Superfast Broadband Programme

State aid evaluation

Main Report

January 2023

Ipsos

Contents

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.
	Gigabit	**Gigabit broadband -** able to deliver download speeds of at least one gigabit per second (Gbps), equivalent of 1,000 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 basis.
	ISP	**Internet Service Provider** – An organisation which provides households / businesses access to the internet. ISPs do not always own the

[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

		infrastructure used to provide services, and can utilise the infrastructure owned by network providers to provide services.
Type of telecoms provider	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 / discount rate	**Weighted Average Cost of Capital** (discount rate for Openreach) - 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).
	Present Value (PV)	The current value of a future monetary value, which have been discounted (using a standard discount rate) to allow for the time value of money.
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.

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.

Executive Summary

Ipsos UK was commissioned by the Building Digital UK (BDUK) directorate of the Department for Digital, Culture, Media and Sport (DCMS) in October 2021 to undertake a second State aid evaluation of the UK National Broadband Scheme (NBS) 2016 (hereafter called the 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. In November 2011 (the earliest data that is available), Superfast Broadband connections were available to 58 percent of premises in the UK.

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).

Phase 3 of the Superfast Broadband Programme was funded under a new State aid Decision covering contracts awarded between 2016 and 2020 (State aid SA. 40720 (2016/N)). Contracts awarded under Phase 3 by early-2022 involved over £1bn[2] in committed 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.

Evaluation aims and methodological approach

The aims and objectives of the State aid evaluation of the Superfast Broadband Programme are to provide evidence to answer the seven key State aid evaluation questions, as set out in the National Broadband Scheme (NBS) evaluation plan, with a particular focus on the Phase 3 contracts:

- Question 1: To what extent has the aid resulted in increased access to a Next Generation Access (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?

[2] This figure is based on the Superfast Status Update (CORA) data

- 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 the overall benefits of the Superfast Broadband Programme to businesses 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.

This report builds on a preceding analysis undertaken in 2020 that covered all Phases of the programme (largely because delivery of Phase 3 contracts was insufficiently advanced at the time)[3]. This report focuses exclusively on the impacts of contracts funded under the 2016 to 2020 UK National Broadband Scheme.

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 NGA coverage and take-up was completed by implementing a series of econometric analysis that compared areas benefitting from the programme to other postcodes that were eligible for subsidies. 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. Econometric analysis of economic and social outcomes using areas that have received connectivity at an earlier stage and those connected at a later date have also been used (again achieving Level III on the Maryland Scientific Methods Scale).

- **Modelling of expected Internal Rates of Return:** An assessment of the 'incentive effect' provided by the subsidies for Phase 3 contracts was completed by comparing the network provider's expected Internal Rate of Return (IRR) to their Weighted Average Cost of Capital (WACC) or discount rate, before and after the award of subsidy. 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. 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 Phase 3 contract areas and their market shares between 2016 and 2022. This was completed using network provider level data compiled independently by Thinkbroadband[4]. 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.

[3] Department for Digital, Culture, Media and Sport (2021) State aid evaluation of the Superfast Broadband Programme. Available at: https://www.gov.uk/government/publications/superfast-broadband-programme-state-aid-evaluation-report-2020 (Accessed in November 2022).
[4] 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/

- **Cost benefit analysis:** A cost-benefit analysis of the programme was also completed to explore issues relating to the cost effectiveness of Phase 3 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[5] and the approaches put forward for valuing economic and non-market impacts. Full details of this analysis are set out in Technical Appendix 3.

- **In-depth research with network providers:** The evaluation was supported by a programme of in-depth research with 14 telecommunication companies (including direct beneficiaries of the programme, other network providers 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 current conditions in the telecommunications market, the progress made in delivering the Superfast Broadband contracts and the impact the programme has had on beneficiaries and the wider market.

Key findings

The key findings 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 a NGA network being deployed in 'white' NGA areas?

Subsidised coverage through Phase 3 of the Programme led to a significant positive impact on the availability of superfast and gigabit capable broadband services by the end of September 2021. Subsidised coverage increased the share of premises in the programme area able to access superfast speeds by 44 to 48 percentage points, and the share of premises with gigabit capable coverage by 43 to 59 percentage points. The impact of the programme on NGA availability was relatively small, however, indicating that in its absence, most premises would have benefitted from some form of enhanced connectivity (albeit via technologies less able to deliver download speeds of 30Mbit/s or higher). These findings are consistent with prior research into the impacts of the programme on broadband coverage.

Estimates of the overall number of additional premises benefitting from NGA, superfast and FTTP/Gigabit capable availability by September 2021 showed that:

- **NGA coverage:** The programme is estimated to have led to 50,000 to 117,000 additional premises with NGA coverage (with a larger estimate of 117,000 premises derived from panel models considered implausibly large given the observed trends in 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 7 and 17 percent, with most estimates towards the lower end of this range. This implies that to a large degree, premises benefitting from the Superfast Broadband Programme would have received some form of NGA coverage in its absence.

- **Superfast availability:** The Programme is estimated to have increased the number of premises that can access superfast broadband services (30Mbit/s or above) by 202,000 to 247,000 by the end of September 2021. The associated rate of additionality ranges from 69 percent to 85 percent. This indicated that while many premises may have received NGA coverage in the absence of the

[5] 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

Programme, these premises would not have been able to access at least superfast speeds (indicating the programme has been highly effective in delivering against its primary objective).

- **FTTP/Gigabit capable coverage:** Subsidised coverage is estimated to have led to 193,000 to 298,000 additional premises with FTTP/Gigabit capable coverage. The rate of additionality ranges from 66 percent to 102 percent (with most estimates in the region of 90 percent). This indicates that the programme has also been highly effective in bringing gigabit capable technologies to rural areas, and these areas were highly unlikely to have benefitted from commercial deployments over the time horizons considered in this evaluation.

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 led to a significant increase in the maximum download speeds of connections taken by households and/or businesses by September 2021 (34 to 60 Mbit/s). However, the impacts of the programme on average download speeds were relatively small. This indicates that 'early adopters' have taken advantage of the enhanced broadband connectivity enabled by the Programme. However, the Programme had not led to widespread take-up of faster broadband services by September 2021. It should be noted that most subsidised coverage was delivered in 2019 and 2020. As take-up will lag deployment, it is premature to draw any firm conclusions on the impact of the programme on take-up of faster internet services. Again, this is consistent with prior research into the impacts of the programme on take-up.

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. Network providers project an average IRR of -2.7 percent in the absence of subsidies at the tendering stage, they are now expected to generate an average IRR of between -5.4 percent and -8.1 percent. This highlights that subsidies would almost certainly be needed to stimulate investments in gigabit capable network deployment in these areas. This is also consistent with the high rates of additionality associated with gigabit capable networks described in the preceding chapter (i.e. network providers were highly unlikely to roll out similar investments in the absence of public subsidies).

The expected IRR was 7.9 percent with subsidies at the tendering stage and are projected to fall to between 2.9 percent and 5.5 percent based on evidence on actual build costs and take-up. These rates of return are lower than the network provider's discount rate, indicating that BDUK has avoided the risk of providing excess subsidies to network providers (as for Phases 1 and 2 of the programme). This also suggests that contracts would be unprofitable even with public funding. This could be explained if the network provider considered future profitability beyond the clawback period (from which all profits made would be retainable by the supplier). Given the dominant position of the network provider in question, economic losses may also have been tolerable if they were able to subsidise network deployment via revenues earned from customers in other areas.

The clawback mechanism helped prevent network providers earning excess returns and limited the public contribution to the minimum needed to ensure the commercial viability of network deployments in Phases 1 and 2. However, in the case of Phase 3 contracts, the clawback mechanisms has reduced the expected IRRs further to between -1.2 percent and -3.6 percent (increasing the size of the economic losses earned by network provider). This raises possible questions regarding the commercial sustainability of the network build, although revenues are expected to exceed to operating costs in the longer run.

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 2022. Openreach dominates the market, representing more than three quarters of the broadband market. The other beneficiaries of the Superfast Broadband Programme represented less than one percent of the market in all years.

The market share for Openreach across Superfast contract areas however declined between 2016 and 2022, from around 97 to 85 percent of all broadband connections. While this is higher than the national average (between 70 and 80 percent), the decline in market share aligns with the national trends for Openreach.

In areas where Openreach have delivered contracts, they have maintained their market share between 2016 and 2022 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 80 percent of internet connections in 2022. Fibre to the Cabinet (FTTC) connections represented the largest proportion of NGA connections in all years (around a third of all broadband connections in 2016 and just over a half in 2020 and 2022). As with the national pattern, FTTC is the dominant technology for NGA connections, representing most of the connections in Phase 3 areas – however, this percentage is lower than the national average (around 40 percent in 2022 in Phase 3 areas compared to 50 percent nationally). FTTP connections represent a higher proportion of the market in Phase 3 areas than nationally in 2022 (24 percent in 2022 compared to 10 percent nationally). This suggests that the take-up of FTTP connections nationally is lower than take-up in Phase 3 areas – which would be expected given that the Phase 3 Superfast Broadband contracts are required to provide gigabit capable networks, and the majority of contracts are doing this through FTTP technologies.

The number of infrastructure providers operating on the postcodes benefitting from subsidised upgrades increased between 2016 and 2022. Although there has been an increase in the number of network providers offering services in Phase 3 areas, most non-beneficiary network providers tended to provide services to only a small number of postcodes within the Phase 3 project areas. This suggests there has not been a large degree of overbuild or crowding out of investment.

The number of ISPs operating in Phase 3 areas has increased between 2016 and 2020, but decreased by 2022. There are a higher number of ISPs with customers in Phase 1 contract areas than Phase 2 and Phase 3. This is unlikely to be due to ISPs stopping providing services to a particular area but continuing elsewhere, and could be a function of a small intervention area where individuals are satisfied with their internet connection, and therefore do not undertake a speed test.

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

The gross public sector cost per additional covered premises over three years was £1,418 for Phase 3 contracts. After allowing for clawback, this will fall to £1,225 to £1,276 per premises passed (depending on whether take-up stabilises at 60 or 85 percent in the long-term).

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[6]. However, it should be noted that the cost per premise passed for these European programmes will be dependent on the type of infrastructure investments made to reach premises, and this information was not available.

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

None of the Phase 3 contracts currently listed on the Superfast Status Report 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 six contracts have been terminated. All of these contracts were awarded and terminated by the same Local Body and were awarded to two beneficiaries. These contracts were terminated by the Local Body, due to the inability of the beneficiaries (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 now close to the maximum expected at PFM stage and has caught up following a slow start to delivery.

Wider economy effects

The present value of net public spending required to deliver the Superfast Broadband Programme over the lifetime of Phase 3 contracts was estimated to be £273m in nominal terms.

The findings of the evaluation indicate that the programme has led to a range of economic and social benefits in the areas benefitting from Phase 3 coverage between 2016 and 2021. The key results included:

- **Local employment impacts:** Subsidised coverage from Phase 3 was estimated to have increased employment in the areas benefitting from the programme by 0.88 percent, leading to the creation of 6,261 local jobs by March 2021. The programme as a whole was estimated to have led to 23,700 more local jobs up to March 2021.
- **Turnover:** Subsidised coverage also increased the turnover of firms located in the areas benefitting from Phase 3 of the programme by 1.6 percent by 2021, increasing the annual turnover of local businesses by £827m per annum. Estimates for the whole programme suggested that turnover of firms in areas benefiting from coverage increased by 1.4 percent (equating to around £2.6bn).
- **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 –

[6] 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

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 from Phase 3 coverage rose by 0.42 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 0.17 percent by 2021, indicating that subsidised coverage has also raised the efficiency of firms. It should be noted that while subsidised coverage had a stable effect on turnover, impacts on employment increased with time. This led to the strength of the gains in turnover per worker appearing to decay 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 between 0.6 and 0.8 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 9.8 for every 10,000 premises upgraded.

- **House prices:** The programme led to an increase in house prices (of between £1,900 and £4,900) 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:** Phase 3 is estimated to have led to a cumulative total of £7.2m in productivity gains between 2016/17 and 2021/22. This rises to between £20.8m and £23.1m over the 2016/17 to 2030 period. Additional economic benefits from the reduction in long-term unemployment is estimated to be £5.5m between 2016/17 and 2021/22, rising to between £15.7m and £17.4m over the 2016/17 to 2030 period.

- **Social benefits:** Based on its impacts on house prices between 2016/17 and 2021/22, the programme is estimated to have led to social benefits valued at between £370.3m and £946.9m.

The estimated Benefit to Cost Ratio (BCR) was between £1.76 and £4.57 per £1 of net lifetime public sector costs based on its impacts between 2016/17 and 2021/22. This assumes that the house price premium is a reasonable approximation of the average welfare gain associated with the programme, and that the house price premium can be applied to all premises in the upgraded areas. The width of the range is driven largely by modelling uncertainty regarding the size of the house price premium associated with subsidised coverage. Allowing for future economic benefits to 2030, the BCR is estimated to rise to between £1.87 and £4.70 per £1 of net public sector spending.

However, it is possible that the house premium overstates the average welfare gain associated with enhanced broadband connectivity. Therefore, a lower bound estimate was derived by assuming the house price premium only provided a reasonable approximation of the welfare gains associated with the programme in cases where houses were sold after the premises was upgraded (114,162). The BCR for the lower bound estimate is between £0.78 and £1.97 per £1 of net lifetime public sector costs between

2016/17 and 2021/22, and between £0.89 and £2.11 per £1 of net public sector spending allowing for economic benefits to 2030.

1 Introduction

Ipsos UK was commissioned by the Building Digital UK (BDUK) directorate of the Department for Digital, Culture, Media and Sport (DCMS) in October 2021 to undertake a second State aid evaluation of the UK National Broadband Scheme (NBS) 2016 (hereafter called the Superfast Broadband Programme).[7] This document presents the final State aid evaluation report, examining the impacts of the programme between 2016 and 2022.

1.1 Description of the 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. In November 2011 (the earliest data that is available), Superfast Broadband connections were available to 58 percent of premises in 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 (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).

Phase 3 of the Superfast Broadband Programme was funded under a new State aid Decision covering contracts awarded between 2016 and 2020 (State aid SA. 40720 (2016/N)). Contracts awarded under Phase 3 by early-2022 involved over £1bn[8] in committed 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.

1.2 Aims and objectives of the evaluation

The aims and objectives of the State aid evaluation of the Superfast Broadband Programme are to provide evidence to answer the seven key State aid evaluation questions, as set out in the National Broadband Scheme (NBS) evaluation plan, with a particular focus on the Phase 3 contracts:

- Question 1: To what extent has the aid resulted in increased access to a Next Generation Access (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?

[7] The previous State aid evaluation report is available at: https://www.gov.uk/government/publications/superfast-broadband-programme-state-aid-evaluation-report-2020

[8] This figure is based on the Superfast Status Update (CORA) data

- 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?
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- 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 the overall benefits of the Superfast Broadband Programme to businesses 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.

This report builds on a preceding analysis undertaken in 2020 that covered all Phases of the programme (largely because delivery of Phase 3 contracts was insufficiently advanced at the time)[9]. This report focuses exclusively on the impacts of contracts funded under the 2016 to 2020 UK National Broadband Scheme.

1.3 Method

The methodology used to undertake the State aid evaluation of the Superfast Broadband Programme follows the requirements set out in the UK NBS evaluation plan[10] 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 availability of the data required to undertake the analysis foreseen. These limitations are set out in Section 1.4 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 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 for Phase 3 contracts was completed by comparing the network provider's expected

[9] Department for Digital, Culture, Media and Sport (2021) State aid evaluation of the Superfast Broadband Programme. Available at: https://www.gov.uk/government/publications/superfast-broadband-programme-state-aid-evaluation-report-2020 (Accessed in November 2022).
[10] 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 November 2020)

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 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. 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 Phase 3 contract areas and their market shares between 2016 and 2022. This was completed using network provider level data compiled independently by Thinkbroadband[11]. 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 Phase 3 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[12] 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:** The evaluation was supported by a programme of in-depth research with 14 telecommunication companies (including direct beneficiaries of the programme, other network providers 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 current conditions in the telecommunications market, the progress made in delivering the Superfast Broadband contracts and the impact the programme has had on beneficiaries and the wider market. Interviews were transcribed and analysed, with perspectives offered validated against the objective evidence available from monitoring information where possible. Key findings were also validated by key BDUK officials responsible for the design and delivery of the programme.

[11] 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/

[12] 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

1.4 Outcomes and how they have been measured, over what period

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 1.1: 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 2016 to September 2021
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 2016 to September 2021 June 2016 to September 2021
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 (WACC) / Discount rate	Modelling based on Project Financial Models (PFMs), observed costs (Finance Trackers), and reported take-up (C3 reports)	January 2016 to September 2021
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	2016 to 2022
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	2016 to 2022
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)	Observed costs (Finance Trackers), and reported take-up (C3 reports) and qualitative findings	N/A

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

1.5 Limitations

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 yet to be completed. Much of the data on which the evaluation is based was also only available to September 2021. Just over half (52 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.

- **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. 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-2021 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). The COVID-19 pandemic may also have had some negative impacts, such as the beneficiaries ability to deliver upgrades (although telecommunications providers did not think this was a substantial issue) and on wider economic performance.

- **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 Table 1.2 below. These changes were communicated to the European Commission by the BDUK Benefits and Evaluation team in May and October 2020.

Table 1.2: Unavailable data sources and alternatives used

Intended data source	Alternative data source	Key differences
It was anticipated that Ofcom would provide premises level data on NGA coverage between 2016 and 2020 (relevant to Q1 and Q2).	Ofcom Connected Nations report September 2021.	The data runs to September 2021 and is only available at postcode level. Analyses have lower spatial resolution and cover a less extensive period than envisaged. However, as sample sizes are substantial, this does not limit the statistical precision.
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 projects in Phase 3 had all the required information to calculate IRRs.	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. 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 and qualitative information	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.

1.6 Structure of report

The remaining sections of this report are structured as follows:

- Section 2 provides an overview of the Superfast Broadband Programme, the analytical framework deployed in the evaluation and the delivery of the programme at the point of the analysis taking place;
- Section 3 outlines the evidence of the effectiveness of the Superfast Broadband Programme;
- Section 4 details the evidence of the direct impacts of the Superfast Broadband Programme on programme beneficiaries;
- Section 5 presents the evidence of the indirect impacts of the Superfast Broadband Programme on programme beneficiaries;
- Section 6 shows the wider economic effects of the Superfast Broadband Programme on businesses and households;
- Section 7 describes the evidence of the proportionality and appropriateness of the intervention; and
- Section 8 summarises the key conclusions from the evaluation.

2 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.

2.1 Superfast Broadband Programme

The first Ofcom Infrastructure report in November 2011 showed that 58 percent of UK households had access to Next Generation Access broadband services capable of delivering superfast broadband speeds (download speeds exceeding 30Mbps)[13]. NGA technologies encompass the installation of fibre-optic networks to connect the telephone exchange to the cabinets serving customers (Fibre-to-the-Cabinet) or to their premises (Fibre-to-the-Premises), 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, although the areas targeted were still those that were not expected to be reached by commercial deployment of superfast broadband. 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.

2.2 Theory of Change

This section sets out an overarching theory of change for the programme based on the frameworks developed for prior studies, which are set out in more detail in Technical Annex 3. The theory of change has been augmented to consider how the programme's impacts may have been conditioned by the

[13] Ofcom (2011) Communications and Infrastructure report 2011. Available at: https://webarchive.nationalarchives.gov.uk/ukgwa/20200803095351/https:/www.ofcom.org.uk/research-and-data/multi-sector-research/infrastructure-research (Accessed October 2022). In 2011, Ofcom used 24 Mbps as the Superfast speed threshold – see footnote 1 in the Ofcom report.

COVID-19 pandemic as well as broader contextual changes in the wider broadband market (explained further below).

2.2.1 Infrastructure Effects

The first order effects of the programme will be primarily in terms of the additional superfast broadband infrastructure brought about by subsidies by BDUK and associated increases in available speeds. The extent of these effects will be determined by a number of factors:

- **Additionality:** Making subsidies available for infrastructure delivery involves a risk that private sector providers face an incentive to seek public funds for investments that they would have made anyway (enabling them to earn higher rates of return). The extent to which the Superfast Broadband programme will produce an increase in superfast broadband availability will depend on the effectiveness of the mechanisms used to allocate public resources to infra-marginal schemes (i.e. upgrades to cabinets that would not have been deemed by suppliers to be commercially viable without a public subsidy). The programme involves a number of processes that are designed to maximise the extent to which public funding is directed at marginal activity:

  - **Allocation of subsidies:** Subsidies were allocated to local authorities on the basis of an ex-ante assessment (by BDUK) of the gap funding requirement 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 on the basis of the gap funding needed to reach the 95 percent coverage at the lowest cost (maximising the number of premises covered for the available subsidy[14]). There was an aspiration that local authorities would match BDUK resources with local funds on a 1:1 basis (including their own funds, ERDF funding and the Local Growth Fund). A number of local authorities were deemed ineligible for BDUK support on the basis that existing commercial plans were already extensive.

  - **Open Market Review and public consultation:** Local authorities were required to manage an Open Market Review process and public consultation process before they issued tenders (under Phase 1 and 2 of the scheme), and this process was repeated for Phase 3 of the Programme. The first stage of this process involved local authorities requesting suppliers of broadband services to describe their commercial plans to roll-out basic and superfast broadband coverage over a defined time window. This resulted in an initial identification of postcodes where there were no commercial plans to roll-out superfast broadband ('white' postcodes), postcodes where one provider was offering or expected to offer superfast broadband services ('grey' postcodes), and postcodes where multiple providers were offering or expected to offer superfast broadband ('black' postcodes). There was a subtle change in the process for Phase 3, where suppliers were asked to provide data at a premises level, rather than at a postcode level (as was the case in

[14] However, under initial calculations, this would have resulted in 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 and Wales in the manner suggested.

Phase 1 and 2). The view on future superfast broadband availability provided by the suppliers was then subject to public consultation to refine this view.

- **Tendering:** This view of the future trajectory of the local broadband availability was expressed in the form of a Speed and Coverage Template which accompanied a tendering exercise in which local authorities sought to procure additional investment in upgrading the local telecommunications infrastructure (either through a framework of suppliers established by BDUK or via an Official Journal fi the European Union (OJEU) process[15]). Only 'white' postcodes were eligible for subsidised infrastructure, with competing suppliers outlining which postcodes (and premises in Phase 3) they proposed to cover for the available funding. Suppliers were required to provide a project financial model, which included estimates of the overall costs associated with delivering the project, and take-up assumptions (determining expectations of future revenues), which determined the overall level of subsidy to be offered.

- **Underspend:** Protections for the public sector against the risk that suppliers overestimated their delivery costs were put in place through the introduction of a mechanism to recover any underspend. The principle underlying contracts was that the supplier paid first, then BDUK and lastly local authorities. In the event of any underspend, funds are returned to local authorities and BDUK through a clawback mechanism (the supplier could opt to place these funds in an 'investment fund' during Phase 1 and 2 of the Programme to help resource further schemes or extend the contract coverage to a greater number of premises than originally offered – during Phase 3 overclaimed funds were paid back to the local authority).

- **Gain-share:** Further protections for the public sector were introduced through gain-share clauses in contracts. If take-up proved to be higher than anticipated at the tendering stage, then suppliers are required to return a share of the excess revenues to BDUK.

- **Impact of COVID-19:** COVID-19 may have altered the economics of investments in broadband technologies. On the one hand, the introduction of social distancing arrangements led to an increase in demand for data amongst households as many shifted to more remote working arrangements. This may feed through into greater demand for faster broadband services, improving the commercial viability of investments in the deployment of superfast and gigabit capable networks. This could reduce the additionality of some investments supported by the programme. At the same time, frictions and supply issues caused by COVID-19 could also increase the costs of deployment (although stakeholders consulted as part of the familiarisation process indicated that network providers had generally managed these effectively).

- **Vibrancy of the broadband market:** Stakeholders engaged in familiarisation consultations also highlighted that over the course of Phase 3 of the programme, the broadband market has become increasingly vibrant. Openreach, Virgin Media, as well as several alternative network providers have begun to invest in the deployment of FTTP networks and other gigabit capable technologies. These investments have been concentrated in the urban centres where network providers are expected to earn the greatest returns, and there is a risk that this reduces the attractiveness of

[15]OJEU process refers to a procurement which is advertised through the OJEU.

network build in rural areas owing to the opportunity costs associated with prioritising projects only expected to earn a marginal return.

However, these trends could also increase the additionality of coverage brought forward with BDUK investment to the degree that subsidies have diverted investment from urban centres (allowing rural areas to benefit from gigabit capable technologies much more rapidly than they may otherwise have done). Stakeholders also highlighted that Phase 3 of the programme may also lead to spill-over effects as the deployment of gigabit capable networks in rural areas has reduced the marginal costs of extending those networks to nearby areas. This could lead to some areas receiving gigabit capable coverage more rapidly than they would have otherwise done in the absence of the programme as network providers plan their rollout.

- **Supplier behaviour during Open Market Review process:** Some suppliers may see an incentive to understate their commercial plans during the Open Market Review process to increase the likelihood they are able to secure a subsidy for activity they saw as not commercially viable without subsidy. Discussions with BDUK suggested, however, there may be disincentives for this type of behaviour in that an understatement of commercial plans may risk the emergence of a subsidised competitor and, indeed, qualitative interviews with suppliers suggested that there was suspicion that some suppliers were using the Open Market Review process to overstate their commercial plans to protect themselves from these types of risk and preserve local monopolies. Given that the Open Market Review process offered a market signal to both businesses and households regarding the likely future availability of superfast broadband, any effects of this nature may have negative economic consequences through the misallocation of private sector development/resources to areas in which superfast broadband did not ultimately emerge.

The process evaluation completed as part of the previous State aid report highlighted some of the issues caused by the static nature of the Open Market Review process, in that it only captures commercial deployment plans at a point in time. This has been reviewed for the roll-out of Project Gigabit (which can be seen as a successor programme to the Superfast Broadband Programme). However, stakeholders consulted during the familiarisation stage indicated that, owing to the growth of interest in gigabit capable technologies, some network providers have extended their commercial roll out plans to some areas in the build plans of Phase 3 contracts. This has required some premises to be 'descoped,' creating some efficiency issues and a risk that in some cases, subsidised networks could be overbuilt by commercial deployments more rapidly than originally anticipated.

- **Supplier behaviour during the tendering process:** The underspend and gainshare mechanisms of the contract should, in principle, have eliminated systematic incentives for suppliers to overstate the gap funding requirement (since any overstatement of costs at the tendering stage would be recovered via the underspend clawback mechanism[16], and any understatement of future revenues would be recovered via the gain-share mechanism). Understating expected costs or overstating take-up expectations would result in the supplier ultimately taking a loss.

Stakeholders also highlighted possible ex-post risks arising from the potential impacts of Openreach's Equinox pricing product (explained in more detail in Section 2.3.3 below), and fears that this could

[16] Unless subsidies encourage less efficient delivery.

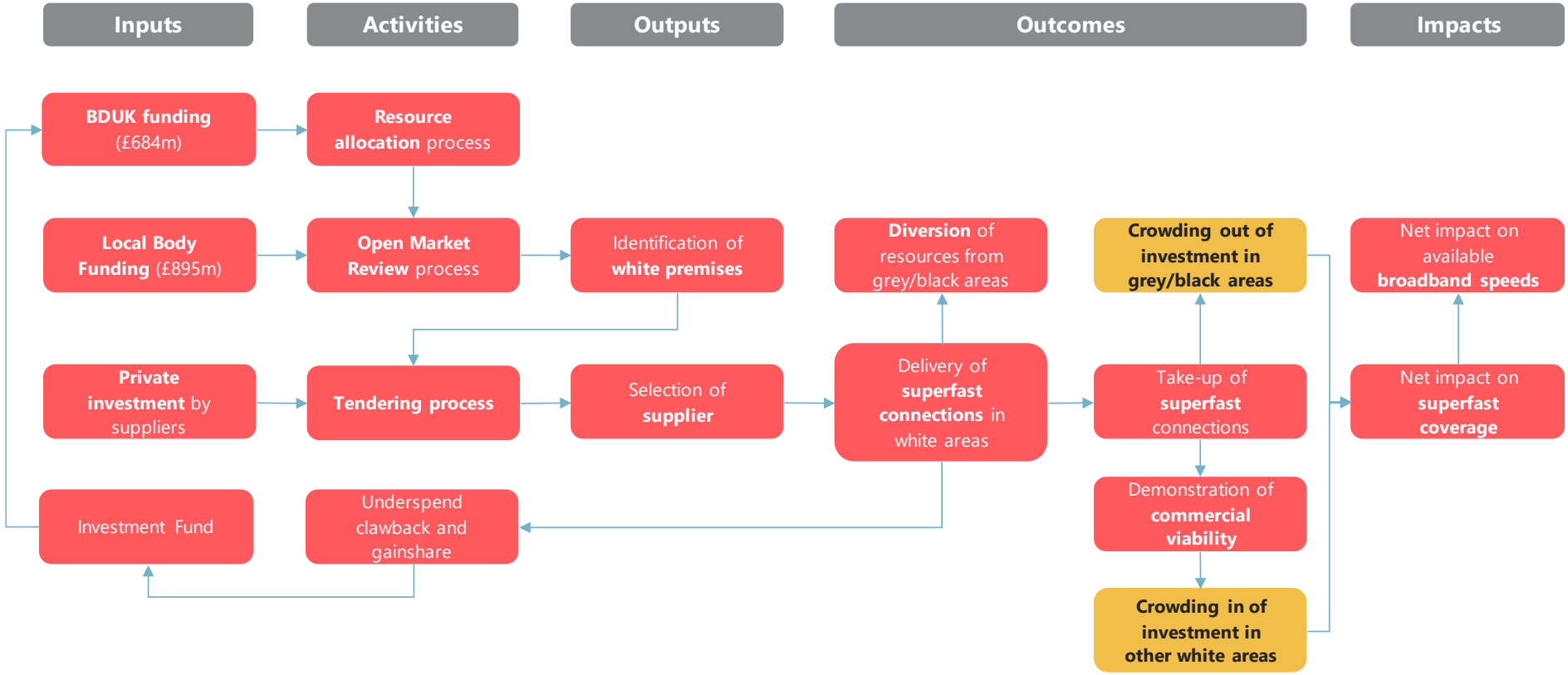
reduce revenues earned on investments in the deployment of gigabit capable technologies. The risk here is that gap funding awarded through the programme does not prove sufficient to make the investments in broadband deployment commercially viable in practice, leading to possible issues with commercial sustainability.

- **Crowding out:** The provision of subsidies for superfast broadband investment may have had a negative impact on other areas if suppliers face resource constraints – either in the labour market or in financial 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 in 'grey' or 'black' areas (partly offsetting the effects of the programme in 'white' areas).

- **Variability across space and time:** The pattern of effects of the programme could be expected to vary across areas with different characteristics. On the presumption that the supplier installation decision can be simplified to a basic NPV criterion, then it might be expected that local variability in the effects of the programme will be driven largely by factors determining the cost of installation and maintenance (such as local topography, characteristics of the local network – such as the prevalence of exchange only lines, distance from regional population centres) and demand for the technology (e.g. incomes of households, the industrial structure of the local economy, or the speed of existing broadband services). These factors are also unlikely to be static over time (technological progress may result in reductions in the cost of installation, while demand for higher speeds may rise as more data intensive applications emerge).

This process is summarised in the logic model below.

Figure 2.1: Logic Model – Infrastructure Effects of the Superfast Broadband Programme



2.2.2 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. This report does not cover all anticipated benefits of the programme – for example, environmental benefits have been considered out of scope at this stage. 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).

2.3 Context

This section outlines the key context in which the Superfast Broadband operates and some recent developments in the broadband market that have the potential to influence the outcomes of the programme.

2.3.1 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.[17]

- 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;
- Gigabit broadband, able to deliver download speeds of at least one gigabit per second (Gbps), equivalent of 1,000 Mbps.

The 2021 Connected Nations[18] report illustrated that the UK Government target of 97 percent coverage of at least SFBB by 2020[19] had been reached.[20]

2.3.2 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 34 percent), Sky (23 percent), Virgin Media (20 percent), and TalkTalk (10 percent).[21] In addition to these, there are regional network providers such as KCOM, or

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

[18] Ofcom (2021). Connected Nations 2021 UK Report. Available at: https://www.ofcom.org.uk/research-and-data/multi-sector-research/infrastructure-research/connected-nations-2021 (Accessed November 2022).

[19] Although this was a UK Government target, it was not a stated objective for the Superfast Broadband Programme – rather the Programme was used to help the UK Government achieve this aim.

[20] 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.

[21] Ofcom (2022) The Communications Market 2022. Available at: https://www.ofcom.org.uk/research-and-data/multi-sector-research/cmr/the-communications-market-2022 (Accessed October 2022).

full-fibre service providers such as Hyperoptic and Gigaclear, and small network providers in rural areas (providing broadband services based on satellite or mobile technologies), which together have a market share of approximately 14 percent.

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 which reached around 91 percent of all UK premises in 2018 (the majority of this being provided by Fibre to the Cabinet (FTTC) connections, with Fibre to the Premises (FTTP) increasing in recent years). 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.

Virgin Media is the third-largest provider and the main competitor of Openreach in terms of broadband infrastructure, and in 2017 reached around 50 percent of all households.[22] Follo29wing recent upgrades of its network, most of the premises connected to Virgin Media's network should be able to access gigabit capable speeds.[23]

Investment in the market

Increased competition is evident in investments made in companies providing fibre broadband networks. Many fibre network providers have received substantial financial investments in recent years to build new fibre broadband networks. Examples of this include:

- Connectfibre receiving "significant" investment in March 2022;[24]
- Lightspeed Broadband receiving a cumulative total of £115 million investment by December 2021;[25]
- Truespeed receiving £75 million in January 2022;[26]
- Borderlink receiving a cumulative £174.5 million investment by January 2022;[27]
- Toob receiving £87.5 million in December 2021;[28]
- Zzoomm securing £100 million debt investment in October 2021;[29]

[22] Ofcom (2022). Communications Market Report 2022. Available at: https://www.ofcom.org.uk/research-and-data/multi-sector-research/cmr/the-communications-market-2022/communications-market-report-2022-interactive-data (Accessed November 2022).
[23] Ofcom (2021). Connected Nations 2021 UK Report. Available at: https://www.ofcom.org.uk/research-and-data/multi-sector-research/infrastructure-research/connected-nations-2021 (Accessed November 2022).
[24] https://www.ispreview.co.uk/index.php/2022/02/connect-fibre-get-funding-for-full fibre-rollout-in-east-of-england.html (Accessed March 2022)
[25] https://www.ispreview.co.uk/index.php/2021/12/lightspeed-broadbands-uk-fttp-rollout-gets-gbp60m-funding-boost.html (Accessed March 2022)
[26] https://www.ispreview.co.uk/index.php/2022/01/truespeed-start-2022-with-gbp100m-boost-for-uk-full fibre-rollout.html (Accessed March 2022)
[27] https://www.ispreview.co.uk/index.php/2022/01/borderlink-get-gbp164m-for-full fibre-rollout-in-north-england-and-scotland.html (Accessed March 2022)
[28] https://www.ispreview.co.uk/index.php/2021/12/toob-gets-gbp87-5m-funding-to-boost-uk-fttp-broadband-rollout.html (Accessed March 2022)
[29] https://www.ispreview.co.uk/index.php/2021/10/zzoomms-uk-gigabit-fibre-rollout-boosted-by-gbp100m-investment.html (Accessed March 2022)

- Cityfibre receiving £1.1 billion in finance in September 2021;[30]
- Digital Infrastructure (DI) launching after receiving £100 million investment in 2021;[31]
- Gigaclear securing £525 million in debt funding in 2020;[32] and
- Hyperoptic securing £750 million in two deals in 2018;[33]

Alongside this investment among alternative providers of broadband services, the larger providers of broadband networks (Openreach and Virgin Media) have also increased their investment in fibre networks. In early 2022, it was reported that Virgin Media was seeking to raise hundreds of millions of pounds of investment to support their fibre network rollout.[34] Openreach have also committed to expanding their fibre network, and in 2021 the cost of this additional roll out was estimated to be £15 billion to provide fibre coverage to 80 percent of UK premises.[35] Further to this, information from the scoping consultations suggested that BT Group were currently trying to sell BT Sport, a subscription sports channel, in order to raise capital to further invest in their fibre network.

This investment suggests that alongside the Superfast Broadband Programme network build, there is also likely to be a large volume of commercial network build occurring at the same time. As highlighted above, this could potentially have an impact on the ability of suppliers to deliver (or the level of priority given to) Superfast Broadband contracts.

2.3.3 Regulation of the telecommunications market in the UK

Ofcom

Ofcom is the National Regulatory Authority 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.[36] 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.[37]

Regulation of Openreach

Openreach Ltd is a fixed-line telecoms infrastructure company, wholly owned by BT Group. Openreach are responsible for the development and maintenance of and installations across the UK's formerly nationalised telecoms infrastructure. In 2006, Openreach was set up as a business division of BT that

[30] https://www.ispreview.co.uk/index.php/2021/09/cityfibre-secure-gbp1-1bn-to-fuel-uk-fttp-broadband-rollout.html (Accessed March 2022)
[31] https://www.digitalinfra.co.uk/latest-news/new-era-full fibre-network-operator-accesses-ps100m-investment (Accessed March 2022)
[32] https://www.ispreview.co.uk/index.php/2020/04/rural-isp-gigaclear-signs-525m-long-term-funding-strategy.html (Accessed March 2022)
[33] https://www.ispreview.co.uk/index.php/2022/02/hyperoptic-aim-gigabit-broadband-at-2-million-uk-homes-by-2023.html (Accessed March 2022)
[34] https://www.ispreview.co.uk/index.php/2022/01/virgin-media-o2-uk-reportedly-seeks-funding-for-fttp-rollout.html (Accessed March 2022)
[35] https://www.ispreview.co.uk/index.php/2021/05/bt-raise-fttp-broadband-target-to-25-million-uk-premises.html (Accessed March 2022)
[36] Ofcom (2019). Accessed at: https://www.gov.uk/government/organisations/ofcom on (Accessed November 2019).
[37] European Commission (2019). Overview. Telecommunications. Available at: https://ec.europa.eu/competition/sectors/telecommunications/overview_en.html on (Accessed November 2019).

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),[38] 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.[39] 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.[40]

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).[41]

Following an Ofcom statement in June 2019,[42] Openreach allowed access for retail service providers to their Physical Infrastructure Access (PIA) portfolio, allowing them 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.[43]

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

[38] See https://www.ofcom.org.uk/phones-telecoms-and-internet/information-for-industry/policy/digital-comms-review

[39] Ofcom (2016). Update on plans to reform Openreach. Available at: https://www.ofcom.org.uk/about-ofcom/latest/media/media-releases/2016/update-on-plans-to-reform-openreach (Accessed November 2019).

[40] Ofcom (2018). New Ofcom rules to boost full-fibre broadband, 23 February 2018. Available at https://www.ofcom.org.uk/about-ofcom/latest/media/media-releases/2018/new-rules-boost-full-fibre (Accessed November 2019).

[41] Hutton, G. (2019). BT and Openreach House of Commons Briefing Paper, Number CP 7888, 11 January 2019.

[42] Ofcom (2019). Statement: Promoting competition and investment in fibre networks – review of the physical infrastructure and business connectivity markets. Available at: https://www.ofcom.org.uk/consultations-and-statements/category-1/review-physical-infrastructure-and-business-connectivity-markets (Accessed November 2019).

[43] It should be noted that the majority of third party services are provided using LLUA/VULA mechanism, rather than through PIA.

Openreach infrastructure to a supplier's own PoP in the digital exchange (through a separate Cablelink product).[44]

Wholesale Telecoms Market Review

In March 2021, Ofcom published the Wholesale Fixed Telecoms Market Review (WFTMR), which introduced new regulation and pricing controls for the broadband market. The aim of this regulatory change was to promote competition and investment in gigabit-capable networks.[45] The key aspects of the WTFMR are:[46]

- **Access to Openreach's telegraph poles and underground ducts:** Openreach will continue to be required to allow all network operators to lay their own fibre networks using Openreach's infrastructure through its Physical Infrastructure Access (PIA) product. Different approaches to regulating Openreach's residential broadband products will be taken in different parts of the UK:
  - In competitive areas where there is established competition, Ofcom will not regulate Openreach's broadband products.
  - In areas with the potential for material competition (70 percent of UK), Openreach will continue to be required to provide wholesale access to its network.
  - In areas where Openreach is the only network provider, Ofcom have set a cost-based charge control which allows Openreach to recover the costs of both its existing copper network and its investment in a new FTTP (Fibre to the Premises) network.
- **Increase the price which Openreach is allowed to charge for FTTP broadband:** Openreach will be allowed to charge more (£1.70 per month extra) for their 40 Mbps service if it is delivered over FTTP rather than FTTC.
- **Promote network competition:** There are two main measures which Ofcom has introduced to promote network competition, which are:
  - Openreach are prohibited from offering geographic discounts on its superfast and FTTC broadband wholesale services; and
  - Openreach are required to give at least 90 days' notice of the introduction of certain commercial terms (such as volume discounts) that might prevent retail ISPs from using competing networks.
- **Provide support for Openreach in retiring its copper network:** Ofcom stated Openreach should not be penalised for having to run two parallel networks (a copper and a full fibre network), and Ofcom are supporting Openreach in the migration of customers to FTTP services. Ofcom state they will progressively transfer regulation (including price protections) from copper to FTTP services in exchange areas where fibre is available.

[44] Openreach (2019). Physical Infrastructure Access. Available at: https://www.openreach.co.uk/orpg/home/products/ductandpoleaccess/ductandpoleaccess.do (Accessed November 2019).
[45] https://www.ofcom.org.uk/phones-telecoms-and-internet/information-for-industry/telecoms-competition-regulation/the-openreach-monitoring-unit
[46] https://www.ofcom.org.uk/__data/assets/pdf_file/0022/216085/wftmr-statement-volume-1-overview.pdf

The WFTMR also introduced additional regulatory measures around leased lines, plans for regulation of the broadband market (and how their decisions will be informed) and maintaining a quality service.

Pricing in the market

A recent development (at the time of writing) in the fibre broadband market has been the introduction of the Equinox pricing offer. This pricing offer provides ISPs a discounted price to utilise Openreach's wholesale fibre network if they stop making slower broadband products (ADSL and FTTC products) to customers, encouraging customers to utilise FTTP connections. ISPs would have the discounted price available to them if at least 80 percent of their new sales were for FTTP products. This product would provide lower costs for ISPs to use Openreach's fibre network, and these savings could be passed on to the consumer, boosting take-up of FTTP connections and potentially benefitting the consumer.[47] The discounted connection charge is £25 for new-to-network connections and £50 for other connections.[48]

However, the proposed pricing offer has been challenged by many alt-nets that are currently building new fibre networks. They state that the Equinox offer provides wholesale access at a lower price than it costs to deliver the service, and that this results in an anti-competitive practice in areas where Openreach competes with alt-nets. In essence, the discount provided by Equinox means that Openreach offer a price which cannot be matched by their competitors, and this will drive the competitors out of the market leaving Openreach as the sole provider.[49]

The Equinox pricing offer was referred to Ofcom, the regulator in the broadband market. This is because Openreach are required to notify Ofcom of all pricing changes prior to introducing them, as part of the regulatory requirement from the separation of Openreach and BT. In September 2021, Ofcom published a ruling that there was no requirement for Ofcom to act on the Equinox pricing offer, and that Openreach could make this offer to ISPs.[50] Cityfibre have subsequently launched a legal challenge to the Ofcom decision on the Equinox pricing offer.[51] This challenge took place in the summer of 2022 and was dismissed by Ofcom.

2.4 Programme delivery

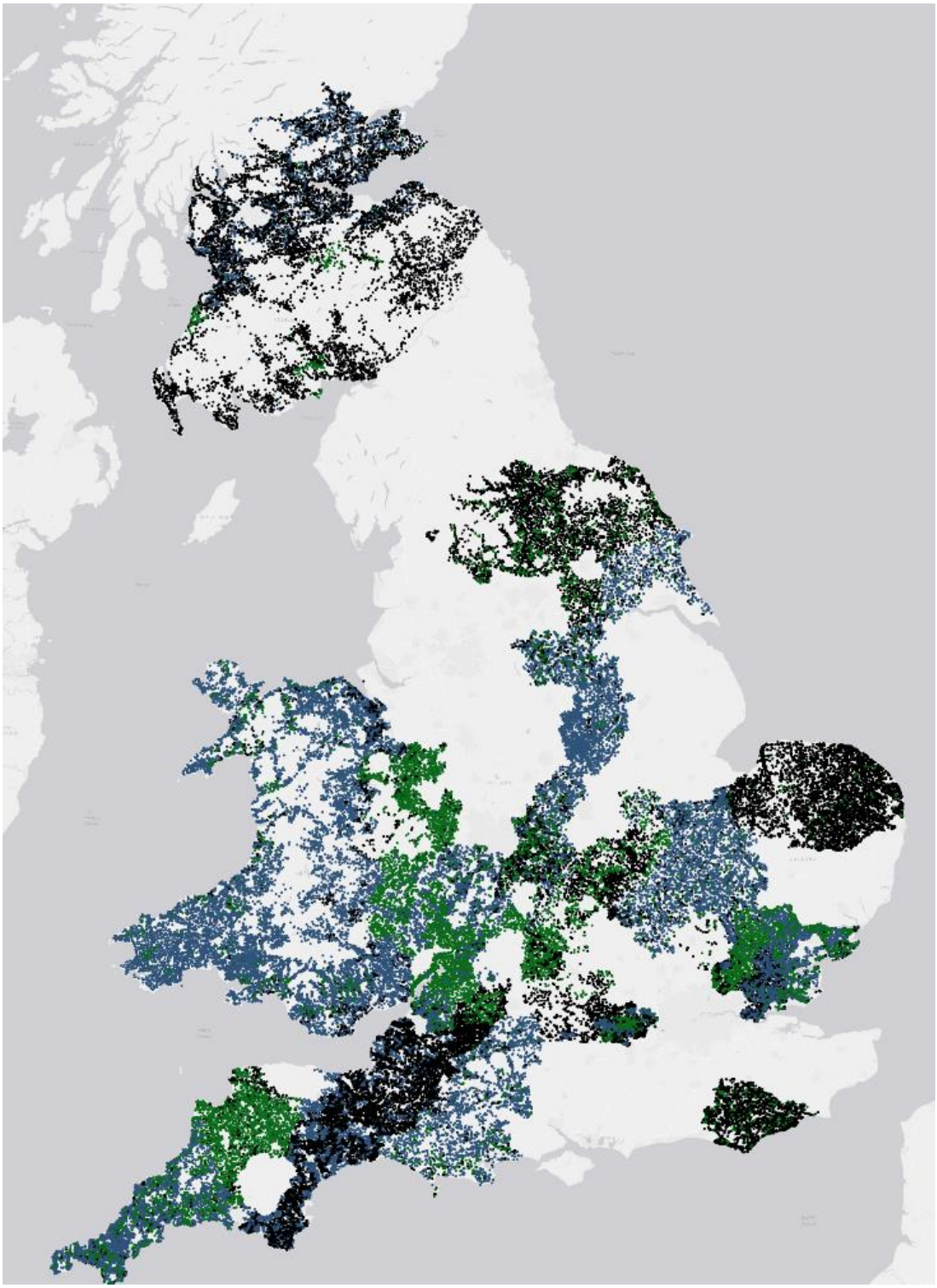
2.4.1 Target areas for Phase 3 contracts

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 identifies those premises that are not expected to receive superfast coverage under the commercial plans of network providers (white postcodes) and are therefore eligible for subsidised coverage.

These templates are completed by network providers as part of the tendering process, where they set out which premises will be upgraded as part of the proposed network build (the build plan). Premises on 64,000 postcodes were included in the build plans of Phase 3 contracts (four percent of the postcodes in the UK). Premises on 54,000 postcodes were identified as eligible for the programme but were not included in the build plans of Phase 3 contracts.

[47] https://www.ispreview.co.uk/index.php/2021/09/rivals-sigh-as-ofcom-clear-openreach-fttp-broadband-price-cut.html
[48] https://www.ofcom.org.uk/__data/assets/pdf_file/0032/222989/Equinox-condoc.pdf
[49] https://www.ispreview.co.uk/index.php/2021/09/rivals-sigh-as-ofcom-clear-openreach-fttp-broadband-price-cut.html
[50] https://www.ofcom.org.uk/__data/assets/pdf_file/0032/222989/Equinox-condoc.pdf
[51] https://telecoms.com/512541/cityfibre-challenges-ofcom-ruling-on-openreach-fttp-pricing/

Figure 2.2: Eligible postcodes inside and outside of the build plans of Phase 3



Source: SCT templates, C3 Reports, Ipsos analysis; green denotes built to as of September 2022, black is 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.

The postcodes included in the build plans of Phase 3 contracts were linked to other datasets 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 2.1. 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 in Phase 3 build plans than in 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 at least 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 (74 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 similar across groups, though average wages were lower in those areas included in Phase 3 build plans than in areas not included in 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[52] of the Programme. 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 unserved premises 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.

[52] BDUK (2018) Superfast Broadband Programme Evaluation: Annex A – Reducing the Digital Divide.

Table 2.1: Characteristics of postcodes included in Phase 3 build plans

Characteristics	Postcodes in Phase 3 build plans	Postcodes receiving subsidised coverage by Sep. 2021	White postcodes not included in Phase 3 build plans
Broadband availability and take-up in 2012			
% of postcodes with Next Generation Access	14.9	14.3	39.6
Average maximum download speed (Mbit/s) of connections[53]	9.3	10.0	13.4
Average download speeds (Mbit/s) of connections	6.2	9.7	13.9
Broadband availability and take-up in 2016			
% of postcodes with Next Generation Access	70.4	72.4	79.8
% of postcodes with superfast (30Mbit/s) access	25.2	25.2	55.6
Average number of premises on postcode with superfast connections[54]	1.7	5.1	8.1
Network characteristics in 2013			
Length of line from exchange to premises (m)	3,588	3,050	2,165
Share of premises with exchange only lines (%)	22.3	13.0	4.5
Delivery points at serving exchange	6,231	10,765	17,601
Delivery points at serving cabinet	242.7	300.5	381.0
% of postcodes in Virgin Media footprint	0.7	14.7	48.4
Number of residential delivery points	11.1	14.9	19.6
Number of non-residential delivery points	1.0	1.1	0.7
Estimated cost to upgrade serving cabinet (£)	65,549	63,939	61,834
Estimate upgrade cost per premises upgraded (£)	325.5	307.9	179.3
Area characteristics in 2013			
% of postcodes in rural areas	74	54	64
Working age population (in Output Area)	170	195	200
Population aged 65+ (in Output Area)	62	55	50
Population density in OA (population per square km)	634	1,659	4,412
Premises density in OA (premises per square km)	402	988	2569
Gross weekly earnings in LA (£)	465	537	519
Employment rate in LA (%)	71.8	74.4	71.1
Unemployment rate in LA (%)	6.1	7.1	8.2

Source: Ipsos Analysis

2.4.2 Delivery of Phase 3 contracts

Delivery of the Programme began in 2016 and analysis of C3 reports provided by BDUK indicated that around 292,618 premises received subsidised coverage by September 2021 (over 37,000 postcodes). It should be noted that most coverage was towards the latter stages of the time horizon for this evaluation.

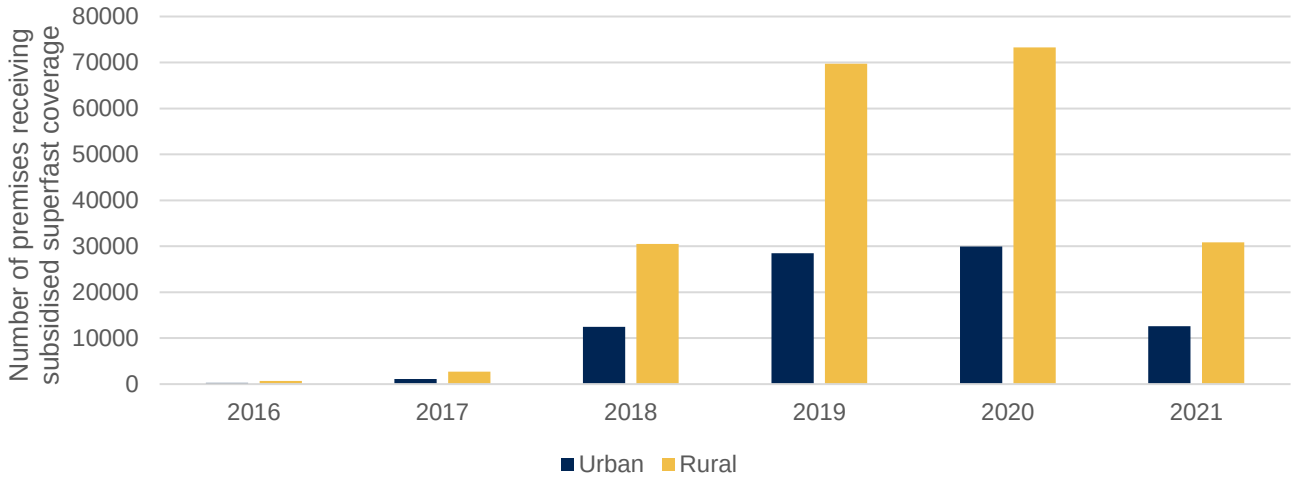
[53] Note that this does not factor in the number of premises on a postcode able to reach a certain maximum download speed

[54] There were around 11.3 premises per postcode on postcodes in the build plans of Phase 3 schemes.

Additionally, unlike prior Phases of the programme, Phase 3 contracts prioritised gigabit capable technologies with the majority of premises passed by FTTP (rather than Fibre-to-the-Cabinet).

As take-up of superfast broadband services will follow deployment, it should be noted that the estimates of the impact of the programme presented in this paper are likely to understate the eventual impact of the programme on take-up.

Figure 2.3: Number of premises receiving superfast (30Mbit/s[55]) coverage subsidised by BDUK, areas for which Phase 3 SCTs are available, 2016 to 2021



Source: C3 reports, Ipsos analysis.

[55] 24MBits for Phase 1 and Phase 2

3 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 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 with officials within BDUK. Technical details of the econometric analysis are provided in Technical Appendix 1.

3.1 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.

Table 3.1: Key outcomes

Outcome	Overview
NGA coverage	The percentage of premises able to access broadband through NGA technologies – wireless, FTTC, FTTP and Wireless. This is 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 30Mbit/s. 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/Gigabit capable coverage[56]	Phase 3 of the programme prioritised technologies capable of delivering gigabit speeds which has concentrated investment in FTTP delivery. Connected Nations data for 2020 and 2021 provided information on gigabit capable coverage, while in prior years it provided details on FTTP coverage. This broader measure includes non-FTTP technologies capable of gigabit speeds. Consultation with BDUK and Ofcom indicated that Virgin Media gigabit capable coverage accounted for much of the difference between the FTTP coverage and gigabit capable coverage (and the roll-out of Virgin Media coverage did not begin in large volumes until 2020). As such, an assumption has been made that FTTP and gigabit capable coverage were equivalent before 2020.
Number of connections of 30Mbit/s or higher	The number of households or businesses taking up a 30Mbit/s connection is a primary outcome measure defined in the State aid evaluation plan agreed between DCMS and the European Commission.

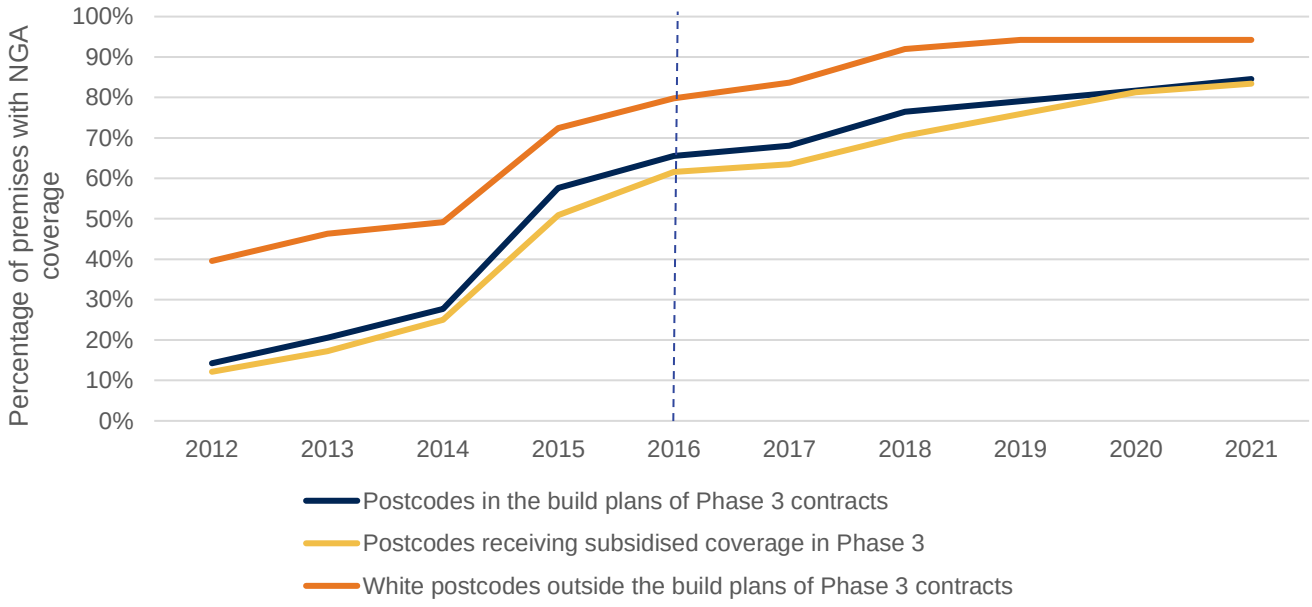
[56] A request for information on Virgin Media gigabit capable coverage in 2019 has been submitted to check our understanding.

Outcome	Overview
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.

3.2 Changes in coverage

The following figure shows changes in availability of Next Generation Access (NGA) broadband (FTTC, FTTP/Gigabit capable, Wireless or Cable) between 2012 and 2021 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 66 percent to 85 percent between June 2016 and September 2021. 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).

Figure 3.1: Changes in Next Generation Access (NGA) coverage – areas in Phase 3 build plans and other white postcodes, 2012 to 2021

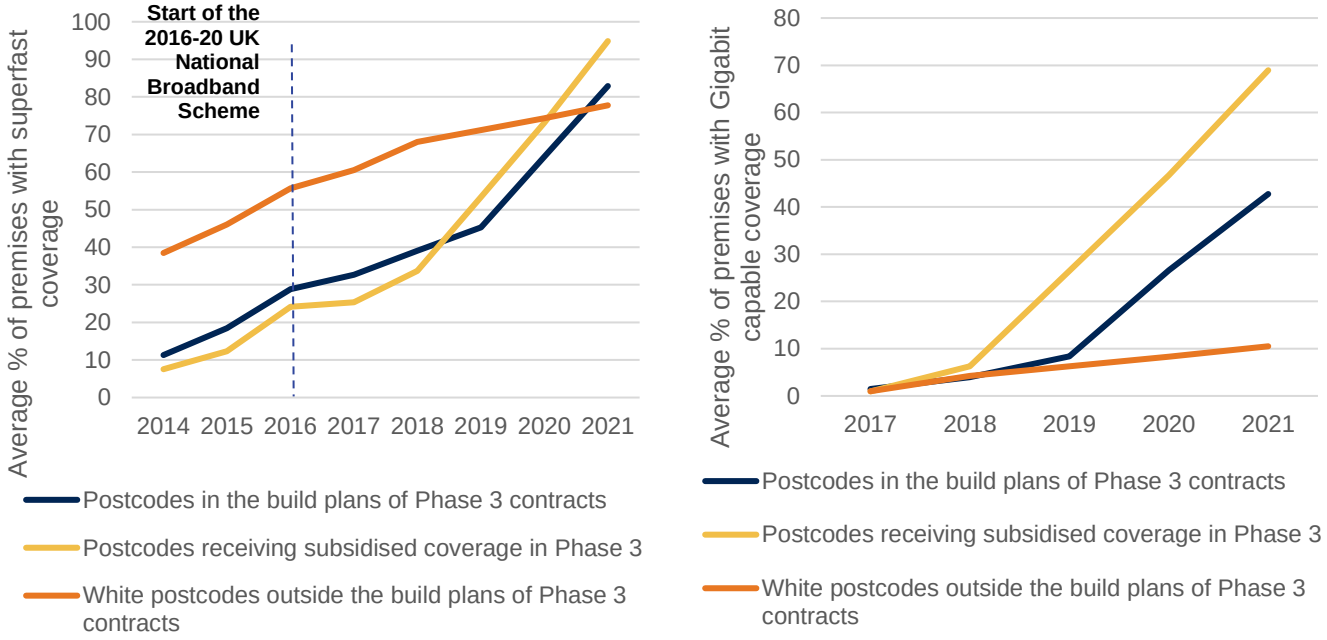


Source: C3 reports, Ofcom Connected Nations, Ipsos analysis.

Superfast broadband 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). However, in line with the delivery profile, areas within Phase 3 build plans saw coverage expand much more rapidly between 2019 and 2021, rising from 45 percent to over 80 percent of premises

over the period. FTTP/Gigabit capable coverage also rose more rapidly in the programme area than on other white postcodes.

Figure 3.2: Changes in superfast broadband (at least 30Mbit/s) and Gigabit capable coverage (% of premises), areas in Phase 3 build plans and other white postcodes, 2014 to 2021



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

3.3 Impact on NGA and Superfast coverage

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 2021. 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 2021 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 2021 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 2021. 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 2021, 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.

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 2021 (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.

Subsidised coverage through Phase 3 of the Programme led to significant positive impact on the availability of superfast and gigabit capable broadband services by the end of September 2021. Subsidised coverage increased the share of premises in the programme area able to access superfast speeds by 41 to 47 percentage points, and the share of premises with gigabit capable coverage by 43 to 56 percentage points. The impact of the programme on NGA availability was relatively small, however, indicating that in its absence, most premises would have benefitted from some form of enhanced connectivity (albeit via technologies less able to deliver download speeds of 30Mbit/s or higher). These findings are consistent with prior research into the impacts of the programme on broadband coverage.

Table 3.2: Estimated broadband availability impact of Phase 3 on areas benefitting from subsidised coverage by September 2021

Outcome	Difference-in-Differences	Propensity Score Matching with Difference in Differences	Control group regression
NGA availability (% of premises)	3.2 to 7.5	4.4	3.5
Superfast availability (% of premises)	45.8 to 46.6	43.5	40.9
Gigabit capable availability (% of premises)	52.2 to 56.2	50.2	43.2

Source: Ipsos analysis

3.3.2 Additionality of subsidised broadband infrastructure

Estimates of the overall number of additional premises benefitting from NGA, superfast and FTTP/Gigabit capable availability by September 2021 have been derived by multiplying the estimated impact of the programme on the share of premises with enhanced broadband by the number of premises on the postcode:

- **NGA coverage:** The Programme is also estimated to have led to 17,000 to 40,000 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 6 and 14 percent, with most estimates towards the lower end of this range. This implies that to a large degree, premises benefitting from the programme would have received some form of NGA coverage in its absence, though any improvements in local connectivity would not have delivered the significant improvements in available speeds achieved through the programme.

- **Superfast availability:** The Programme is estimated to have increased the number of premises that can access at least superfast broadband services (30Mbit/s or above) by 202,000 to 247,000 by the end of September 2021. The associated rate of additionality ranges from 69 percent to 85 percent. This indicated that while many premises may have received NGA coverage in the absence of the Programme, these premises would not have been able to access at least superfast speeds (indicating the programme has been highly effective in delivering against its primary objective).

- **FTTP/Gigabit capable coverage:** Subsidised coverage is estimated to have led to 193,000 to 298,000 additional premises with FTTP/Gigabit capable coverage. The rate of additionality ranges from 66 percent to 102 percent (with most estimates in the region of 90 percent). This indicates that the programme has also been highly effective in bringing gigabit capable technologies to rural areas, and these areas were highly unlikely to have benefitted from commercial deployments over the time horizons considered in this evaluation.

3.4 Take-up of subsidised coverage

Take-up of superfast broadband coverage also rose rapidly in the programme area relative to other white postcodes by September 2021:

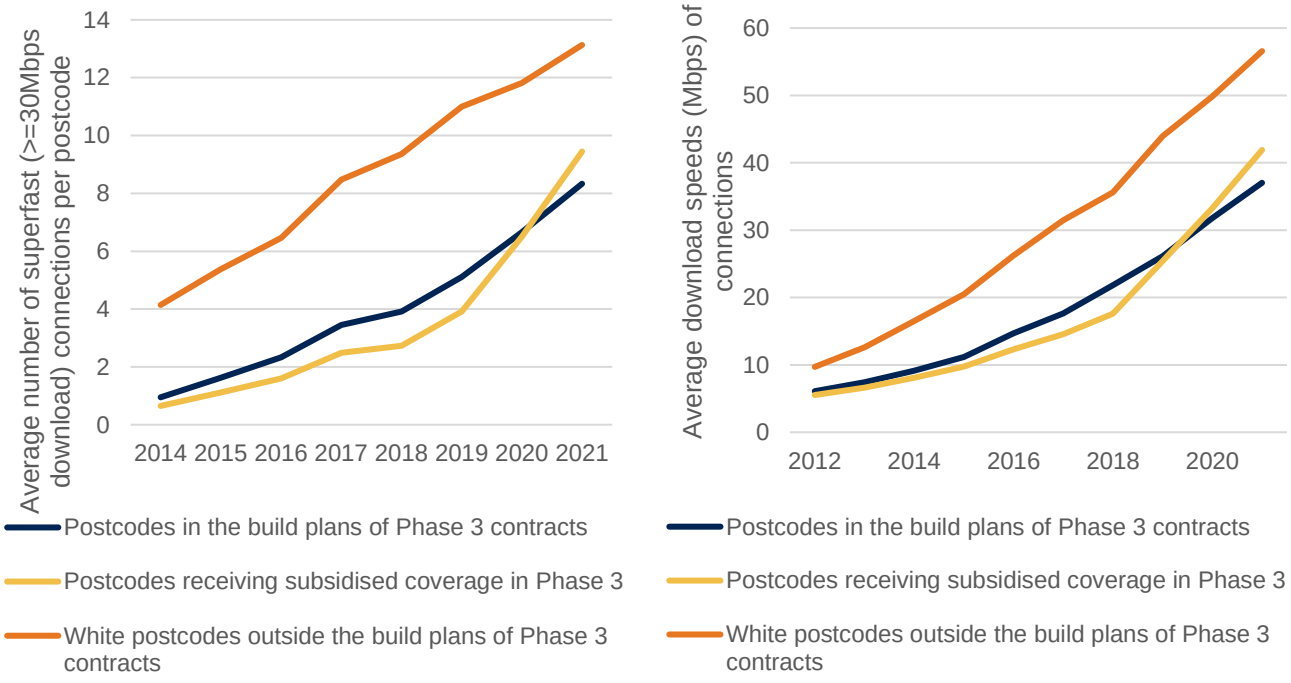
- **Number of superfast (30Mbit/s) connections:** The average number of superfast connections on postcodes in the build plans of Phase 3 schemes grew from 2.3 in 2016 to 8.3 in 2021. Connections

on postcodes receiving subsidised coverage rose even more rapidly, from 1.6 in 2016 to 9.4 in 2021. The number of superfast connections rose at a lower rate on other white postcodes not included in the build plans of Phase 3 schemes.

- **Average download speeds:** The average download speeds of connections on postcodes included in the build plans of Phase 3 contracts rose from 15 Mbit/s to 37 Mbit/s between 2016 and 2021 (152 percent). Growth in average download speeds was even more rapid on postcodes receiving subsidised coverage by September 2021 (rising to 42 Mbit/s). However, average download speeds remained lower than across other white postcodes that were not covered by the programme over the period.

As in 2020, there were more marked differences in the maximum download speeds of connections (shown in Figure 3.3). Maximum downloads speeds on the postcodes included in the build plans of Phase 3 schemes rose at a faster rate to those on other white postcodes. Maximum download speeds again rose most rapidly in those areas that had received subsidised coverage. Areas receiving coverage by September 2021 saw average maximum download speeds reach 124Mbit/s. This is indicative of users taking advantage of the faster speeds made available through FTTP (the availability of which was more widespread in these areas in 2021).

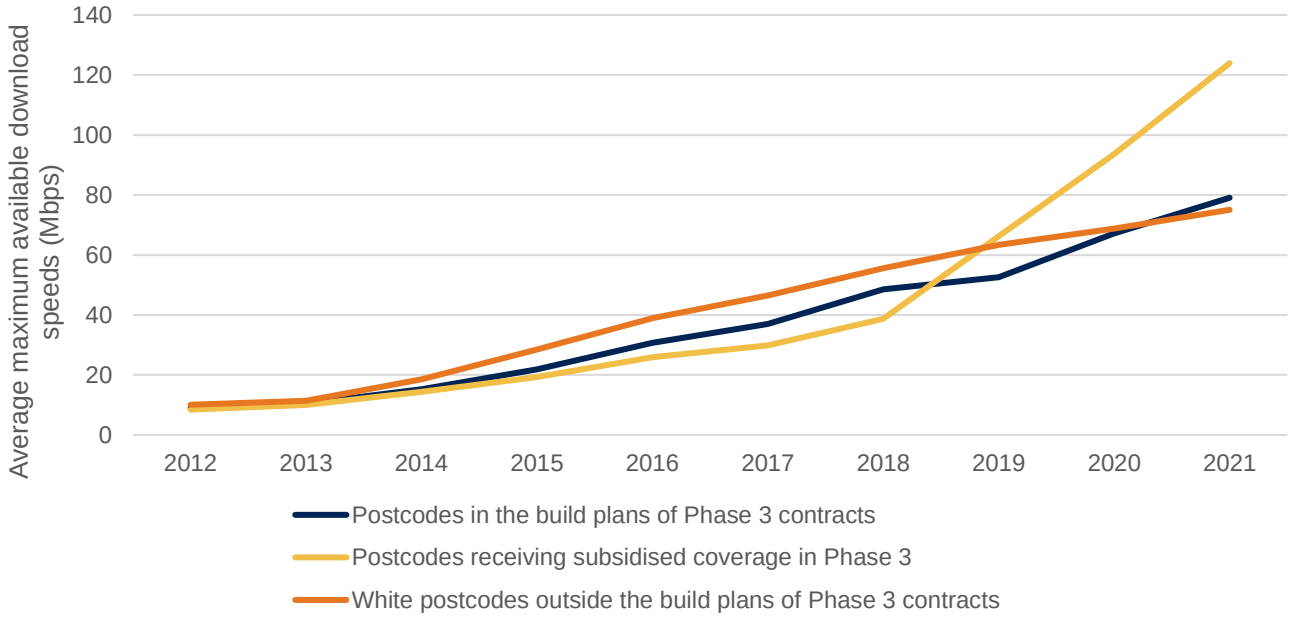
Figure 3.3: Number of superfast (30Mbit/s) connections and average download speeds of connections – areas in Phase 3 build plans and other white postcodes, 2014 & 2012 to 2021



Source: C3 reports, Ofcom Connected Nations, Ipsos analysis[57].

[57] Data on superfast connections only available from 2014 onwards in Ofcom Connected Nations data

Figure 3.4: Maximum download speeds of connections, areas in Phase 3 build plans and other white postcodes, 2016 to 2021



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

3.5 Impact on take-up of subsidised coverage

An assessment of the impacts of Phase 3 contracts on download speeds was completed using the same methods as described in Section 3.3, using Connected Nations data between 2016 and 2021.

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 2021. The models provided a consistent view on the effects of the programme.

Subsidised coverage led to a significant increase in the maximum download speeds of connections taken by households and/or businesses by September 2021 (34 to 60 Mbit/s). However, the impacts of the programme on average download speeds were relatively small. This indicates that 'early adopters' have taken advantage of the enhanced broadband connectivity enabled by the Programme. However, the Programme had not led to widespread take-up of faster broadband services by September 2021. It should be noted that most subsidised coverage was delivered in 2019 and 2020. As take-up will lag deployment, it is premature to draw any firm conclusions on the impact of the programme on take-up of faster internet services. Again, this is consistent with prior research into the impacts of the programme on take-up.

Table 3.3: Estimated download / upload speed impact of Phase 3 on areas benefitting from subsidised coverage by September 2021

Outcome	Difference-in-Differences	Propensity Score Matching with Difference in Differences	Control group regression
Maximum download speeds of connections (Mbps)	34.7 to 59.2	52.6	33.7
Average upload speeds of connections (Mbps)	5.8 to 6.3	4.4	0.9

Outcome	Difference-in-Differences	Propensity Score Matching with Difference in Differences	Control group regression
Number of connections with download speed of 30Mbps+	0.8 to 1.2	3.9	-1.0

Source: Ipsos analysis

4 Direct impact 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, though it should be noted that this modelling could only be completed for contracts awarded to Openreach owing to restrictions in data availability. 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.

4.1 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[58] or IRR) to the network providers' Weighted Average Cost of Capital (WACC), also called the discount rate[59] . As highlighted in the State aid evaluation plan, if the actual IRR earned on the investments made exceeds the discount rate 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).

4.1.1 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.

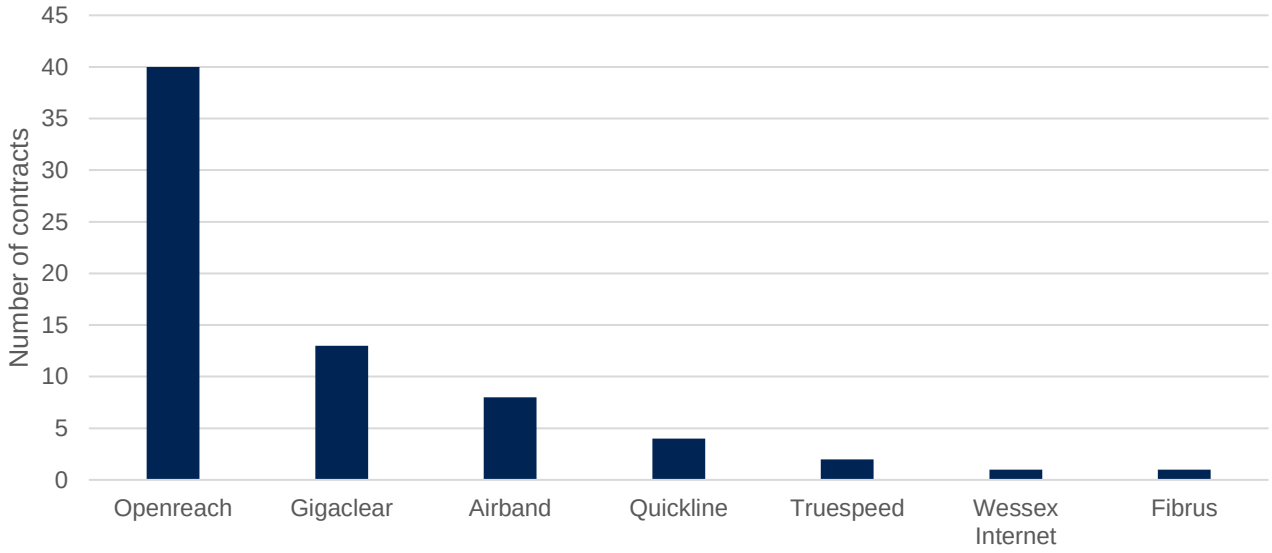
In Phases 1 and 2, Local Bodies predominantly used the BDUK framework to procure the providers' services to deliver the infrastructure. This approach restricted the number of possible bidders to two (one of which did not engage for any tenders). In Phase 3, as required by the State aid judgement under 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 (although the areas targeted remained where premises do not have or are not planned to receive a broadband service of at least 30 Mbps), 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 in the previous evaluation 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). The figure below sets out the number of contracts awarded by supplier with Openreach holding the majority with 58 percent.

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

[59] 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 4.1: Number of contracts awarded by beneficiary



Source: Superfast Status Report, November 2022

Table 4.1: Superfast Broadband Programme budget by phase

	Phase 3 contracts
Average premises	7,696
Average contract value (£m)	£20.2

Source: Superfast Status Report, November 2022. Note: actual spend not available for this iteration of the evaluation.

4.1.2 Methodology for modelling future IRRs

The aim of this analysis is to compare an updated estimate of IRRs earned by suppliers against their discount rate. This involves two key challenges:

- **Data**: Suppliers have a contractual obligation to provide Local Bodies with information on the actual costs of the network build and the share of premises passed and connected. However, suppliers are not required to provide information on on-going operational costs or revenues earned (i.e. pricing), and these cannot be observed directly.
- **Time horizons:** the IRR associated with the network build is determined over a long time period (20 years), which requires certain assumptions over future patterns of delivery and take-up, even if the deployment phase has been completed.

In light of this, a modelling exercise was conducted to project future costs and revenues, and subsequently the IRR over the contract period. This meant that actual data (up to Q4 21/22) was used to estimate future trends, replicating as closely as possible the assumptions made by the suppliers at bidding stage. In certain cases (e.g. lack of actual data, delays to deployment), additional assumptions were made to obtain an estimate of future cash flows. The expected future cash flows were then used to determine the IRR.

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:

- **Contract sample:** The analysis concerns a sample of 27 contracts awarded to Openreach. These were contracts for which roll-out had started by the time the analysis was carried out, and copies of PFMs, Finance Trackers, and WSS/C3 reports were held by BDUK. For the WSS/C3 reports, the analysis considers the latest available report for all contracts (in general up to Q4 21/22).

- **Delays to deployment:** In addition to considerations around data availability, it should be noted that there are known delays to deployment of the contracts under Phase 3. Reasons for the delays are not entirely known, although potential reasons were mentioned during the course of interviews with suppliers and BDUK:

  - Supply chain delays;
  - Labour shortages, caused by increasing competition from market entrants and limited supply of qualified staff;
  - Difficulties in the build;
  - Wayleave issues;
  - Value-for-money challenges;
  - Project management challenges and planning amendments proposed by suppliers.

  This means that the deployment timeline of most contracts might have changed compared to expectations at PFM stage. Based on the expected end of deployment date contained in the Status Report, it appears that closed contracts are delayed on average by slightly more than five quarters. Information on the revised expected rate of premises passed which could be used to determine future build capex (Capital expenditure **–** expenditure to buy/maintain/improve fixed assets) beyond the end of the actual data is not available. In order to correct for under-estimation of build capex where deployment is still ongoing, assumptions have been made regarding future trends in build capex. Similarly, actual public funding is accounted for alongside future public funding, which is derived from the PFM. Further details of this treatment can be found in Technical Annex 2.

- **Gainshare and take-up clawback:** Lastly, regarding gainshare and take-up clawback, based on discussions with BDUK, it is assumed that take-up review points occur in year 2, 4, 6, and 7 after the end of the deployment phase (with year 7 being the ‘checkpoint F’, marking contract closure). To this end, the deployment phase considered is that of the PFM.

4.1.3 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, the expected IRR associated with the contracts in scope (-2.7 percent) is substantially lower than the supplier’s discount rate (10.4 percent) and are mostly negative. This means that in the supplier’s predictions, contracts would have been loss making in the absence of public funding.

- **Commercial viability with subsidy:** For the contracts in scope, IRR2 (factoring in subsidy payments) was 7.9 percent on average.

4.1.4 Expected and actual costs

At the bidding stage, the expected qualifying costs associated with the network build for the contracts in scope were estimated by the supplier to be approximately £203m, although these predictions are likely to be exceeded in the medium term. Analysis of information and actual costs to date suggests:

- The total capex build cost will exceed £267m;
- The supplier is expected to incur additional costs of over £64m by FY 24/25 (when all build is expected to be completed) compared to what was originally planned;
- Some of the variation may be due to differences in the number of contracted premises and any change requests that have been subsequently agreed with relevant Local Bodies (e.g. switching some FTTC connections to FTTP, which is more expensive);
- Some exogenous factors responsible for project delays (as evidenced by lower-than-expected capex in the early years) might have eventually led to higher prices, for example in case of heightened competition in the industry for resources in short supply (e.g. skilled workers, components).

4.1.5 Actual and predicted take-up

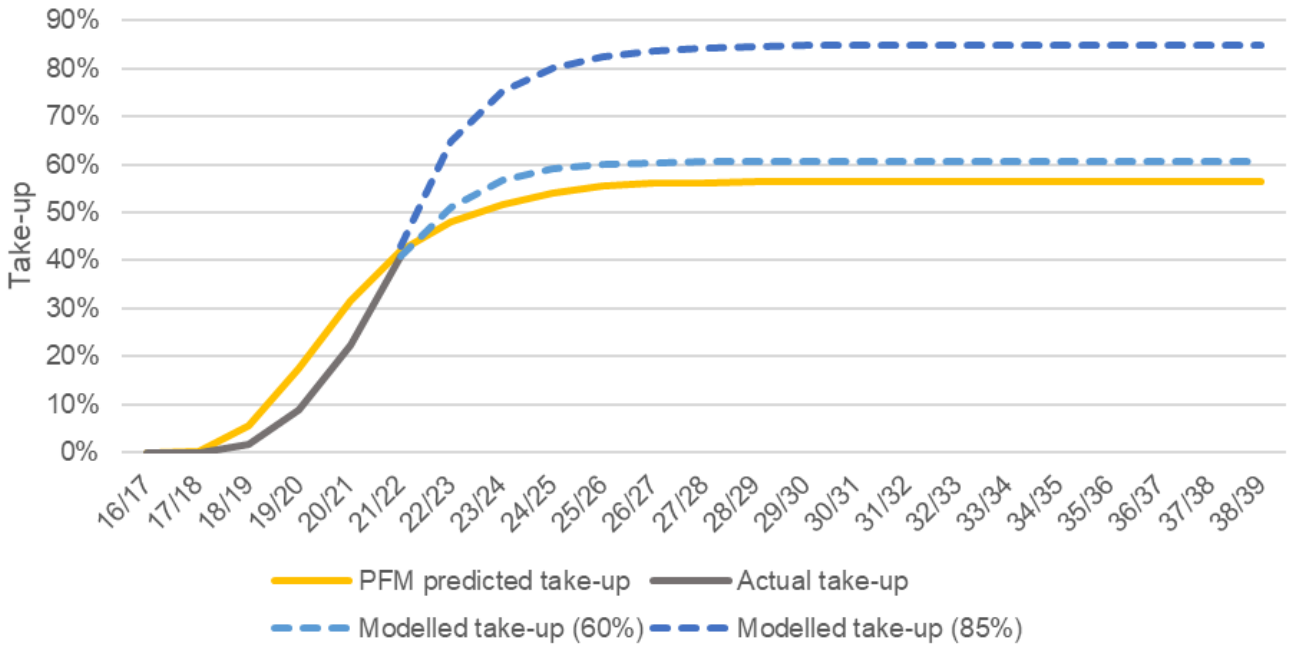
Take-up levels represent the number of premises connected to the network as a percentage of the total premises passed. Actual connections are used to forecast trends in opex and revenue, as well as any relevant clawback, and ultimately the IRR. Figure 4.2 below compares the take-up level expected by the supplier at the PFM stage compared to actual (to date) and modelled (future) take-up. The key findings are listed below:

- **Expected take-up:** predictions of take-up at PFM stage ranged from 50% to 61%.
- **Actual take-up:** after some delays in the initial quarters of deployment, where PFM take-up is higher than actual take-up, the level of take-up reached in FY 21/22 is already close to the maximum level of average take-up expected by the supplier in the PFM.
- **Future take-up:** Two scenarios of future take up have been modelled. In the first scenario, it has been assumed that, beyond FY 21/22, take-up is expected to further increase up to 60 percent[60], reaching over 92,500 premises across the 27 contracts. In the second scenario, it has been assumed that take-up will reach 85 percent in the long term[61], reaching around 129,500 premises.

[60] This assumption utilises the actual information on take-up provided by the programme beneficiaries and their assumptions at the bidding stage. This assumption was agreed with BDUK.

[61] This assumption is based around the predicted copper 'switch off' in 2030, with the majority of premises moving onto the fibre network provided by the programme beneficiary. It is assumed that as the area was commercial unviable for the Superfast Broadband Programme, it will remain unviable, and the beneficiary will have a local monopoly in the market, meaning a higher take-up rate. This assumption was agreed with BDUK.

Figure 4.2: Predicted and actual/modelled take-up

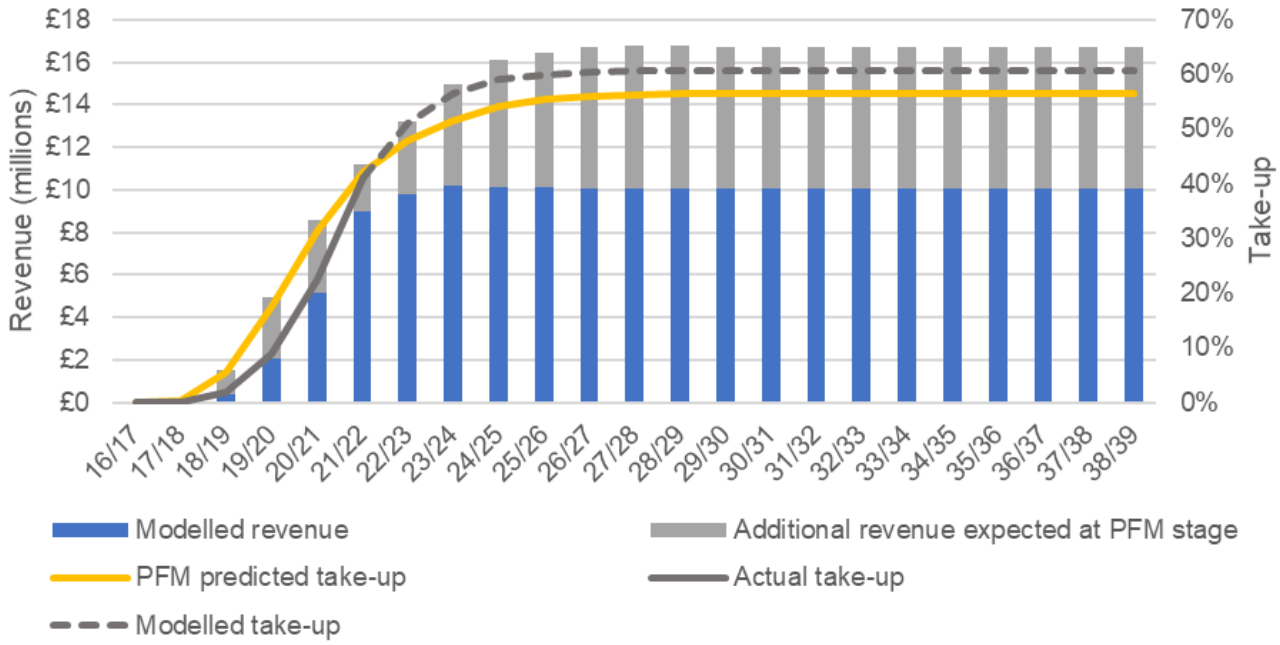


Source: Ipsos' analysis based on WSS/C3 reports.

4.1.6 Expected and forecast revenue and operational costs

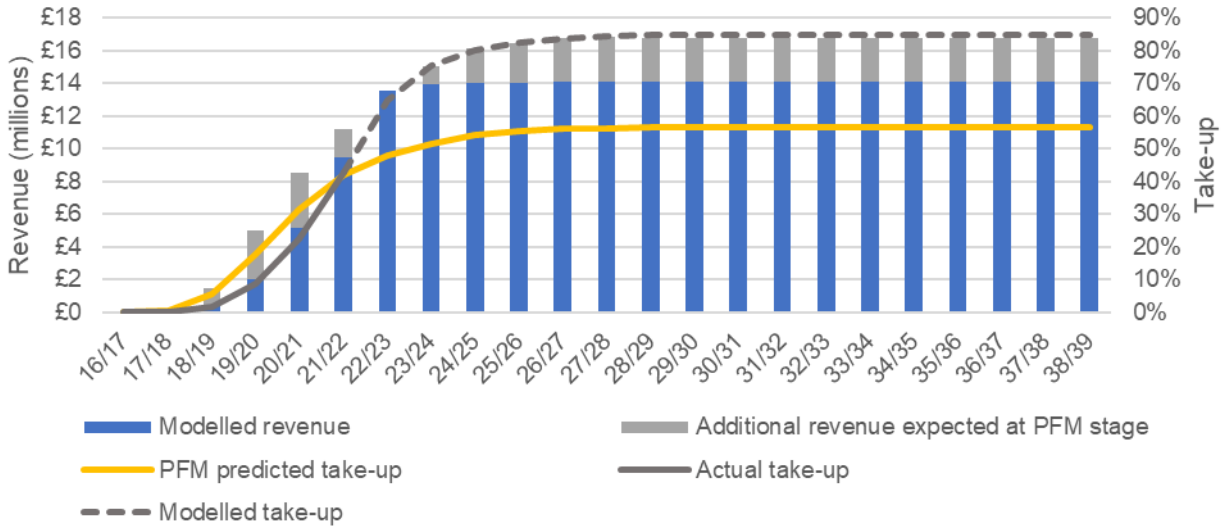
The take-up projections were used to estimate expected revenues and operational costs (based on the average revenue per user assumptions put forward by the tenderer and the estimated operational cost per user inferred from their financial projections). Figure 4.3 below presents the modelled revenue against the network provider predictions at the tendering stage using a 60 percent assumption around future take-up, and Figure 4.4 presents the modelled revenue using the 85 percent take-up assumption. This highlights that the costs of Phase 3 network deployment have been assessed to exceed expectations, and total revenues are expected to be lower than expected under both take-up scenarios.

Figure 4.3: Network provider predictions of revenue against modelled data (using 60 percent take-up assumption)



Source: Ipsos' analysis based on PFM, Finance Tracker, and WSS/C3 reports data.

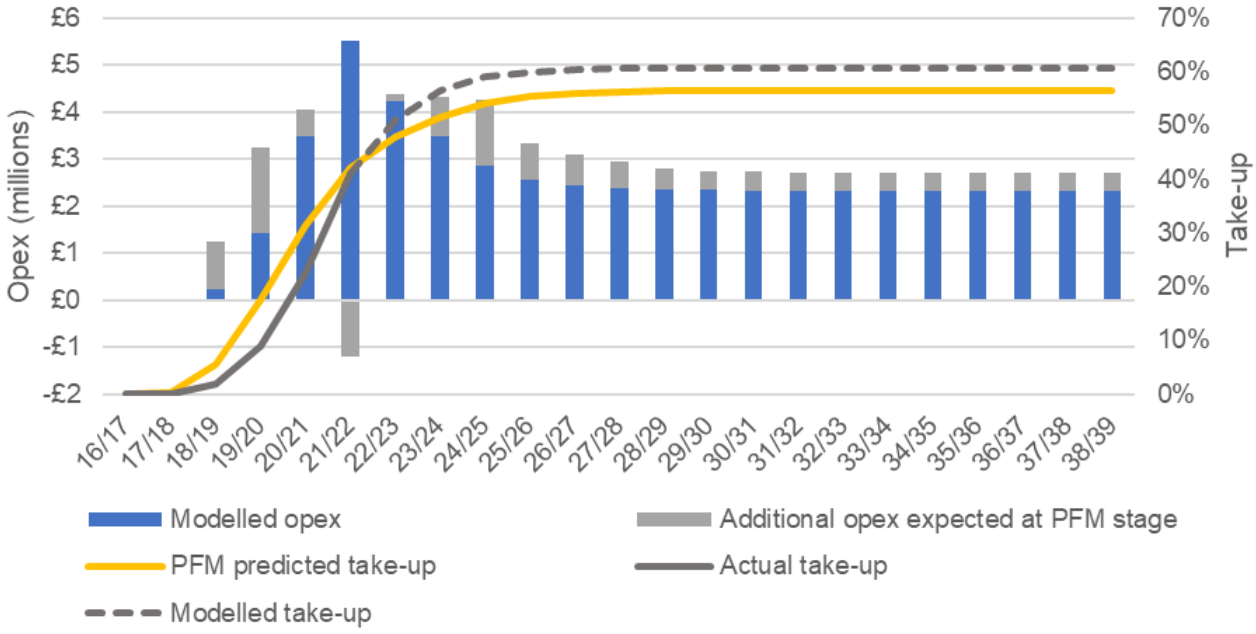
Figure 4.4: Network provider predictions of revenue against modelled data (using 85 percent take-up assumption)



Similarly, Figures 4.5 and 4.6 below present modelled operating costs under the two take-up scenarios. Modelled operating costs in Phase 3 include network and wholesale connection operating expenditure, deployment closure costs, ongoing contractual reporting, wholesale cessation costs and wholesale migration costs. It appears that in the 60 percent take-up scenario there is some minor underspend of opex compared to baseline estimates. Although take-up (as a percentage) is expected to be slightly higher than PFM predictions, the actual number of premises connected is lower than expected at PFM stage, hence a lower opex than estimated at PFM stage. In the 85 percent take-up scenario, the modelled opex slightly exceeds the predictions made at PFM stage – this is in line with the fact that the modelled take-up is around 30 percentage points higher than the average take-up level expected at PFM stage. Costs (and

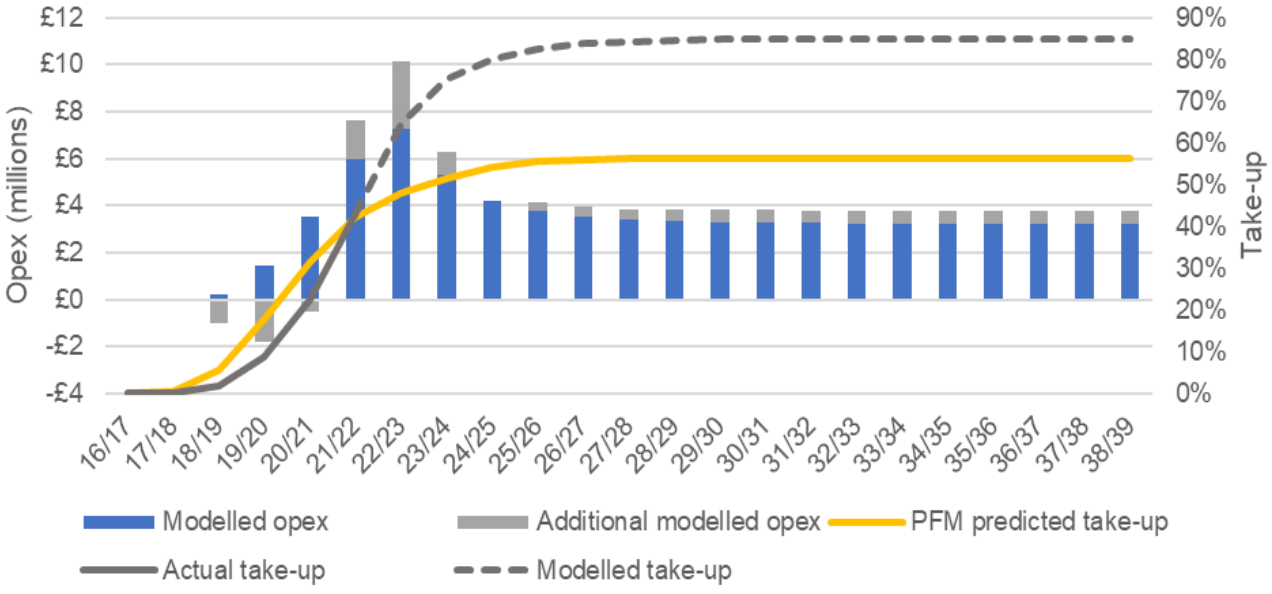
revenues) may also be affected by the inflationary context in which the contracts have been delivered (though no adjustments for this have been made in the modelling process).

Figure 4.5: Baseline operating cost projections against modelled revenue for Phase 3 contracts (in scope) (using 60 percent take-up assumption)



Source: Ipsos' analysis based on PFM, Finance Tracker, and C3 reports data

Figure 4.6: Baseline operating cost projections against modelled revenue for Phase 3 contracts (in scope) (using 65 percent take-up assumption)



Source: Ipsos' analysis based on PFM, Finance Tracker, and C3 reports data

4.1.7 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:** Without subsidy, most contracts would have been expected to be loss-making (IRR3), with an average rate of return of between -5.4 percent and -8.1 percent (depending on the take-up assumption used). Comparing these results to ex-ante expectations (-2.7 percent, IRR1), this suggests that higher capital costs are expected to reduce the profitability of the contracts.

- **Commercial viability with subsidy:** With subsidies, the average estimated IRR is estimated to be between 2.9 percent and 5.5 percent (depending on the take-up assumption used). This remains lower than the supplier's discount rate (10.4 percent, see Table 4.2), and it is anticipated that the supplier will earn economic losses on its investments. As highlighted above, this does not account for potential profits earned beyond the lifetime of contracts. However, while this appears to indicate that BDUK have avoided providing potentially distortionary subsidies, there are also possible questions regarding the sufficiency of the subsidies (as they are not expected to allow the supplier to earn a normal economic return).

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

To reduce risk that suppliers earn excess returns, two types of clawback mechanisms are in-built in contractual arrangements, as described below:

- **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.

Estimates of clawback have been made based on the assumptions detailed in Technical Annex 2. In particular, assumptions were made around the timing of the end of the deployment phase for each contract. As take-up is expected to exceed PFM expectations within the lifetime of contracts, based on the assumptions made in agreement with BDUK on the timing of take-up review points, most contracts are subject to take-up clawback. Additionally, while no contract is expected to underspend on its capital costs, some contracts have been reduced in scale in ways that were not fully reflected in the available documentation. In these cases, reductions in the levels of public funding were accounted for via implementation clawback. The take-up clawback mechanism is expected to reduce the supplier's return further from 2.9 percent to between -1.2 percent and -3.6 percent on average (depending on the take-up assumption used). This is substantially lower than the discount rate stipulated by the supplier at PFM stage and suggests the supplier will make an economic loss on the contracts.

4.1.9 Summary of results

The estimated IRRs are set out in the table below. The findings indicate:

- **Incentive effect:** Delivery of Phase 3 contracts were expected to be commercially challenging, with network providers projecting an average IRR of -2.7 percent in the absence of subsidies at the tendering stage. Actual build costs have exceeded expectations (with investments now expected to generate an average IRR of between -5.4 percent and -8.1 percent). This highlights that subsidies would almost certainly be needed to stimulate investments in gigabit capable network deployment in these areas. This is also consistent with the high rates of additionality associated with gigabit

capable networks described in the preceding chapter (i.e. network providers were highly unlikely to roll out similar investments in the absence of public subsidies).

- **Economy:** The expected IRR was 7.9 percent with subsidies for suppliers when they submitted their tender and are projected to fall to between 2.9 percent and 5.5 percent based on evidence on current information on actual build costs and take-up. These rates of return are lower than the network providers discount rate, indicating that BDUK has avoided the risk of providing excess subsidies to network providers (as for Phases 1 and 2 of the programme). This also suggests that contracts would be unprofitable even with public funding. This could be explained if the network provider considered future profitability beyond the clawback period (from which all profits made would be retainable by the supplier), which would have raised longer-term returns. Given the dominant position of the network provider in question, these economic losses may also have been tolerable if they were able to subsidise network deployment via revenues earned from customers in other areas.

- **Clawback mechanism:** The clawback mechanism helped prevent network providers earning excess returns and limited the public contribution to the minimum needed to ensure the commercial viability of network deployments in Phases 1 and 2. However, in the case of Phase 3 contracts, the clawback mechanisms has reduced the expected IRRs further to between -1.2 percent and -3.6 percent (increasing the size of the economic losses earned by network provider). It is possible that the level of subsidies provided were insufficient, and while the network provider is not expected to see accounting losses on the investments, there are questions regarding the commercial sustainability of the network build (though as noted, it is likely that these economic losses will be offset by profits earned by deployments elsewhere).

Table 4.2: Internal Rates of Return – Phase 3 contracts

Rate of return	Estimated IRR
Rates of return (prior to award of subsidies)	
Expectation at tendering stage (IRR1)	-2.7%
Updated in light of actual build costs and take-up (IRR3)	-5.4% to -8.1%
Rates of return (after the award of subsidies)	
Expectation at tendering stage (IRR2)	7.9%
Updated in light of actual build costs and take-up (IRR4)	2.9% to 5.5%
Rates of return (after the award of subsidies and clawback)	
Updated in light of actual build costs and take-up (IRR5)	-1.2% to -3.6%
Weighted average cost of capital for comparison (discount rate for Openreach)	10.4%

4.2 Effects on market position of direct beneficiaries

This section examines the degree to which the 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 the national level, the level of individual Phase 3 contract areas and at the level of all Phase 3 contracts delivered by the same network provider.

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 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 and there could be biases in this data. Additionally, there are a number of contracts with low numbers of speed tests completed, and 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.

4.2.1 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, total broadband connections supplied through the Openreach network dominate the market, with between 70 and 80 percent of take-up of all broadband connections in all years being made through the Openreach network (including Sky and TalkTalk, as these retailers utilise the Openreach network). Openreach has a less dominant position in relation to NGA connections, although its market share rises from 61 to 67 percent.

- **Programme beneficiaries:** Between 2016 and 2022, the market share of total broadband connections for the beneficiaries decreased, driven by a decrease of the market share for Openreach (via Sky and TalkTalk). However, the market share of the NGA market has increased – due to the increase in NGA services offered through the Openreach network. For the smaller network providers, the market share of total broadband connections has increased from close to zero in 2016 to just under one percent in 2022, and to just over one percent of the NGA market (see Table 4.3 below).

Table 4.3: Market share of the total broadband market for Superfast Broadband beneficiaries (percentage of total number of broadband connections)

Network provider	Total broadband market			NGA market		
	2016	2020	2022	2016	2020	2022
Openreach (including Sky and TalkTalk)	*78.08%*	*75.16%*	*71.03%*	*60.46%*	*67.23%*	*65.99%*
Airband	0.01%	0.09%	0.06%	0.12%	0.12%	0.08%
Gigaclear	0.08%	0.18%	0.35%	0.15%	0.25%	0.43%
Callflow	0.02%	0.02%	0.01%	0.02%	0.02%	0.01%
Relish	0.00%	0.01%	0.01%	0.00%	0.02%	0.02%
Fibrus	0.00%	0.00%	0.09%	0.00%	0.00%	0.11%
Quickline	0.02%	0.04%	0.06%	0.06%	0.07%	0.08%
Wessex	0.05%	0.09%	0.30%	0.16%	0.18%	0.36%
Total programme participants	**78.26%**	**75.59%**	**71.93%**	**60.97%**	**67.89%**	**67.07%**
Virgin Media	*19.86%*	*17.10%*	*20.64%*	*36.90%*	*23.30%*	*24.84%*
Other providers	*1.88%*	*7.31%*	*7.43%*	*2.13%*	*8.81%*	*8.09%*

Source: Thinkbroadband data

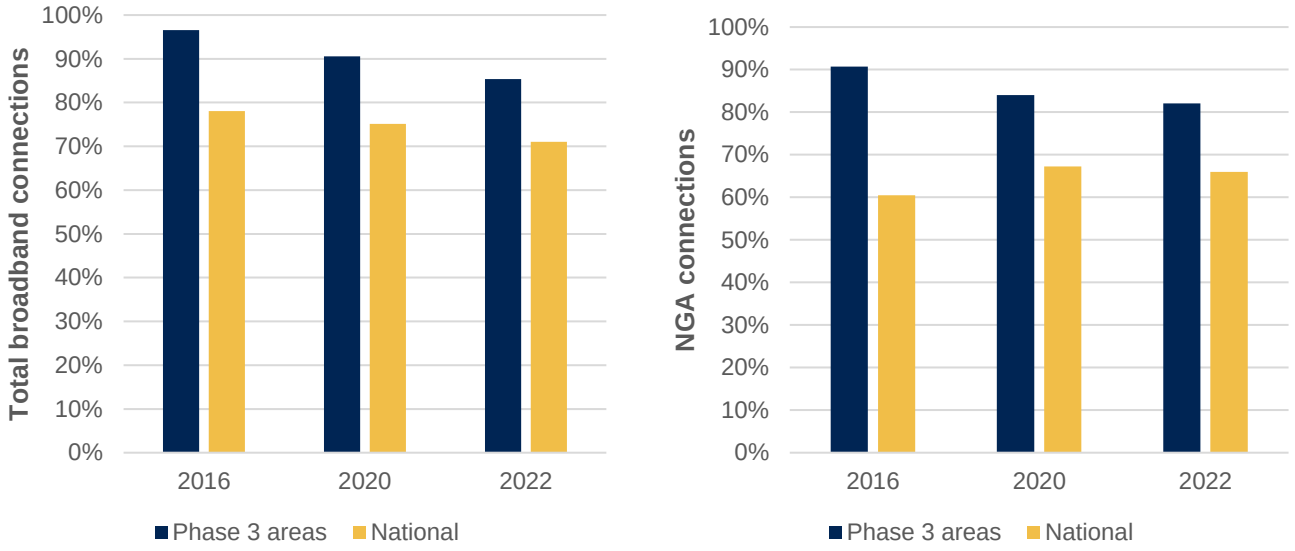
4.2.2 Overall market shares across Superfast Broadband contract areas

The market share of the broadband market for the network providers across the areas that the Superfast Broadband Programme has or is currently operating in for Phase 3 of the Programme (postcodes which the Superfast Broadband Programme has provided enhanced connectivity to)[62] 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 these areas declined between 2016 and 2022, from around 97 to 85 percent of all broadband connections. While this is higher than the national average (between 70 and 80 percent), the decline in market share aligns with the national trends for Openreach. In terms of NGA connections, the pattern in Phase 3 areas remains the same, with a decrease in Openreach's market share in the Phase 3 areas (91 to 82 percent of all NGA connections), but this is not matched by the national trends, where there is no clear pattern for Openreach's market share (see Figures below).

[62] These areas were identified from the C3 reports of suppliers.

Figure 4.7: Openreach market share in Phase 3 contract areas and nationally, for total broadband connections and NGA connections, 2016 - 2022

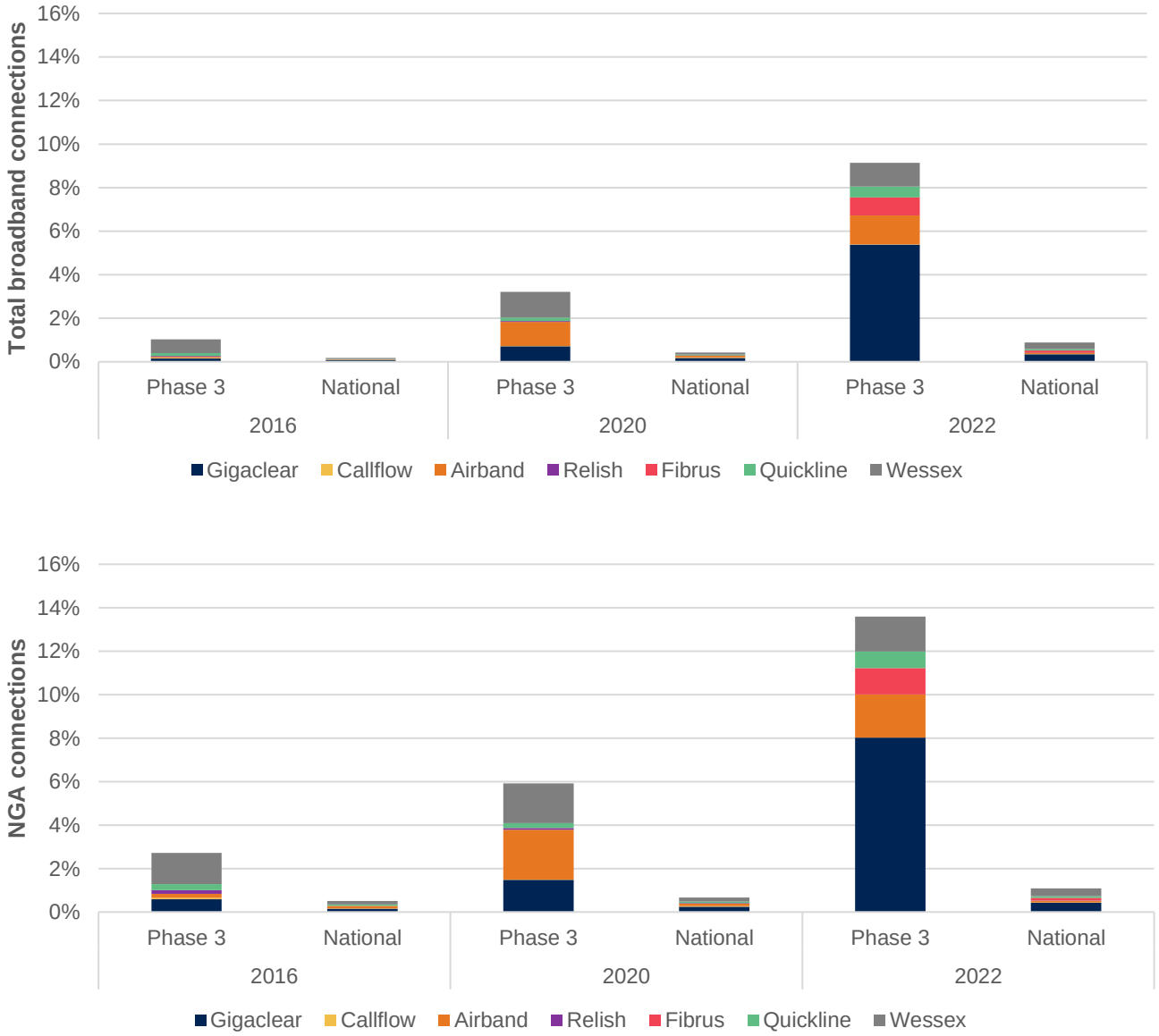


Source: Thinkbroadband speed test data

The market share for all broadband connections and NGA 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 2022 in Phase 3 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. Similar patterns are seen in terms of their share of NGA connections. However, the overall market share of these network providers is still relatively low even at the local level, with no network provider having more than five percent of the total broadband market in 2022 in the areas the Programme has delivered connections.

Figure 4.8: Other beneficiaries market share in Phase 3 contract areas and nationally, for total broadband connections and NGA connections, 2016 - 2022



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 4.5

4.2.3 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). This analysis showed:

- **Openreach:** In Phase 3 contract areas where Openreach delivers the project, the market share of Openreach declined between 2016 and 2022 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 33 percent between 2016 and 2022. 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 88 to 61 percent over the period.

- **Other providers:** This pattern is repeated for areas where other network providers have been contracted to deliver Superfast Broadband projects. The market share total connections taken by these providers rose from 1 to 14 percent between 2016 and 2022. Again, this appears to have been achieved at the expense of the Openreach – which saw its market share of total broadband connections decline from 88 percent in 2016 to 76 percent in 2022 in these areas.

5 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.[63]

5.1 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 5.1: 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.	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 2022. 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.[64] 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*[65]

Outcome measures that do not align with the State aid evaluation plan have been italicised.

[63] 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.

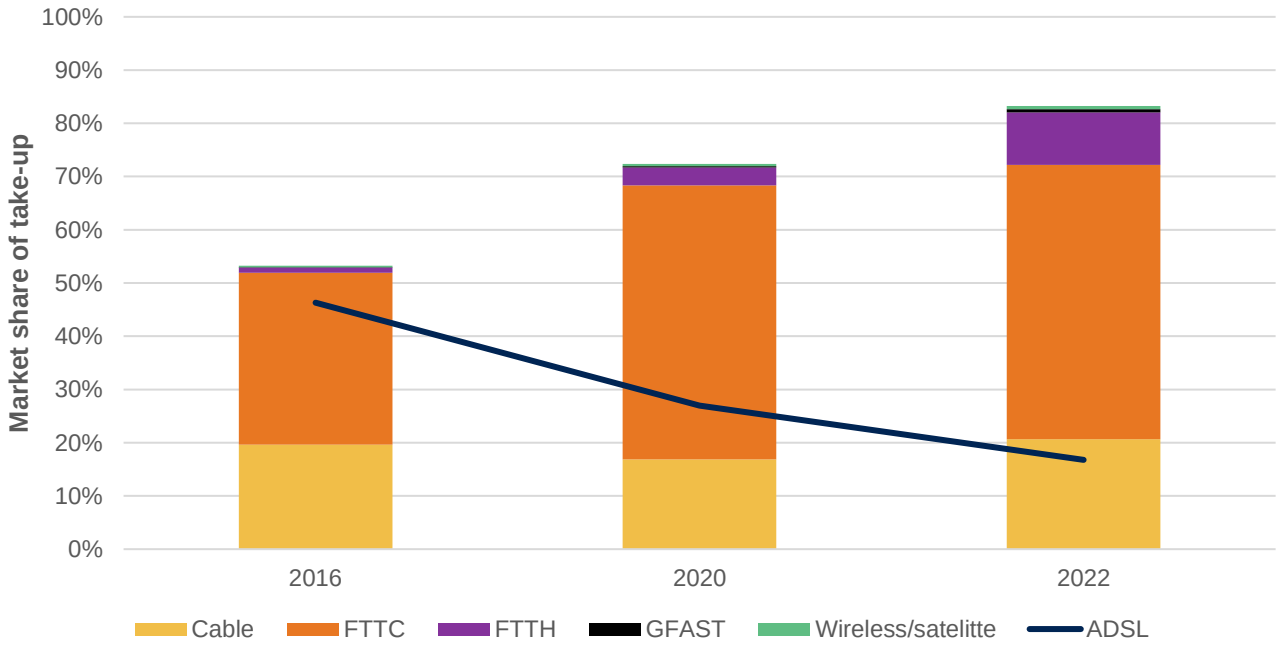
[64] It is not possible to estimate the degree to which the data may be inaccurate. However, the data is likely to become less accurate when analysing smaller geographic areas, and this should be taken account of when interpreting the results.

[65] 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.

5.2 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 80 percent of internet connections in 2022. 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 and 2022). FTTP connections have grown to represent 10 percent of the market in 2022 (up from three percent in 2020), with the proportion of wireless/satellite connections remaining steady at around one percent in all years.

Figure 5.1: Market share of broadband take-up for NGA and ADSL connections

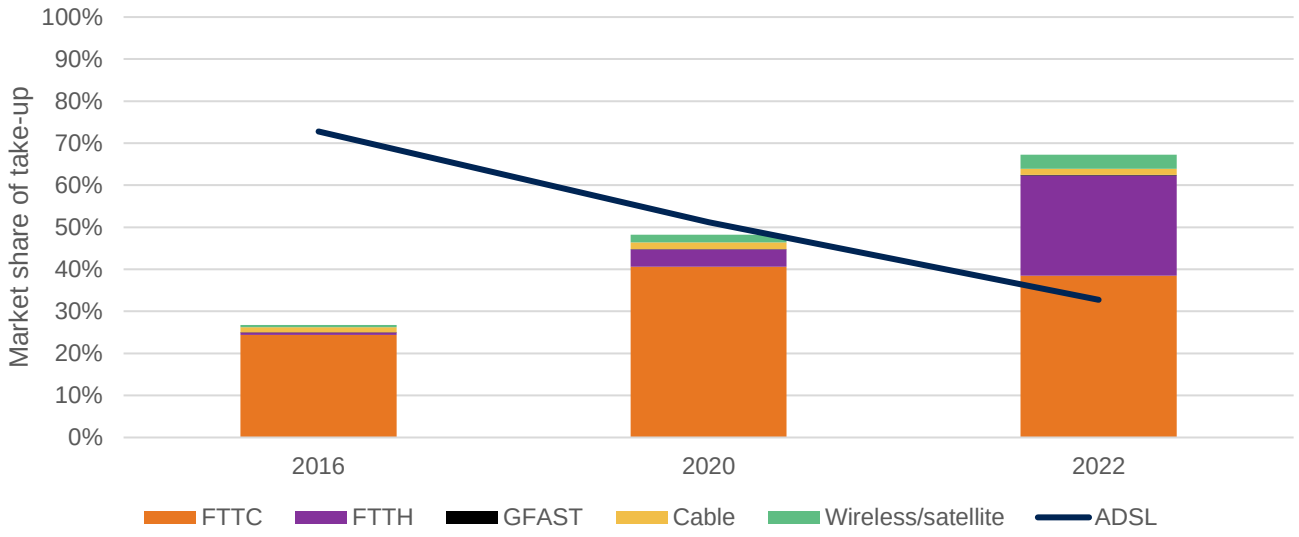


Source: Thinkbroadband data

5.2.1 Superfast Broadband delivery area analysis

This analysis was undertaken separately for the delivery areas for Phase 3 of the Superfast Broadband Programme as illustrated in the figure below. This found that between 2016 and 2022, there was an increase in NGA take-up in Phase 3 contract areas of 40 percentage points. As with the national pattern, FTTC is the dominant technology for NGA connections, representing most of the connections in Phase 3 areas – however, this percentage is lower than the national average (around 40 percent in 2022 in Phase 3 areas compared to 50 percent nationally). FTTP connections represent a higher proportion of the market in Phase 3 areas than nationally in 2022 (24 percent in 2022 compared to 10 percent nationally). This suggests that the take-up of FTTP connections nationally is lower than take-up in Phase 3 areas – which would be expected given that the Phase 3 Superfast Broadband contracts are required to provide gigabit capable networks, and the majority of contracts are doing this through FTTP technologies.

Figure 5.2: Market share of broadband take-up in Superfast Broadband Phase 3 areas, 2016 to 2022



Source: Thinkbroadband

5.3 Number of infrastructure providers offering NGA services

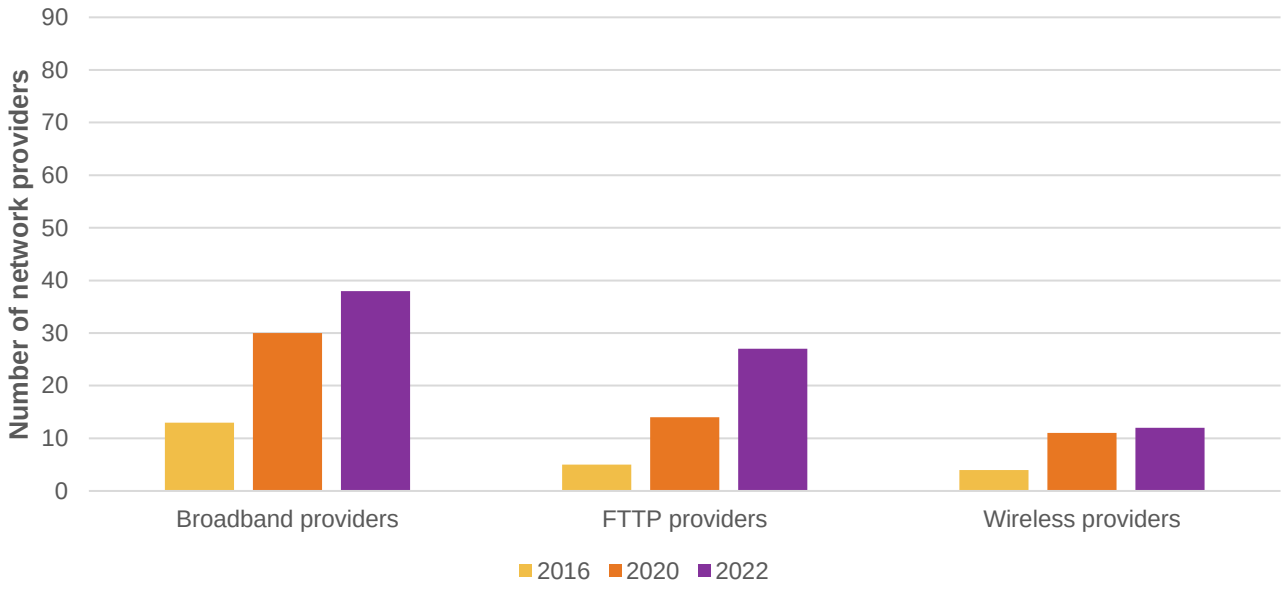
The figure below shows the change in the number of network providers[66] operating in postcodes that had received subsidised coverage under Phase 3 contracts between 2016 and 2022. In 2016, there were a total of 13 broadband providers operating in the areas covered by Phase 3, which had risen to 38 by 2022. This is below the national total and the total of network providers operating in areas covered by Phase 1 and Phase 2 of the Programme (75 in Phase 1 areas and 58 in Phase 2 areas). The number of FTTP providers and wireless network providers has also increased between 2016 and 2022 (from five to 27 FTTP providers and four to 12 wireless providers). This may indicate that the programme has helped promote greater competition in these areas.

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.

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.

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

Figure 5.3: Total number of network providers in Phase 3 Superfast Broadband treatment areas



Source: Thinkbroadband

Table 5.2: Coverage of non-beneficiaries in Superfast Broadband delivery areas, 2022

Network provider	Phase 3[67]
Virgin	2.65%
Duplia	1.29%
Wildanet	0.92%
Voneus	0.64%
Cityfibre	0.50%
Glide FTTP	0.47%
ITS	0.35%
Trooli	0.35%
Boundless wireless	0.33%

Source: Thinkbroadband coverage dataset

5.4 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), and this had grown to over 160 by 2022.[68]

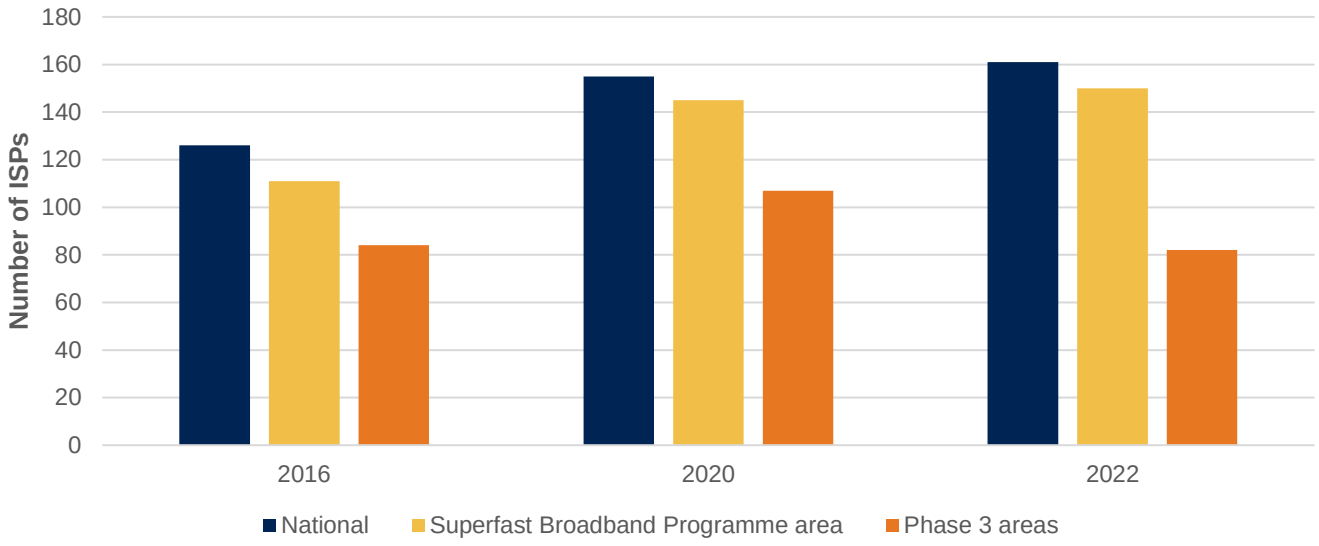
[67] The degree of coverage from non-beneficiary network providers appears lower for Phase 3 contract areas than for Phase 1 and Phase 2 contract areas. This should be expected, as the Phase 3 areas are expected to be less commercially viable, therefore less likely to have been built to by non-beneficiaries.

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

In both 2020 and 2022, all ISPs provided NGA services to at least one customer in the UK. However, there were changes between 2016 and 2022 in the proportion of customers which were utilising NGA connections between ISPs. In 2016, around 70 percent of ISPs had over half of their customer base using NGA connections – in 2020 and 2022 this had grown to over 90 percent of ISPs.

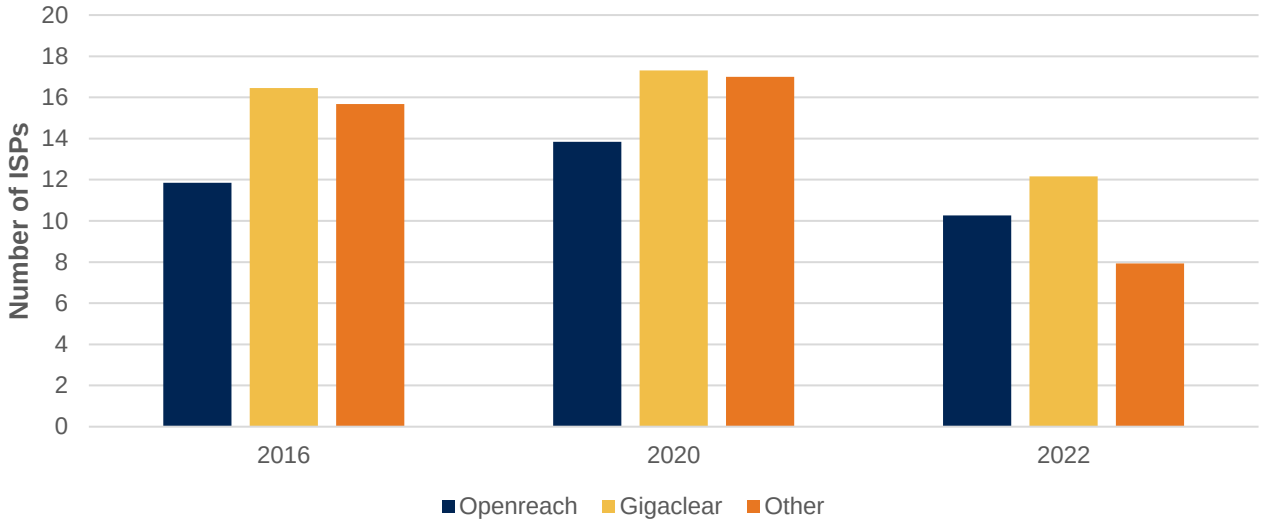
A similar pattern to that seen nationally is observed in the Superfast Broadband delivery areas. There has been an increase in the number of ISPs with customers between 2016 and 2022. However, this pattern is not observed in Phase 3 contract areas – where there is a rise in ISPs between 2016 and 2020 but a decrease by 2022. This pattern for Phase 3 contracts is observed across all beneficiary contract areas, with a decrease in the number of ISPs between 2020 and 2022, following an increase up to 2020. This is unlikely to be due to ISPs stopping providing services to a particular area but continuing elsewhere, and could be a function of a small intervention area where individuals are satisfied with their internet connection, and therefore do not undertake a speed test.

Figure 5.4: Total number of ISPs operating in the UK, in Superfast Broadband Programme areas and Phase 3 areas, 2016 to 2022



Source: Thinkbroadband

Figure 5.5: Average number of ISPs offering services in the Superfast Broadband project Phase 3 areas and beneficiary, 2016 to 2022



Source: Thinkbroadband

6 Economic impacts

This section of the report summarises the results of a series of econometric analyses exploring the economic and social impacts of Phase 3, and provides a cost-benefit analysis of the Superfast Broadband Programme Phase 3. Full details of these analyses are provided in Technical Appendix 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.

6.1 Costs

BDUK monitoring data gave details of 67 contracts that had been signed as part of the Superfast Broadband programme under Phase 3 of the programme. The gross contract value of the public funding associated with these contracts was over £1bn at the point of award (in nominal terms), providing funding for the capital costs associated with upgrading network infrastructure in the programme area[69].

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

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

- **Clawback:** In addition, there was sufficient information available in relation to 27 contracts to enable a modelling exercise in which projections were developed to estimate levels of take-up clawback based on projections of future take-up. As described in Technical Appendix 2, implementation clawback was also included to account for reductions in the scale of contracts. Details of these analyses are set out in Technical Appendix 2. As the focus on this analysis is on premises upgraded

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

by the end of 2021/22, estimates of future take-up clawback were scaled in line with the share of contracted premises that had been delivered by the end of March 2022.

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

The resultant estimates of costs to the end of March 2022 are set out in Table 6.1. The value of actual public spending associated with Phase 3 contracts by the end of March 2022 was estimated at £273.3m (with a present value of £239.2m in 2016/17). These contracts were expected to return £27.5m to £7.8m to the public sector via clawback (with a present value of £21.6m to 28.9m). This gives an estimated net cost to the public sector of £236.0m to £245.8m (with a present value of £210.2m to £217.5m). In addition to the caveats outlined above, it should be noted that these estimates do not include administrative costs to BDUK, Local Bodies, or network providers.

Table 6.1: Expected net public sector costs (£m, 2019 prices)

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

Source: BDUK, Ipsos UK analysis

6.2 Additionality

The economic impacts set out in Technical Appendix 3 explore the impacts of subsidised coverage. However, the results do not factor in the possibility that some coverage may have been brought forward through commercial deployments in the absence of the programme. Estimates of the additionality of the coverage funded through the programme are taken from Technical Appendix 1, which examined the share of the premises involved that would not have been upgraded in the absence of the programme (and how this evolved with time). These findings suggested that:

- **Superfast vs gigabit availability:** The level of additionality associated with gigabit coverage was higher than for superfast availability. This implies that while many households would not have benefitted from gigabit infrastructure in the absence of the programme, some may have benefitted from upgrades that enabled superfast broadband services. Average levels of additionality across the two technological standards were used for the purposes of this analysis (reflecting an assumption of diminishing returns to speeds).

- **Evolution over time:** The level of additionality was estimated to peak in the year after the premises was upgraded (at 81 percent). Additionality was estimated to decay to 49 percent in the fourth-year post-installation (an average rate of decay of 16 percent per annum). This aligns with patterns observed for prior Phases of the programme. However, the estimated level of additionality associated with Phase 3 was notably higher than for prior Phases[70], indicating that the areas concerned were substantially less likely to benefit from commercial deployments without public sector support. This is reinforced by the findings set out in Technical Appendix 2, which show that the rates of return associated with Phase 3 contracts are likely to fall below network providers' cost of capital in many cases (even with public subsidies).

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

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

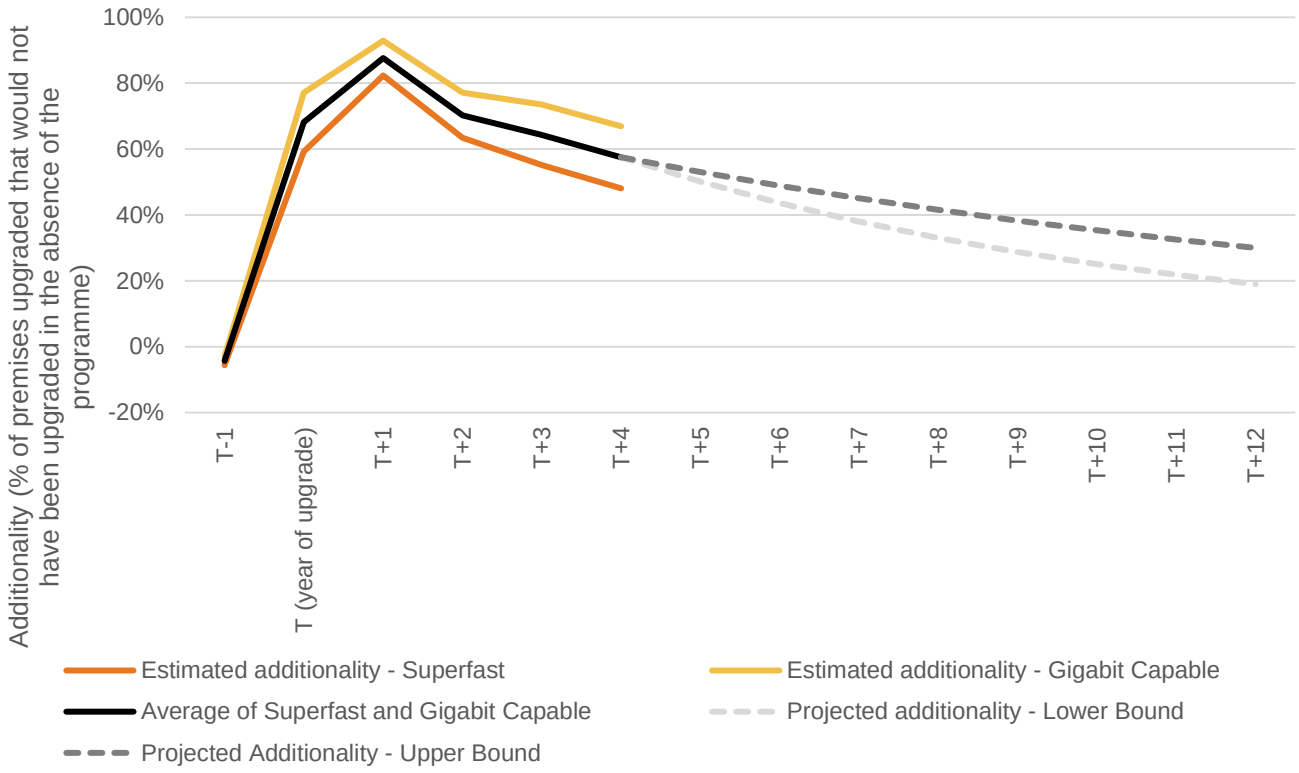
  - **Upper bound estimate:** The lower bound projection appears potentially pessimistic given parallel findings in relation to the commercial viability of investments in FTTP in areas covered by Phase 3 contracts. While commercial deployments of FTTP have expanded rapidly since 2020, it might be expected that some areas will never be covered by commercial deployments without substantial technical innovations to reduce deployment costs (or if network providers are able to subsidise such deployments with profits earned from investments in commercially viable areas). An upper bound scenario, in which additionality decays at a slower rate to 30 percent in 2029/30 was adopted to capture this possibility.

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

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

[70] See Technical Annex 1 from the State aid evaluation report 2020. Available at: https://www.gov.uk/government/publications/superfast-broadband-programme-state-aid-evaluation-report-2020.

Figure 6.1: Additionality profile over time



Source: Ipsos UK analysis

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

Table 6.2: Estimated number of additional premises passed, 2012/13 to 2029/30

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

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

6.3 Economic and social benefits

6.3.1 Local economic impacts between 2016 and 2021

A series of econometric analyses linking records of the postcodes benefitting from Phase 3 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:

- **Local employment impacts:** Subsidised coverage from Phase 3 was estimated to have increased employment in the areas benefitting from the programme by 0.88 percent, leading to the creation of 6,261 local jobs by March 2021. The programme as a whole was estimated to have led to 23,700 more local jobs up to March 2021.

- **Turnover:** Subsidised coverage also increased the turnover of firms located in the areas benefitting from Phase 3 of the programme by 1.6 percent by 2021, increasing the annual turnover of local businesses by £827m per annum. Estimates for the whole programme suggested that turnover of firms in areas benefiting from coverage increased by 1.4 percent (equating to around £2.6bn).

- **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 '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 from Phase 3 coverage rose by 0.42 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 0.17 percent by 2021, indicating that subsidised coverage has also raised the efficiency of firms. It should be noted that while subsidised coverage had a stable effect on turnover, impacts on employment increased with time. This led to the strength of the gains in turnover per worker appearing to decay 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 between 0.6 and 0.8 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 9.8 for every 10,000 premises upgraded.

6.3.2 Productivity gains

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

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

As such – and in line with the principles of the HM Treasury Green Book - only the effects of the programme in terms of raising productivity are considered to qualify as economic benefits at the national level. The evaluation provided a range of results to indicate that the programme has supported improvements in productivity – including raising the turnover of per worker and wages of employees of firms located in areas benefiting from subsidised coverage under Phase 3 (which rose by 0.6 and 0.8 percent respectively in response to the upgrades).

GVA based measure of economic benefits

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

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

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

- **Short term impact on GVA per premises upgraded.** It is assumed that firms did not change the shares of labour and other inputs used in production in response to the subsidised coverage, and the effect on turnover per worker can be interpreted as an improvement in productivity. Applying the

average GVA as a percentage of turnover across the UK as whole over the 2016 to 2021 period (32 percent)[71], this gives an effect on GVA per premises upgraded of £20 (per annum).

The assumptions were applied to the profile of additional premises upgraded set out in the preceding section. Summary results covering the 2016/17 to 2021/22 period (benefits to date) and the 2016/17 to 2029/30 period (including projected benefits) are set out in the table below. The present value of GVA benefits (with a baseline of 2012/13) are estimated at £8.4m by 2018/19 and between £20.8m and £23.1m by 2029/30.

This approach may understate the economic benefits of the programme. If spatially stable firms displace sales from less productive firms, then there will also be benefits associated with the transfer of output from less to more productive producers which are not captured in this analysis. The programme is also assumed not to lead to productivity gains for relocating firms (as the quality of their broadband access prior to the relocation is unknown). Additionally, the relocation of firms to the programme area may also produce agglomeration economies (e.g. resulting from knowledge 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 6.3: Additional GVA resulting from productivity gains (£m, 2019 prices, low – high range)

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

Source: BDUK, Ipsos UK analysis

6.3.3 Unemployment impacts

The results of the evaluation suggested that for every 10,000 premises upgraded there was a corresponding on-going reduction in the number of unemployed claimants of 34.3 claimants. The extent to which these effects might be understood as net economic benefits will be linked to how far the programme drew individuals out of (or helped them avoid) extended periods of involuntary worklessness in which they were not productively deployed (rather than short-term episodes of unemployment[72]).

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[73]) 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 9.8.

[71] Source: Annual Business Survey, ONS
[72] Though some of these episodes will have otherwise evolved into long-term unemployment.
[73] DCMS (2018) Economic and Public Value Impacts of the Superfast Broadband programme.

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[74], it is estimated that these effects could have led to an additional £5.5m in national economic output (GVA) by 2022 (in present value terms). This effect is estimated to rise to between £15.7m to £17.4m in the longer term (though to the extent this is driven by relocation of economic activity, there may have been corresponding increases in long-term unemployment elsewhere).

Table 6.4: Additional GVA resulting from reduction in long-term unemployment (£m, 2019 prices, low – high range)

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

Source: BDUK, Ipsos UK analysis

6.3.4 Social benefits

The findings of the study suggested that the programme led to an average increase in house prices of between £1,900 and £4,900 suggesting that buyers were willing to pay a premium to obtain houses benefitting from subsidised upgrades. Based on hedonic pricing approaches, this can potentially be interpreted as a measure of the average gain in social welfare associated with access to superfast and gigabit capable broadband networks (i.e. on the basis that the maximum households are willing to pay should reflect the marginal gain in wellbeing derived from access to the technology). However, there are several issues of interpretation that create some complexities in this approach:

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

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

[74] 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).

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

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

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

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

The following table provides a summary of the results.

Table 6.5: Land value uplift arising from impacts on house prices (£m, 2019 prices)

	Low house price premium (0. 78%)	High price premium (1.43%)
Welfare impacts confined to households purchasing homes		
Land value uplift (£m, present value)	370.3	946.9
Land value uplift (£m, only sold properties)	157.2	402.1

Source: BDUK, Ipsos UK analysis

6.4 Benefit to Cost Ratios

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

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

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

- **Lower bound estimates:** As noted above, it is possible that the house premium overstates the average welfare gain associated with enhanced broadband connectivity. Using the lower bound estimates of the social benefits of the programme outlined above, whereby the house price premium only provided a reasonable approximation of the welfare gains associated with the programme in cases where houses were sold after the premises was upgraded (114,162), the long-term BCR would fall to between £0.89 and £2.04. This will clearly understate the net benefits of the programme, as it assumes that existing residents derive no value from superfast broadband availability.

- **Comparisons with prior findings:** Previous analysis set out in the 2020 State aid evaluation report found that the Benefit Cost Ratio associated with the overall programme was substantially higher (£3.6 to £5.1 between 2012 and 2030[75]). The average benefit per premises upgraded for Phase 3 was in line with (if not higher than) estimates for prior Phases. However, unit cost of upgrades to the public sector was markedly higher for Phase 3 than for prior phases of the programme. The net cost per additional premises passed was by 2022/23 was estimated at £1,270 for Phase 3, versus £217 for all Phases of the programme. This increase in cost was driven by a change in technical focus to gigabit capable technologies (which are more costly to deploy) and a change in spatial focus to areas that are harder to reach. Contracts awarded under Phase 3 are also expected to generate substantially lower levels of implementation and take-up clawback than contracts awarded under Phase 1 (which were often commercially viable without subsidy).

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

Table 6.6: Benefit to Cost Ratios, 2016 to 2022 and 2016 to 2030

Period	2016 to 2022		2016 to 2030	
	Low additionality / house price effects	High additionality / house price effects	Low additionality / house price effects	High additionality / house price effects
	Benefits			
Productivity gains (£m)	7.3	7.3	20.8	23.1
Long term unemployment (£m)	5.5	5.5	15.7	17.4
House prices (£m)	370.3	946.9	370.3	946.9
Total	**383.1**	**959.8**	**407.0**	**987.7**
	Costs			
Lifetime cost (£m)	210.2 to 217.5	210.2 to 217.5	210.2 to 217.5	210.2 to 217.5
Benefit to cost ratio	**1.76 to 1.82**	**4.41 to 4.57**	**1.87 to 1.94**	**4.54 to 4.70**

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

Lower bound estimate of total benefits and costs				
Total benefits (£m, house premium applies to sold houses only)	170.0	414.9	237.5	442.1
Lifetime cost (£m)	210.2 to 217.5	210.2 to 217.5	210.2 to 217.5	210.2 to 217.5
Lower bound BCR (£)	**0.78 to 0.81**	**1.91to 1.97**	**0.89 to 0.92**	**2.04 to 2.11**

Source: BDUK, Ipsos UK analysis

7 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.

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.

7.1 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.

7.1.1 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 to support the cost-benefit analysis).

Over £1bn of public sector funding appears to have been committed across Phase 3 contracts with a total of 531,029 contracted premises passed. This equates to an ex-ante gross public sector cost per premises covered of £2,636[76].

Table 7.1: Contracted cost per premises passed in Phase 3

Contract phase	Contracted public sector cost (£m)	Contracted premises passed	Gross public subsidy per gross premises passed (£)
Phase 3	1,400	531,029	2,636

Source: Ipsos UK analysis; Superfast Status Report, November 2022

[76] This figure is based on the Superfast Status Update (CORA) data

7.1.2 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 2021/22. The expected gross public spend per premises passed is lower overall at £945 (rather than £2,636).

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. The gross public sector cost (i.e. before clawback) per additional covered premises over three years was £1,418. After allowing for clawback, this will fall to £1,225 to £1,276 per premises passed (depending on whether take-up stabilises at 60 or 85 percent in the long-term).

Table 7.2: Expected gross cost per premises and additional premises passed

Contract phase	Expected public sector cost (£m)	Premises passed by March 2021/22	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 (before clawback)	273.3	289,063	192,700	945	1,418
Phase 3 to date (after clawback)	236.0 to 245.8	289,063	192,700	816 to 850	12,255 to 1,276

Source: Ipsos UK analysis; Superfast Status Report, November 2022

7.1.3 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 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:

- 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.

It should be noted that the cost per premise passed for the programmes presented above will be dependent on the type of infrastructure investments made to reach premises, and this information was not available. However, the high level analysis shows 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) 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 values listed above as it focuses on the cost of connections rather than the cost of coverage.

7.2 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), take-up volumes, average revenue per user, average operational costs per user for each winning network provider.

7.2.1 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 67 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 six 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 two beneficiaries. These contracts were terminated by the Local Body, rather than the beneficiary. The reason for the termination was the inability of the beneficiaries (and its supply chain) to deliver the network build outlined in their bids to the required quality within the specified timeframe of the contract.

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 many 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.

7.2.2 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.

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. After some delays in the initial quarters of deployment, where PFM take-up was higher than actual take-up, the level of take-up reached in FY 21/22 was already close to the maximum level of average take-up expected by the supplier in the PFM.

7.2.3 Original forecast average revenue / cost per user[77]

Beneficiaries reported the Average Revenue Price per Unit (ARPU) in the PFM. For the 27 contracts analysed for the incentive effect of the State aid, the ARPU is £7.81. This was estimated using the contract level ARPU's presented in Technical Annex 2. The average monthly operational cost over the lifetime of the programme was estimated to be £2.10 (once a steady state of operational costs has been achieved). It can be seen that the estimated quarterly ARPU is higher than the quarterly Average Operational Cost per Unit, suggesting that the beneficiary expected the networks to be sustainable in the long run.

[77] It was not possible to estimate the actual average revenue and actual average cost per connection, as this information is not collected from the programme beneficiaries.

8 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?

Subsidised coverage through Phase 3 of the Programme led to significant positive impact on the availability of superfast and gigabit capable broadband services by the end of September 2021. Subsidised coverage increased the share of premises in the programme area able to access superfast speeds by 44 to 48 percentage points, and the share of premises with gigabit capable coverage by 43 to 59 percentage points. The impact of the programme on NGA availability was relatively small, however, indicating that in its absence, most premises would have benefitted from some form of enhanced connectivity (albeit via technologies less able to deliver download speeds of 30Mbit/s or higher). These findings are consistent with prior research into the impacts of the programme on broadband coverage.

Estimates of the overall number of additional premises benefitting from NGA, superfast and FTTP/Gigabit capable availability by September 2021 showed that:

- **NGA coverage:** The programme is estimated to have led to 50,000 to 117,000 additional premises with NGA coverage (with a larger estimate of 117,000 premises derived from panel models considered implausibly large given the observed trends in 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 7 and 17 percent, with most estimates towards the lower end of this range. This implies that to a large degree, premises benefitting from the Superfast Broadband Programme would have received some form of NGA coverage in its absence.

- **Superfast availability:** The Programme is estimated to have increased the number of premises that can access superfast broadband services (30Mbit/s or above) by 202,000 to 247,000 by the end of September 2021. The associated rate of additionality ranges from 69 percent to 85 percent. This indicated that while many premises may have received NGA coverage in the absence of the Programme, these premises would not have been able to access at least superfast speeds (indicating the programme has been highly effective in delivering against its primary objective).

- **FTTP/Gigabit capable coverage:** Subsidised coverage is estimated to have led to 193,000 to 298,000 additional premises with FTTP/Gigabit capable coverage. The rate of additionality ranges from 66 percent to 102 percent (with most estimates in the region of 90 percent). This indicates that the programme has also been highly effective in bringing gigabit capable technologies to rural areas, and these areas were highly unlikely to have benefitted from commercial deployments over the time horizons considered in this evaluation.

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 led to a significant increase in the maximum download speeds of connections taken by households and/or businesses by September 2021 (34 to 60 Mbit/s). However, the impacts of the programme on average download speeds were relatively small. This indicates that 'early adopters' have taken advantage of the enhanced broadband connectivity enabled by the Programme. However, the Programme had not led to widespread take-up of faster broadband services by September 2021. It should be noted that most subsidised coverage was delivered in 2019 and 2020. As

take-up will lag deployment, it is premature to draw any firm conclusions on the impact of the programme on take-up of faster internet services. Again, this is consistent with prior research into the impacts of the programme on take-up.

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. Network providers project an average IRR of -2.7 percent in the absence of subsidies at the tendering stage, they are now expected to generate an average IRR of between -5.4 percent and -8.1 percent. This highlights that subsidies would almost certainly be needed to stimulate investments in gigabit capable network deployment in these areas. This is also consistent with the high rates of additionality associated with gigabit capable networks described in the preceding chapter (i.e. network providers were highly unlikely to roll out similar investments in the absence of public subsidies).

The expected IRR was 7.9 percent with subsidies at the tendering stage and are projected to fall to between 2.9 percent and 5.5 percent based on evidence on actual build costs and take-up. These rates of return are lower than the network provider's discount rate, indicating that BDUK has avoided the risk of providing excess subsidies to network providers (as for Phases 1 and 2 of the programme). This also suggests that contracts would be unprofitable even with public funding. This could be explained if the network provider considered future profitability beyond the clawback period (from which all profits made would be retainable by the supplier). Given the dominant position of the network provider in question, economic losses may also have been tolerable if they were able to subsidise network deployment via revenues earned from customers in other areas.

The clawback mechanism helped prevent network providers earning excess returns and limited the public contribution to the minimum needed to ensure the commercial viability of network deployments in Phases 1 and 2. However, in the case of Phase 3 contracts, the clawback mechanisms has reduced the expected IRRs further to between -1.2 percent and -3.6 percent (increasing the size of the economic losses earned by network provider). This raises possible questions regarding the commercial sustainability of the network build, although revenues are expected to exceed to operating costs in the longer run.

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 2022. Openreach dominates the market, representing more than three quarters of the broadband market. The other beneficiaries of the Superfast Broadband Programme represented less than one percent of the market in all years.

The market share for Openreach across Superfast contract areas however declined between 2016 and 2022, from around 97 to 85 percent of all broadband connections. While this is higher than the national average (between 70 and 80 percent), the decline in market share aligns with the national trends for Openreach.

In areas where Openreach have delivered contracts, they have maintained their market share between 2016 and 2022 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 80 percent of internet connections in 2022. Fibre to the Cabinet (FTTC) connections represented the largest proportion of NGA connections in all years (around a third of all broadband connections in 2016 and just over a half in 2020 and 2022). As with the national pattern, FTTC is the dominant technology for NGA connections, representing most of the connections in Phase 3 areas – however, this percentage is lower than the national average (around 40 percent in 2022 in Phase 3 areas compared to 50 percent nationally). FTTP connections represent a higher proportion of the market in Phase 3 areas than nationally in 2022 (24 percent in 2022 compared to 10 percent nationally). This suggests that the take-up of FTTP connections nationally is lower than take-up in Phase 3 areas – which would be expected given that the Phase 3 Superfast Broadband contracts are required to provide gigabit capable networks, and the majority of contracts are doing this through FTTP technologies.

The number of infrastructure providers operating on the postcodes benefitting from subsidised upgrades increased between 2016 and 2022. Although there has been an increase in the number of network providers offering services in Phase 3 areas, most non-beneficiary network providers tended to provide services to only a small number of postcodes within the Phase 3 project areas. This suggests there has not been a large degree of overbuild or crowding out of investment.

The number of ISPs operating in Phase 3 areas has increased between 2016 and 2020, but decreased by 2022. There are a higher number of ISPs with customers in Phase 1 contract areas than Phase 2 and Phase 3. This is unlikely to be due to ISPs stopping providing services to a particular area but continuing elsewhere, and could be a function of a small intervention area where individuals are satisfied with their internet connection, and therefore do not undertake a speed test.

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

The gross public sector cost per additional covered premises over three years was £1,418 for Phase 3 contracts. After allowing for clawback, this will fall to £1,225 to £1,276 per premises passed (depending on whether take-up stabilises at 60 or 80 percent in the long-term).

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[78]. However, it should be noted that the cost per premise passed for these European programmes will be dependent on the type of infrastructure investments made to reach premises, and this information was not available.

[78] 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

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

None of the Phase 3 contracts currently listed on the Superfast Status Report 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 six contracts have been terminated. All of these contracts were awarded and terminated by the same Local Body and were awarded to two beneficiaries. These contracts were terminated by the Local Body, due to the inability of the beneficiaries (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 now close to the maximum expected at PFM stage and has caught up following a slow start to delivery.

Wider economy effects

The present value of net public spending required to deliver the Superfast Broadband Programme over the lifetime of Phase 3 contracts was estimated to be £273m in nominal terms.

The findings of the evaluation indicate that the programme has led to a range of economic and social benefits in the areas benefitting from Phase 3 coverage between 2016 and 2021. The key results included:

- **Local employment impacts:** Subsidised coverage from Phase 3 was estimated to have increased employment in the areas benefitting from the programme by 0.88 percent, leading to the creation of 6,261 local jobs by March 2021. The programme as a whole was estimated to have led to 23,700 more local jobs up to March 2021.

- **Turnover:** Subsidised coverage also increased the turnover of firms located in the areas benefitting from Phase 3 of the programme by 1.6 percent by 2021, increasing the annual turnover of local businesses by £827m per annum. Estimates for the whole programme suggested that turnover of firms in areas benefiting from coverage increased by 1.4 percent (equating to around £2.6bn).

- **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 '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 from Phase 3 coverage rose by 0.42 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 0.17 percent by 2021, indicating that subsidised coverage has also raised the efficiency of firms. It should be noted that while subsidised coverage had a stable effect on turnover, impacts on employment increased with time. This led to the strength of the gains in turnover per worker appearing to decay 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

between 0.6 and 0.8 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 9.8 for every 10,000 premises upgraded.

- **House prices:** The programme led to an increase in house prices (of between £1,900 and £4,900) 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:** Phase 3 is estimated to have led to a cumulative total of £7.2m in productivity gains between 2016/17 and 2021/22. This rises to between £20.8m and £23.1m over the 2016/17 to 2030 period. Additional economic benefits from the reduction in long-term unemployment is estimated to be £5.5m between 2016/17 and 2021/22, rising to between £15.7m and £17.4m over the 2016/17 to 2030 period

- **Social benefits:** Based on its impacts on house prices between 2016/17 and 2021/22, the programme is estimated to have led to social benefits valued at between £370.3m and £946.9m.

The estimated Benefit to Cost Ratio (BCR) was between £1.76 and £4.57 per £1 of net lifetime public sector costs based on its impacts between 2016/17 and 2021/22. This assumes that the house price premium is a reasonable approximation of the average welfare gain associated with the programme, and that the house price premium can be applied to all premises in the upgraded areas. The width of the range is driven largely by modelling uncertainty regarding the size of the house price premium associated with subsidised coverage. Allowing for future economic benefits to 2030, the BCR is estimated to rise to between £1.87 and £4.70 per £1 of net public sector spending.

However, it is possible that the house premium overstates the average welfare gain associated with enhanced broadband connectivity. Therefore, a lower bound of total benefits has been estimated, with a BCR between £0.78 and £1.97 per £1 of net lifetime public sector costs between 2016/17 and 2021/22, and between £0.89 and £2.11 per £1 of net public sector spending allowing for economic benefits to 2030.

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Superfast Broadband Programme

State aid evaluation
Technical Appendix 1: Reducing the Digital Divide
January 2023

Ipsos

Contents

Glossary

Deadweight	Investments funded by the public sector that would have otherwise been brought forward by the private sector (i.e. would have happened anyway)
Exchange Only Lines	Premises connected directly to the telephone exchange, rather than to a cabinet that is connected to the telephone exchange. These premises tend to be either very close to the telephone exchange or at long distances in remote locations.
FTTC	Fibre to the Cabinet – a technology involving the installation of fibre optic lines to connect the cabinet to the service exchange, with premises connected to the cabinet using the copper network.
FTTP	Fibre to the Premises – a technology delivering very fast broadband speeds, using fibre optic connections across the full connection between the premises and the Exchange.
Gigabit capable coverage	Refers to any technology able to provide download speeds of 1Gbit/s or faster.
NGA	Next Generation Access – broadband technologies capable of delivering superfast speeds, including Wireless, Fibre-to-the-Cabinet, Fibre-to-the-Premises, and cable.
OMR	Open Market Review – a process completed by Local Bodies to obtain information on the commercial plans of network providers to invest in superfast broadband infrastructure.
Overbuild	The deployment of a new broadband network that competes with an existing broadband network operated by a different network provider.
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.

Summary

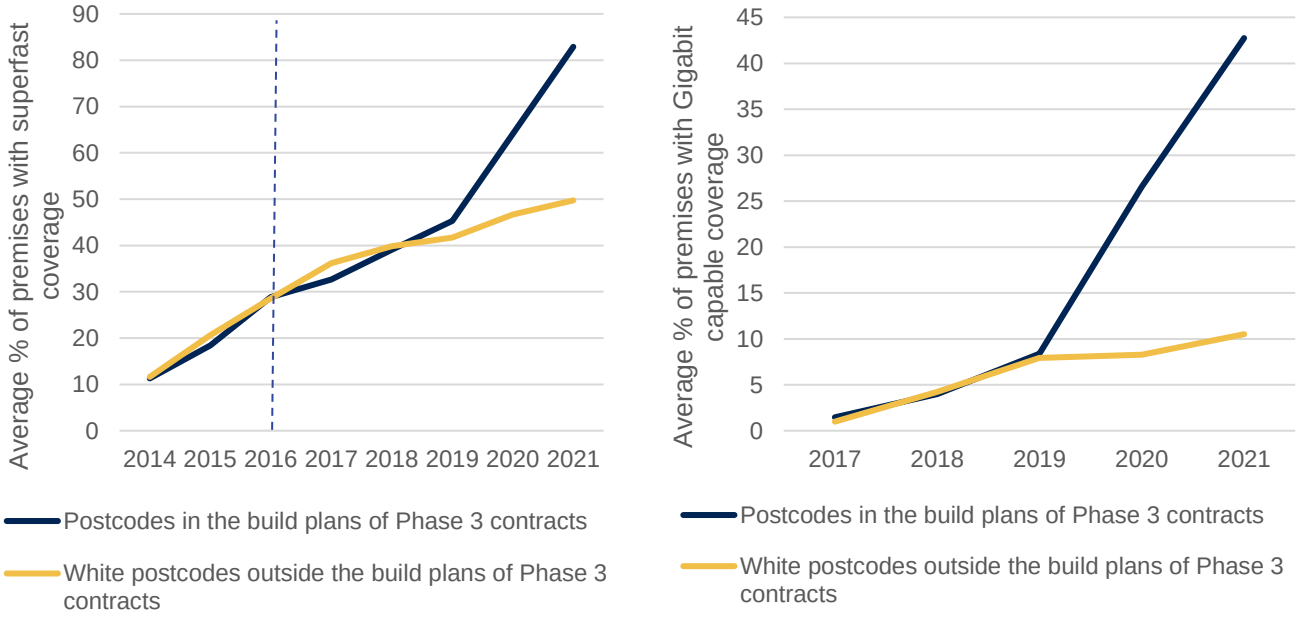
The Superfast Broadband Programme was announced in 2010 in response to concerns that the commercial deployment of superfast broadband infrastructure would fail to reach many parts of the UK. Phase 3 of the Superfast Broadband Programme was funded under a new State aid Decision covering contracts awarded between 2016 and 2020 (State aid SA. 40720 (2016/N)). This paper sets out the results of a series of analyses exploring the impact of the Superfast Broadband Programme on superfast broadband and full fibre/gigabit capable coverage and the take-up of superfast broadband services. The analyses focus on the impacts of Phase 3 of the programme by September 2019.

Overview of results

The findings of the evaluation indicated that Phase 3 of the Superfast Broadband Programme had a significant impact on the availability of superfast and gigabit capable broadband services, particularly as delivery of the programme expanded after 2019.

As illustrated in the following figure, superfast and gigabit capable coverage expanded rapidly in areas benefiting from the programme relative to equivalent postcodes that were not covered by Phase 3 contracts. 80 and 40 percent of premises in the programme area were able to access superfast (at least 30Mbit/s) and gigabit capable services respectively by the end of September 2021.

Figure A: Changes in superfast broadband (at least 30Mbit/s) and Gigabit capable coverage (% of premises), areas in Phase 3 build plans and matched white postcodes[1], 2014 to 2021



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

The results of statistical analyses confirmed these results:

- **Impact on broadband coverage:** Subsidised coverage through Phase 3 of the Programme led to significant positive impact on the availability of superfast and gigabit capable broadband services by the end of September 2021. Subsidised coverage increased the share of premises in the programme area able to access superfast speeds by 46 to 47 percentage points, and the share of premises with

[1] 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.

gigabit capable coverage by 52 to 56 percentage points above what would have been achieved in the absence of the programme since 2017.

The impact of the programme on NGA availability (i.e. technologies able in principle to deliver superfast, though not necessarily the faster speeds being targeted by Phase 3 contracts) was relatively small, however, indicating that in its absence, most premises would have benefitted from some form of enhanced connectivity (albeit via technologies less able to deliver download speeds of 30Mbit/s or higher).

- **Impact on take-up:** Subsidised coverage led to a significant increase in the maximum download speeds of connections taken by households and/or businesses by September 2021 (34 to 62 Mbit/s). However, the impacts of the programme on average download speeds were relatively small. This indicates that 'early adopters' have taken advantage of the enhanced broadband connectivity enabled by the Programme. However, the Programme had not led to widespread take-up of faster broadband services by September 2021. It should be noted that most subsidised coverage was delivered in 2019 and 2020. As take-up will lag deployment, it is premature to draw any firm conclusions on the impact of the programme on take-up of faster internet services.

Overall, findings on coverage to September 2021 are larger than those evidenced to 2019 and are in line with past research on the Superfast Broadband Programme. The results were also broadly consistent across different methodologies raising confidence in the findings.

Table A: Estimated impact of Phase 3 on areas benefitting from subsidised coverage by September 2021

Outcome	Estimated impact (high to low range)
NGA[2] availability (% of premises)	3.2 to 7.5
Superfast availability (% of premises)	40.9 to 46.6
Gigabit capable availability (% of premises)	43.2 to 56.2
Average download speeds of connections (Mbps)	0 to 0.6
Maximum download speeds of connections (Mbps)	33.7 to 59.2
Average upload speeds of connections (Mbps)	0.9 to 6.3
Number of connections with download speed of 30Mbps+	-1.0 to 3.9

Source: Ipsos analysis. '-' denotes that the result was not statistically significant.

Additionality of subsidised broadband infrastructure

The findings of the evaluation also indicated that few premises would have otherwise received superfast or gigabit capable coverage by the end of 2019, and levels of deadweight were generally limited:

- **Superfast availability:** The Programme is estimated to have increased the number of premises that can access at least superfast broadband services (30Mbit/s or above) by 202,000 to 247,000 by the end of September 2021. The associated rate of additionality ranges from 69 percent to 85 percent. This indicated that while many premises may have received NGA coverage in the absence of the

[2] Refers to technology and NGA does not guarantee Superfast speeds. NGA was selected as the primary outcome measure when the State aid evaluation plan was agreed. However, changes in the availability of local data on connectivity via the Connected Nations report has allowed analysis against a wider set of outcomes.

Programme, these premises would not have been able to access at least superfast speeds (indicating the programme has been highly effective in delivering against its primary objective).

- **FTTP/Gigabit capable coverage:** Subsidised coverage is estimated to have led to 193,000 to 298,000 additional premises with FTTP/Gigabit capable coverage. The rate of additionality ranges from 66 percent to 102 percent (with most estimates in the region of 90 percent). This indicates that the programme has also been highly effective in bringing gigabit capable technologies to rural areas, and these areas were highly unlikely to have benefitted from commercial deployments over the time horizons considered in this evaluation.

- **NGA coverage:** The Programme is also estimated to have led to 17,000 to 40,000 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 6 and 14 percent, with most estimates towards the lower end of this range. This implies that to a large degree, premises benefitting from the programme would have received some form of NGA coverage in its absence, though any improvements in local connectivity would not have delivered the significant improvements in available speeds achieved through the programme.

Table B: Estimated additionality of NGA, Superfast and Gigabit capable coverage

	Additional premises with enhanced coverage by September 2021	Additionality (share of premises that would not have received enhanced coverage by end of Sep 2021)
NGA availability	17,000 – 40,000	6 – 14%
Superfast availability	202,000 – 247,000	69 – 85%
Gigabit availability	193,000 – 298,000	66 – 102%

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 across the target area as whole.

Previous results of this analysis suggested that the Programme had a negative effect on enhanced broadband availability across the overall Programme area (suggesting it had delayed coverage in some area). Such effects are no longer visible now the analysis has been extended to 2021, indicating that any negative effects via the delay of deployment were only temporary.

1 Introduction

This paper sets out the results of a series of analyses exploring the impact of the Superfast Broadband Programme on superfast broadband and full fibre/gigabit capable coverage and take-up of superfast broadband services, focusing on the impacts of Phase 3 of the Programme.

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 parts of the UK due to the cost of installing the technology relative to expected revenues.[3] 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[4] covering the 2016 to 2020 period. Contracts awarded under this State aid scheme (sometimes 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. There were 67 Phase 3 contracts underway at the time of writing.

1.2 Evaluation questions

This analysis tackles three key evaluation questions defined in the State aid evaluation plan[5] 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[6] (NGA) network in white[7] NGA areas?
- **Question 2:** To what extent has the target of the intervention been used and what speeds are available?

[3] 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 March 2022).

[4] 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 March 2022).

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

[6] 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 March 2022).

[7] 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.

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

1.3 State aid evaluation methodology[8]

The methodology used for the analysis builds on the approach set out in the State aid evaluation plan (and is consistent with prior analyses). This involved two main approaches:

- **Difference-in-differences:** This approach compares changes in NGA coverage and take-up between June 2016 and September 2021 on postcodes benefitting from Phase 3 contracts and a comparison group of postcodes that were identified as white in the Open Market Review process but were not included in the build plans of Phase 3 contracts. The evaluation plan defined postcodes benefitting from the Programme as those that received subsidised coverage by September 2021 (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 coverage and take-up on white postcodes that were not included in the build plans of Phase 3 contracts between 2016 and 2021. 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 were made to the above methodology that was defined in the State aid evaluation plan to extend the scope of the analyses and probe 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 (30Mbit/s) 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 the availability of technologies capable of delivering gigabit speeds (1,000Mbit/s).

- **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 plans 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

[8] All analyses were implemented with STATA software package.

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.

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.

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 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 resources brought by the Local Body). 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 credible 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,
  - **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.

[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.

- **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. Only 'white' premises were eligible for subsidised infrastructure, with competing providers outlining which 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 equalise 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 underlying principle 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 coverage to a greater number of premises than originally offered.

- **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, several factors could 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 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 funding could fund superfast infrastructure in areas that would otherwise have benefitted from commercial deployments. Threats to the accuracy of the information gathered through the OMR include:

  - **Comprehensiveness:** The OMR process aimed 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. If some potential providers did not provide their commercial plans, there is a risk that some 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 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 also

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

provided evidence that some network providers 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 increased 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 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 some 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 business 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 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 access Openreach's Physical Infrastructure Access (PIA) product more efficiently, 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, contractual mechanisms 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 the 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. 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.

  The effectiveness of these mechanisms will be linked to the level of competition for the subsidies awarded. In the absence of competition, the network 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

[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.

in the presence of competition, as it would reduce the value for money associated with the tender and increase the likelihood the procurement was lost to a competitor. Phase 3 contracts were all awarded through an open OJEU process and many tenders attracted multiple bids.

- **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 Programme 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

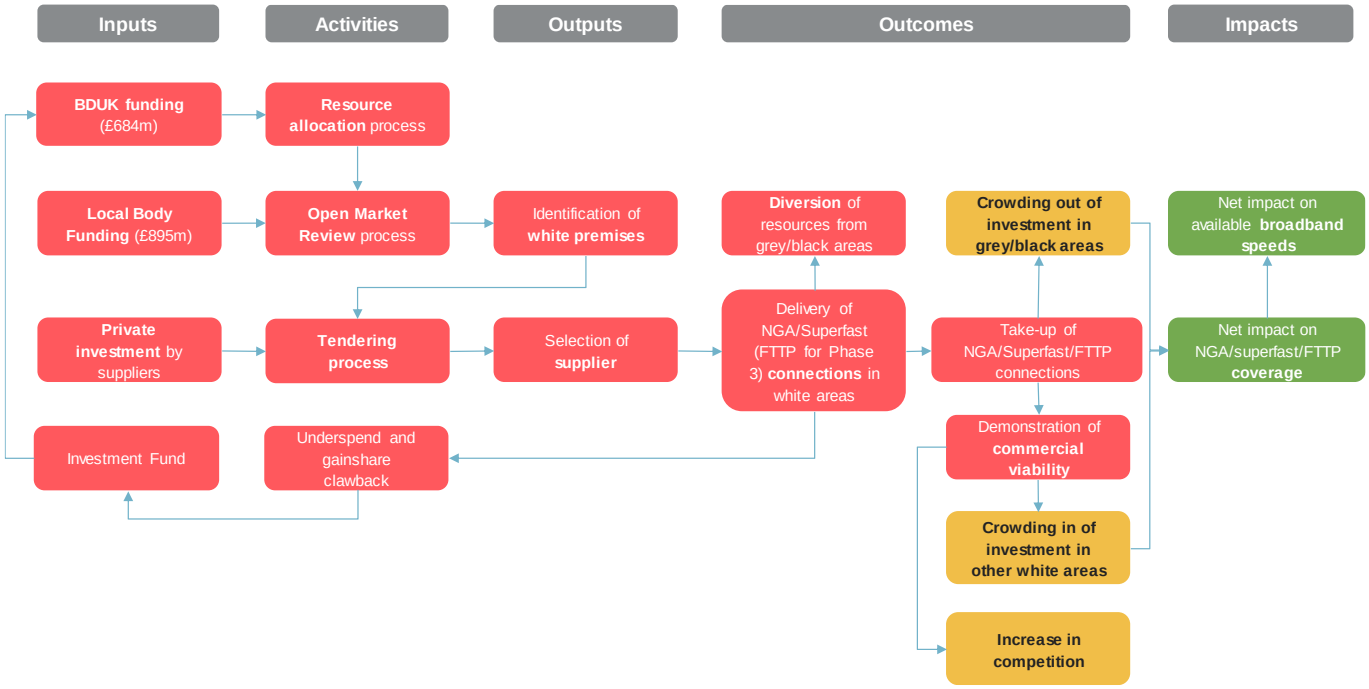
wholesale market prices). These requirements could potentially stimulate additional competition in wholesale or retail markets.

- **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.

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



Source: Ipsos analysis

3 Programme overview

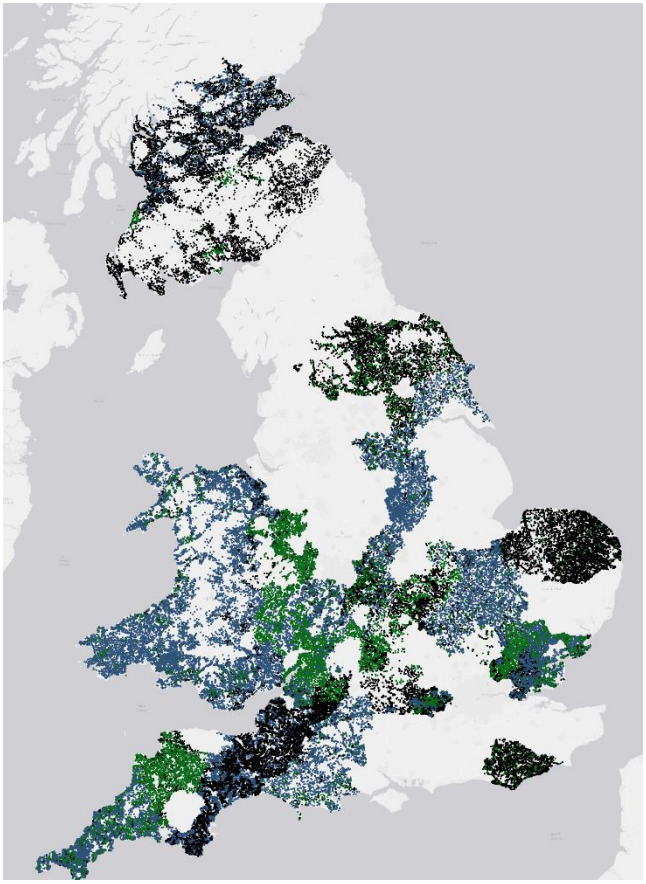
This section provides an overview of the delivery of the Superfast Broadband Programme between 2012 and 2021 with an emphasis on the delivery of Phase 3 contracts. This section draws on an analysis of management data describing the target areas of contracts awarded under the programme and delivery of the programme to September 2021.

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 identifies those premises that are not expected to receive superfast coverage under the commercial plans of network providers (white postcodes) and are therefore eligible for subsidised coverage.

These templates are completed by network providers as part of the tendering process, where they set out which premises will be upgraded as part of the proposed network build (the build plan). Premises on 64,000 postcodes were included in the build plans of Phase 3 contracts (four percent of the postcodes in the UK). Premises on 54,000 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



Source: SCT templates, C3 Reports, Ipsos analysis; green denotes built to as of September 2022, 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.

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

Status	Phase 3	
	Number of postcodes	% of postcodes in UK
White postcode within build plan defined in SCT	64,473	4.3
White postcode out of build plan defined in SCT	53,729	3.5
Grey or black postcode in SCT	43,602	2.6
Total	**161,804**	**10.7**
Number of SCTs	65[14]	

Source: SCT templates, Ipsos analysis

3.2 Characteristics of postcodes benefitting from the programme

The postcodes included in the build plans of Phase 3 contracts were linked to other datasets 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 3.2. 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 in 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 at least 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 (74 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 similar across groups, though average wages were lower in those areas included in Phase 3 build plans than in areas not included in 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

[14] A total of two SCTS were excluded as they did not provide the required detail and no alternatives were available.

Phase 2[15] of the Programme. 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 unserved premises 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. 2021	White postcodes not included in Phase 3 build plans
Broadband availability and take-up in 2012			
% of postcodes with Next Generation Access	14.9	14.3	39.6
Average maximum download speed (Mbit/s) of connections[16]	9.3	10.0	13.4
Average download speeds (Mbit/s) of connections	6.2	9.7	13.9
Broadband availability and take-up in 2016			
% of postcodes with Next Generation Access	70.4	72.4	79.8
% of postcodes with superfast (30Mbit/s) access	25.2	25.2	55.6
Average number of premises on postcode with superfast connections[17]	1.7	5.1	8.1
Network characteristics in 2013			
Length of line from exchange to premises (m)	3,588	3,050	2,165
Share of premises with exchange only lines (%)	22.3	13.0	4.5
Delivery points at serving exchange	6,231	10,765	17,601
Delivery points at serving cabinet	242.7	300.5	381.0
% of postcodes in Virgin Media footprint	0.7	14.7	48.4
Number of residential delivery points	11.1	14.9	19.6
Number of non-residential delivery points	1.0	1.1	0.7
Estimated cost to upgrade serving cabinet (£)	65,549	63,939	61,834
Estimate upgrade cost per premises upgraded (£)	325.5	307.9	179.3
Area characteristics in 2013			
% of postcodes in rural areas	74	54	64
Working age population (in Output Area)	170	195	200
Population aged 65+ (in Output Area)	62	55	50
Population density in OA (population per square km)	634	1,659	4,412
Premises density in OA (premises per square km)	402	988	2569
Gross weekly earnings in LA (£)	465	537	519
Employment rate in LA (%)	71.8	74.4	71.1
Unemployment rate in LA (%)	6.1	7.1	8.2

Source: Ipsos Analysis

[15] BDUK (2018) Superfast Broadband Programme Evaluation: Annex A – Reducing the Digital Divide.

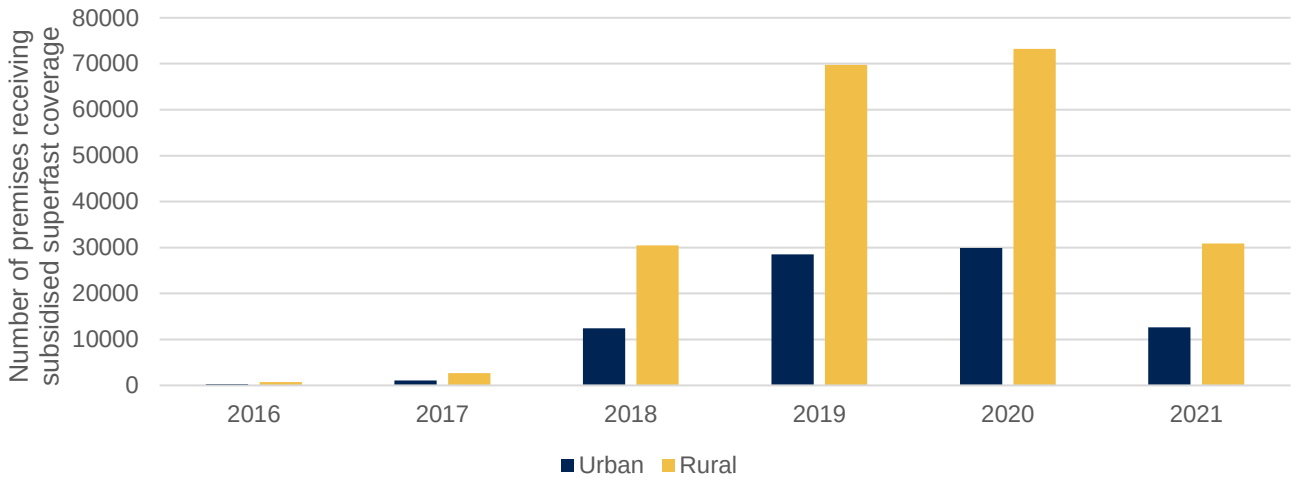
[16] Note that this does not factor in the number of premises on a postcode able to reach a certain maximum download speed

[17] There were around 11.3 premises per postcode on postcodes in the build plans of Phase 3 schemes.

3.3 Delivery

Delivery of the Programme began in 2016 and analysis of C3 reports provided by BDUK indicated that around 292,618 premises received subsidised coverage by September 2021 (over 37,000 postcodes). It should be noted that most coverage was towards the latter stages of the time horizon for this evaluation. As take-up of superfast broadband services will follow deployment, it should be noted that the estimates of the impact of the programme presented in this paper are likely to understate the eventual impact of the programme on take-up.

Figure 3.2: Number of premises receiving superfast (30Mbit/s[18]) coverage subsidised by BDUK, areas for which Phase 3 SCTs are available, 2016 to 2021



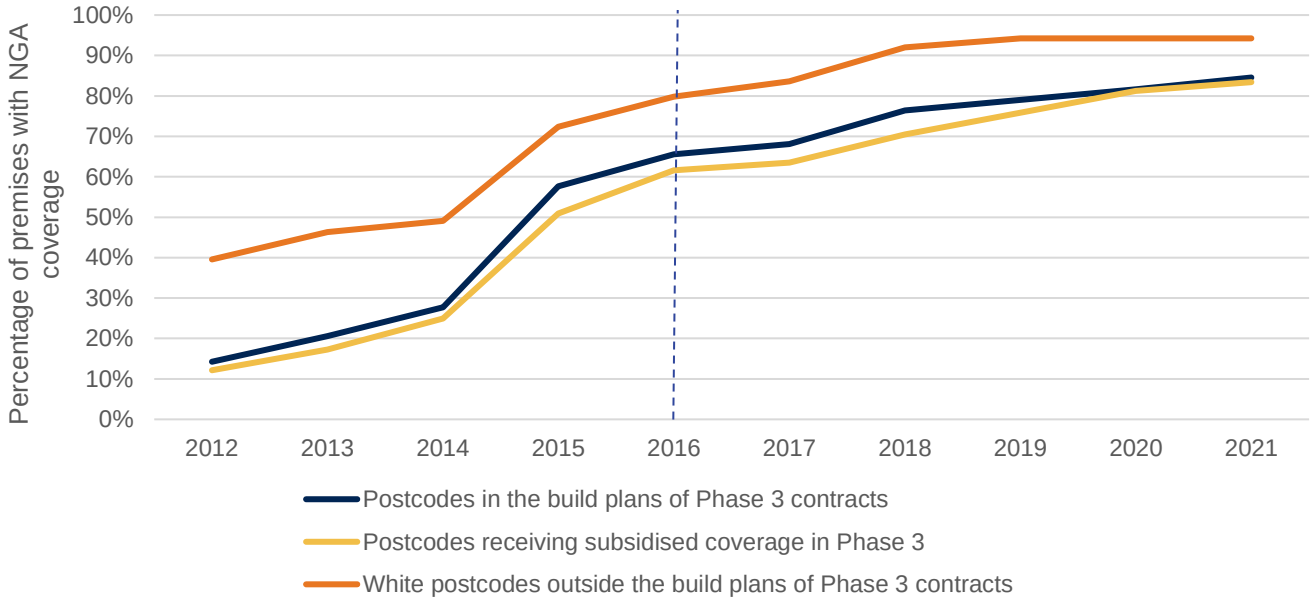
Source: C3 reports, Ipsos analysis.

3.4 Changes in connectivity in the target area

The following figure shows changes in availability of Next Generation Access (NGA) broadband (FTTC, FTTP/Gigabit capable, Wireless or Cable) between 2012 and 2021 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 66 percent to 85 percent between June 2016 and September 2021. 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).

[18] 24MBits for Phase 1 and Phase 2

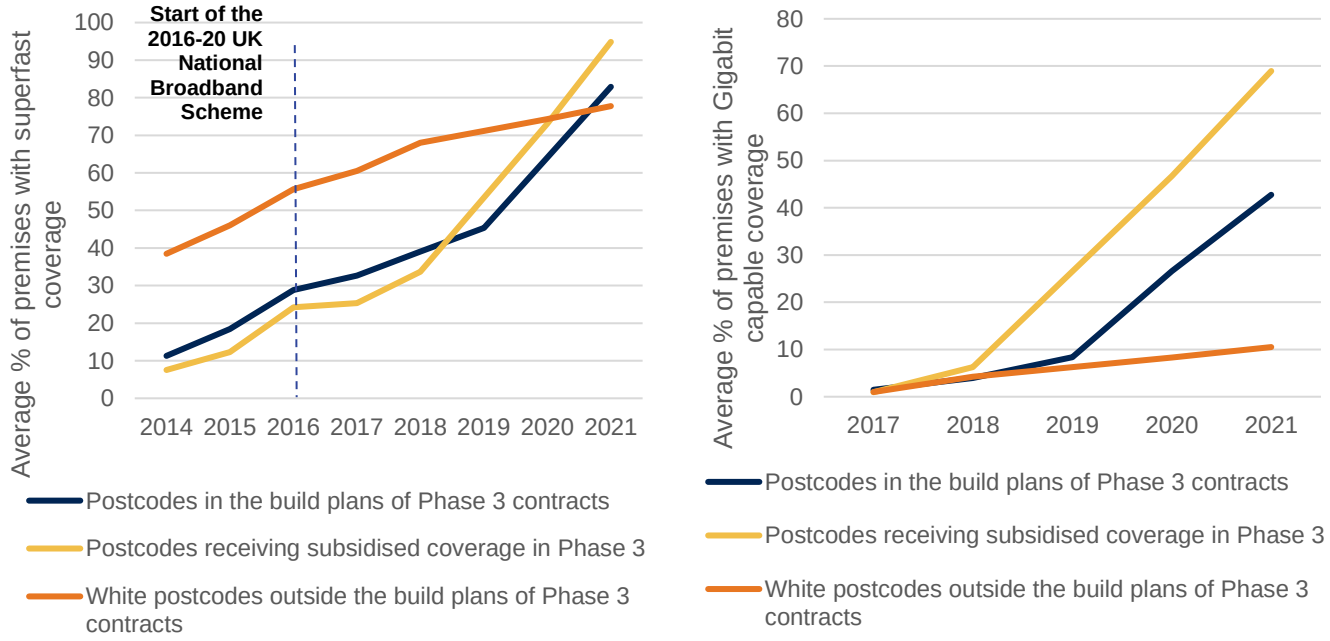
Figure 3.3: Changes in Next Generation Access (NGA) coverage – areas in Phase 3 build plans and other white postcodes, 2012 to 2021



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

Superfast broadband 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). However, in line with the delivery profile, areas within Phase 3 build plans saw coverage expand much more rapidly between 2019 and 2021, rising from 45 percent to over 80 percent of premises over the period. FTTP/Gigabit capable coverage also rose more rapidly in the programme area than on other white postcodes.

Figure 3.4: Changes in superfast broadband (at least 30Mbit/s) and Gigabit capable coverage (% of premises), areas in Phase 3 build plans and other white postcodes, 2014 to 2021



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

3.5 Take-up of subsidised coverage

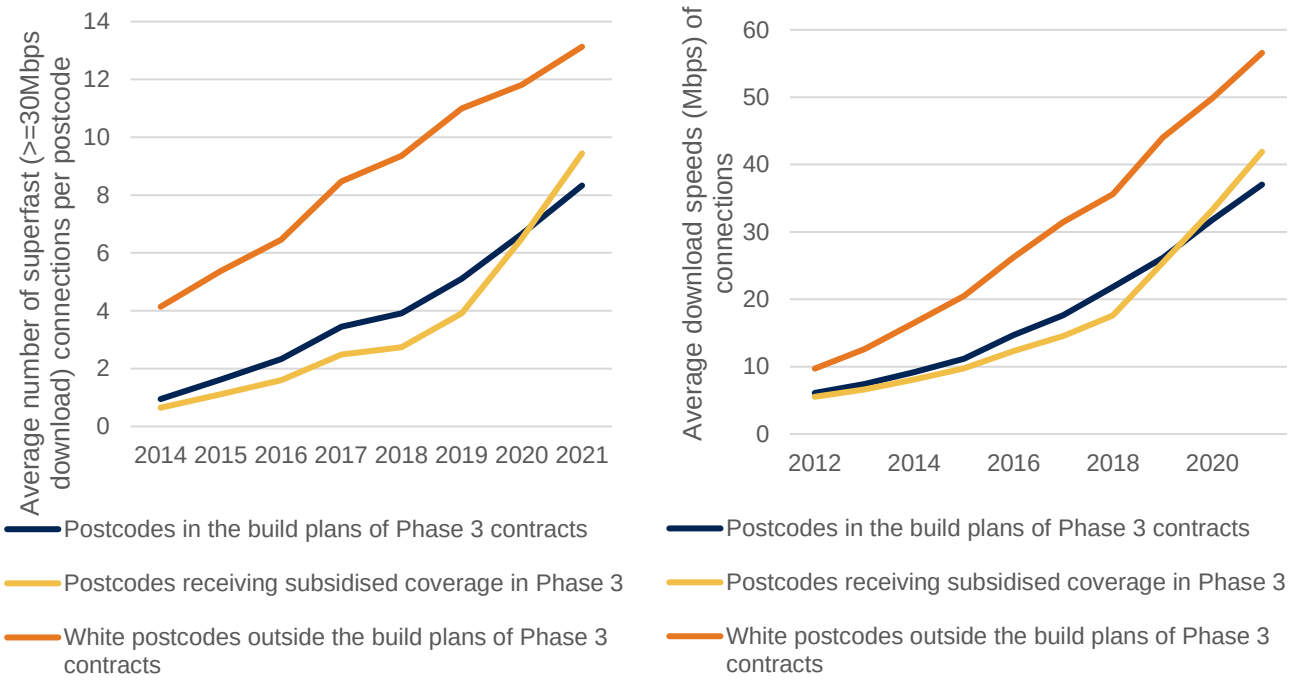
Take-up of superfast broadband coverage also rose rapidly in the programme area relative to other white postcodes by September 2021:

- **Number of superfast (30Mbit/s) connections:** The average number of superfast connections on postcodes in the build plans of Phase 3 schemes grew from 2.3 in 2016 to 8.3 in 2021. Connections on postcodes receiving subsidised coverage rose even more rapidly, from 1.6 in 2016 to 9.4 in 2021. The number of superfast connections rose at lower rate on other white postcodes not included in the build plans of Phase 3 schemes.

- **Average download speeds:** The average download speeds of connections on postcodes included in the build plans of Phase 3 contracts rose from 15 Mbit/s to 37 Mbit/s between 2016 and 2021 (152 percent). Growth in average download speeds was even more rapid on postcodes receiving subsidised coverage by September 2021 (rising to 42 Mbit/s). However, average download speeds remained lower than across other white postcodes that were not covered by the programme over the period.

As in 2020, there were more marked differences in the maximum download speeds of connections (shown in Figure 3.6). Maximum downloads speeds on the postcodes included in the build plans of Phase 3 schemes rose at a faster rate to those on other white postcodes. Maximum download speeds again rose most rapidly in those areas that had received subsidised coverage. Areas receiving coverage by September 2021 saw average maximum download speeds reach 124Mbit/s. This is indicative of users taking advantage of the faster speeds made available through FTTP (the availability of which was more widespread in these areas in 2021).

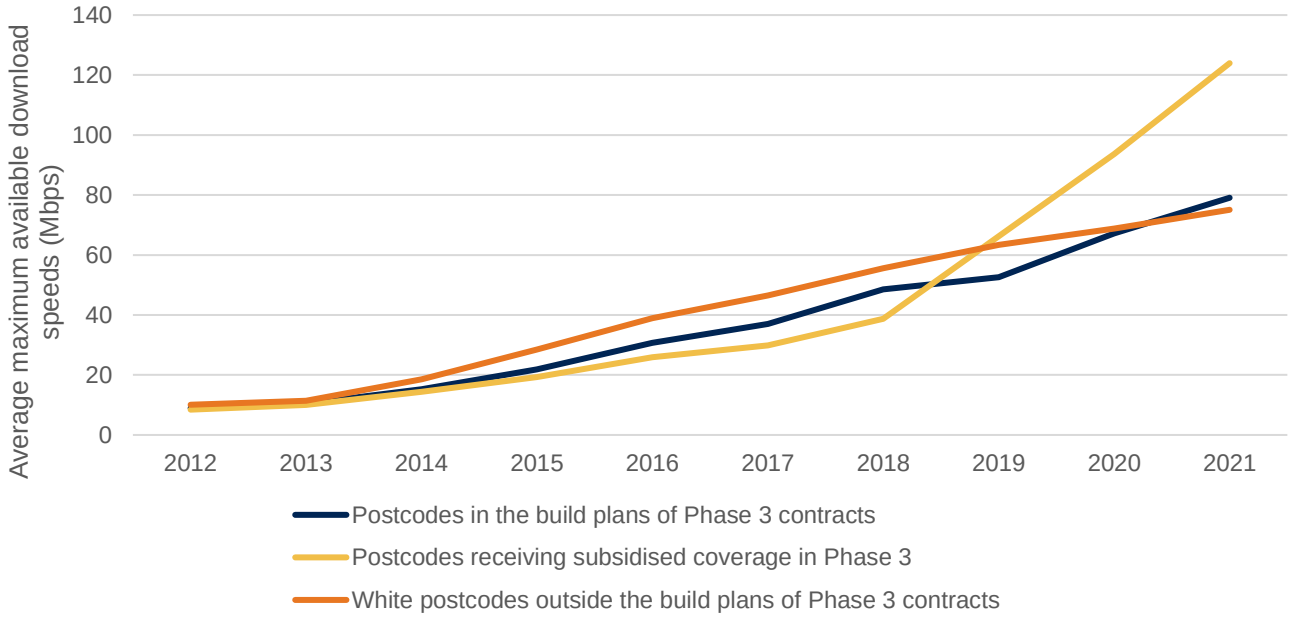
Figure 3.5: Number of superfast (30Mbit/s) connections and average download speeds of connections – areas in Phase 3 build plans and other white postcodes, 2014 & 2012 to 2021



Source: C3 reports, Ofcom Connected Nations, Ipsos analysis[19].

[19] Data on superfast connections only available from 2014 onwards in Ofcom Connected Nations data

Figure 3.6: Maximum download speeds of connections, areas in Phase 3 build plans and other white postcodes, 2016 to 2021



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

4 Phase 3 connectivity impacts

This section provides an assessment of the impact of Phase 3 contracts on the connectivity outcomes by September 2021. 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.

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 2021. 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 to 2021 releases providing a snapshot for September of the relevant year.
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 with all available SCTs, which covered almost all local schemes that had been contracted under Phase 1, 2 and 3 by September 2021.
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 2021 gave details of some 8m 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.

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 30Mbit/s. 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/Gigabit capable coverage[20]	Phase 3 of the programme prioritised technologies capable of delivering gigabit per second speeds which has concentrated investment in FTTP delivery. Connected Nations data for 2020 and 2021 provided information on gigabit capable coverage, while in prior years it provided details on FTTP coverage. This broader measure includes non-FTTP technologies capable of gigabit speeds. Consultation with BDUK and Ofcom indicated that Virgin Media gigabit capable coverage accounted for much of the difference between the FTTP coverage and gigabit capable coverage (and the roll-out of Virgin Media coverage did not begin in large volumes until 2020). As such, an assumption has been made that FTTP and gigabit capable coverage were equivalent before 2020.
Number of connections of 30Mbit/s or higher	The number of households or businesses taking up a 30Mbit/s 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 stated 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

[20] A request for information on Virgin Media gigabit capable coverage in 2019 has been submitted to check our understanding.

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. White postcodes not included in the build plans of Phase 3 contracts are likely to differ in systematic ways to those that benefitted 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 defined the treatment as postcodes that have been included in Phase 3 build plans and had at least one premise upgraded by the end of September 2021. While this approach enables an assessment of the effects of the programme on areas that have benefitted from subsidised upgrades, this also introduces possible biases driven by unobserved differences between those areas that benefitted from early delivery and those benefitting at a later stage. Such an approach will also fail to capture any effects of the programme on areas that were yet to benefit from subsidised upgrades (e.g. delaying superfast rollout). 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 the complexities involved, 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 used to establish an estimate of the change in broadband availability. This approach takes the difference between the weighted mean[21] of the outcomes of interest (i.e. the percentage of premises with NGA, superfast and FTTP/Gigabit capable coverage) before and after intervention across the control and treatment groups to give the change in coverage in NGA white areas due to intervention.

$$\Delta outcome_{intervention1621} = (outcome_{T21} - outcome_{T16}) - (outcome_{C21} - outcome_{C16})$$

The percentage change in coverage between 2016[22] and 2021 attributable to the programme is equal to the difference in outcomes in 2021 and 2016 for postcodes benefitting from the programme $(outcome_{T21} - outcome_{T16})$ and the comparison group of postcodes that were eligible in Phase 3 but not included in build plans $(outcome_{C21} - outcome_{C16})$[23].

[21] Weighted by total premises per postcode

[22] This is 2017 for FTTP given lack of inclusion of this variable in the 2016 Connected Nations data

[23] Note that T subscript denotes the Treatment Group, and the C subscript denotes the Control Group.

The difference-in-difference model is robust to unobserved but time invariant 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, areas included in Phase 3 build plans saw a different pattern of investment in coverage over time relative to other white postcodes, which could lead to possible distortions in the results. 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 Phase 3 delivery increased the percentage of premises covered by NGA, superfast and Gigabit capable by eight, 47 and 56 percentage points respectively on those postcodes that had benefitted from subsidised coverage by September 2021.

  In terms of take-up measures, the Programme was associated with no significant impact on the number of superfast connections, though effects on the maximum download speeds of connections were positive (around 59Mbps on average). This suggests that while the programme did not increase the overall numbers of households taking faster connections by September 2021, those that have taken faster connections have been able to obtain faster speeds. As highlighted previously, given that delivery was concentrated in 2019 and 2020, it is premature to draw any firm conclusions on the impact of the programme on take-up.

- **Postcodes in Phase 3 build plans:** The estimated impact of the Programme was smaller when the models were applied to all postcodes in the build plans of Phase 3 schemes (reflecting that not all postcodes would have benefitted from subsidised coverage at this time). The estimated impacts on the percentage premises covered by NGA, superfast, and Gigabit capable were 3.2, 30.6 and 30.5 percentage points respectively.

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[24] & 2021			Change in outcome between 2016/17[25] & 2021		
Outcome	Other white postcodes	Treatment group	Estimated impact	Other white postcodes	Treatment group	Difference
Treatment group	Postcodes delivered to by September 2021			All postcodes in Phase 3 build plans		
Coverage outcomes						
NGA availability (% of premises)	16.8	24.6	7.8***	17.1	20.3	3.2***
Superfast availability (% of premises)	21.2	67.8	46.6***	21.2	51.9	30.6***
Gigabit capable availability (% of premises)	9.1	65.3	56.2***	9.1	39.6	30.5***
Take-up outcomes						
Average download speeds of connections (Mbps)	28.4	29.1	-0.7	28.4	21.4	-7.0***
Maximum download speeds of connections (Mbps)	59.4	94.1	34.7***	33.6	46.5	12.9***
Average upload speeds of connections (Mbps)	6.3	12.2	5.9***	9.7	12.2	2.5***
Number of connections with download speed of 30Mbps+	7.5	6.4	1.2***	7.5	5.8	-1.7

*Source: Ipsos analysis; *** represents differences significant at 99 percent, ** at 95 percent and * at 90 percent*

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[26] 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 2021 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).

[24] 2017 for FTTP

[25] ibid

[26] The equation shows the 'first-difference' version of the difference-in-difference approach.

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 (with variables selected based on evidence regarding the key determinants of commercial viability based on relevant academic literature[27] and consultations with BDUK officials):

- **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 at least 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

[27] E.g. Ahlfeldt et al (2014) Speed 2.0: Evaluating Access to Universal Digital Highways

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 were 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[28]. 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).

4.4.2 Results

The results using a regression approach are presented in Table 4.4 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/Gigabit capable technologies by 4.1, 43.4, and 51.7 percentage points respectively (in those postcodes benefitting from subsidised upgrades by September 2021). As with the preceding analysis, the effect of the programme on FTTP availability was larger than for superfast availability (implying that some

[28] 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).

premises receiving FTTP coverage would have otherwise received superfast coverage through other technologies).

- **Coverage on all postcodes in the build plans of Phase 3 SCTs:** The findings with all postcodes in build plans as the treatment group were similar. These suggested that the share of premises covered by NGA, superfast and FTTP/Gigabit capable technologies increased by 2.1, 29.5, and 28 percentage points respectively in these areas.

- **Speeds and take-up:** The results this time round indicated that the programme has had a positive impact on several take-up measures. Maximum speeds and average upload speeds in particular indicated increases.

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.

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. 2021				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	60,436	21,348	21,348	21,348	117,120	109,514	109,514	109,514
Adjusted R-squared	0.0111	0.7181	0.7031	0.5908	0.0022	0.6159	0.6913	0.4982
NGA availability (% of premises)	7.6***	5.2***	5.2***	4.1***	3.2***	2.3***	2.2***	2.1***
Superfast availability (% of premises)	47.5***	45.8***	45.8***	43.4***	31.3***	29.9***	29.9***	29.5***
Gigabit capable availability (% of premises)	57.3***	52.1***	52.2***	51.7***	31.2***	28.9***	28.9***	28.0***
Average download speeds of connections (Mbps)	-0.8***	-0.2	-0.2	n/a	-7.8***	-3.9***	-3.8***	n/a
Maximum download speeds of connections (Mbps)	60.7***	58.9***	59.2***	n/a	12.1***	11.5***	11.4***	n/a
Average upload speeds of connections (Mbps)	6.0***	5.6***	5.7***	n/a	3.4***	3.1***	3.1***	n/a
Number of connections with download speed of 30Mbps+	1.2***	0.6***	0.8***	n/a	-0.6	-0.4	-0.4	n/a

*Source: Ipsos analysis; *** represents differences significant at 99 percent, ** at 95 percent and * at 90 percent*

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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 Section 4.4.1.

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 section 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 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.

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

[29] The model took the form: $\Delta outcome_i = \beta_0 + \beta_1 TD + \boldsymbol{\beta x_i} + \epsilon_i$

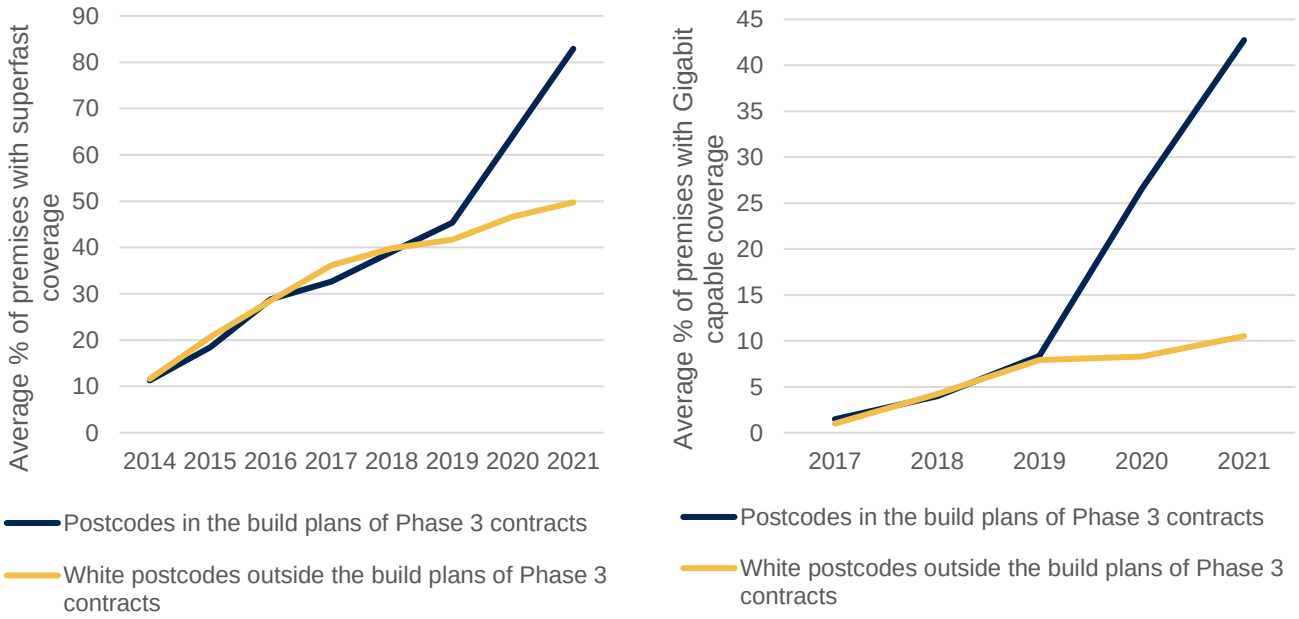
[30] This took the form of a Probit model: $\Pr(Yi = 1|Xi) = \phi(Xi\beta)$. In this model, Y is a binary indicator describing whether postcode i was included within the build plan of a local scheme (1 = yes, and 0 = no) and X is a vector of factors describing the characteristics of the postcode that are thought to influence its inclusion in the scheme.

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 4.5 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 1.2 and 3.9 percent (from between 13.8 and 35.6). 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.

The charts below illustrate the evolution of superfast and gigabit capable coverage over time for the postcodes in the build plans for Phase 3 relative to those in the matched comparison area. This clearly demonstrates the success of the matching algorithm in reducing the differences between areas pre-intervention (and illustrates the impact of the programme on superfast and gigabit capable coverage).

Figure 4.1: Changes in superfast broadband (at least 30Mbit/s) and Gigabit capable coverage (% of premises), areas in Phase 3 build plans and matched white postcodes, 2014 to 2021



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

As illustrated in the table below, 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.

Table 4.5: Overview of Characteristics of Matched Samples

Treatment group	Postcodes delivered to by September 2021						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	35,564			16,372			61,493			25,938		
Number of unmatched postcodes	109			49			190			84		
Mean standardized bias (pre-match)	37.4			21.6			27.7			14.5		
Mean standardized bias (post-match)	4.1			2.9			1.8			1.3		
Variable	Treated	Control	Sig.	Treated	Control	Sig.	Treated	Control	Sig.	Treated	Control	Sig.
Number of suppliers in postcode (2012)	2.18	2.22	*	2.30	2.33		2.42	2.44	**	2.46	2.48	**
Number of suppliers in postcode (2016)	2.40	2.43	*	2.49	2.51		2.48	2.48		2.52	2.52	
Superfast % of premises (2014)	8.01	8.15		6.73	6.63		11.80	11.27	**	9.87	9.47	*
Superfast % of premises (2015)	12.21	13.18	*	13.16	12.54		18.87	17.62	***	20.97	19.61	***
Superfast % of premises (2016)	23.12	26.42	***	25.73	24.91		28.97	28.02	***	34.01	32.79	**
NGA % or premises (2012)	0.16	0.17	**	0.14	0.15		0.16	0.16	*	0.12	0.12	
NGA % or premises (2013)	0.26	0.31	**	0.23	0.28	***	0.26	0.27	***	0.20	0.21	**
NGA % or premises (2014)	0.34	0.38	***	0.33	0.37	***	0.35	0.35	*	0.32	0.33	*
NGA % or premises (2015)	0.60	0.62	***	0.61	0.61		0.66	0.67	**	0.67	0.68	*
NGA % or premises (2016)	0.71	0.74	**	0.71	0.73	*	0.75	0.75		0.77	0.77	
% of postcodes in LA with NGA, (2013)	0.40	0.41	***	0.41	0.41		0.42	0.42	*	0.41	0.41	
% of postcodes in LSOA with NGA, (2013)	0.29	0.32	***	0.28	0.31	**	0.28	0.29	**	0.23	0.24	*
Line Length (m)	8.14	8.14		8.06	8.10	*	8.08	8.07		7.94	7.96	
Final speed	6.60	6.47		7.02	7.00		6.85	7.01	***	7.41	7.50	*
Premises with EO lines 2013	2.32	2.25		3.71	3.47		2.30	2.40	*	3.83	3.89	
Delivery points at serving exchange	6788.20	7767.81	***	6776.06	7646.12	***	6540.95	6635.81	*	6125.51	6249.74	
Delivery points at serving cabinet	220.23	232.05	***	238.43	256.47	***	254.81	255.57		272.98	274.40	
Virgin Media availability	0.00	0.00		0.00	0.00		0.01	0.01	*	0.00	0.00	
Estimated Upgrade Cost (£)	66829.38	67346.52		68695.98	69364.08		68922.42	68626.62	*	70372.86	69970.98	

Cost Per Premises Upgraded	358.60	348.59		333.56	316.04	*	340.10	338.11		290.63	280.82	**
Working Age Population	202.03	205.23	**	202.06	208.10	**	180.40	183.57	***	179.78	184.05	***
Population Aged 65 and Over	66.45	68.36	***	67.03	66.71		58.64	59.39	***	59.72	61.13	***
(Log) Population Density	4.39	4.45	*	4.75	4.75		4.62	4.63		5.09	5.08	
(Log) Premises Density	3.80	3.89	*	4.15	4.16		4.06	4.07		4.51	4.51	
Gross Weekly Wages (in LA)	506.09	501.98	***	510.53	508.93		513.76	513.02	*	513.00	510.62	**
Employment Rate (in LA)	76.09	76.01		76.13	76.04		75.71	75.82	**	75.43	75.58	**
Unemployment Rate (in LA)	6.28	6.12	***	6.26	6.13	*	6.51	6.43	***	6.58	6.52	*
No. prems with superfast available (2014)	1.67	1.63	***	1.53	1.49		2.60	2.47	**	2.37	2.28	
No. prems with superfast available (2015)	2.37	2.38		3.02	2.91		3.87	3.59	***	5.07	4.85	
No. prems with superfast available (2016)	3.95	4.13		5.59	5.28		5.53	5.31	**	7.93	7.73	
No. superfast connections (2016)				1.14	1.00	*				1.66	1.63	*
No. superfast connections (2015)				0.65	0.60					0.94	0.93	
No. superfast connections (2014)				0.23	0.23					0.30	0.30	
Average Download Speeds (2012)				5.19	5.20					5.67	5.65	
Maximum Download Speeds (2012)				8.46	8.38					9.15	9.16	
Average Download Speeds (2013)				5.75	5.78					6.35	6.35	
Maximum Download Speeds (2013)				9.98	10.15					10.68	10.79	*
Average Download Speeds (2014)				7.00	7.05					7.81	7.84	
Maximum Download Speeds (2014)				14.47	14.83					16.01	16.24	
Average Download Speeds (2015)				8.57	8.47					9.77	9.78	
Maximum Download Speeds (2015)				19.09	18.91					22.50	22.52	
Average Download Speeds (2016)				11.08	10.60	**				13.08	13.09	
Maximum Download Speeds (2016)				25.36	24.21					30.86	30.99	
Average Upload Speeds (2014)				0.89	0.87					0.97	0.97	
Average Upload Speeds (2015)				0.89	0.87					0.97	0.97	
Average Upload Speeds (2016)				1.55	1.53					1.81	1.76	**

*Source: Ofcom Connected Nations, C3 Reports, SCTs, Ipsos analysis; *** represents differences significant at 99 percent, ** at 95 percent and * at 90 percent*

4.5.4 Results

A matching approach will only be effective in providing an unbiased assessment of the impact of the Programme if they 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 may be other factors influencing the cost of installation that were not controlled for, 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.

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 section 4.3. The key results are set out in Table 4.6. However, there was very little difference in the estimated results to those associated with the difference-in-difference models described above (implying that the preceding results were not biased by observed differences between the two groups of postcodes).

Table 4.6: Estimated impact of Phase 3 schemes on coverage and take-up, regression-based difference-in-difference results

	Model 9	Model 10
Treatment postcodes	Postcodes delivered to by September 2021	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	18,763 to 47,382	33,744 to 84,623
Adjusted R-squared	0.012 to 0.532	0.001 to 0.611
Coverage outcomes		
NGA availability (% of premises)	4.4***	2.0***
Superfast availability (% of premises)	43.5***	28.3***
Gigabit capable availability (% of premises)	50.2***	28.4***
Take-up outcomes		
Average download speeds of connections (Mbps)	-0.1	-2.4***
Maximum download speeds of connections (Mbps)	52.6***	10.0***
Average upload speeds of connections (Mbps)	4.4***	3.0***
Number of connections with download speed of 30Mbps+	3.9***	-0.2

*Source: Ipsos analysis; *** represents differences significant at 99 percent, ** at 95 percent and * at 90 percent*

4.6 Longitudinal panel models

The difference-in-difference models outlined in sections 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 2021. 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 4.7 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 Gigabit capable availability:** The panel models showed that NGA, superfast and FTTP/Gigabit capable coverage increased in response to the delivery of subsidised coverage. For each premises upgraded, the number of premises with NGA, superfast and gigabit capable availability rose by 0.40, 0.69 and 0.66 respectively in the most robust models, 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).

- **Take-up:** The results showed a similar pattern of findings for take-up measures as preceding analyses. These findings indicated that the Programme had no significant effect on the number of superfast connections, however, for each premise upgraded on a postcode, average speeds taken up increased by a negligible amount whilst maximum speeds rose around 48Mbits/s.

Table 4.7: Estimated impact of subsidised coverage on superfast availability and take-up – Phase 3 2016 to 2021

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	418,374 to 1,044,703	418,374 to 1,044,703	418,374 to 1,044,703	418,374 to 1,044,703	418,374 to 1,044,703
Adjusted R-squared	0.022 to 0.160	0.082 to 0.227	0.143 to 0.244	0.074 to 0.255	0.113 to 0.383
Coverage outcomes (effects per premise upgraded per postcode)					
Number of premises with NGA access	0.48***	0.48***	0.49***	0.40***	0.48***
Number of premises with superfast access	0.71***	0.71***	0.71***	0.69***	0.71***
Number of premises with Gigabit capable availability	0.69***	0.69***	0.69***	0.66***	0.69***
Take-up outcomes (effects per premise upgraded per postcode)					
Average download speed of connections (Mbps)	0.11***	0.11***	0.11***	0.11***	0.11***
Maximum available speed of connections (Mbps)	48.02***	48.02***	48.02***	47.37***	48.02***
Average upload speeds of connections (Mbps)	0.42***	0.42***	0.42***	-	0.42***
Number of superfast connections	-0.01	-0.00	-0.00	-0.01	-0.01

*Source: Ipsos analysis; *** represents differences significant at 99 percent, ** at 95 percent and * at 90 percent*

4.6.2 Additionality over time

The results above only compare changes in 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 suggested 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:

$$\Delta NGA_{it} = \gamma_1 \Delta C_{it+1} + \gamma_2 \Delta C_{it} + \gamma_3 \Delta C_{it-1} + \gamma_4 \Delta C_{it-2} + \gamma_5 \Delta C_{it-3} + \gamma_6 \Delta C_{it-4} + \theta \Delta t + \alpha^{L} \Delta t + \alpha^{T} + \alpha^{L} \alpha^{T} + \varepsilon_{it}$$

The results are set out in the table below and suggest that the scheme did have a negative effect on NGA, superfast and FTTP availability in the year before premises received subsidised coverage (equivalent to between 6 and 11 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, 0.53 additional premises received NGA coverage per premises upgraded (53 percent additionality), 0.55 additional premises received superfast coverage per premises upgraded (55 percent additionality) and 0.77 additional premises received FTTP coverage per premises upgraded (77 percent additionality). The estimates below give overall additionality of 20, 40 and 57 percent over the four-year period for NGA, superfast and FTTP respectively.

The general pattern over time remains consistent across coverage types in the table below and this allows for the plotting of additionality over time. The results shown in 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 (implying that the programme has helped accelerate some commercial deployments as well as bring coverage to premises that may never have received enhanced broadband).

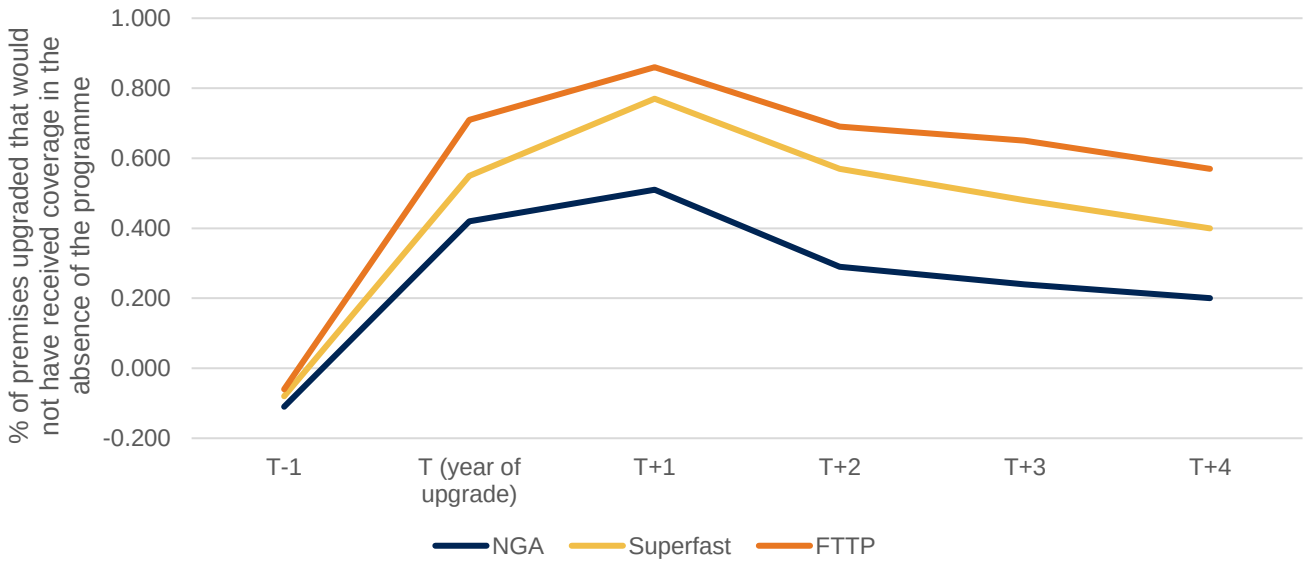
Additionally, estimates of the rate at which the programme accelerated commercial deployments are based on delivery in the first years of the programme (which may not be representative, given the large increases in delivery observed post 2019). As such, it is also plausible that additionality decays at a slower rate moving forward.

Table 4.8: Estimated Additionality Over Time – Longitudinal Panel Models

	NGA	Superfast	FTTP
Areas reaching 100% NGA coverage excluded?	Yes	Yes	Yes
Eligible areas excluded?	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes
2013 Output Area controls	Yes	Yes	Yes
Change in covered premises per premises receiving subsidised coverage (T-1)	-0.110***	-0.080***	-0.060***
Change in covered premises per premises receiving subsidised coverage (T)	0.530***	0.630***	0.770***
Change in covered premises per premises receiving subsidised coverage (T+1)	0.090***	0.220***	0.150***
Change in covered premises per premises receiving subsidised coverage (T+2)	-0.220***	-0.200***	-0.170***
Change in covered premises per premises receiving subsidised coverage (T+3)	-0.050***	-0.090***	-0.040***
Change in covered premises per premises receiving subsidised coverage (T+4)	-0.040***	-0.080***	-0.080***
Total effect 4 years post delivery	0.20	0.40	0.57
Observations	111,282	111,282	111,282
Adjusted R-Squared	0.47	0.54	0.51

*Source: Ipsos UK analysis; BDUK C3 reports & Ofcom Connected Nations; *** represents differences significant at 99 percent, ** at 95 percent and * at 90 percent*

Figure 4.2: Additionality estimates of Phase 3 NGA, superfast and FTTP coverage over time



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

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:

$$outcome2019_i outcome2021_i = \beta_0 + \boldsymbol{\beta x_i} + \epsilon_i$$

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\Gigabit capable coverage). A negative binomial function was utilised for the number of suppliers[31].

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 & Gigabit capable percentage availability:** These results were again similar to those presented in the difference-in-difference regression analysis above for these outcomes. Results for Gigabit capable coverage using this approach showed an additional 44.6 percentage points in FTTP/Gigabit capable coverage attributable to the programme in line with earlier findings above.

- **Take-up outcomes:** Application of the control group regression approach identified similar effects on all take-up outcomes.

[31] Negative binomial regression is a technique used for modelling count variables, usually for over-dispersed count outcome variables

Table 4.9: Control group coverage regression results – Phase 3 in 2021

	Counterfactual	Actual	Difference	Counterfactual	Actual	Difference
Treated postcodes	Delivered as of Sep 2021			All in build plans		
Coverage outcomes:						
Change in % NGA availability	87.6	90.8	3.2***	89.3	91.0	1.7*
Change in % SFB availability	51.4	92.3	40.9***	55.2	88.0	32.8***
Change in % Gigabit capable availability	13.8	57.0	43.2***	11.1	55.5	44.4***
Change in superfast enabled premises	10.6	12.1	1.5*	11.8	13.1	1.3*
Change in Gigabit capable enabled premises	3.1	7.4	4.3**	1.9	5.4	3.5*
Take-up outcomes:						
Change in average download speed (Mbps)	26.8	27.4	0.6*	27.4	27.5	0.1
Change in max download speed (Mbps)	69.5	103.2	33.7***	61.3	100.2	38.9***
Change in average upload speed (Mbps)	15.3	16.2	0.9**	13.4	15.4	2.0**
Change in number of superfast connections (Mbps)	5.7	4.7	-1.0***	5.5	4.9	-0.6*

*Source: Ipsos analysis; *** represents differences significant at 99 percent, ** at 95 percent and * at 90 percent*

4.8 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, Superfast or FTTP 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[32] (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, Superfast or FTTP. 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, Superfast or FTTP 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).

4.8.1 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 20km away and 20km to 30km. For superfast, the models implied a lower degree of crowding out in the year of delivery and one year after with effects only visible in the 10km to 20km band. There was no evidence of effects on FTTP coverage in nearby areas and overall the level of crowding out estimated is negligible in these models.

[32] 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.

Table 4.10: Estimated Level of Crowding Out – up to 2019

	Model 1	Model 2	
	No lagged effects	Effect in year t	Effect in year t+1
NGA			
0 to 10km	-0.0002***	-0.0002***	0.0002
10 to 20km	-0.0001	-0.0001*	0.0001*
20 to 30km	-0.0001**	-0.0003***	0.0004***
30 to 40km	0.0001***	0.0001***	0.0000
40 to 50km	0.0001	0.0000	0.0001
Total effect	-0.0002	-0.0001	
Superfast			
0 to 10km	-0.0000	-0.0000	-0.0000
10 to 20km	-0.0001**	-0.0001**	-0.0001
20 to 30km	-0.0000	-0.0000	-0.0001
30 to 40km	0.0001	0.0001	0.0002
40 to 50km	0.0001	0.0001	0.0001
Total effect	-0.0001	-0.0001	
FTTP			
0 to 10km	-0.0001	-0.0001	-0.0000
10 to 20km	-0.0000	-0.0000	-0.0001
20 to 30km	-0.0000	-0.0000	-0.0001
30 to 40km	0.0001	0.0001	0.0000
40 to 50km	0.0001	0.0001	0.0001
Total effect	-	-	

*Source: Ipsos UK analysis; BDUK C3 reports & Ofcom Connected Nations; ***, ** & * represent statistical significance at 99.9, 99 and 95 percent respectively*

4.9 Cost effectiveness

4.9.1 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 to support the cost-benefit analysis).

A total of £1.4bn of public sector funding appears to have been committed across Phase 3 contracts with a total of 531,029 contracted premises passed. This equates to an ex-ante gross public sector cost per premises covered of £2,636.

Table 4.11: Contracted cost per premises passed in Phase 3

Contract phase	Contracted public sector cost (£m)	Contracted premises passed	Gross public subsidy per gross premises passed (£)
Phase 3	1,400	531,029	2,636

Source: Ipsos UK analysis; Superfast Status Report, November 2022

4.9.2 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 2021/22. The expected gross public spend per premises passed is lower overall at £945 (rather than £2,636). 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. The gross public sector cost (i.e. before clawback) per additional covered premises over three years was £1,418. After allowing for clawback, this will fall to £1,225 to £1,276 per premises passed (depending on whether take-up stabilises at 60 or 80 percent in the long-term).

Table 4.12: Expected gross cost per premises and additional premises passed

Contract phase	Expected public sector cost (£m)	Premises passed by March 2021/22	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 (before clawback)	273.3	289,063	192,700	945	1,418
Phase 3 to date (before clawback)	236.0 to 245.8	289,063	192,700	816 to 850	1,225 to 1,276

Source: Ipsos UK analysis; Superfast Status Report, November 2022

4.10 Overview of findings

4.10.1 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 2021 (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:** Subsidised coverage through Phase 3 of the Programme led to significant positive impact on the availability of superfast and gigabit capable broadband services by the end of September 2021. Subsidised coverage increased the share of premises in the programme area able to access superfast speeds by 44 to 48 percentage points, and the share of premises with gigabit capable coverage by 43 to 59 percentage points. The impact of the programme on NGA availability was relatively small, however, indicating that in its absence, most premises would have benefitted from some form of enhanced connectivity (albeit via technologies less able to deliver download speeds of 30Mbit/s or higher). These findings are consistent with prior research into the impacts of the programme on broadband coverage.

- **Impact on take-up:** Subsidised coverage led to a significant increase in the maximum download speeds of connections taken by households and/or businesses by September 2021 (34 to 62 Mbit/s).

However, the impacts of the programme on average download speeds were relatively small. This indicates that 'early adopters' have taken advantage of the enhanced broadband connectivity enabled by the Programme. However, the Programme had not led to widespread take-up of faster broadband services by September 2021. It should be noted that most subsidised coverage was delivered in 2019 and 2020. As take-up will lag deployment, it is premature to draw any firm conclusions on the impact of the programme on take-up of faster internet services. Again, this is consistent with prior research into the impacts of the programme on take-up.

Table 4.13: Estimated impact of Phase 3 on areas benefitting from subsidised coverage by September 2021

Outcome	Difference-in-Differences	Propensity Score Matching with Difference in Differences	Control group regression
NGA availability (% of premises)	3.2 to 7.5	4.4	3.5
Superfast availability (% of premises)	45.8 to 46.6	43.5	40.9
Gigabit capable availability (% of premises)	52.2 to 56.2	50.2	43.2
Average download speeds of connections (Mbps)	-	-	0.6
Maximum download speeds of connections (Mbps)	34.7 to 59.2	52.6	33.7
Average upload speeds of connections (Mbps)	5.8 to 6.3	4.4	0.9
Number of connections with download speed of 30Mbps+	0.8 to 1.2	3.9	-1.0

Source: Ipsos analysis. '-' denotes that the result was not statistically significant.

4.10.2 Additionality of subsidised broadband infrastructure

Estimates of the overall number of additional premises benefitting from NGA, superfast and FTTP/Gigabit capable availability by September 2021 have been derived by multiplying the estimated impact of the programme on the share of premises with enhanced broadband by the number of premises on the postcode:

- **NGA coverage:** The programme is estimated to have led to 50,000 to 117,000 additional premises with NGA coverage (with a larger estimate of 117,000 premises derived from panel models considered implausibly large given the observed trends in 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 7 and 17 percent, with the most estimates towards the lower end of this range. This implies that to a large degree, premises benefitting from the Superfast Broadband Programme would have received some form of NGA coverage in its absence.

- **Superfast availability:** The Programme is estimated to have increased the number of premises that can access superfast broadband services (30Mbit/s or above) by 202,000 to 313,000 by the end of

September 2021. The associated rate of additionality ranges from 69 percent to 107 percent. This indicated that while many premises may have received NGA coverage in the absence of the Programme, these premises would not have been able to access at least superfast speeds (indicating the Programme has been highly effective in delivering against its primary objective).

- **FTTP/Gigabit capable coverage:** Subsidised coverage is estimated to have led to 193,000 to 378,000 additional premises with FTTP/Gigabit capable coverage. The rate of additionality ranges from 66 percent to 129 percent (with most estimates just above 100 percent). This indicates that the Programme has also been highly effective in bringing gigabit capable technologies to rural areas.

Table 4.14: Estimated additionality of NGA, Superfast and Gigabit capable 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	7.5	531,105	292,618	39,833	14%
DiD regression with controls	5.2	531,105	292,618	27,617	9%
Matched sample regression	4.4	531,105	292,618	23,369	8%
Control group regression	3.2	531,105	292,618	16,995	6%
Panel models	-	531,105	292,618	117,047	40%
Superfast availability					
Simple DiD	46.6	531,105	292,618	247,495	85%
DiD regression with controls	45.8	531,105	292,618	243,246	83%
Matched sample regression	43.5	531,105	292,618	231,031	79%
Control group regression	40.9	531,105	292,618	217,222	74%
Panel models	-	531,105	292,618	201,906	69%
FTTP/Gigabit capable availability					
Simple DiD	56.2	531,105	292,618	298,481	102%
DiD regression with controls	52.2	531,105	292,618	277,237	95%
Matched sample regression	50.2	531,105	292,618	266,615	91%
Control group regression	43.2	531,105	292,618	229,437	78%
Panel models	-	531,105	292,618	193,128	66%

Source: Ipsos analysis

4.10.3 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 across the target area as whole. These findings are summarised in the following table.

Previous results of this analysis suggested that the Programme had a negative effect on enhanced broadband availability across the overall Programme area (suggesting it had delayed coverage in some area). Such effects are no longer visible now the analysis has been extended to 2021, indicating that any negative effects via the delay of deployment were only temporary. While the estimated effects of the Programme across the programme area are smaller than for areas that received subsidised coverage, this would be expected given the inclusion of areas that had not yet received subsidised coverage.

Table 4.15: Estimated impact of Phase 3 on all postcodes in the build plans of Phase 3 schemes by September 2021

Outcome	Difference-in-Differences	Propensity Score Matching with Difference in Differences	Control group regression
NGA availability (% of premises)	2.2 to 3.2	2.0	1.7
Superfast availability (% of premises)	29.9 to 30.6	28.3	32.8
Gigabit capable availability (% of premises)/	28.9 to 30.5	28.4	44.4
Average download speeds of connections (Mbps)	-3.8 to -7	-2.4	No effect
Maximum download speeds of connections (Mbps)	11.4 to 12.9	10.0	38.9
Average upload speeds of connections (Mbps)	2.5 to 3.1	3.0	2
Number of connections with download speed of 30Mbps+	-0.4	No effect	-0.6

Source: Ipsos analysis. '-' denotes that the result was not statistically significant.

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Superfast Broadband Programme

State aid evaluation
Technical Appendix 2: Financial Analysis
January 2023

Ipsos

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Contents

Key terms and acronyms

The table below lists some of the most common terminology and acronyms used in this report.

Term or acronym	Description
FTTP	Fibre to the premises. This refers to an access network structure in which the optical fibre runs from the local exchange to the end user's premises.
FTTC	Fibre to the cabinet. This describes an access network structure in which the optical fibre extends from the local 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.
PFM	**Project Financial Model –** a document which includes all of the financial information (build costs, expected take-up, discount rate / WACC etc.), which is developed by programme beneficiaries at the start of the local project.
Implementation clawback	Subsidies returned to the public sector in the event that build costs are lower than originally contracted.
Capex	**Capital expenditure –** expenditure to buy/maintain/improve fixed assets.
Opex	**Operational expenditure –** ongoing expenditure associated with delivering a product / running a business.
IRR	Internal rate of return identifies the discount rate that sets the present value of a cash flow to zero throughout the lifetime of a project.
Supplier	Telecommunications providers that own the infrastructure used to deliver internet services.
Take-up	Share of premises that have access to Superfast broadband that decide to subscribe to the service.
Discount rate / WACC	The discount rate, or Weighted Average Cost of Capital (WACC), is a measure of the cost of capital faced by suppliers[1].

[1] For the purposes of this analysis, the term discount rate is used rather than the WACC. This is because the discount rate used in the PFM at bidding stage may differ from the actual WACC, which is not observable to the research team. It has been assumed, for the purposes of the analysis, that the discount rate used by the supplier equals the WACC. The difference between the discount rate and WACC of beneficiaries not included in the analysis has not been considered.

Executive Summary

This methodological appendix provides modelling of the expected future profitability of contracts awarded to suppliers under the 2016 to 2020 UK National Broadband Scheme (known as Phase 3 of the Superfast Broadband programme). The stages of delivery of the contracts modelled within this analysis varies, with one contract formally closed, 17 where delivery is completed but the contract is not formally closed, and 12 in delivery.

Key evaluation question

This analysis addresses the following evaluation question as 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 to the Superfast Programme

The rationale for the Superfast Broadband 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 supplier's cost of capital. These investments would therefore not be commercially viable. The programme seeks to provide the minimum level of 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 supplier).

The aim of the analysis is to explore whether public subsidies were needed to provide an incentive to suppliers 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, based on the relevant State Aid Decision.[2] This involves comparing the expected rates of return on the investments made to the cost of capital faced by the supplier. If the returns earned by the supplier exceed their cost of capital, then this would call into question the strength of the incentive provided by subsidies and/or the degree to which the public has provided the minimum level of subsidy needed for the project to proceed.

Key findings

- **Commercial viability without subsidy (IRR1):** based on projections provided by the supplier[3] at 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 supplier.
- **Commercial viability with subsidy (IRR2):** for the contracts in scope, IRR2 (factoring in subsidy payments) was 7.9% on average. This is 2.5 percentage points below the supplier's discount rate,

[2] European Commission C(2016) 3208 final, SA. 40720 (2016/N) – National Broadband Scheme for the UK for 2016-2020.

[3] The contracts in scope all belong to the same supplier. For further detail about the selection of contracts in scope, please refer to the main report.

which would suggest that these contracts would be unprofitable even with public funding. This could be explained if the network provider considered future profitability beyond the clawback period (from which all profits made would be retainable by the supplier), which would have raised longer-term returns. This is consistent with what was observed in previous phases of the programme[4].

- **Commercial viability without subsidy (IRR3):** the analysis shows that without subsidy, most contracts appear to be loss-making (with IRRs ranging between -5.4% and -8.1% with an assumption of 85% take-up and 60% take-up respectively), as the estimated IRR is significantly below the supplier's discount rate (10.4%). Under the assumption of 60% take-up, aside from two contracts (BEDS203 and BERK204), all contracts have a negative IRR3. Under the assumption of 85% take-up, an additional contract's IRR (SYRK202) is marginally positive.

- **Commercial viability with subsidy (IRR4):** given that build capex and opex on average have exceeded the original expectations, and that modelled revenues have not grown proportionally, the average estimated IRR4 is 2.9% (with 60% take-up) or 5.5% (with 85% take-up). In both cases, the IRRs are lower than the supplier's required discount rate.

- **Costs:** there are strong indications that costs have increased throughout the lifetime of the contracts. Differences between PFM-stage estimates and actual figures are considerable in the case of build capex (more than £11m of overspend compared to plans). According to evidence collected through other strands of the study, this might be due to a wide range of factors that have contributed to increased deployment and operation costs. All the overspend is borne by the supplier.

- **Revenue:** Revenues expected at bidding stage are higher than revenues modelled in this analysis under both take-up scenarios. This suggests that profit margins are reduced by rising costs, which are not offset by income generated from connections.

[4] Ipsos (2020), State aid evaluation of the UK National Broadband Scheme Technical Appendix 2 – Modelling of Internal Rates of Return, page 18.

1 Introduction

This report provides an overview of the expected future profitability of contracts awarded during Phase 3 of the UK National Broadband Scheme (also referred to as Superfast Broadband Programme). As illustrated in the ensuing sections, the report is based on an analysis of a sample of 30 contracts.

1.1 Key evaluation question

This analysis addresses the following evaluation question 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

This analysis aims to explore whether public funding was needed to provide an incentive for network suppliers to extend broadband coverage to areas that did not have access to Superfast coverage.

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, as governed by the relevant State Aid Decision issued in 2016.[5] This involves comparing the expected rates of return on the investments made to the cost of capital faced by suppliers.

The motivation for this analysis stems from the results of classical economic theory that suggests that, in a competitive market with no transaction costs, the private sector will maximise profits by implementing projects that generate a rate of return that at least equal their cost of capital. Otherwise, projects would be deemed to be unviable. The rationale for the programme is underpinned by the assumption that there are some areas of the UK where investment 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'). At the same time, 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 supplier).

It is not feasible for the public sector, however, to perfectly observe the expected costs and revenues associated with potential investments in Superfast coverage before subsidies are awarded. Suppliers also have an incentive to seek subsidies for investments that may be 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 suppliers to reveal their investment plans and to ensure that subsidies are directed towards premises that would not be covered under commercial deployment plans. 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 lower than originally expected or if revenues exceed original expectations, particularly due to higher-than-expected take-up) via a clawback mechanism.

[5] European Commission C(2016) 3208 final, SA. 40720 (2016/N) – National Broadband Scheme for the UK for 2016-2020.

This section examines the effectiveness of these arrangements by comparing the expected rate of return on the contracts awarded (the Internal Rate of Return, or IRR) to the suppliers Weighted Average Cost of Capital (WACC). For the purposes of this analysis, we refer to the discount rate rather than the WACC because the discount rate used in the PFM at bidding stage for Openreach is different than its WACC, as confirmed by BDUK. This may not be the case for other suppliers who may have used their WACC in the PFMs at bidding stage (and therefore the terms WACC and discount rate may be used interchangeably). 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

This section provides a brief summary of the main characteristics of the contracts awarded during Phase 3 of the Superfast programme.

1.3.1 Tendering of contracts

Contracts were awarded to suppliers by Local Bodies via a competitive tendering process. BDUK is not party to these contracts; instead, it acts as the National Competency Centre and enters a grant agreement (also called Budget Transfer Agreement) with the local bodies in order to provide funding for the programme.[6] Local Bodies are thus able to change standard terms and conditions, however this is subject to BDUK's approval.[7] Under this contractual arrangement between Local Bodies and suppliers, and pursuant to the requirement set out in the 2016 State Aid Decision[8], the winning supplier finances, designs, builds, owns, and operates the network and earns profits on the revenues generated by the infrastructure.[9] This feature of the model aims to allow private providers to leverage existing infrastructure whilst also encouraging continuous investment in the network.

The funding is provided via 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 suppliers' cost of capital.[10] The minimum subsidy is determined by the supplier's Project Financial Model (PFM), which is submitted as part of the tendering process. This provides estimations of:

- **Number of premises** to receive subsidised coverage under the proposed plan (by type of technology);
- **Capital and operational costs** associated with the proposed network build, and operational costs associated with providing Superfast services to customers;

[6] BDUK (2020). Contracts: Superfast. An Overview of the Contract for the Superfast Programme.
[7] BDUK (2020). Contracts: Superfast. An Overview of the Contract for the Superfast Programme.
[8] European Commission C(2016) 3208 final, SA. 40720 (2016/N) – National Broadband Scheme for the UK for 2016-2020.
[9] BDUK (2016). Funding options for BDUK funded broadband infrastructure, available 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 (last accessed 20 October 2022).
[10] BDUK (2016). Funding options for BDUK funded broadband infrastructure, available 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 (last accessed 20 October 2022).

- The **share of premises that will take up Superfast broadband** over time (including customer churn);
- **Prices** to be charged to customers taking up different packages and/or technologies;
- **Revenues** earned from customers taking up Superfast services, based on the expectations of future take-up;
- The supplier's **WACC** (used as the supplier's cost of capital in this analysis).

These factors determine the expected rate of return (the IRR) that the bidder expects to earn on the proposed network build in a particular area. The difference between the IRR and the supplier's WACC would determine the maximum level of subsidy available. Subsidies are provided to the winning supplier in instalments, following the completion of contractual milestones and for qualifying costs only. Qualifying costs refer to capitalisable expenditure directly attributable to delivering the deployed services and incremental to current business.

1.3.2 Clawback mechanism

The design of the tendering process described above with its gap-funding model aims to set the IRR equal to the supplier's WACC if the supplier provides an accurate assessment of the expected costs and revenues associated with the network build for a specific contract. The actual IRR earned by the supplier could vary from these estimates if:

- There is variance between the **build and operational costs** provided at PFM stage, and the actual costs incurred by the supplier during the lifetime of the contract;
- **Take-up** is higher or lower than expected at PFM stage, affecting revenues; or
- The **price** charged to customers is different than assumed at PFM stage, also affecting revenue.

In addition, the contract approach seeks to minimise the risk that bidders could behave strategically by overinflating build costs or underestimating expected take-up, as both these factors influence the level of public subsidy required to make the project viable. In order to control for this risk, the Phase 3 contract model incorporated two clawback mechanisms:

- **Implementation clawback:** if the PFM contains overly pessimistic assumptions on capital and operational costs, or if unanticipated cost savings occur during the build, implementation clawback adjusts for lower-than-expected costs at the end of the deployment period (known as 'checkpoint F', which marks contract closure).
- **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 the supplier's expectations at PFM stage. This may occur if take-up is higher than originally anticipated in the lifetime of the contract. In such circumstances, the gap reduces, and therefore the part of the profit that exceed PFM estimates at specific take-up review points is shared with the Local Body for up to seven years after contract closure, based on specific take-up review points in the contract (these typically occur in years 2, 4, 6, and 7 after the end of the deployment phase).

1.4 Methodology

This section explains the key aspects of the methodology followed for this analysis. Further details on the methodology are reported in the Annex.

1.4.1 Approach to estimating take-up

Take-up represents the number of premises connected as a share of all target premises. This is obtained by using actual information on take-up (as reported by the supplier), which is then used to model future take-up. Actual data on take-up is available up to and including Q4 FY 21/22. After the last available quarter of actual data, take-up is forecast until the end of the contract period (20 years) via a generalised logistic function. The modelling relies on two distinct assumptions of 60% and 85% take-up. The assumption of 60% take-up is in line with assumptions made by the supplier at bidding stage. In addition, the assumption of 60% take-up is also due to the fact that, although the areas were commercially unviable when build began, there has been an influx of capital into the fibre broadband market and an increase in alt-net provision, which could potentially lead to overbuild in the areas covered by the Superfast programme in the future, thus increasing competition and reducing the market share of the supplier awarded funding. For the 85% take-up assumption, such level of take-up might be achieved due to a copper 'switch-off' foreseen by 2030. It is assumed that 15% of individuals will either not access broadband or access it through wireless (e.g. via 5G), and that the remaining 85% of customers will take up Superfast broadband services with the supplier awarded funding. Both these scenarios have been modelled, and the modelled curve is adjusted to ensure that its functional forms mirrors as closely as possible the actual take-up data to date.

1.4.2 Approach to estimating IRR

The aim of this analysis is to compare an updated estimate of IRRs earned by suppliers against their WACC. This involves two key challenges:

- **Data:** suppliers have a contractual obligation to provide Local Bodies with information on the actual costs of the network build and the share of premises passed and connected. However, suppliers are not required to provide information on on-going operational costs or revenues earned (i.e. pricing), and thus these cannot be observed directly.
- **Time horizons:** the IRR associated with the network build is determined over a long time period (20 years), which requires certain assumptions over future patterns of delivery and take-up, even if the deployment phase has been completed.

In light of this, a modelling exercise was conducted to project future costs and revenues, and subsequently the IRR over the contract period. This meant that actual data (up to Q4 21/22) was used to estimate future trends, replicating as closely as possible the assumptions made by the supplier at bidding stage. In certain cases (e.g. lack of actual data, delays to deployment), additional assumptions were made to obtain an estimate of future cash flows. The expected future cash flows were then used to determine the IRR.

1.4.3 IRR calculation

The IRR is the discount rate that makes the net present value (NPV) of a project zero, depicted by the equation below. The value of r (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. In BDUK's PFM template the IRR is obtained by using the IRR function in Excel. For the purpose of this analysis, five types of IRR have been considered for each contract (in line with the State Aid Evaluation Plan) and are defined in the following table. Further details on the calculation of IRR, as well as of other items, are available in the Annex.

Table 1.1: IRR definition

IRR	Description	Overview	Data sources used
IRR1	The **original IRR before state aid** (baseline).	Estimated by the supplier at the time of bid based on expected build costs, operational costs and revenues. This provides the suppliers estimated return on the investment, without subsidy, at the tendering stage.	Expected cash flows are provided in the PFM developed by the supplier.
IRR2	The **original IRR after state aid** (estimated by the supplier at the time of bid).	Estimated by the supplier at the time of bid based on expected build costs, operational costs, revenues and the proposed subsidy. This provides the suppliers estimated return on the investment, with subsidy, at tendering stage. The IRR2 would be expected to align approximately with the supplier's WACC, because the supplier should receive the minimum level of subsidy needed to make the project viable.	Expected cash flows with subsidy payments are provided in the PFM developed by the supplier.
IRR3	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, operational costs (based on actual and projected take-up), and revenues (modelled based on actual and expected future 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. It should therefore show that the project would have been unviable in the absence of state intervention.	Information on actual build costs is provided in Finance Trackers. Information on actual take-up is taken from WSS/C3 reports provided by the supplier to Local Bodies. Take-up is projected based on actual trends to provide a future projection for the remainder of the project. The prediction is made by using a sigma function to approximate for the actual connection pattern. The upper limit takes a value of 60%[11] or 85% in turn (see Section 1.4.1 for rationale behind assumptions). 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 customer.
IRR4	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.	Information on actual subsidy payments was derived from the Finance Tracker reports provided by suppliers to the Local Bodies. Where deployment was ongoing, assumptions were made about the payment of future instalments.
IRR5	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, and after subsidy payments, and after clawback is applied (if needed).	As for IRR4, the IRR5 is calculated based on information on forecast implementation and take-up clawback. The working assumption for take-up review points, as agreed with BDUK, is 2, 4, 6 and 7 years after the end of the deployment period.

[11] In contracts where actual take-up exceeds 60%, the upper limit is equivalent to the take-up level in the last quarter of available data, rounded to the ne

1.5 Data sources

The following sources of information have been used to develop the analysis:

- **Project Financial Models (PFMs):** suppliers were required to submit a PFM with their bid for contracts. As highlighted above, PFMs provide suppliers' expectations at the point of tendering[12] in relation to:
  - how many premises will be passed and when under the proposed scheme;
  - the costs associated with delivery broken down by type;
  - the level of expected take-up;
  - revenue forecasts;
  - on-going operational costs;
  - inflation assumptions.
- **Finance Trackers:** details on the actual costs incurred during build and amounts financed by the local body are summarised by suppliers in Finance Trackers, submitted to local bodies and shared with BDUK.
- **WSS/C3 reports:** the actual cumulative number of connected premises per quarter is reported in the WSS section of the C3 report, along with the total number of premises to be passed.
- **Contract Summary Reports:** this file contains information on the completion date (or forecast completion date) of all Superfast contracts.

Inflation has been recognised as a risk to the supplier's rate of return however these effects are not yet acknowledged by the programme and are not therefore incorporated into the analysis. It is not anticipated that public subsidy to the supplier will increase as a result of rising costs as there are limitations as to what suppliers can claim for. As a result, overspend on contracts is burdened by the supplier. There is some anecdotal evidence reported to BDUK that Openreach have employed various strategies to offset these costs themselves.

1.6 Limitations

The modelling exercise seeks to compare the original assumptions formulated by the supplier in the PFM with actual information and forecasts to predict future cashflows. However, the modelling exercise also relies on a number of assumptions (detailed in the subsequent sections), which are needed in order to complement the monitoring information held by BDUK.

The analysis concerns a sample of 27 contracts (all awarded to Openreach), out of 67 Phase 3 contracts delivered by various suppliers. Overall, 29 contracts were contracts for which roll-out had started by the time the analysis was carried out, and copies of PFMs, Finance Trackers, and WSS/C3 reports were all

[12] PFMs can be updated at subsequent checkpoint 'E' (i.e. change requests) if applicable.

held by BDUK. In addition, two contracts were excluded because actual data from Finance Trackers was deemed insufficient for the analysis due to the contracts being in the very early stages of delivery. For the WSS/C3 reports, the analysis considers the latest available report for all contracts (in general up to Q4 21/22). Therefore, the contracts in scope are not necessarily representative of all contracts awarded; contracts were deemed in scope after an initial scoping exercise that identified the sample of 27 contracts for which all the information necessary to the analysis was available (see section 1.5).

In addition to considerations around data availability, it should be noted that there are known delays to deployment of the contracts under Phase 3. Reasons for the delays mentioned during the course of interviews with suppliers and BDUK included the following:

- Supply chain delays;
- Labour shortages, caused by increasing competition from market entrants and limited supply of qualified staff;
- Difficulties in the build;
- Wayleave issues;
- Value-for-money challenges;
- Project management challenges and planning amendments proposed by suppliers.

This means that the deployment timeline of some contracts might have changed compared to expectations at PFM stage. Based on the expected end of deployment date contained in the Status Report[13], it appears that closed contracts are delayed on average by slightly more than five quarters. This information has been used to model future capex. In order to correct for under-estimation of build capex where deployment is still ongoing, assumptions have been made regarding future trends in build capex. Similarly, actual public funding is accounted for alongside future public funding, which is derived from the PFM. Further details of this treatment can be found in the Annex.

Lastly, as regards gainshare and take-up clawback, based on discussions with BDUK, it is assumed that take-up review points occur in year 2, 4, 6, and 7 after the end of the deployment phase (with year 7 being the full contract closure). To this end, the deployment phase considered is that of the PFM.

[13] Superfast Status Report Data by Contract – 30.09.2022

2 IRR analysis

The following sections describe the results from the modelling exercise undertaken as part of the analysis of a sample of 30 Phase 3 contracts. The contracts were selected based on the availability of key sources of information facilitated by BDUK and the Local Bodies in charge of managing the tendering and delivery process (as described in Section 1.5). All contracts in scope of the analysis were awarded to Openreach.

2.1 IRR at bidding stage (IRR1 and IRR2)

The expected IRRs at bidding stage are based on the projected cash-flows provided by the network provider in its PFM for each contract over a 20-year period. These provide the estimated IRR of the proposed network build before and after 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 supplier. Table 2.1: below summarises these two IRRs based on PFM data.

- **Commercial viability without subsidy (IRR1):** on average, the IRR associated with the contracts in scope is substantially lower than the supplier's WACC (10.4%[14]) and are mostly negative. This means that in the supplier's predictions, contracts would have been loss making in the absence of public funding.

- **Commercial viability with subsidy (IRR2):** for the contracts in scope, IRR2 (factoring in subsidy payments) was 7.9% on average. This is 2.5 percentage points below the supplier's WACC, which would suggest that these contracts would be unprofitable even with public funding. This could be explained if the network provider considered future profitability beyond the clawback period (from which all profits made would be retainable by the supplier), which would have raised longer-term returns. This is consistent with what was observed in previous phases of the programme[15].

Table 2.1: IRR at PFM stage for contracts in scope

Contract	Project IRR pre-subsidy (IRR1)	Project IRR post-subsidy (IRR2)	Contract	Project IRR pre-subsidy (IRR1)	Project IRR post-subsidy (IRR2)
BEDS202	-4.1%	8.2%	**NORF202**	-5.6%	7.3%
BEDS203	-3.8%	7.9%	**NOTT202**	0.3%	8.0%
BERK204	5.4%	8.7%	**NYRK202**	-4.0%	8.1%
CAMB202	-5.3%	7.7%	**OXFD202**	-7.6%	8.3%
CORN202	-4.5%	7.8%	**SGLO202**	-0.1%	8.8%
DORS202	-1.5%	8.1%	**SGOV202**	-15.0%	7.8%
ESSX205	6.3%	8.8%	**SGOV203**	-9.1%	8.4%
ESSX206	-0.4%	8.1%	**SUFF202**	-7.3%	7.4%
ESSX208	1.4%	7.8%	**SYRK202**	1.4%	7.8%
ESSX209	1.8%	8.6%	**WALE201**	-4.1%	7.1%
ESSX210	-3.3%	8.3%	**WALE202**	-6.0%	6.6%
ESSX211	-5.5%	7.3%	**WALE203**	-1.4%	7.4%
ESUS202	-1.2%	7.0%	**WILT203**	1.3%	8.1%

[14] As per PFM.
[15] See previous State aid evaluation of the Superfast Broadband Programme, available at: https://www.gov.uk/government/publications/superfast-broadband-programme-state-aid-evaluation-report-2020.

HERT202	-5.6%	7.6%	**WORC202**	-0.9%	8.1%
LEIC202	-3.1%	8.3%	**WWCK202**	-0.3%	8.8%
			Average	-2.7%	7.9%
			Median	-3.2%	8.0%
			25th percentile	-5.4%	7.6%
			75th percentile	-0.1%	8.3%

Source: Ipsos' analysis based on PFM data.

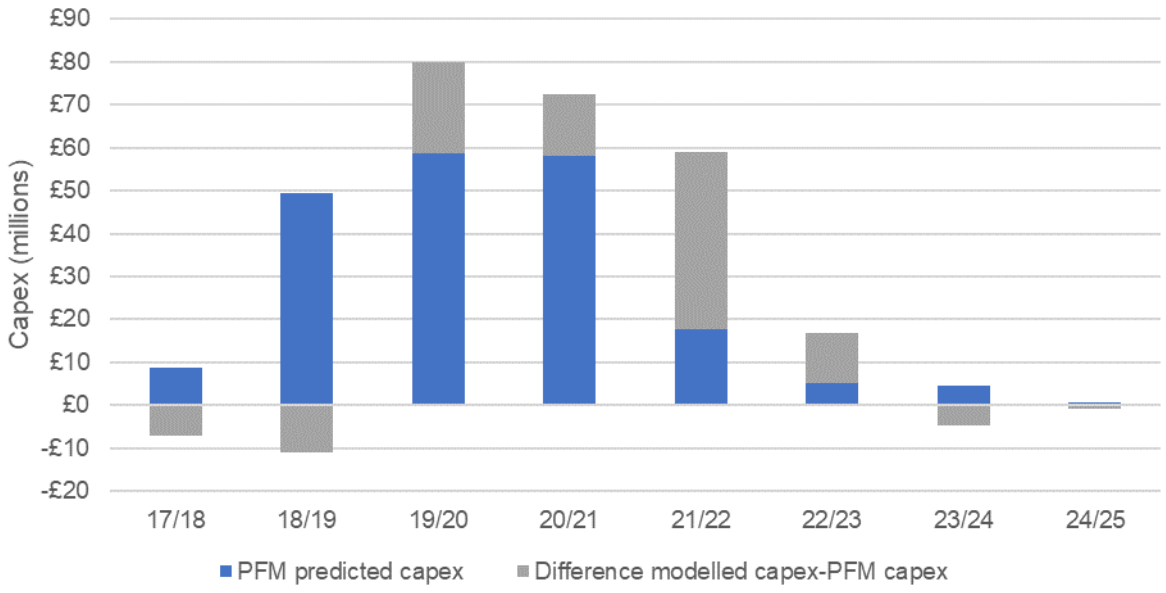
2.2 Build costs

Build costs are represented by capex, which includes expenses associated with FTTC and FTTP build, as well as Project Management Office (PMO) expenditure, and build costs listed as 'other' in the PFM.

At bidding stage, the expected qualifying costs associated with the network build for the contracts in scope were estimated by the supplier to be approximately £203m. As can be seen from Figure 2.1:, these predictions are likely to be exceeded in the medium term. Analysis of information and actual costs to date suggests:

- The total capex build cost will exceed £267m;
- The supplier is likely to incur additional costs of over £64m by FY 24/25 (when all build is expected to be completed) compared to what was originally planned;
- Some exogenous factors responsible for project delays (as evidenced by lower-than-expected capex in the early years) might have eventually led to higher prices, for example in case of heightened competition in the industry for resources in short supply (e.g. skilled workers, components).

Figure 2.1: Build capex (baseline vs. modelling)



Source: Ipsos' analysis based on PFM and Finance Tracker data.

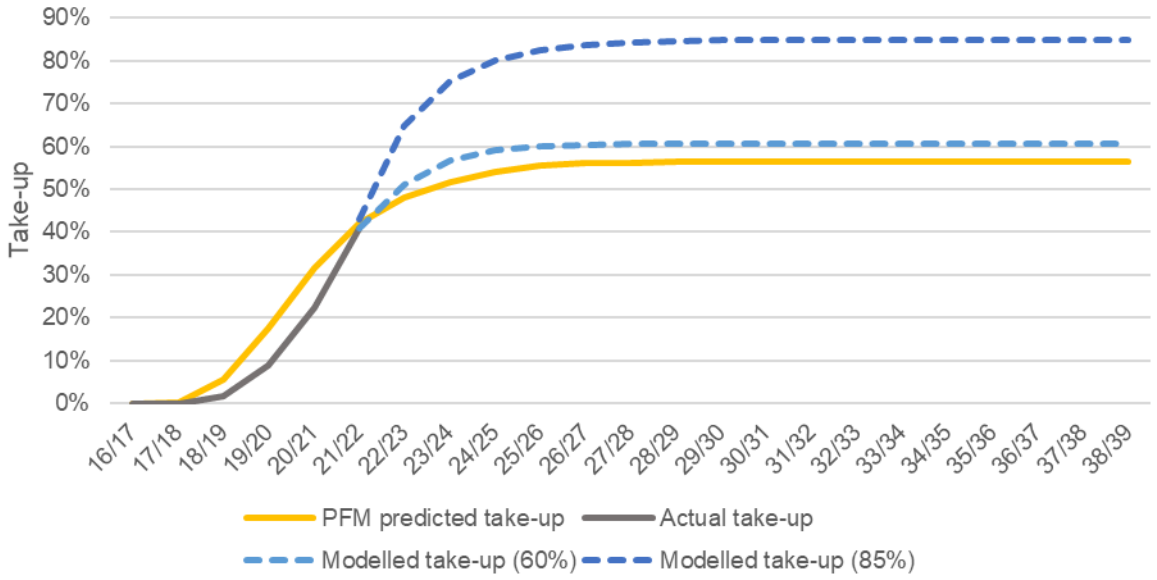
2.3 Take-up

Take-up levels represent the number of premises connected to the network as a percentage of the total premises passed. Actual connections are used to forecast trends in opex and revenue, as well as any relevant clawback, and ultimately the IRR. The analysis models two distinct scenarios: one where take-up reaches a maximum of 60% of premises passed, and another where it reaches 85% (as explained in Table 1.1:).

Figure 2.2:: below compares the take-up level expected by the supplier at the PFM stage to actual (to date) and modelled (future) take-up. The key findings are listed below:

- **Expected take-up:** predictions of take-up at PFM stage ranged from 50% to 61%.
- **Actual take-up:** after some delays in the initial quarters of deployment, where PFM take-up is higher than actual take-up, the level of take-up reached in FY 21/22 is already close to the maximum level of average take-up expected by the supplier in the PFM.
- **Future take-up:** Under a 60% take-up assumption, beyond FY 21/22 take-up is expected to further increase up to 60%, reaching over 92,500 premises across the 29 contracts[16]. Under the assumption of 85% take-up, the expectation would be that around 129,500 premises would take up Superfast broadband.

Figure 2.2: Take-up (60% and 85% take-up assumptions)



Source: Ipsos' analysis based on WSS/C3 reports.

Take-up is expressed as the ratio between the number of premises connected and the number of premises passed (or that will be passed, in the case of open contracts). In some cases, there are considerable differences between the expected number of premises to be passed at PFM stage, and the number of premises that WSS/C3 reports indicate as the target to be passed. This is likely to be due to change

[16] See section 1.6 for details on the selection criteria used to determine contracts in scope.

requests that have been approved throughout the lifetime of the contract and that have altered both the number and the type of premises to pass. This is illustrated in Table 2.2: below.

Table 2.2: PFM target premises and WSS/C3 target premises

Contract	PFM premises	ORMPs (WSS)	Difference	Contract	PFM premises	ORMPs (WSS)	Difference
BEDS202	1593	1208	-24%	**NORF202**	7072	2,384	-66%
BEDS203	647	287	-56%	**NOTT202**	1865	2,815	51%
BERK204	7857	7578	-4%	**NYRK202**	15572	17493	10%
CAMB202	5363	3671	-32%	**OXFD202**	1250	517	-59%
CORN202	7349	10915	49%	**SGLO202**	2588	3,959	53%
DORS202	3215	4885	52%	**SGOV202**	21746	2,533	-88%
ESSX205	5899	7654	30%	**SGOV203**	37914	1,547	-96%
ESSX206	5718	6514	14%	**SUFF202**	5458	315	-94%
ESSX208	1820	1397	-23%	**SYRK202**	6943	6,797	-2%
ESSX209	2086	2176	4%	**WALE201**	7702	8,911	16%
ESSX210	3843	2324	-40%	**WALE202**	3353	6,460	93%
ESSX211	1923	430	-78%	**WALE203**	8529	13,283	56%
ESUS202	4575	6060	32%	**WILT203**	1611	2,005	24%
LEIC202	2805	2092	-25%	**WORC202**	3568	4,206	18%
				WWCK202	10237	8,849	-14%
				Total	190101	152341	-20%

Source: Ipsos' analysis based on WSS/C3 reports.

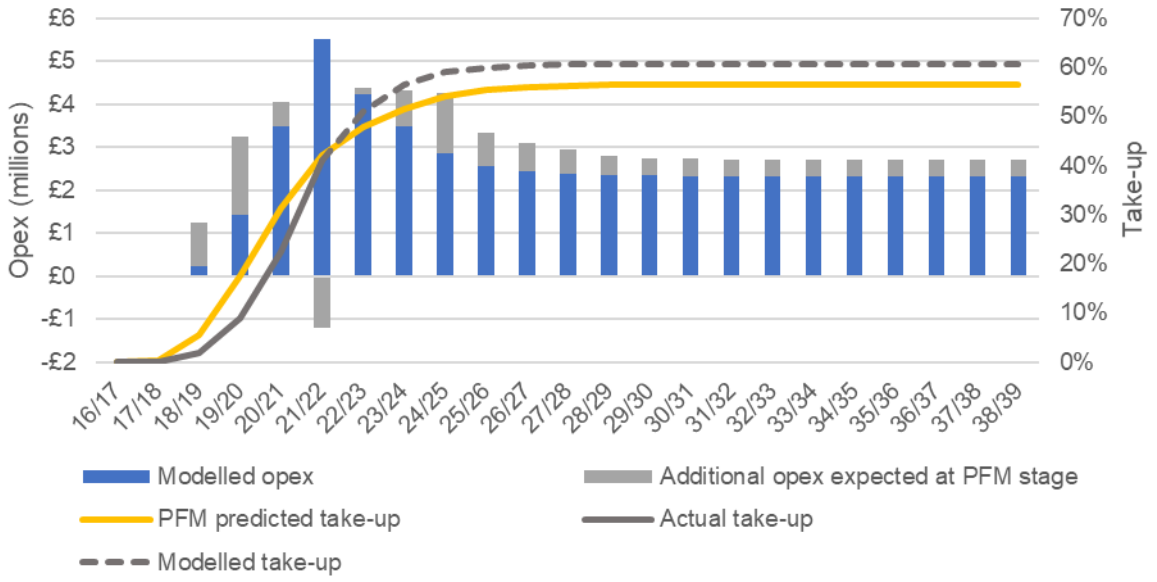
2.4 Operating expenditure (opex)

Operating costs include network and wholesale connection opex, ongoing contractual reporting costs, and network component delivery support opex. PFM predictions and modelled opex are shown in Figure 2.3: below, alongside take-up. Opex is calculated using unit cost assumptions and take-up (see Appendix for methodological detail), therefore the results are presented under two scenarios (60% and 85% take-up).

Under a 60% take-up scenario, it appears that there is some minor underspend of opex compared to baseline estimates. Although take-up (as a percentage) is expected to be slightly higher than PFM predictions, the actual number of premises connected is lower than expected at PFM stage (as shown in Table 2.2:), and therefore a lower opex than estimated at PFM stage. It is important to note that suppliers were not able to amend the assumptions made at PFM stage once the contract was signed. Opex is predicted to be slightly less than £11m lower than anticipated at PFM stage by the end of FY38/39[17]. However, costs are likely to be affected by the current inflationary context, as well as other contract-specific factors that might cause prices to rise.

[17] End of the 20-year period.

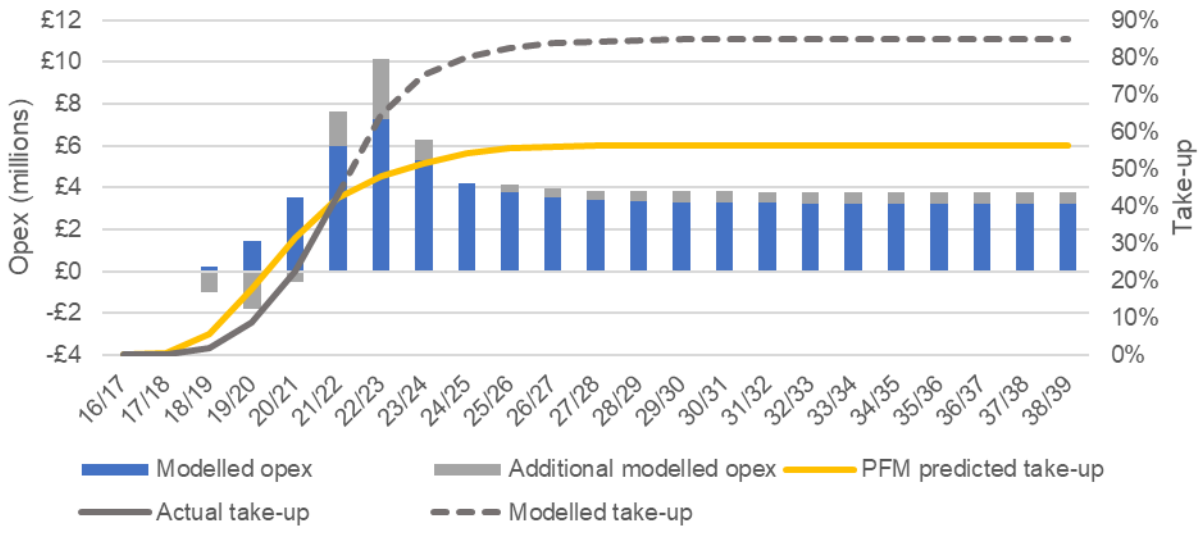
Figure 2.3: Opex (60% take-up assumption)



Source: Ipsos' analysis based on PFM, Finance Tracker, and WSS/C3 reports data.

Figure 2.4: below presents opex under the second scenario, where take-up will reach 85%. In this case, modelled opex slightly exceeds the predictions made at PFM stage – this is in line with the fact that the modelled take-up is around 30 percentage points higher than the average take-up level expected at PFM stage. The supplier overspend is in the region of £9 million.

Figure 2.4: Opex (85% take-up assumption)



Source: Ipsos' analysis based on PFM, Finance Tracker, and WSS/C3 reports data.

2.5 Revenue

Revenue is directly affected by take-up, (actual and modelled take-up, the latter modelled under both take-up scenarios), along with the average revenue per user (ARPU) figures provided in the supplier's PFMs. Monthly ARPUs (obtained from the contracts' PFMs) are reported in Table 2.3: below.

Table 2.3: Monthly ARPUs

Contract	FTTC	FTTP
BEDS202	N/A	£7.52
BEDS203	N/A	£7.52
BERK204	£7.94	£10.49
CAMB202	£5.38	£5.88
CORN202	£7.94	£10.49
DORS202	£7.94	£10.49
ESSX205	£7.94	£10.49
ESSX206	£7.94	£10.49
ESSX208	£5.99	£7.52
ESSX209	£5.99	£7.52
ESSX210	£5.38	£5.88
ESSX211	£5.38	£5.88
ESUS202	£5.36	£13.49
HERT202	£5.38	£11.69
LEIC202	£5.38	£5.88
NORF202	£5.38	£5.88
NOTT202	£5.99	£7.52
NYRK202	£7.94	£10.49
OXFD202	£5.38	£5.88
SGLO202	£7.94	£10.49
SGOV202	£5.38	£5.88
SGOV203	£5.38	£5.88
SUFF202	£5.38	£5.88
SYRK202	£5.78	£7.25
WALE201	N/A	£7.25
WALE202	N/A	£7.25
WALE203	£4.66	£7.25
WILT203	£7.94	£10.49
WORC202	£5.36	£13.49
WWCK202	£7.94	£10.49

Source: PFM data.

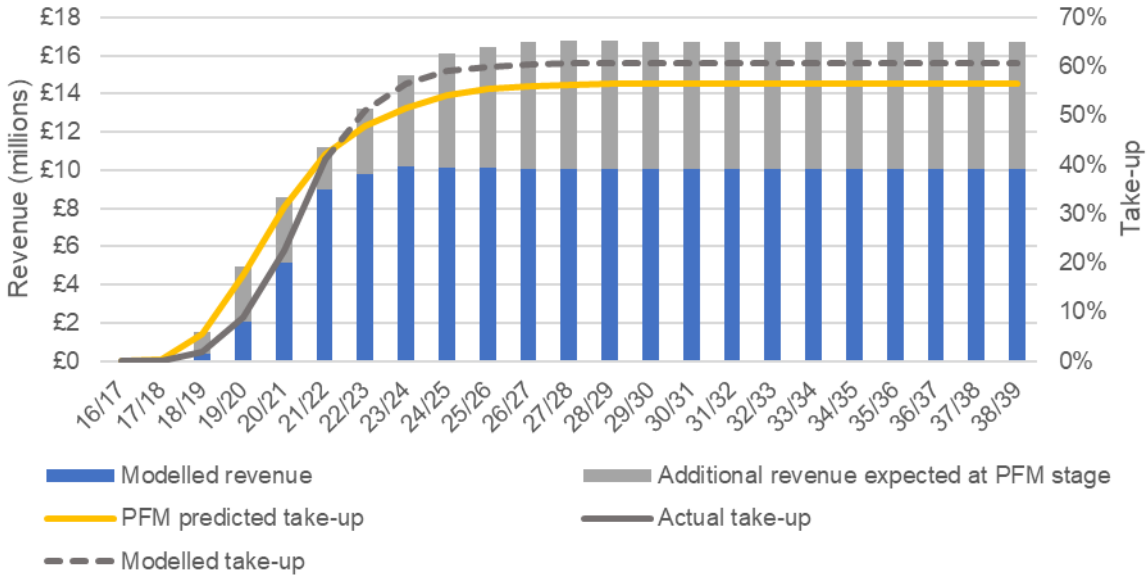
ARPUs were used to predict supplier revenues over the lifetime of the contracts.

- **Connections:** revenue is directly affected by the number of premises connected. The take-up calculations and the estimated future take-up are based on the most up-to-date forecast of the target number of premises passed from WSS/C3 reports. However, in several cases, there are considerable differences between the number of premises considered to be in scope at PFM stage, and the number of target premises in WSS/C3 reports. This makes the comparison between PFM predictions of revenue and actual / future revenue more difficult.

- **Future revenue:** Based on the modelling exercise conducted, future revenue is estimated for 60% and 85% take-up separately. When considering the assumption of 60% take-up (Figure 2.5:) revenue is lower than the expected at PFM stage by around £116.9m. Under the assumption of

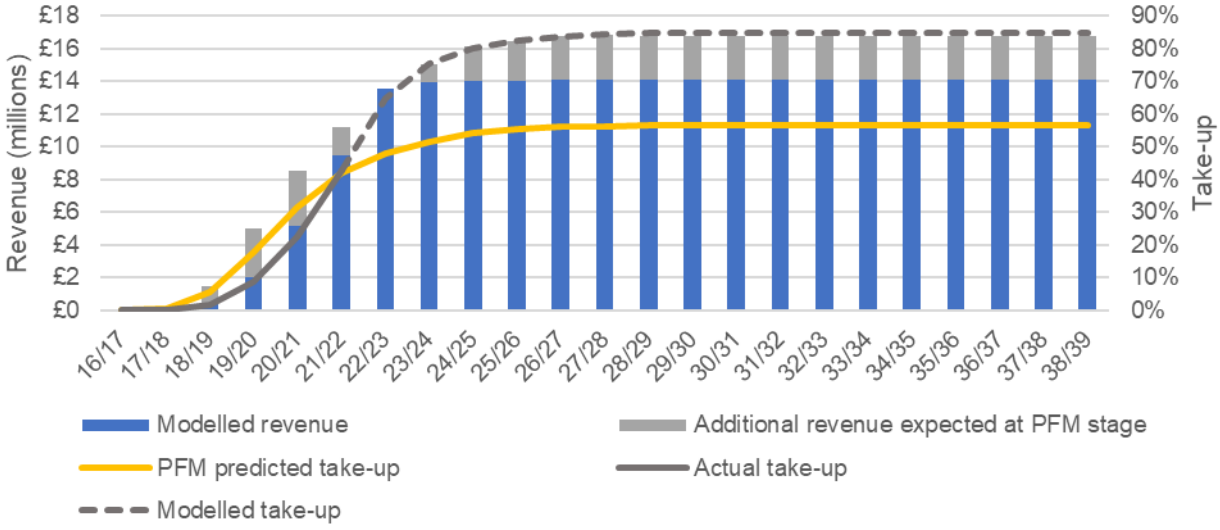
85% take-up, revenue still falls short of PFM expectations, although the gap is reduced (around £48.8m) as a result of higher modelled take-up (Figure 2.6:).

Figure 2.5: Revenue (60% take-up assumption)



Source: Ipsos' analysis based on PFM, Finance Tracker, and WSS/C3 reports data.

Figure 2.6: Revenue (85% take-up assumption)



2.6 IRR before clawback (IRR3 and IRR4) under 60% take-up scenario

Table 2.4: below provides an illustration of IRR3 (before funding and before clawback) and IRR4 (after public funding but before clawback) under the assumption of 60% take-up. The main findings are outlined below:

- **Commercial viability without subsidy:** without subsidy, most contracts appeared to be loss-making (IRR3), as the estimated IRR is below the supplier's WACC (10.4%). Aside from two contracts (BEDS203 and BERK204), all contracts have a negative IRR3.

- **Commercial viability with subsidy:** given that build capex and opex on average have exceeded the original expectations, and that modelled revenues have not grown proportionally, the average estimated IRR4 is 2.9%, lower than the supplier's required WACC.

Table 2.4: IRRs based on actual and modelled build costs, operational costs, and revenues, before clawback[18] (60% take-up assumption)

Contract	Updated IRR (pre-funding pre-clawback) (IRR3)	Updated IRR (pre-clawback) (IRR4)	Contract	Updated IRR (pre-funding pre-clawback) (IRR3)	Updated IRR (pre-clawback) (IRR4)
BEDS202	-12.6%	-10.4%	**LEIC202**	-7.9%	12.9%
BEDS203	5.9%	58.7%	**NORF202**	-13.4%	12.7%
BERK204	2.7%	4.8%	**NOTT202**	-7.4%	-5.3%
CAMB202	-11.8%	10.5%	**NYRK202**	-6.2%	5.2%
CORN202	-5.1%	6.3%	**OXFD202**	-17.0%	12.6%
DORS202	-9.2%	-6.7%	**SGLO202**	-4.0%	-0.1%
ESSX205	-2.2%	-1.4%	**SUFF202**	-19.0%	10.6%
ESSX206	-4.8%	0.4%	**SYRK202**	-2.6%	4.7%
ESSX208	-6.3%	-2.0%	**WALE201**	-10.3%	-5.2%
ESSX209	-5.8%	-2.6%	**WALE202**	-12.3%	-9.7%
ESSX210	-17.6%	-13.0%	**WALE203**	-8.4%	-3.4%
ESSX211	-19.3%	8.5%	**WILT203**	-5.4%	-1.2%
ESUS202	-5.8%	-3.1%	**WORC202**	-4.5%	-1.3%
			WWCK202	-8.3%	-4.7%
			Average	-8.1%	2.9%
			Median	-7.4%	-1.2%
			25th percentile	-12.1%	-4.0%
			75th percentile	-5.0%	7.4%

Source: Ipsos' analysis based on contract monitoring data.

2.7 IRR before clawback (IRR3 and IRR4) under 85% take-up scenario

Table 2.5: below presents the same IRRs but under the assumption that take-up reaches 85%. The main findings are outlined below:

- **Commercial viability without subsidy:** similar to the previous scenario, contracts are generally loss-making with the estimated IRR being below the supplier's WACC (10.4%).

- **Commercial viability with subsidy:** the average estimated IRR4 (before clawback) is 5.5%, lower than the supplier's required WACC, but higher than in the case of the 60% take-up scenario due to the higher share of customers signing up for superfast broadband.

Table 2.5: IRRs based on actual and modelled build costs, operational costs, and revenues, before clawback (85% take-up assumption)

Contract	Updated IRR (pre-funding pre-clawback) (IRR3)	Updated IRR (pre-clawback) (IRR4)	Contract	Updated IRR (pre-funding pre-clawback) (IRR3)	Updated IRR (pre-clawback) (IRR4)

[18] Following scoping discussions, two contracts (SGOV202 and SGOV203) are not included in this list due to the significant delays that have affected delivery.

BEDS202	-10.2%	-7.8%	**LEIC202**	-5.2%	15.1%
BEDS203	10.5%	60.6%	**NORF202**	-10.8%	13.8%
BERK204	4.7%	6.9%	**NOTT202**	-4.8%	-2.6%
CAMB202	-9.7%	11.4%	**NYRK202**	-3.2%	9.4%
CORN202	-2.4%	9.8%	**OXFD202**	-14.9%	14.1%
DORS202	-6.4%	-3.6%	**SGLO202**	-1.0%	3.2%
ESSX205	0.3%	1.0%	**SUFF202**	-16.8%	11.5%
ESSX206	-2.1%	3.4%	**SYRK202**	0.1%	7.5%
ESSX208	-3.2%	1.3%	**WALE201**	-7.5%	-2.2%
ESSX209	-2.7%	0.6%	**WALE202**	-9.7%	-6.8%
ESSX210	-15.4%	-10.8%	**WALE203**	-5.4%	0.1%
ESSX211	-17.1%	9.1%	**WILT203**	-2.4%	2.1%
ESUS202	-2.6%	0.3%	**WORC202**	-1.4%	2.0%
			WWCK202	-5.7%	-1.8%
			Average	-5.4%	5.5%
			Median	-4.8%	2.1%
			25th percentile	-9.7%	-0.9%
			75th percentile	-2.2%	9.6%

Source: Ipsos' analysis based on contract monitoring data.

2.8 Clawback

If suppliers underestimate build cost assumptions or if unexpected cost savings are made during the deployment phase, or if take-up is higher than expected originally, clawback mechanisms are in place to recoup public subsidy.

In order to reduce risk that suppliers earn excess returns, two types of clawback mechanisms are in-built in contractual arrangements, as described below:

- **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.

These are discussed in turn below, prior to the presentation of the IRR after clawback (IRR5).

2.8.1 Implementation clawback

For a number of contracts, capex forecasted at PFM stage is higher than the actual and modelled capex that the supplier is expected to incur based on this analysis. These instances will trigger the implementation clawback, which seeks to prevent excess subsidy from being paid to the supplier. For example, the implementation clawback may kick-in if the number of premises to be passed has decreased following a change request. Implementation clawback totals around £18m across the contracts in scope.

2.8.2 Take-up clawback

Take-up clawback is calculated at specific points in time throughout the lifetime of contracts. Take-up review points were assumed to be 2, 4, and 6 years after the end of the deployment phase as indicated in the PFM. In these quarters, actual and forecast take-up is compared to the take-up expected at PFM. The

take-up clawback is then calculated based on the Project Unit Margin (PUM) of each contract, i.e. the average profit per customer over the term of the contract. If take-up is higher in the model, the take-up clawback mechanism kicks in, and clawback is calculated on the net additional take-up reached. In total, take-up clawback is expected to amount to around £9m.

2.9 IRR after clawback (IRR5)

2.9.1 IRR5 (60% take-up assumption)

In the case of 60% take-up, applying clawback (on take-up and implementation) tends to bring down the profitability of contracts, as illustrated in Table 2.6: below. The average IRR5 across the contracts is -3.6%, which suggests a lack of profitability. However, this is not to be expected where contracts are loss-making, as the gainshare mechanism is in place to redistribute profits. It is therefore assumed that there will be a capping in place to prevent clawback being retained from loss-making or under-performing contracts.

Table 2.6: IRR based on actual and modelled build costs, operational costs, and revenues, after clawback[19] (60% take-up assumption)

Contract	Updated IRR (post-clawback) (IRR5)	Contract	Updated IRR (post-clawback) (IRR5)
BEDS202	-10.4%	**LEIC202**	-2.0%
BEDS203	-3.0%	**NORF202**	-4.3%
BERK204	4.6%	**NOTT202**	-5.7%
CAMB202	-3.2%	**NYRK202**	3.8%
CORN202	3.9%	**OXFD202**	-6.1%
DORS202	-7.4%	**SGLO202**	-1.0%
ESSX205	-1.6%	**SUFF202**	-6.7%
ESSX206	-0.1%	**SYRK202**	0.7%
ESSX208	-2.0%	**WALE201**	-6.1%
ESSX209	-2.7%	**WALE202**	-11.0%
ESSX210	-13.2%	**WALE203**	-4.2%
ESSX211	-7.4%	**WILT203**	-1.7%
ESUS202	-3.3%	**WORC202**	-1.5%
		WWCK202	-4.7%
		Average	-3.6%
		Median	-3.2%
		25th percentile	-6.1%
		75th percentile	-1.5%

Source: Ipsos' analysis based on contract monitoring data.

2.9.2 IRR5 (85% take-up assumption)

With the assumption of 85% take-up, IRR5 still suggest that contracts are generally loss-making (average IRR -1.2%), although the increased take-up leads to a less negative IRR compared to the previous scenario of 60% take-up.

[19] Following scoping discussions, two contracts (SGOV202 and SGOV203) are not included in this list due to the significant delays that have affected delivery.

Table 2.7: IRR based on actual and modelled build costs, operational costs, and revenues, after clawback (85% take-up assumption)

Contract	Updated IRR (post-clawback) (IRR5)	Contract	Updated IRR (post-clawback) (IRR5)
BEDS202	-7.9%	**LEIC202**	0.1%
BEDS203	-1.7%	**NORF202**	-2.8%
BERK204	6.5%	**NOTT202**	-3.2%
CAMB202	-1.4%	**NYRK202**	6.1%
CORN202	6.1%	**OXFD202**	-3.4%
DORS202	-4.8%	**SGLO202**	1.6%
ESSX205	0.7%	**SUFF202**	-4.8%
ESSX206	2.5%	**SYRK202**	3.2%
ESSX208	1.2%	**WALE201**	-3.9%
ESSX209	0.0%	**WALE202**	-8.8%
ESSX210	-11.3%	**WALE203**	-1.5%
ESSX211	-6.3%	**WILT203**	1.1%
ESUS202	-0.4%	**WORC202**	1.4%
		WWCK202	-2.1%
		Average	-1.2%
		Median	-1.4%
		25th percentile	-3.7%
		75th percentile	1.3%

Source: Ipsos' analysis based on contract monitoring data.

2.10 Conclusions

The evidence suggests that post-clawback, IRRs are on average negative (-3.6% and -1.2% under the 60% and 85% take-up scenarios respectively). Contracts' IRR are either negative or below the cost of capital faced by the supplier (10.4% WACC). Nevertheless, even without clawback, the average IRR across the portfolio reaches 2.9% and 5.5% under each scenario, which remain lower than the supplier's WACC. This suggests that public subsidy was required to deliver commercially sustainable networks under both take-up scenarios.

It would be expected that the clawback mechanism, in most cases, will not have been required as the supplier would not be making excess profits. Overall, the analysis suggests that public funding was required for the areas covered by the contracts in scope, and that there was not an incentive effect for the supplier.

3 Appendix – Methodology

This methodological appendix provides modelling of the expected future profitability of contracts awarded to suppliers under the Phase 3 of the UK National Broadband Scheme (known as Superfast Broadband programme). Although most contracts were still being delivered at the time of writing, this exercise should give an indication of future profitability of the contracts in scope.

3.1 Key evaluation question

This analysis addresses the following evaluation question, as per the Evaluation Plan:

- Has the aid had a significant incentive effect on the aid beneficiaries?
- Was the subsidy required to deliver commercially sustainable networks?

The aim of the analysis is to explore whether public subsidies were needed to provide an incentive to suppliers to extend FTTC and FTTP 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 supplier.

3.2 Contract design

3.2.1 Subsidy

Contracts are awarded by Local Bodies, with BDUK being the National Competence Centre. BDUK, in fact, is not party to the contract but enters a Grant Agreement (also called Budget Transfer Agreement) with the Local Bodies in order to disburse funding.[20] Under the model, the successful bidder 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 suppliers to leverage existing infrastructure whilst encouraging continuous investment in the network.[21]

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 required to deliver the project. The minimum subsidy is determined by the supplier's Project Financial Model (PFM), which is submitted as part of the tendering process. This provides *ex ante* estimates 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)

[20] 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 23 September 2022.

[21] *Ibid.*

- 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
- The Weighted Average Cost of Capital (WACC) of the supplier

These expectations determine the expected rate of return (the IRR) that would be earned on the proposed network build. Subsidies were provided to the winning supplier in instalments following the completion of contractual milestones and for qualifying costs only. Qualifying costs refer to capitalisable expenditure directly attributable to delivering the deployed services and incremental to current business.[22]

3.3 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 is positive, the revenue generated by the project exceeds the cost of capital, and therefore the project can be expected to be profitable. On the contrary, in the case of a negative IRR, the project is unlikely to generate profits, since the cost of capital is greater than the expected revenue. In symbols, the IRR is the value of r that renders the net present value of the project (NPV) zero.

$$NPV = \sum_{t=1}^{T} \frac{C_t}{(1+r)^t}$$

The net cashflow from the point of view of the supplier 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 supplier 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, revenues, and subsidy payments.

In this study, the IRR (before funding, after funding, and after clawback) are calculated based on the same formula used by suppliers in the financial models submitted along with their contract bids. In fact, a similar approach (i.e. replicating the modelling exercise undertaken by suppliers) has been adopted in order to update the analysis based on actual and modelled data, with the aim of estimating IRR after subsidy and after clawback, in light of actual take-up. The ensuing sections present in detail the methodology used to estimate the revised IRR.

[22] BDUK (2020). *Value for Money: Superfast. An Overview of Value for Money Analysis on the Superfast Programme*.

3.4 Data sources

The following sources of information have been used to develop the analysis:

- **Project Financial Models (PFMs):** tender participants were required to submit a PFM with their bid for contracts. As highlighted above, PFMs provide suppliers' expectations at the point of tendering[23] in relation to:
  - how many premises will be passed and when under the proposed scheme;
  - the costs associated with delivery broken down by type;
  - the level of expected take-up;
  - revenue forecasts;
  - on-going operational costs;
  - inflation.
- **Finance Trackers:** details on the actual costs incurred during build, as well as financing paid by the local body, are summarised by suppliers in Finance Trackers, submitted to local bodies and shared with BDUK.
- **WSS/C3:** the actual cumulative number of connected premises per quarter is reported in the WSS section of the C3 report, along with the total number of premises to be passed.
- **Contract Summary Reports:** This file contains information on the completion date (or forecast completion date) of all Superfast contracts.

Inflation has been recognised a risk to the supplier rates of return, however the effect to the supplier is not yet acknowledged by the programme and has not therefore been incorporated into the modelling of analysis. It is not anticipated that public subsidy to the supplier will increase as a result of rising costs as there are limitations as to what levers suppliers can claim for. Overspend on contracts is burdened by the supplier. There is anecdotal evidence reported to BDUK that Openreach have employed various strategies to offset these costs themselves.

3.5 Limitations of the approach

The modelling exercise seeks to compare the original assumptions formulated by the bidder in the PFM with actual information and forecasts to predict future cashflows. However, the modelling exercise relies also on a number of assumptions (detailed in the subsequent sections), which are needed in order to complement the monitoring information held by BDUK (the National Competency Centre in the programme).

The analysis concerns a sample of 30 contracts awarded to Openreach. These were the contracts for which roll-out had started by the time the analysis was carried out, and copies of PFMs, Finance Trackers,

[23] PFMs can be updated at subsequent checkpoint 'E' (i.e. change requests) if applicable.

and WSS/C3 reports were held by BDUK. As regards WSS/C3 reports, the analysis considers the latest available report for all contracts. This is usually the status of connections in Q4 21/22.

In addition to considerations around data availability, it needs to be underlined that there are known delays to deployment of the contracts under Phase 3. However, it is unclear whether this is due to a single factor or a number of the following reasons, which were mentioned during the course of interviews with suppliers and BDUK:

- Supply chain delays;
- Labour shortages, caused by increasing competition from market entrants and limited supply of qualified staff;
- Difficulties in the build;
- Wayleave issues;
- Value-for-money challenges;
- Project management challenges and planning amendments proposed by suppliers.

This means that the roll-out (i.e. deployment) timeline of most contracts might have changed compared to expectations at PFM stage. However, no data is available on the expected rate of premises passed, which could be used to determine future build capex beyond the end of the actual data available. In order to correct for under-estimation of build capex where deployment is still ongoing, assumptions have been made regarding future trends in build capex (Section 3.10). Similarly, actual public funding is accounted for alongside future public funding, which is derived from the PFM (Section 3.9).

Lastly, as regards gainshare and take-up clawback, based on discussions with BDUK, it is assumed that take-up review points occur in year 2, 4, 6, and 7 after the end of the deployment phase. To this end, the deployment phase considered is that of the PFM. The timing of gainshare influences IRRs.

3.6 Take-up

Take-up (i.e. the number of premises connected) is derived from a combination of actual and predicted information and is analysed separately for FTTC (where applicable) and FTTP.

Actual data on take-up is available up to and including Q4 FY 21/22 from C3 reports. After the last available quarter of actual data, take-up is forecast until the end of the contract period (20 years) via the following generalised logistic function:

$$(t) = A + \frac{K - A}{(1 + Q \cdot e^{-g \cdot t})^{\frac{1}{v}}}$$

The function ranges between a lower asymptote (A) and an upper asymptote (K). In addition, g is the growth rate, t the inflection point, and v (positive) influences the inflection point and the shape of the curve. In the model, the function takes the following specification:

$$take - up = \frac{\mathrm{K}}{(1 + 1.4 \cdot e^{-g \cdot t})^{\frac{1}{v}}}$$

The function can only be positive ($A = 0$), since take-up increases on a quarterly basis. The function's upper limit (K), is set in turn at 60% and 85%, which is the level at which take-up is expected to plateau, both for FTTC and FTTP[24]. In order to match actual connection data as closely as possible, the parameters g, v (with $v \neq 0$) and Q are tailored to each contract's actual take-up curve to ensure that future predicted take-up is as close as possible to the functional shape of actual take-up. It follows that the higher the number of actual take-up quarters a contract has, the more accurate the form of the future take-up curve is.

3.7 Revenue

Actual and modelled take-up data is used to inform the calculation of revenue throughout the lifetime of each contract. Total revenue is composed of recurring and non-recurring revenue, described in detail below.

3.7.1 Recurring revenue

Recurring revenue (i.e. wholesale revenue[25]) is calculated for both FTTC and FTTP as follows:

*Recurring revenue = Take-up * ARPU[26] * revenue inflation (deflation) assumption*

The revenue inflation (deflation) assumption is assumed by the network operator as constant throughout the period and equal to 1.

3.7.2 Non-recurring revenue

The following types of non-recurring revenue have been considered for FTTC and FTTP churned volumes.

- **Connection:** the installation price included in PFMs and customer growth net of churn based on actual figures and predicted take-up afterwards:

*Installation revenue = (connections + net customer growth) * installation price * revenue inflation (deflation) assumption*

- **Cease:** this relates to the predicted termination of contracts:

*Cessation revenue = cease volumes * service cessation cost * revenue inflation (deflation) assumption*

- **CP:CP:** revenue deriving from customer migration:

*Migration revenue = CP:CP volumes * service migration cost * revenue inflation (deflation) assumption*

[24] In contracts where actual take-up exceeds 60%, the upper limit is equivalent to the take-up level in the last quarter of available data, rounded to the next integer.
[25] 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 deployed). 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 (last accessed: 20 September 2022).
[26] Average revenue per user, derived from the PFM of each contract.

All cost figures for installation, cessation, and migration have been derived from the PFMs. Inflation is assumed constant and equal to 1.

3.8 Opex

In line with the PFM, opex comprises three different components.

- **Connection opex:** For FTTC and FTTP, this includes the revised number of connections and the unit connection costs:

*Connections*connections opex*[27]

- **Deployment closure opex:** This is included in the PFM but is negligible overall and is therefore excluded from the re-forecast exercise.
- **Ongoing Contractual Reporting:** This is taken directly from the PFM.
- **GEA connection**: for FTTC and FTTP:

*(connections + customer growth net of churn) * GEA*

- **Cease:** for FTTC and FTTP:

*ceased customers*cease cost*

- **GEA FTTx:**

*(CP:CP FTTP+CP:CP FTTC)*GEA FTTx*

If the PFM contained a change request that affected deployment opex, the revised total figure was spread across the same number of quarters of deployment opex as in the original PFM. Project delays might have impacted the timing of deployment opex; in the absence of a revised project timeline, deployment opex was accounted for in line with the PFM's original timeline. Nevertheless, opex forms a minimal amount of cost towards the total deployment cost, and therefore shifts in the timeline are unlikely to affect the overall calculation of IRR in a considerable manner.

3.9 Public funding

Public funding information is derived from both the PFM and the Finance Tracker. Since most contracts were ongoing at the time when this analysis was carried out, in some cases it is possible that future payments are due by the Local Bodies to the supplier. Therefore, the model includes all the quarters of available actual data on public funding (until Q3 or Q4 21/22). In addition, if the difference between the PFM expected subsidy payments and the public funding received by the supplier is positive (i.e. at PFM stage, the expected subsidy was greater than what the supplier had received according to the Finance Tracker), the difference is either included as a lump-sum after Q3 21/22, or in instalments (spread over 4, 10, or 20 quarters, depending on the size of the outstanding public funding[28]).

[27] Includes FVA connections.

[28] Examples of this are the SGOV202 and SGOV203 contracts, where over £120m and £84m of public funding were yet to be received by the supplier (Q3 2021/2022).

3.10 Capex

Eligible capex is incurred only during the build phase of contracts. For all contracts in scope, the revised capex figures include the three components listed below.

- **FTTC/FTTP build:** these costs depend on the type of infrastructure (FTTC or FTTP), including, for example, planning, access fibre cables, civils, fibre spine, access copper ties (for FTTC), and headends (for FTTP).
- **Other capex:** this includes costs that are common to both FTTC and FTTP.
- **Project management office (PMO) capex:** this includes project and contract management.

The supplier reports these figures for each contract in the contract's finance tracker. Thus, the model uses actual figures up to the last available quarter of available data (either Q3 or Q4 21/22).

However, to date most contracts are still open, which might mean that additional capex is yet to be incurred by the supplier on those contracts. Whilst the underlying approach to actual capex is the same for both open and closed contracts, closed contracts include an assumption relating to future capex.

For contracts that are still open at the time of this analysis, future capex is estimated differently depending on the difference between the supplier's estimates at PFM stage and actual data reported in the WSS/C3.

- **If capex predicted in the PFM is lower than actual capex** at the time of the analysis, the average of the last third of actual capex (FTTC+FTTP+FTTx+PMO) is distributed across each quarter up to and including the final quarter as indicated in BDUK's Summary Report.
- **If PFM capex is higher than the capex spent to date**, the contract is likely to be in the early stages of deployment, and therefore the difference between PFM capex and actual capex is divided in equal instalments throughout the expected build period, up to and including the final quarter of build as per BDUK's Summary Report.

3.11 Clawback

Clawback is calculated for build capex and take-up.

3.11.1 Capital clawback

Capital clawback is calculated based on build capex and is determined by comparing build capex incurred and future build capex with the baseline prediction of build capex provided by the supplier in the PFM. The calculation of capital clawback relies on the two main elements indicated below.

- **Baseline build estimate:** this is the expected build capex calculated by the supplier at bidding stage.
- **Revised build capex:** this is the sum of the actual build capex spent to date by the supplier and, in the case of open contracts, it includes assumed future capex.

3.11.2 Take-up clawback

Take-up clawback calculations are based on data from various sources, as illustrated in Table 1.1.

Table 3.1: Gainshare and clawback

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
Project investment ratio (PIR)	PFM
Gainshare investment ratio (GIR)	Equals Outturn Investment Ratio (OIR)
Take-up review points	At year 2, 4, 6, and 7 from contract start date as per BDUK guidance

3.12 Cash flow

The previously determined revenue, opex, and capex, as well as any clawback, have been used to calculate cashflow throughout the project timeline. The structure of the cashflow is summarised in Table 3.2: below.

Table 3.2: Cash flow

Cashflow item	Source
Revenue	PFM (ARPUs) and revised take-up (Section 1.3)
Opex	PFM (opex inputs) and revised take-up (Section 1.4)
EBITDA	*revenue – opex*
Build Capex	Finance tracker and assumptions (only open contracts) (Section 1.5)
Adjusted cashflow **pre-funding**	*EBITDA – capex*
Public funding	Finance tracker. If differences exist between BDUK records of paid public funding and the PFM, the difference is added in the quarter following the last quarter of available data. In the case of contracts with large sums of funding yet to be paid (>£10m), the remainder is spread equally across several quarters.
Adjusted cashflow **post funding**	*cashflow pre-funding + public funding*
Capital Clawback	Calculated (Section 1.6.1)
Take-up Clawback	Calculated (Section 1.6.2)
Clawback capping	Where take-up clawback is above net funding (*total public funding – capital clawback*), it triggers a capping of the clawback

Total clawback	*capital clawback + take-up clawback + 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

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December 2022

Evaluation of the Superfast Broadband Programme

Technical Appendix 3: Economic & Social Impacts

Ipsos

Contents

Glossary

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

Acknowledgements

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

1 Introduction

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

1.1 Aims and objectives

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

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

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

Table 1.1: Coverage of the BDUK Benefits Realisation Framework

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

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

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

1.2 Methodology

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

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

1.3 Key issues

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

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

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

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

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

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

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

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

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

1.4 Structure of this report

The remainder of this report is structured as follows:

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

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

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

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

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

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

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

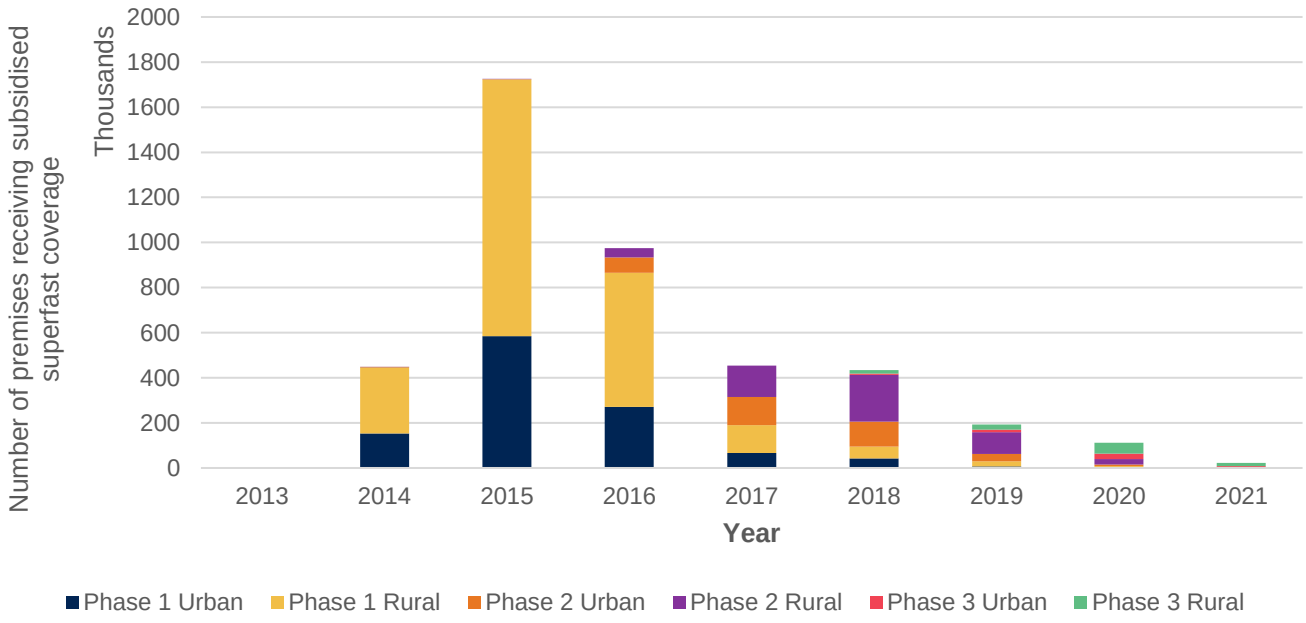
2 Analytical framework

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

2.1 Superfast Broadband Programme

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

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



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

2.2 Impacts on businesses and local economic performance

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

- **Take-up:** It is expected that the benefits of the programme will be realised – in the first instance – by firms taking up superfast broadband connections. Incentives to adopt the technology could be limited to firms for which it would be profitable to take-up superfast connectivity (relative to basic or

[3] 24MBits for Phase 1 and Phase 2

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

slower broadband speeds), but who are not so dependent on bandwidth that they faced incentives to obtain faster connectivity through lease[5]d lines or by relocating to areas where faster speeds were already available. This creates an expectation that the primary users of the superfast coverage made available will be small and medium-sized or new enterprises (SMEs) making use of asymmetric subscriber lines – rather than large firms with the scale needed to make leased lines commercially viable or digitally intensive firms where faster and more reliable connectivity is central to the underlying business model. The shift in emphasis from FTTC to gigabit capable technologies in Phase 3 of the programme may alter these incentives – making faster speeds (and symmetric connections) available may increase the number and types of firms that could potentially benefit from the programme.

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

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

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

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

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

e.g. actions performed for assembly equipment. 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 ways. As noted, these improvements may take time to arise, and complementary business investments may be required to take advantage of higher speeds.

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

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

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

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

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

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

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

  - **Agglomeration and disagglomeration:** Such a process could also trigger in-migration of skilled labour, encouraging further concentration of economic activity in areas benefitting from upgraded broadband infrastructure, and enabling firms to benefit from the efficiency gains

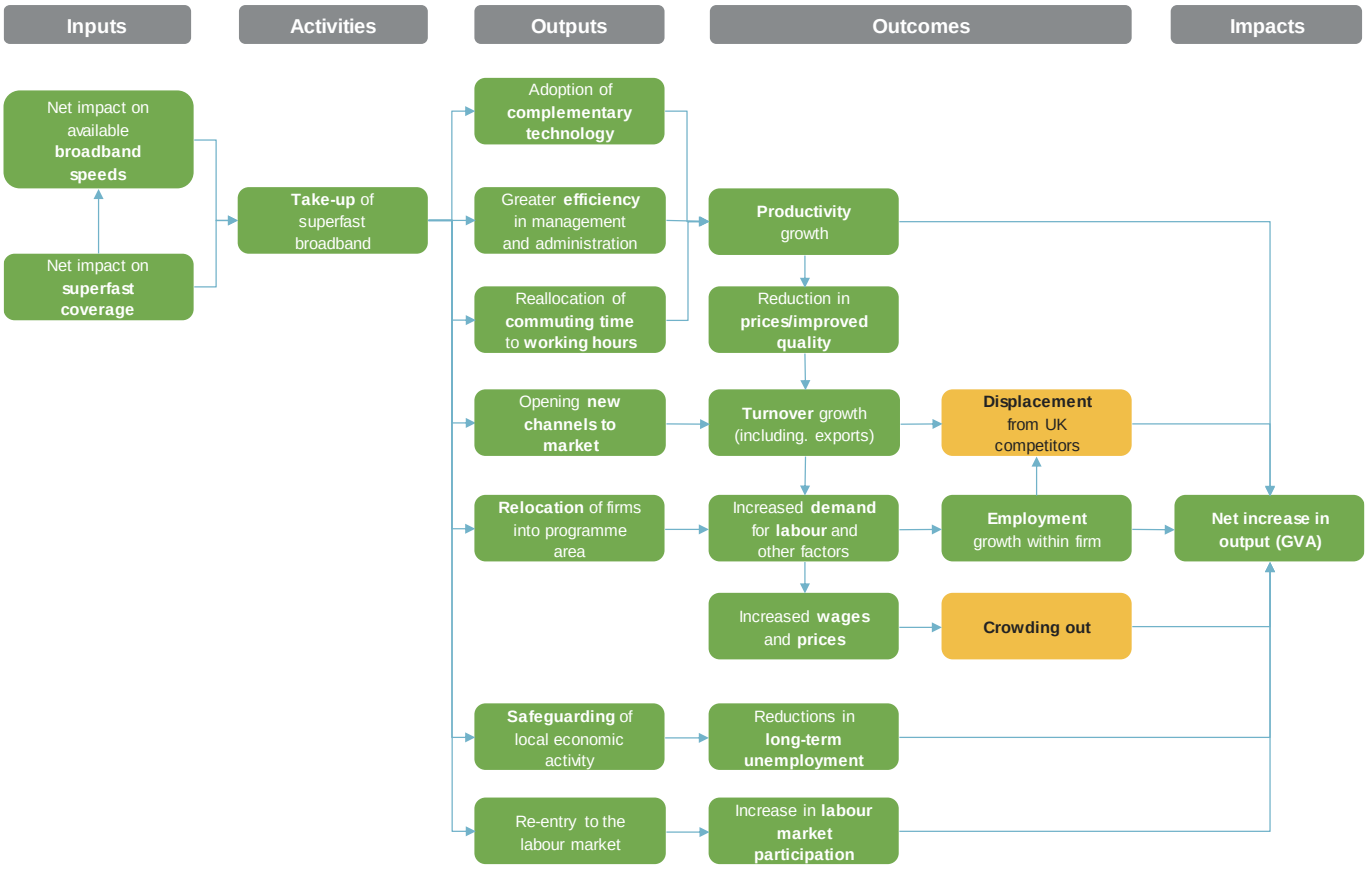
[12] In light of these issues, the HM Treasury Green Book recommends that the focus of economic appraisal should be on increases in the productive capacity of the economy, rather than on short term demand side effects.

[13] Whitcare et al. (2014) Broadband's contribution to economic growth in rural areas: Moving towards a causal relationship

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 through increased demand for inputs such as labour. In turn, this may encourage lower productivity firms to reduce their output or relocate to lower cost locations. Many of these effects could be expected to play out over the medium term.

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



2.3 Impacts on workers

The programme may also have the following effects on workers:

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

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

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

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

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

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

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

broadband access and how firms respond to those issues – e.g. how far they seek to meet these skills challenges through training existing staff or recruitment, and what happens to workers that do not have the skills required.

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

2.4 Impacts on households

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

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

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

- **Social interaction:** Faster broadband may also open new modes of communication between residents. While use of email and social media may not be dependent on higher bandwidths (and

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

can be straightforwardly used via mobile telecommunications networks), the COVID-19 pandemic temporarily popularised the use of video conferencing (previously used for remote meetings in a business context) as a mode of interpersonal communication. This technology requires greater bandwidths and subsidised coverage has the potential to improve well-being by supporting more extensive social interactions within and beyond the communities in which residents live (potentially reducing social isolation for some). However, there are some questions as to how far this mode of communication will endure now social distancing restrictions have largely been removed.

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

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

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

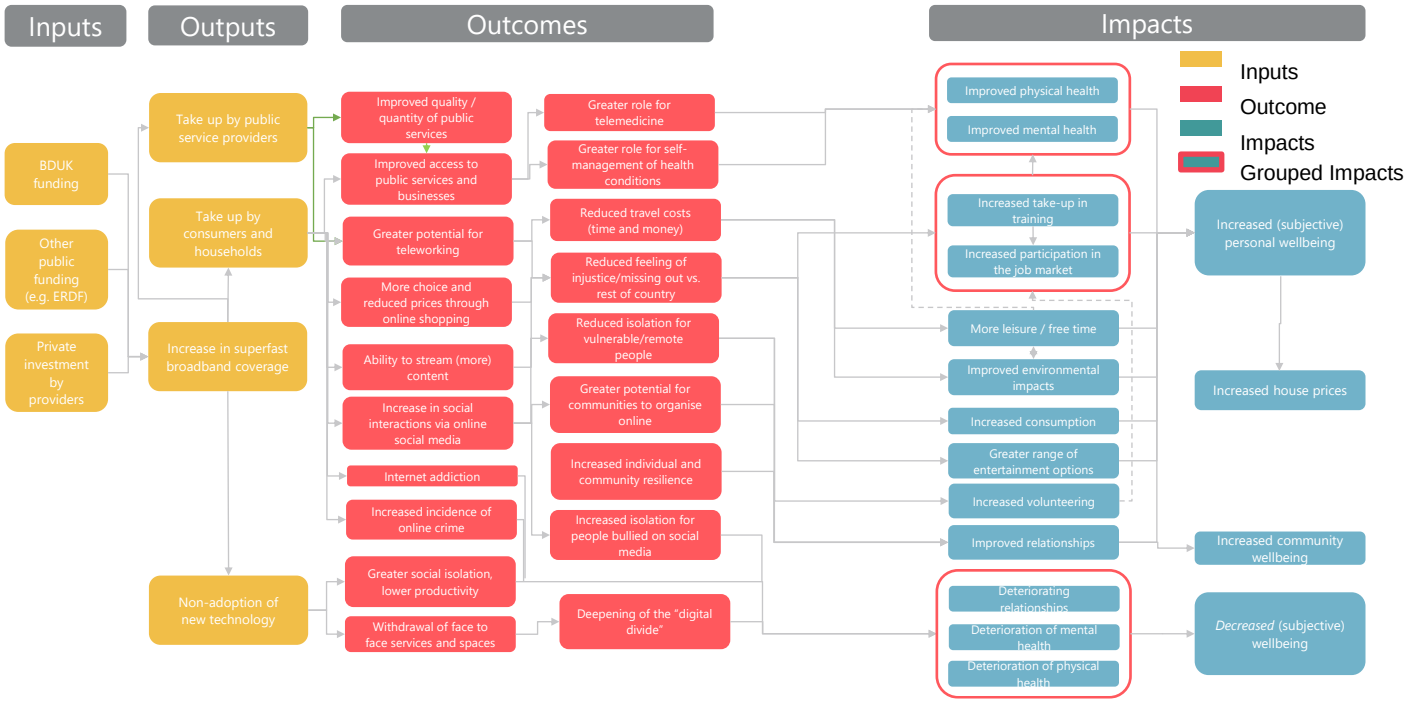
- **Rural population growth:** Migration of population to rural areas could also lead to pressures on local housing markets. This could also have a negative impact on the well-being of residents for example, if it increases equilibrium rents or stimulates house building activity on previously undeveloped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

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

[25] Pantic (2014) Online Social Networking and Mental Health, Cyberpsychology, Behaviour and Social Networking

[26] Natarajan et al (2020) Civil Society Perspectives on Inequality: Focus Group Research Finding, Submission to UK2070 Commission.

Figure 2.3: Household impacts of superfast broadband



2.5 Impacts on public sector service delivery

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

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

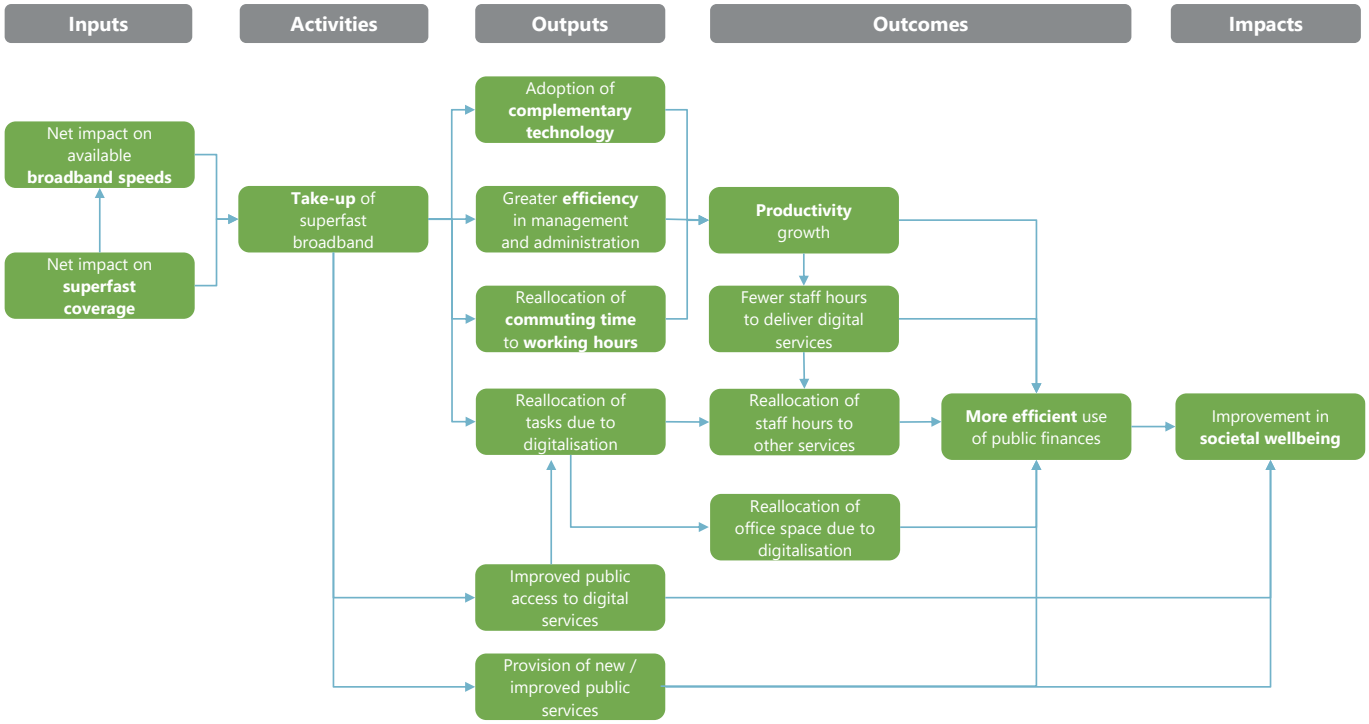
- **Service transformation:** Perhaps more consequentially, improved connectivity may also facilitate the digitalisation of public services (also enabled by improved service delivery). The range of possible applications are extensive. These might include enabling simple transactions to be undertaken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

- **Digital divide issues:** Digitalisation of public services can produce social benefits – not just through reducing the cost of delivery but also via improving choice and widening access. However, the ability of resident populations to benefit from digitalisation of public services will partly depend on the extent

to which they can access digital services. If they do not take up faster broadband services or if they do not have the confidence or skills to use online platforms, then some residents may be locked out of new modes of service delivery. This also risks negative distributional impacts if physical modes of delivery are withdrawn or scaled back.

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

Figure 2.4: Public service delivery impacts of superfast broadband



3 Methodological framework

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

3.1 Challenges in for an impact evaluation

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

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

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

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

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

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

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

3.2 Pipeline design

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

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

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

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

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

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

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

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

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

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

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

[28] All models have been estimated with standard errors clustered at the level of unit of analysis (postcode, Output Area or LSOA).
[29] Noting that the fixed effects specification would account for (fixed) differences in baseline characteristics, while including controlling for time varying features of the areas could introduce problems with endogeneity (e.g. if the programme caused changes in local industrial structure).
[30] Note that areas that did not benefit from subsidised upgrades were not included in the analysis, in line with the principles of the pipeline design.

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

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

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

3.3 Limitations

There are some methodological limitations to this approach:

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

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

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

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

  Attempts to mitigate these issues have been made by controlling for the observed characteristics of the areas benefitting from the programme as well as unobserved characteristics that do not change with time. However, there may be time varying but unobserved characteristics of the areas benefitting from the programme that have not been controlled for in the analysis e.g. working travel

patterns or local business clusters. As such, the design does not involve quasi-random allocation between the treatment and comparison groups and the results should be considered to attain Level III on the Maryland Scale.

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

3.4 Validity of the pipeline design

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

4 Impacts on businesses

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

4.1 Data

The following analyses made use of the following datasets.

4.1.1 Business Structure Database

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

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

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

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

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

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

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

Source: Business Structure Database

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

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

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

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

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

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

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

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

4.1.2 C3 reports

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

4.2 Overview

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

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

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

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

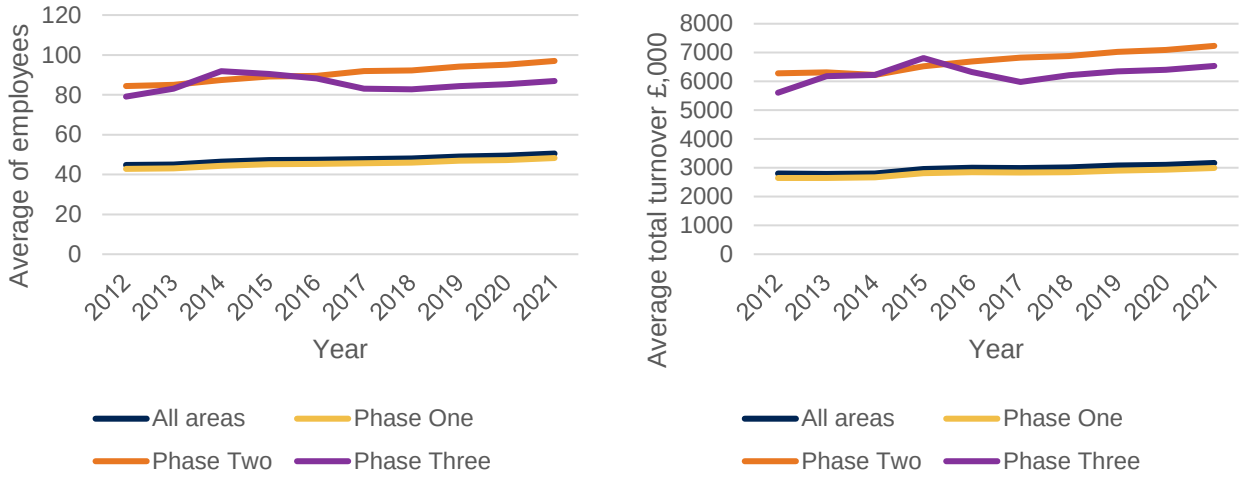
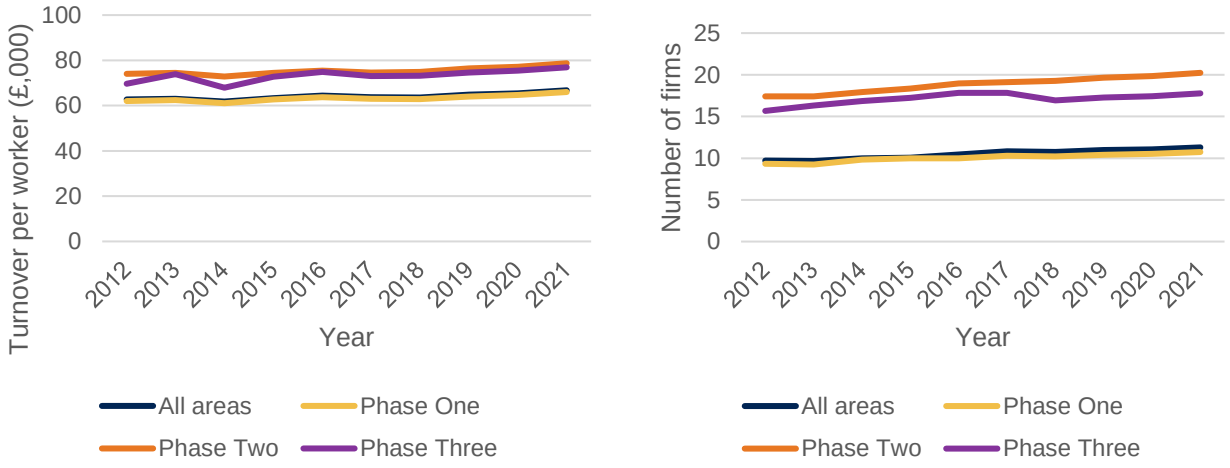


Figure 4.2: Average turnover per worker and average number of firms per output area, output areas benefitting from subsidised coverage (2021 prices)



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

4.3 Results

4.3.1 Business Structure Database

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

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

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

The models also controlled for general trends at the national level (t) and allows for differential trends across different sectors of the economy and businesses of different employment size bands ($X_{i,t=2012}t$). Here, $X_{i,t=2012}$ represents the share of employment in each sector and size-band in 2012, which was

interacted with time to capture unobserved trends affecting different sectors and sizes of firms that would determine growth in the Output Area. The model also controls for any time invariant unobserved differences between output areas (αi). To mitigate against the risk of possible biases driven by unobserved differences between areas benefitting from the programme and areas that were not, the sample was restricted to the 72,738 Output Areas that received subsidised coverage at some point between 2012 and 2021 (i.e. including areas that had not yet benefitted from subsidised upgrades).

Local economic impacts

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

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

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

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

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

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

Impacts by Phase

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

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

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

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

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

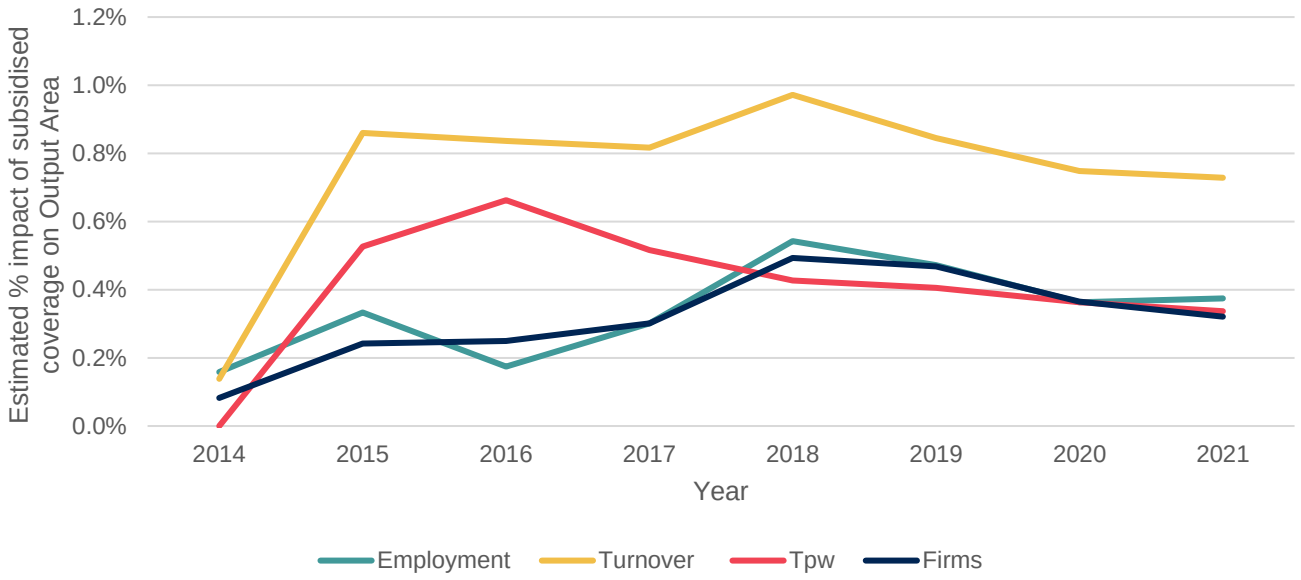
The findings show:

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

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

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

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



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

Spatially stable firms

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

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

- **Overall impacts:** Across all areas upgraded by March 2021, subsidised coverage increased the average employment of spatially stable firms by 0.38 percent and their turnover by 0.55 percent. The estimated effect on turnover per worker was 0.18 percent.

- **By Phase:** Effects were largest for areas upgraded in Phase 3 with those for Phase 1 smallest by 2021 with no significant effect on turnover per worker for these areas. This would suggest that effects decay over time.

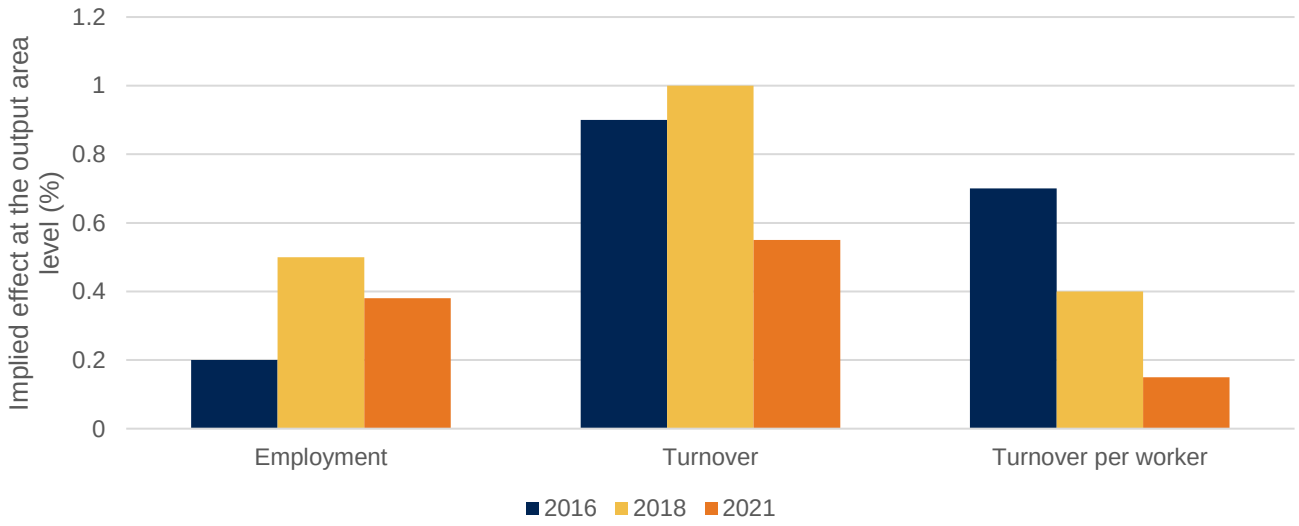
- **Decay over time:** Previous iterations of the evaluation have produced estimates of the employment, turnover and productivity effects up to 2016 and 2018. Figure 4.4 below combines these with the overall results up to 2021 and indicate a declining trend across all outcomes.

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

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

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

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



Single site firms

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

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

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

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

Impacts by technology type and speed

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

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

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

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

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

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

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

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

Impacts by urban and rural areas

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

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

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

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

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

Total local economic impacts

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

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

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

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

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

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

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

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

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

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

[43] Note that this differs from prior estimates of the impact of the programme to 2016 (49,000 jobs) as the findings are configured at the level of the Output Area rather than the postcode. As highlighted in the previous study, displacement effects were likely to be significant.

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

5 Impacts on workers

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

5.1 Data

The following analyses made use of the following datasets.

5.1.1 Annual Survey of Hours and Earnings

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

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

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

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

5.1.2 Claimant Count

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

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

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

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

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

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

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

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

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

5.1.3 C3 Reports

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

5.2 Results

5.2.1 Wage impacts

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

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

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

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

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

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

Overall effects

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

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

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

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

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

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

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

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

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

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

Effects by occupation

Isolating effects by occupation showed varying impacts depending across occupations:

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

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

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

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

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

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

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

5.2.2 Unemployment impacts

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

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

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

Overall effects

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

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

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

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

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

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

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

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

Dose response models

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

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

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

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

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

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

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

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

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

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

Residential vs non-residential effects

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

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

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

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

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

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

6 Impacts on house prices

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

6.1 Key issues

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

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

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

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

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

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

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

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

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

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

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

6.2 Impacts on house prices

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

6.2.1 Data

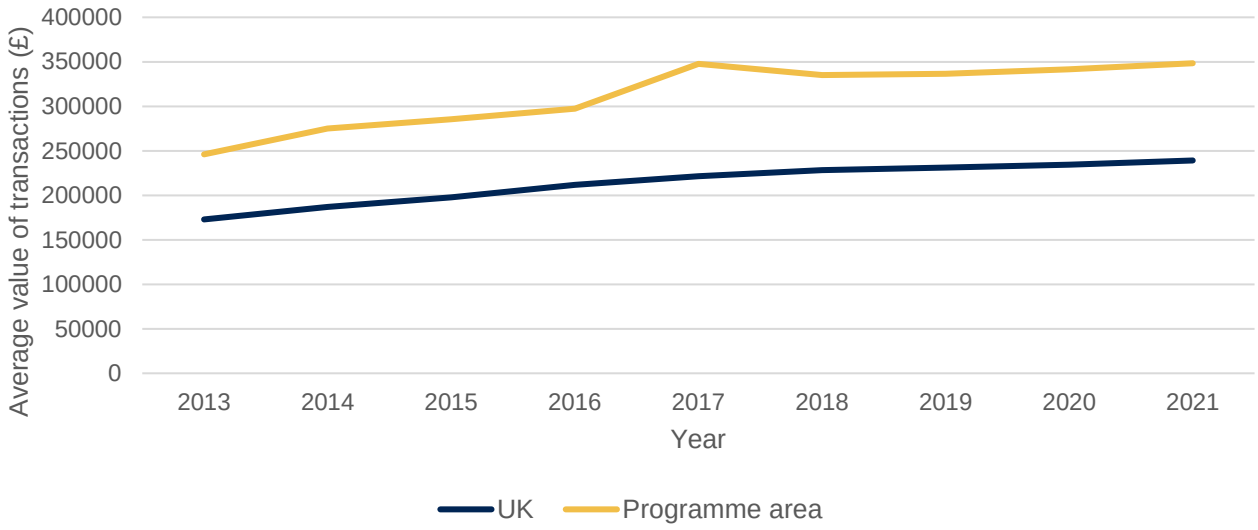
The primary dataset used for the analysis was the transaction level data on houses sold compiled by HM Land Registry. This provides a variety of data on individual housing transactions, including:

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

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

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

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



Source: Land Registry HPI, SCTs, Ipsos analysis

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

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

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

Source: Land Registry, SCTs, Ipsos analysis

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

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

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

6.2.2 Econometric model

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

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

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

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

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

6.2.3 Results

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

7 Impact on public services

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

7.1 General practice

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

7.1.1 Background

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

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

The claimed benefits of video consultations have tended to focus on enhanced time efficiency for GPs and greater convenience for patients. The available evidence on this is mixed. A 2017 study exploring the use of online consultations in 36 GP surgeries found that online video consultations took longer than face-to-face appointments and cost slightly more to deliver (£36 per appointment versus £33). [5859] There is also evidence that greater convenience can induce greater demand. For example, an evaluation of the Babylon GP at Hand service found that patients registering increased their demand for primary care appointments, raising questions about the size of the potential cost savings attached to 'digital first' working practices. [60] A recent review of the potential impacts of online consultation services also highlighted evidence that GPs

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

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

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

7.1.2 Data

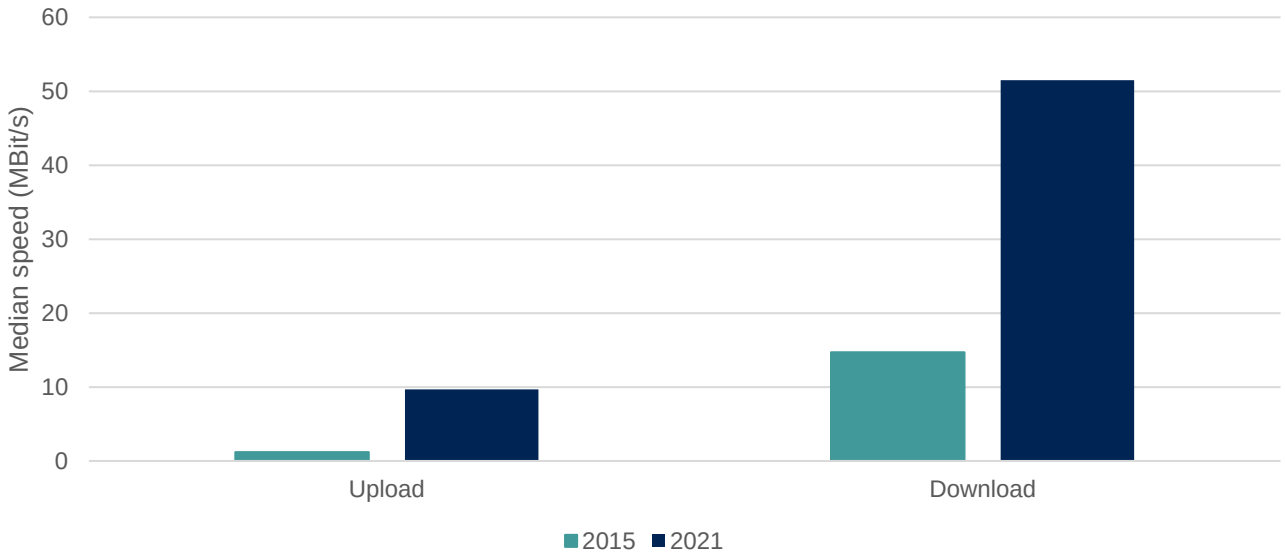
A complete list of general practices was acquired using GP practice data made available through NHS Digital[63]. The data available included details of the patients registered at GPs as well as the scale and composition of the local workforce at GP surgeries. Details of the premises upgraded through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

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

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

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

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



Source: Ofcom Connected Nations, C3 reports, Ipsos analysis

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

Table 7.1: Outcomes for General Practice

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

Source: NHS Digital, GP Patient Survey

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

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

7.1.3 Econometric model

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

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

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

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

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

7.1.4 Impacts on awareness and usage of digital services

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

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

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

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

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

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

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

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

7.1.5 Patient satisfaction

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

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

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

[68] There is a potential technical issue with the linear modelling approach as described above. The fractional outcomes used are bound at 0 and 1 and do not follow a linear distribution. This means that a linear models can provide biased or infeasible estimates (e.g. predicted values below 0 or above 1) - although they do provide a reasonable approximation where observations are clustered on the linear section of the logistic distribution. The reasonableness of using a linear modelling in this case was tested using a Tobit model with censoring at zero and one, a procedure recommended by some researchers. However, as the Tobit model also implies a linear distribution, other researchers have proposed alternative methods for examining fractional outcomes, including Generalised Linear Models with e logistic link function.

[69] https://www.gp-patient.co.uk/surveysandreports

[70] Satisfaction was measured as the proportion of respondents fairly or very satisfied with their overall experience of their last appointment.

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

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

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

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

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

7.1.6 GP resources

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

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

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

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

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

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

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

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

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

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

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

7.2 Primary and secondary education

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

Empirical studies investigating the impact of broadband on educational outcomes have, however, produced mixed findings. While early studies tended to show a positive impact of broadband availability

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

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

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

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

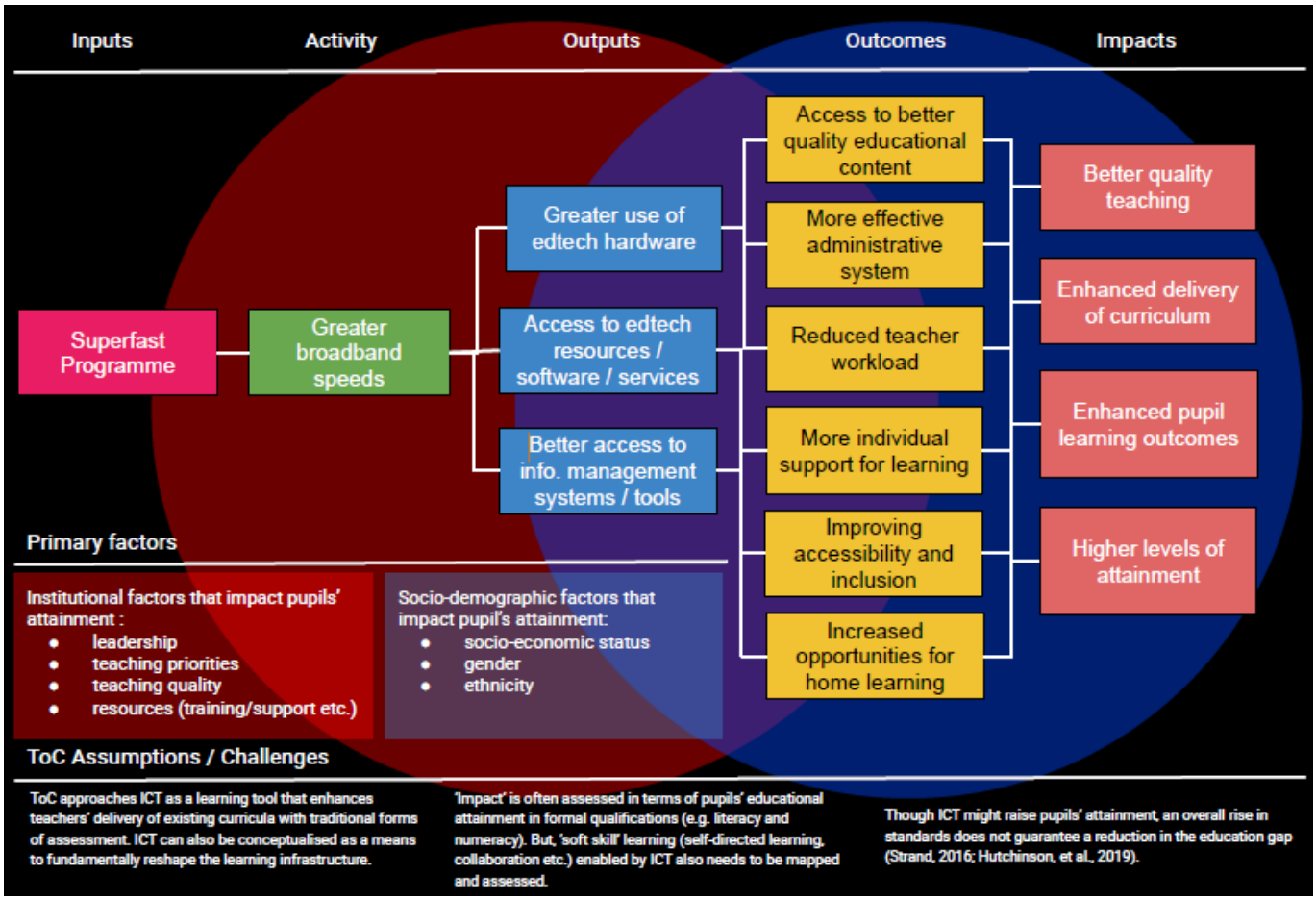
In addition, it is difficult to draw firm conclusions on the impact of ICT from existing literature, and detailed explanations as to the mechanisms through which ICT in schools can improve learning remain somewhat unclear. Amongst the challenges in identifying impact are the fact that the term ‘ICT’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

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

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

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

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



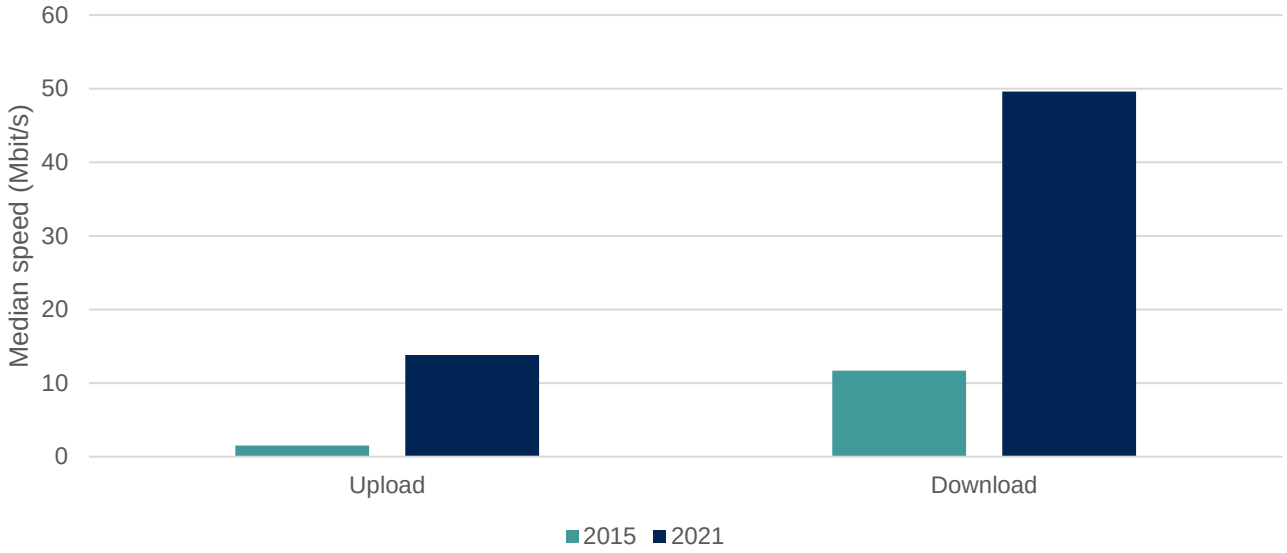
Source: BDUK, Benefits Realisation and Evaluation Team 2020

7.2.2 Data

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

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

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



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

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

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

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

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

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

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

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

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

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

7.2.3 Econometric models

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

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

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

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

7.2.4 Impacts on ICT spending and other school resources

The table below sets out the estimated effect of subsidised coverage on ICT spending and other school resources. Simple fixed effects models (without controls) found significant effects on all outcomes including ICT spend, teaching spend and the number of teachers, with these decreasing by 11 percent and

increasing by 6.4 percent and 2.2 percent respectively. However, these findings were not robust to the addition of further controls and as such the findings are inconclusive.

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

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

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

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

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

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

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

7.2.5 Impacts on number of pupils and pupil composition

The findings below provide estimates of the effects of the programme on pupil headcount and the composition of pupils. Basic fixed effects models point to positive effects on overall pupil numbers (which

would be consistent with the findings set out above for GP surgeries), though these results are not robust to unobserved local authority trends or time specific shocks affecting all schools.

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

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

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

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

7.2.6 Absences

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

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

[78] See footnote 68.

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

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

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

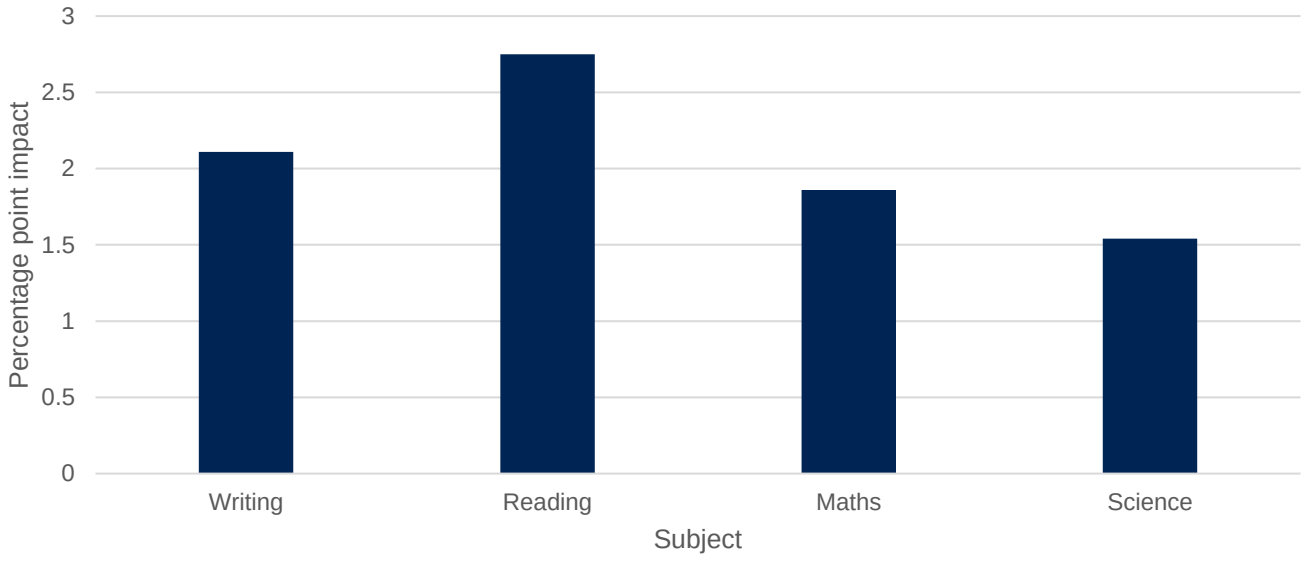
7.2.7 Attainment

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

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

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

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



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

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

8 Cost Benefit Analysis

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

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

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

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

8.1 Costs

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

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

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

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

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

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

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

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

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

Source: BDUK, Ipsos MORI analysis

8.2 Additionality

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

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

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

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

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

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

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

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

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

[85] DCMS (2021) State aid evaluation of the Superfast Broadband Programme: Technical Appendix One

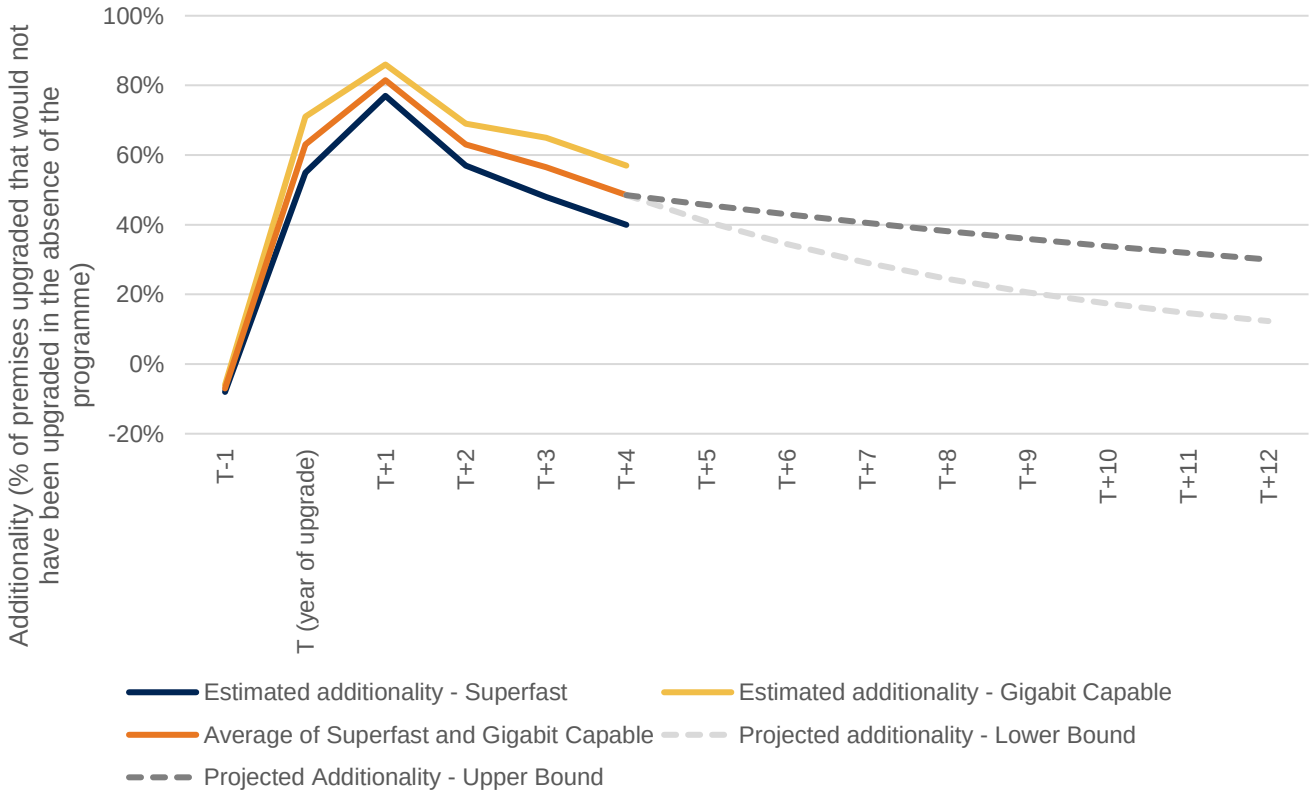
[86] And as such, the findings of this analysis cannot necessarily be transferred to current programmes.

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

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

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

Figure 8.1: Additionality profile over time



Source: Ipsos MORI analysis

The table below provides the estimated number of premises upgraded by March 2020 that would not have had enhanced broadband connectivity in the absence of the programme (in 2021/22 and 2028/29) under the two scenarios for future additionality. The gross number of premises passed is based on C3 reports

provided by BDUK. The number of additional premises passed in 2021/22 is estimated at 192,700. This is estimated to fall to between 58,300 and 102,600 by 2029/30 based on the scenarios described above.

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

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

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

8.3 Economic and social benefits

8.3.1 Productivity gains

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

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

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

GVA based measure of economic benefits

An increase in productivity will increase overall economic output (GVA) as resources are used more efficiently. However, it is important to note that turnover per worker may rise at the local level both because firms become more efficient, and because more productive firms relocate to the area (a displacement

effect that would not lead to improvements in productivity at the national level). To address this issue, the economic benefits of the programme have been estimated based on its effects on firms that did not relocate (i.e. spatially stable firms) over the period of interest, as follows:

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

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

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

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

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

[87] Source: Annual Business Survey, ONS

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

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

Source: BDUK, Ipsos MORI analysis

8.3.2 Unemployment impacts

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

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

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

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

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

Source: BDUK, Ipsos MORI analysis

8.3.3 Social benefits

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

[88] Though some of these episodes will have otherwise evolved into long-term unemployment.
[89] DCMS (2018) Economic and Public Value Impacts of the Superfast Broadband programme.
[90] Note that the results are not highly sensitive to this assumption. If it is assumed that all reductions in unemployment were from the long-term unemployed, then the resultant productivity gains would increase to £19.2m by 2022 and between £55.0m and £61.0m by 2030.
[91] It is assumed that the productivity of the average worker avoiding long-term unemployment due to the programme is lower than the national average, and here we have assumed that workers would gross annual pay at the 25th percentile of all workers (based on the 2017 Annual Survey of Hours and Earnings). This is consistent with DfT Transport Appraisal Guidance treatment of labour supply impacts.

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

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

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

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

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

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

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

The following table provides a summary of the results.

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

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

Source: BDUK, Ipsos MORI analysis

8.4 Benefit to Cost Ratios

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

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

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

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

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

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

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

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

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

Source: BDUK, Ipsos MORI analysis

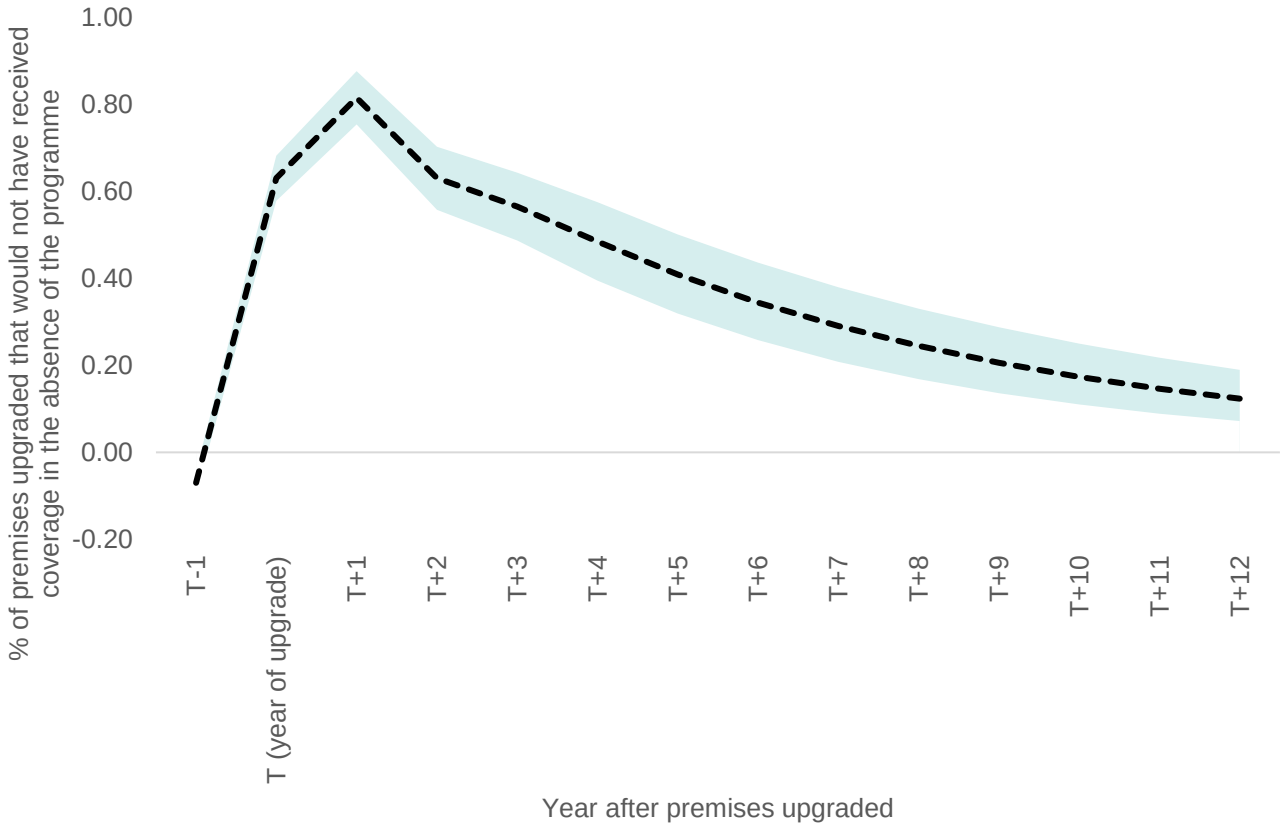
8.5 Margin of error

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

8.5.1 Additionality

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

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



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

8.5.2 Productivity, unemployment and house prices

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

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

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

Source: BDUK, Ipsos MORI analysis

8.5.3 BCRs

The table below illustrates the margin of error around the most conservative estimates set out in Table 8.6 (i.e. those associated with lower additionality). The findings indicate that there is substantial statistical uncertainty in relation to the BCRs associated with subsidised coverage, driven principally by uncertainty (modelling, statistical, and interpretation uncertainty) regarding the size of the effect of the programme on

house prices. After allowing for statistical uncertainty, the BCR associated with the programme could range from £0.17 to £7.11 per £1 of public sector spending (by 2030).

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

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

Source: BDUK, Ipsos MORI analysis

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