	1,349	797	15	567	614
Norfolk	NORF101	Openreach	1	1,004	32,439	22,589	36	14,192	14,721
Norfolk	NORF201	Openreach	2	211	9,139	6,636	5	1,623	3,439
Norfolk	NORF202	Openreach	3	-	-	-	-	-	-
North Lincolnshire	NLNC101	Openreach	1	370	5,131	2,985	51	2,721	2,184
North Lincolnshire	NLNC201	Openreach	2	70	1,457	658	23	650	390
North Yorkshire	NYRK101	Openreach	1	1,770	21,838	15,317	74	9,763	10,402
North Yorkshire	NYRK201	Openreach	2	274	4,767	3,079	22	1,226	1,529
North Yorkshire	NYRK202	Openreach	3	-	-	-	0	0	0
Northamptonshire	NTNS101	Openreach	1	797	10,361	6,381	48	5,399	4,561
Northamptonshire	NTNS201	Openreach	2	253	3,983	2,596	20	910	1,654
Northamptonshire	NTNS202	Gigaclear	3	14	274	218	3	87	134
Northamptonshire	NTNS203	Gigaclear	3	12	111	140	2	48	68
Northern Ireland	NIRE101	Openreach	1	567	10,004	5,989	57	3,202	2,746
Northern Ireland	NIRE201	Openreach	2	511	8,798	7,544	21	1,576	3,259
Northumberland	NTHM101	Openreach	1	605	8,524	5,767	21	3,499	3,635
Northumberland	NTHM201	Openreach	2	68	1,910	1,455	1	264	512
Nottinghamshire	NOTT101	Openreach	1	0	10,397	5,413	54	5,461	3,950
Nottinghamshire	NOTT201	Openreach	2	0	5,132	2,730	21	1,561	1,254
Nottinghamshire	NOTT202	Openreach	3	0	1	2	0	0	0

Oxfordshire	OXFD101	Openreach	1	1,268	15,719	9,887	132	7,647	7,058
Oxfordshire	OXFD101a	Openreach	2	-	-	-	-	-	-
Oxfordshire	OXFD202	Openreach	3	1	23	9	0	19	4
Oxfordshire	OXFD204	Airband	3	-	-	-	-	-	-
Rest of Scotland	SCOT101	Openreach	1	7,509	121,922	80,100	753	43,566	49,146
Rutland	RUTL101	Openreach	1	101	1,299	998	5	804	755
Rutland	RUTL201	Openreach	2	15	292	142	1	102	101
Rutland	RUTL202	Openreach	2	6	169	94	0	30	39
Shropshire	SHRP101	Openreach	1	891	12,404	7,118	37	4,549	4,317
Shropshire	SHRP201	Openreach	2	69	957	926	0	103	386
Shropshire	SHRP202	Airband	3	127	1,616	1,109	17	490	581
South Yorkshire	SYRK201	Openreach	2	980	16,060	11,015	84	3,604	7,469
South Yorkshire	SYRK202	Openreach	3	19	502	258	1	117	125
Staffordshire	STAF101	Openreach	1	894	16,007	8,810	114	7,539	6,015
Staffordshire	STAF201	Openreach	2	215	4,180	2,907	9	662	1,003
Surrey	SURR101	Openreach	1	1,146	12,372	8,655	147	6,175	5,569
Surrey	SURR201	Openreach	2	114	1,252	1,082	9	169	410
Wales	WALE101	Openreach	1	7,394	120,026	74,848	275	47,817	45,923
Wales	WALE101a	Openreach	2	-	-	-	-	-	-
Wales	WALE201	Openreach	3	19	387	251	0	121	136
Wales	WALE202	Openreach	3	22	748	356	0	332	231
Wales	WALE203	Openreach	3	16	551	389	1	208	237
Wiltshire	WILT101	Openreach	1	918	13,988	8,268	55	6,674	5,660
Wiltshire	WILT201	Openreach	2	4	81	45	2	44	37
Wiltshire	WILT202	Gigaclear	3	16	473	327	1	180	115
Wiltshire	WILT203	Openreach	3	24	566	400	2	134	138
South Gloucestershire	SGLO101	Openreach	1	225	3,053	1,892	13	1,613	1,421
South Gloucestershire	SGLO201	Openreach	2	0	1,169	816	21	241	434
South Gloucestershire	SGLO202	Openreach	3	25	260	277	2	175	265
Worcestershire	WORC101	Openreach	1	867	10,902	6,525	58	4,686	4,186
Worcestershire	WORC201	Openreach	2	281	4,285	2,742	15	930	1,314
Worcestershire	WORC202	Openreach	3	17	286	307	2	52	84
Warwickshire	WWCK101	Openreach	1	546	7,895	5,145	43	3,903	3,700
Warwickshire	WWCK201	Openreach	2	303	4,357	3,450	7	718	1,613
Warwickshire	WWCK202	Openreach	3	35	571	599	0	0	0
West Yorkshire	WYRK101	Openreach	1	546	7,895	5,145	43	3,903	3,700
West Yorkshire	WYRK201	Openreach	2	303	4,357	3,450	7	718	1,613
West Sussex	WSUS101	Openreach	1	720	9,326	5,905	45	4,283	3,867
West Sussex	WSUS201	Openreach	2	143	2,459	1,735	12	251	688
Black Country	BLAC201	Openreach	2	384	6,346	3,765	165	2,622	2,830
Telford & Wrekin	TELF201	Openreach	2	145	2,760	1,417	30	854	950
Cornwall	CORN201	Openreach	2	160	2,835	2,038	6	389	640
Cornwall	CORN202	Openreach	3	87	1,450	1,301	1	98	88
Swindon	SWIN201	UKB	2	274	3,823	2,725	54	981	1,468
West Oxfordshire	WOXF201	Gigaclear	3	110	1,488	1,119	8	524	707
Hertfordshire	HERT202	Openreach	3	-	-	-	-	-	-
Buckinghamshire	BKSR202	Openreach	3	-	-	-	-	-	-
Scottish Government	SGOV202	Openreach	3	-	-	-	-	-	-
Scottish Government	SGOV203	Openreach	3	-	-	-	-	-	-

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