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

Technical Appendix 1 - Reducing the Digital Divide

Ipsos MORI



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Glossary

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

Executive summary

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

Programme overview

The analysis tackles three key evaluation questions defined in the State aid evaluation plan¹ agreed between BDUK and the European Commission. These are:

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

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

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

Key outcomes

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

Background

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

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

Key findings

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

- Impact on broadband coverage: Coverage subsidised through Phase 3 of the programme led to positive impacts on broadband availability. These impacts included a small positive impact on NGA availability (an increase in the proportion of premises with NGA coverage of 2 to 11 percentage points with most estimates towards the bottom end of this range). However, subsidised coverage increased the proportion of premises able to access superfast speeds by 10 to 25 percentage points and the proportion of premises with FTTP coverage by 25 to 28 percentage points (aligning with the relatively stronger focus of Phase 3 on gigabit connectivity). These findings indicate that many premises benefitting from the programme would have otherwise received some form of enhanced broadband coverage. However, in most cases these enhancements would not have delivered superfast speeds and would have involved the deployment of an inferior technology.
- Competition: The results consistently suggest that the programme has promoted additional competition and has increased the number of network providers offering broadband services in the target area (by around 0.2 providers on average). The areas benefitting from the programme were less well served by fewer broadband suppliers than other areas of the UK, and this may bring benefits to consumers in the longer-term (e.g. in the form of lower prices or wider choice).
- Impact on take-up: Subsidised coverage has reduced the share of households and businesses that have a superfast connection and the average download speeds of connections. This may be explained by the relatively early stage at which the impacts have been estimated. Only seventeen percent of the contracted premises upgraded had been delivered over the period covered by this analysis (and most these in the final year covered by this analysis). Take-up typically lags availability it took six years for take-up to reach 60 percent of premises upgraded through Phase 1. As such, it is premature to consider the impact of the programme on take-up. However, the observation of negative effects on the number of premises with superfast connection indicates that for some households or businesses, the programme made superfast services available at a later date than they would have otherwise been received (an issue considered in more depth below).

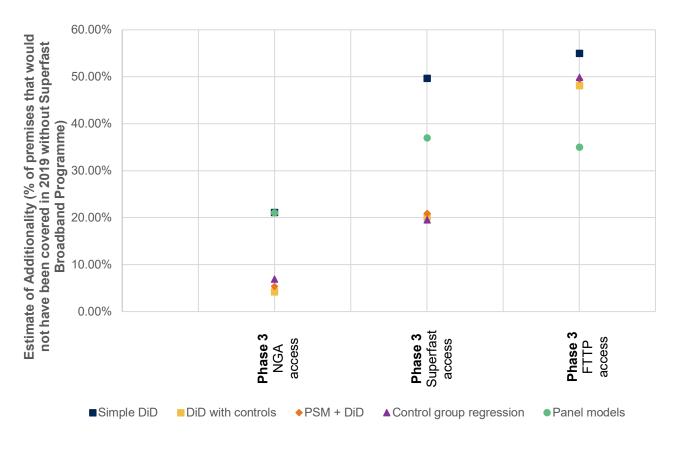
Additionality of subsidised broadband infrastructure

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

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

The range of findings are depicted in the following figure.

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



Impacts on the programme area

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

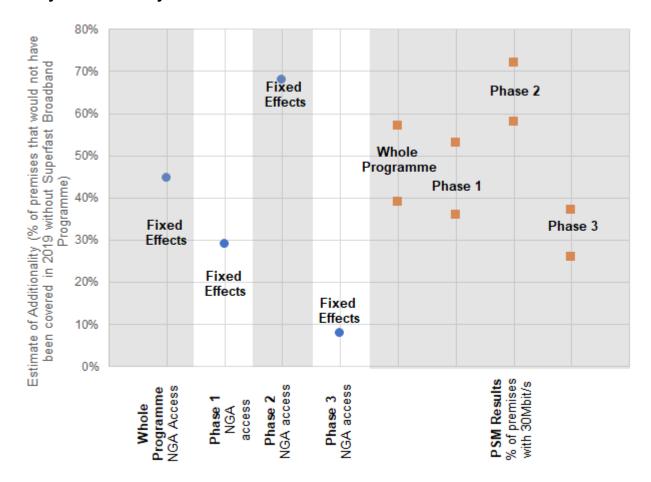
The factors driving this pattern are discussed in the main evaluation report. However, this pattern was also observed in relation to the impacts of Phase 1 and 2. The results set out in Section 5 point to a general pattern in which the programme delays the availability of enhanced broadband coverage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

Impacts of Phase 1, 2 and 3

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

- Impacts on NGA coverage: The results indicated that the Superfast Broadband programme increased the share of premises in the programme area with NGA availability by almost 25 percentage points. The impacts of the programme on NGA coverage appear to have peaked in 2018. This suggests that postcodes that have not benefitted from the programme have started receive commercial deployment of NGA coverage (suggesting that in part, one of the effects of the programme is to accelerate the availability of enhanced infrastructure).
- Impact on superfast broadband availability: The impact of the programme on superfast broadband availability continued to rise by 34 percentage points on the postcodes in the build plans of local schemes by 2019. The effects of the programme on superfast availability were larger than for NGA, and the results do not suggest that these impacts have begun to decay. This would indicate that while some areas benefitting from the programme may have received NGA coverage in the absence of the programme, these technologies would not necessarily have delivered superfast speeds (in common with the findings set out in the preceding section).
- Phase 1: The impact of Phase 1 schemes peaked in 2016. Differences between NGA and superfast broadband coverage on postcodes in the build-plans of Phase 1 schemes and the comparison group got smaller in 2018 and 2019. This suggests these earlier schemes had a significant effect in accelerating access to superfast broadband coverage, although some premises would have otherwise benefitted from upgrades at a later point in time.

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

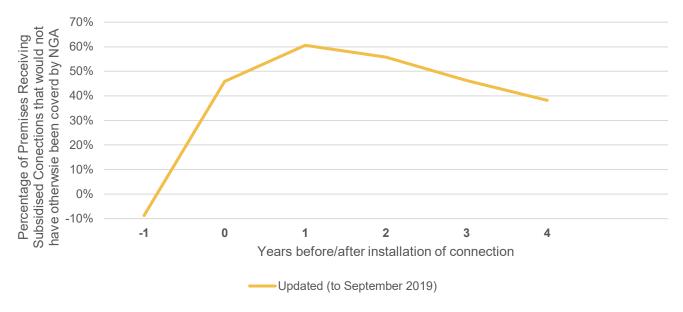


Summary of additionality estimates across methods

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

- Additionality over time: The analysis indicated that additionality peaked in the first year following the delivery of the upgrade (at around 60 percent) before decreasing with time. This indicates that the programme has brought forward superfast coverage for some premises that would have otherwise received it at a later stage. There were also signals that the programme delays coverage for some households or businesses that would have received it earlier. Factors driving these patterns are explored in the main evaluation report.
- Crowding-out: Overall, the analysis suggested a small degree of crowding out from delivery to a
 postcode in the 0 to 10km distance but also a small degree in areas 10km to 20km away and then
 areas 20 to 30km away, all within the year of delivery. One year after, the opposite is true for areas
 10 to 20km away and 20km to 30km. The level of crowding out estimated overall was negligible.
- Take-up: The impact on take-up has increased with time, suggesting that effects on take-up have lagged effects on coverage. For example, while the effect of Phase 1 contracts on the average download speeds of connections were relatively limited by 2016 (three years after delivery of the programme started), these effects appeared to be substantial in 2019.

Estimates of additionality of NGA Coverage over time



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

1 Introduction

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

1.1 Background

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

The Superfast Broadband Programme was extended a second time under a new State aid approval³ covering the 2016 to 2020 period. Contracts awarded under this State aid scheme (commonly known as Phase 3) are the focus of this analysis. These projects had a greater focus on full fibre connectivity than those funded in prior phases, aligning with broader Government objectives to increase Fibre to the Premises (FTTP) coverage in the UK. This third phase evolved from a series of pilots that sought to explore how coverage could be extended past 95 percent of UK premises. At the time of writing, there were 51 Phase 3 projects underway (across 51 lots⁴) supported by £187m of public funding⁵. However, as these projects were at relatively early stages of delivery, the following analysis also explores the longer-term impacts of Phase 1 and Phase 2 schemes.

1.2 Evaluation questions

This analysis tackles three key evaluation questions defined in the State aid evaluation plan⁶ agreed between BDUK and the European Commission. These are:

² DCMS and Rt Hon Jeremy Hunt MP (2010) Media Keynote Speech, the Hospital Club. Available at:

https://www.gov.uk/government/speeches/media-keynote-speech (accessed August 2020).

³ European Commission (2016) SA. 40720 (2016/N) – National Broadband Scheme for the UK for 2016-2020. Available at:

https://ec.europa.eu/competition/state_aid/cases/263954/263954_1760328_135_4.pdf (accessed August 2020).

⁴ As recorded in a June 2020 CORA management information extract. A lot was defined as an individual contract for a specified subset of areas within a scheme area.

⁵ This is out of a total of 51 Phase 3 projects as listed in the Superfast Broadband Management Information

⁶ DCMS (2017) National Broadband Scheme Evaluation Plan. Available at: <u>https://www.gov.uk/government/publications/national-broadband-scheme-evaluation-plan</u>

- Question 1: To what extent has the aid resulted in increased access to a Next Generation Access⁷ (NGA) network in white⁸ NGA areas?
- Question 2: To what extent has the target of the intervention been used and what speeds are available?
- Question 6: Is the gap funding model efficient compared to alternative schemes?

1.3 State aid evaluation methodology

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

Difference-in-differences: This approach compares changes in NGA coverage and take-up between June 2016 and September 2019 on postcodes benefitting from Phase 3 contracts and a comparison group of postcodes that were identified as white in the relevant Open Market Review processes but were not included in the build plans of Phase 3 contracts. The State aid evaluation plan defined postcodes that benefitting from the programme as those that had received subsidised coverage by September 2019 (i.e. areas in the build plans of these schemes, but had not yet benefitted from the programme, were not considered part of the treatment group).

Modelling of coverage in white postcodes (control group regression approach): This involved the development of a statistical model to explain the evolution of NGA coverage and take-up on white postcodes that were not included in the build plans of Phase 3 contracts between 2016 and 2019. This model was used to predict NGA coverage on postcodes benefitting from Phase 3 contracts in the counterfactual scenario in which the programme had not been funded. Predicted NGA coverage was subtracted from observed coverage to estimate the impact of the programme.

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

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

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

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

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

- Selection on observables: The difference-in-differences approach set out in the State aid evaluation plan did not account for systematic but observable differences between the proposed treatment and comparison groups that could bias results. Several additional steps were taken to control for observable differences between the two groups. This included adding control variables to regression based difference-in-difference models and using statistical matching methods to ensure that postcodes benefitting from the programme were only compared to postcodes outside of Phase 3 build plan where they shared similar characteristics.
- Intention-to-treat estimates: The State aid evaluation methodology focused on the impact of the programme on those postcodes that had received subsidised coverage by the time of the analysis. This could potentially lead to biased estimates of the impact of the programme if there are systematic but unobserved differences between those postcodes that received subsidised coverage early in the build programme and those expected to benefit in the future. Supplementary analyses were also carried out using all postcodes in the build plans of Phase 3 contracts as the treatment group for the analysis that are more robust to this potential issue.
- Time horizons: Finally, the data available for this analysis ran to September 2019. At this point, only
 a small share of expected delivery under Phase 3 had been brought forward (around 15 percent). It
 was too early to draw conclusions regarding questions about the long-term impact of Phase 3
 contracts on coverage and take-up. To provide a longer-term view, an analysis was completed
 exploring the effects of all contracts funded through the Superfast Broadband programme (extending
 the scope of the analysis to include Phase 1 and 2 contracts awarded under the 2012 to 2016 UK
 National Broadband Scheme).

2 Analytical framework

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

2.1 Theoretical framework

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

2.1.1 Programme delivery model

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

- Allocation of subsidies: Subsidies were allocated to Local Bodies (responsible for tendering and awarding contracts to deliver infrastructure upgrades) based on BDUK's assessment of the gap funding⁹ 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 cost¹⁰. For Phase 3, resources were allocated to achieve the greatest increase in coverage for the available funding (which included locally available resources brought by the Local Body potentially from past contracts or matched to potential sources such as ERDF or DEFRA funding). Several local authorities were deemed ineligible for BDUK support because existing commercial plans were already extensive.
- Open Market Review (OMR) and public consultation: Local Bodies were required to manage an OMR and public consultation process before they issued tenders. The first stage of this process involved requesting suppliers to describe their commercial plans to roll-out basic and superfast broadband coverage over the next three years. This process classified premises (postcodes in Phase 1 and 2) into three groups:
 - White areas where there were no commercial plans to roll-out superfast broadband within three years.
 - **Grey areas** where one provider was offering or expected to offer superfast broadband services within three years, and,

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

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

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

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

- Tendering: This view on the near term roll out of broadband at the local level was expressed in a Speed and Coverage Template (SCT) used in local tendering exercises in which local authorities sought to procure additional investment in local telecommunications infrastructure. Only 'white' premises or postcodes were eligible for subsidised infrastructure, with competing providers outlining which postcodes/premises they proposed to cover for the available funding. Network providers were required to provide a Project Financial Model (PFM), which included estimates of the overall costs associated with delivering the project, take-up assumptions and expectations of future revenues and on-going operational costs. This model provided an estimate of the internal rate of return (IRR) associated with the project without subsidy. The subsidy offered aimed to equalised the IRR over a seven-year period with the suppliers Weighted Average Cost of Capital (WACC)¹¹.
- Underspend: Protections for the public sector against the risk that suppliers overestimated their delivery costs were put in place by introducing a mechanism to recover underspend. The principle underlying contracts was that the supplier would fully invest its contracted funding. In the event of any underspend, the supplier was required to place unused funds in an Investment Fund to help resource further schemes or extend the contract coverage to a greater number of premises than originally offered. Any unused public funding also remained available for further investment.
- Take-up clawback: Further protections for the public sector were introduced through 'take-up clawback' clauses in contracts. If take-up proved to be higher than anticipated at the tendering stage then suppliers were required to return a share of the excess revenues to the investment fund based on the investment ratio (and again, these funds could be recycled to support further coverage). Take-up clawback was capped such that the amount returned to the public sector could not exceed the value of the subsidy awarded.

2.1.2 Factors influencing additionality

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

- Accuracy of information gathered through the OMR: The level of additionality associated with the programme will be critically dependent on the degree to which the OMR process was effective in accurately identifying 'white' postcodes where no commercial deployment of NGA networks was planned. If the OMR incorrectly identified 'black' or 'grey' areas as 'white' and eligible for subsidies, there is a danger that public funding could be awarded to provide subsidised superfast infrastructure to areas that would otherwise have benefitted from commercial deployments. Possible threats to the accuracy of the information gathered through the OMR include:
 - Comprehensiveness: The OMR process would need to reveal the commercial plans of all network providers that could credibly deploy superfast networks over the timescales of interest. This required Local Bodies to engage effectively with local network providers, as if some potential providers did not provide their commercial plans then there is a risk that some postcodes or premises are mistakenly identified as 'white' and eligible for subsidies. The comprehensiveness of the data gathered is also linked to the standards of evidence applied by Local Bodies when reviewing the credibility of the commercial plans provided by network providers. Evidence from

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

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

- Strategic behaviour during the OMR process: It could be anticipated that some network providers would see an incentive to understate their commercial plans during the Open Market Review process if it would increase the likelihood they could obtain subsidies for investments they would have made anyway. However, suppliers that did not intend to seek subsidies (for example, if they were discouraged by the open wholesale access requirements) may have experienced incentives to overstate their commercial plans to preserve local market dominance or prevent the emergence of subsidised competitors. This latter issue may not affect additionality as it would imply postcodes were mistakenly marked as ineligible for subsidies, but could have economic or social costs (e.g. if the publication of the resultant coverage maps promoted investments in areas where superfast coverage did not ultimately come forward).
- Dynamic nature of commercial deployments: The OMR provided a static view of future commercial deployment plans. However, network providers operate in a dynamic environment in which the deployment plans evolve in response to new information. On-going increases in demand for superfast services observed since the programme was launched will increase the potential revenues that can be earned, making some investments profitable that previously were not. Regulatory innovation¹² has reportedly allowed competing network providers to more efficiently access Openreach's Physical Infrastructure Access (PIA) product, reducing the cost of network deployment via access to the dominant provider's ducts and poles. The length of investment planning cycles (reportedly 12 to 24 months) will also inhibit the ability of network providers to supply concrete deployment plans for extensive periods in the future. As such, some 'white' postcodes may become 'black' over time, potentially resulting in some premises receiving superfast coverage earlier than they otherwise would have.
- Network provider behaviour during the tendering process: Given that it is not possible to perfectly observe the future commercial plans of network providers, the contractual mechanisms put in place provided further protection against the risk that public sector resources were deployed to take forward schemes that were commercially viable. The underspend and take-up clawback mechanisms aimed to reduce the ability of network providers to exploit their superior information to overstate the gap funding requirement. Overstatement of costs at the tendering stage would be recovered via the underspend clawback mechanism¹³. A share of any understatement of future revenues would also be recovered via take up clawback mechanism. Understating expected costs or overstating take-up expectations (e.g. to improve the competitiveness of tenders submitted) could result in the supplier ultimately taking a loss. It should be noted, however, that these protections are internal to the relevant infrastructure provider and would not limit subsidies being allocated to schemes that overbuild or discourage planned deployments by competing suppliers.

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

¹³ Unless subsidies encourage less efficient delivery.

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

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

2.1.3 Indirect impacts

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

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

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

2.1.4 Logic model

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

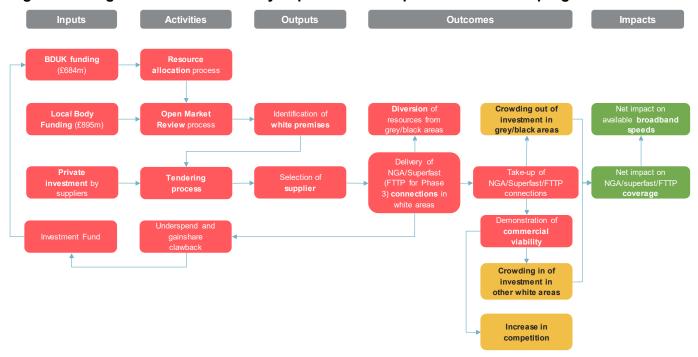


Figure 2.1: Logic model – connectivity impacts of the Superfast Broadband programme

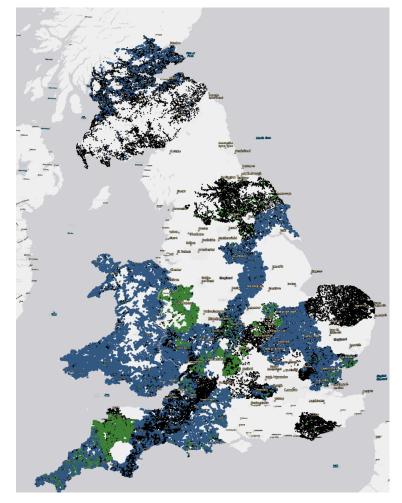
3 Programme overview

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

3.1 Target area for Phase 3 contracts

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

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



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

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

Status	Phase 1		Pha	se 2	Phase 3		
	Number	% of Number postcodes in UK		% of Number postcodes in UK		% of postcodes in UK	
White postcode within build plan defined in SCT	248,521	16.2	95,266	6.2	66,926	4.4	
White postcode out of build plan defined in SCT	99,959	6.5	77,748	5.1	51,534	3.4	
Grey or black postcode in SCT	524,124	34.1	744,233	48.5	39,472	2.6	
Total	872,604	56.8	917,247	59.8	157,932	10.4	
Number of SCTs	38		4	6	63		

Source: SCT templates, Ipsos MORI analysis

3.2 Characteristics of postcodes benefitting from the programme

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

- Availability & coverage: Superfast broadband penetration was lower in postcodes included Phase 3 build plans than on other white postcodes that were eligible for investment, in both 2012 and 2016. This is also reflected in measures of take up, including the average and maximum speeds of connections and the number of superfast connections taken by consumers located on the postcode.
- Network characteristics: Areas in the build plans covered by Phase 3 contracts were also more likely to exhibit characteristics that would increase the costs of deployment or reduce commercial viability. Premises included in the build plans of Phase 3 contracts were characterised by longer line lengths to the serving cabinet which are more expensive to upgrade as copper lines from the serving cabinet are less able to deliver superfast speeds, requiring additional investment in fibre. Demand density was also lower with lower numbers of delivery points per exchange/cabinet and lower population and premises density. This reduces the number of customers that can potentially be served and the potential revenues that can be earned. BDUK modelling completed in 2014 also suggested that the estimated cost of upgrading the serving cabinet would be higher.
- Area characteristics: Postcodes included in the build plans of Phase 3 contracts were more likely to be rural in nature (75 percent of postcodes compared to 64 percent of postcodes eligible but not included in build plans). Employment and unemployment rates in the local authorities were very similar across groups, though average wages were lower in those areas included in Phase 3 build plans.

This indicates network providers selected premises that were costlier to upgrade and were characterised by weaker demand side characteristics. This is the reverse of the patterns observed for Phase 1 and Phase 2¹⁴. This may be related to the comparatively high levels of penetration in white postcodes that were not included in the build plans of Phase 3 contracts. Where existing levels of penetration is high, the remaining premises not served may be concentrated in relatively small pockets. It may not be cost effective to build out networks to fill these gaps in provision. Network providers may have targeted communities with low levels of existing penetration to maximise the size of the local markets that could be addressed.

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

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

Source: Ipsos MORI Analysis

¹⁴ BDUK (2018) Superfast Broadband Programme Evaluation: Annex A – Reducing the Digital Divide.

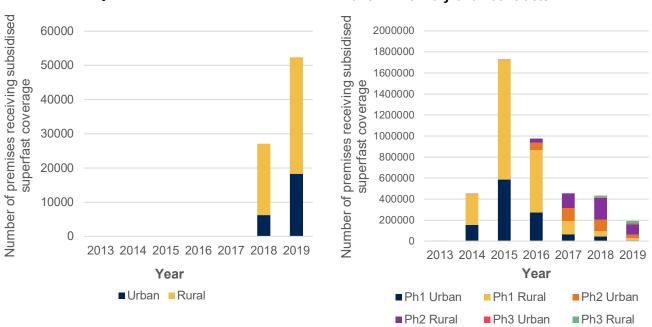
¹⁵ Note that this does not factor in the number of premises on a postcode able to reach a certain maximum download speed

¹⁶ There were around 11.3 premises per postcode on postcodes in the build plans of Phase 3 schemes.

3.3 Delivery

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

Figure 3.2: Number of premises receiving superfast (30Mbps¹⁷) coverage subsidised by BDUK, areas for which Phase 1, Phase 2, and Phase 3 SCTs are available, 2013 to September 2019¹⁸



Panel A: Delivery of Phase 3 contracts

Panel B: Delivery of all contracts

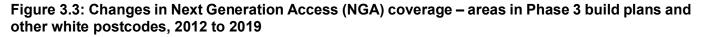
Source: C3 reports, Ipsos MORI analysis. Note that delivery has been assigned to the period covered by the relevant annual Connected Nations report and do not always cover a 12-month period (see Annex A for more details on this).

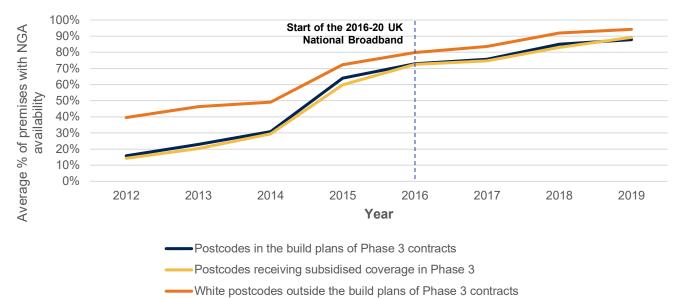
3.4 Changes in connectivity in the target area

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

¹⁷ 24MBits for Phase 1 and Phase 2

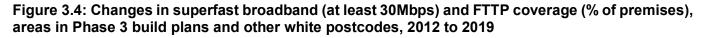
¹⁸ Data allocated to Connected Nation years and not calendar or financial years (distinction provided above in data section)

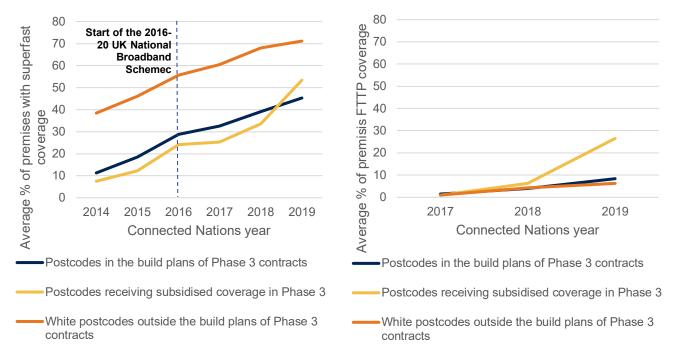




Source: C3 reports, Ofcom Connected Nations, Ipsos MORI analysis.

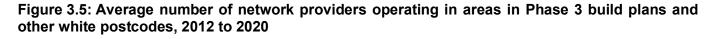
Superfast coverage rose at similar rates in areas covered by Phase 3 build plans and other white postcodes between 2016 and September 2019 (from 29 to 45 percent and from 55 to 71 percent respectively). Superfast coverage expanded rapidly (from 24 to 56 percent of premises) in those areas benefitting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

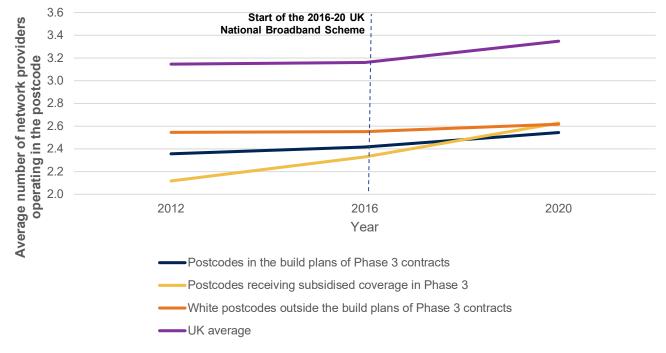




Source: C3 reports, Ofcom Connected Nations, Ipsos MORI analysis. Note data on FTTP coverage is only available from 2017 onwards.

Figure 4.5 shows the change in the number of network providers¹⁹ operating in postcodes that were eligible for subsidies under Phase 3 contracts between 2012 and 2020. In 2016, the average number of network providers operating in the areas covered by Phase 3 build plans was lower than in other white postcodes. This indicates providers were targeting postcodes with less intensive local competition. The average number of network providers operating on the postcodes benefitting from subsidised upgrades rose from 2.3 to 2.6, indicating the programme may have helped promote greater competition in these areas.





Source: C3 reports, ThinkBroadband, Ipsos MORI analysis.

3.5 Take-up of subsidised coverage

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

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

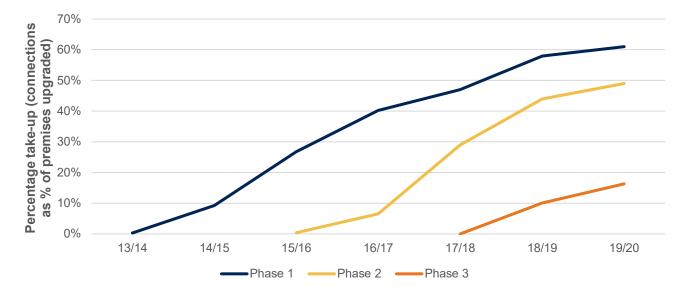


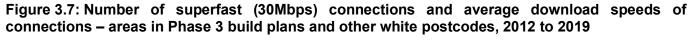
Figure 3.6: Number of connections as a percentage of premises upgraded Q2 2019/20, Phase 1, 2 & 3

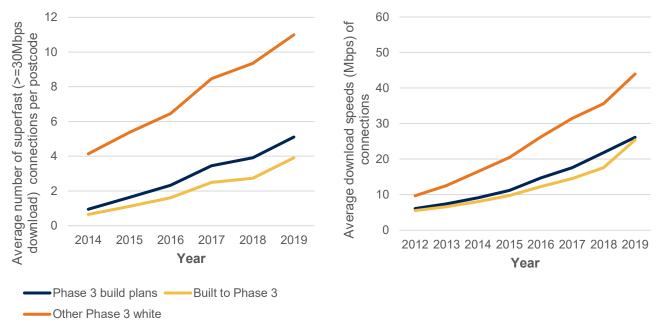
Source: Programme data (WSS C3 reports); Ipsos MORI analysis. Note that 2019/20 is an incomplete year.

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

- Number of superfast (30Mbps) connections: The average number of superfast connections on postcodes in the build plans of Phase 3 schemes more than doubled between 2016 to 2019 (121 percent increase from 2.3 to 5.1). Growth in the number of superfast connections rose slightly more rapidly (by 143 percent) on postcodes receiving subsidised coverage by 2019. Demand for superfast connections also rose on other white postcodes not included in the build plans of Phase 3 schemes, with the number of superfast connections rising by 71 percent on these postcodes over the same period.
- Average download speeds: The average download speeds of connections on postcodes included in the build plans of Phase 3 contracts rose from 14.7 Mbps to 26.2 Mbps between 2016 and 2019 (78 percent). Average download speeds rose more rapidly on postcodes receiving subsidised coverage by September 2019 (106 percent). Growth in average download speeds was more rapid on postcodes that were not included in the build plans of Phase 3 schemes (115 percent) over the same period.

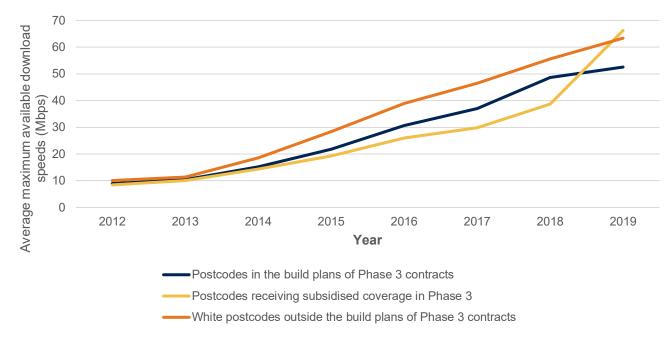
There were more marked differences in the maximum download speeds of connections (shown in Figure 3.7). Maximum downloads speeds on the postcodes included in the build plans of Phase 3 schemes rose at a similar rate to those on other white postcodes. However, maximum download speeds rose most rapidly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





Source: C3 reports, Ofcom Connected Nations, Ipsos MORI analysis²⁰.





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

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

4 Phase 3 connectivity impacts

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

4.1 Data

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

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

Table 4.1: Datasets used in the analysis

4.2 Evaluation design issues

4.2.1 Key outcomes

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

Table 4.2: Key outcomes

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

4.2.2 Definition of the treatment and comparison group

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

- Targeting at white areas: Investment was targeted at white premises where commercial operators claimed they had no plans to roll-out superfast broadband coverage without public subsidies. As such, 'grey' and 'black' premises or postcodes are unlikely provide a suitable counterfactual as they had been deemed commercially viable, and therefore were more likely to have received superfast coverage in the absence of the programme. The inclusion of these areas in a comparison group would understate the impact of the programme. Drawing the comparison group from the population of postcodes that were deemed 'white' in the OMRs but were not included in the build plans of Phase 3 schemes helps ameliorate this problem.
- Supplier choice: However, selecting the comparison group from white postcodes not included in build plans does have some caveats. Suppliers were largely free to choose which white premises were targeted from those identified in the OMR. It is reasonable to assume that suppliers selected those locations that were most commercially viable to maximise their returns. In Phases 1 and 2, suppliers appeared to seek to minimise the net costs of delivering the contract, though in Phase 3 other factors (such as existing penetration of NGA networks and the presence of competitors) appeared to be significant. White postcodes not included in the build plans of Phase 3 schemes are likely to differ in systematic ways to those that benefit from subsidised upgrades, and in ways that may be correlated with the outcomes of interest. Those premises in white areas that did not benefit from BDUK investment may have been the hardest to upgrade profitably, and the least likely to have received superfast coverage in the absence of the programme. Basic comparisons between areas benefitting from the programme and other white postcodes will likely overstate the impact of the

programme. Addressing these issues requires the selection of appropriate analytical methods that control for both observable and unobservable differences between these two groups of areas.

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

The State aid evaluation plan defines the treatment and comparison groups to be used in the analysis. The former is defined as postcodes that have been included in Phase 3 build plans and had at least one premise upgraded by the end of September 2019²¹. While this approach enables an assessment of the effects of the programme that have benefitted from subsidised upgrades, this also introduces possible biases driven by unobserved differences between those areas that have benefitted from early delivery and those benefitting at a later stage. Such an approach will also fail to capture the effects of the programme (e.g. in terms of delaying superfast rollout) on areas that were yet to benefit from subsidised upgrades. To address this, all analyses have also been completed using an expanded definition of the treatment group to include all postcodes within build plans for Phase 3.

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

4.3 Simple difference-in-differences

As described in the State aid evaluation plan, a simple difference-in-difference approach was deployed to establish an estimate of the change in broadband availability takes the before-and-after weighted²² mean of the outcomes of interest for the analysis (i.e. the percentage of premises with NGA, superfast and FTTP coverage) for both the control and treatment groups to give the change in coverage in NGA white areas due to intervention.

$$\Delta outcome_{intervention1619} = (outcome_{T19} - outcome_{T16}) - (outcome_{C19} - outcome_{C16})$$

The percentage change in coverage between 2016²³ and 2019 attributable to the programme is equal to the difference in outcomes in 2019 and 2016 for postcodes benefitting from the programme $(outcome_{T19} - outcome_{T16})$ and the comparison group of postcodes that were eligible in Phase 3 but not included in build plans $(outcome_{C19} - outcome_{C16})^{24}$.

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

²¹ Note that the state aid plan sets out June 2020. This was the date at which Ofcom data was expected to be made available for 2020 when the plan was approved. The release dates of Ofcom data have since changed to December of the relevant year and now provide a snapshot as of September of that year.

²² Weighted by total premises per postcode

²³ This is 2017 for FTTP given lack of inclusion of this variable in the 2016 Connected Nations data

²⁴ Note that T subscript denotes the Treatment Group, and the C subscript denotes the Control Group.

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

The simple difference-in-difference analysis showed:

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

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

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

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

4.4 Regression based difference-in-differences

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

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

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

4.4.1 Control variables

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

- Connectivity in 2012 and 2016: Pre-programme levels of connectivity were considered by including
 observations of NGA access in all years from 2012 to 2016. Superfast coverage from 2014 to 2016
 was also included as a matching variable.
- Competition: The number of network providers operating in the postcode in 2012 and 2016. This
 inclusion was driven by the apparent tendency of Phase 3 suppliers to avoid areas where NGA
 penetration (and by implication depth of local competition) was higher.
- Percentage of postcodes in the LA and the Output Area with NGA access in 2012 and 2013: In Phase 3, the data suggested that suppliers tended to avoid postcodes with high levels of NGA penetration. The expectation was that postcodes located in areas with local authorities and neighbourhoods with low NGA coverage in 2012 and 2013 would have been more likely to have been included within the build plans of local schemes, on the assumption that the Open Market Review process was effective in revealing the commercial plans of providers.
- Line length from the exchange to the cabinet to the postcode in 2013: The length of the line between the serving exchange and the postcode will partly determine the costs associated with enabling superfast broadband speeds, with costs increasing with the overall length of the line. The expectation was that postcodes benefitting from BDUK investment would be associated with longer line lengths than 'grey' and 'black' postcodes, but shorter line lengths than white postcodes that were not included within the build plans of local schemes.
- Number of premises with exchange only lines in 2013: Premises that are connected directly to
 the exchange will cost more to enable with superfast broadband speeds as this requires the
 installation of a new cabinet. The prior expectation was that postcodes with a higher number of
 premises with exchange only lines would be less likely to be included within the build plans of local
 schemes owing to these additional costs.

- Delivery points at the serving cabinet and the serving exchange: The attractiveness of upgrading available broadband services to superfast speeds will also be linked to the number of premises that benefit from the upgrade. As such, it was anticipated those postcodes with fewer delivery points at the serving cabinet and exchange would be less commercially attractive and carry a lower likelihood of being included within the build plans of local schemes, relative to other white postcodes.
- Whether the postcode was in the Virgin Media footprint in 2013: Data was made available on whether the postcode was within the Virgin Media footprint in 2013. The availability of Virgin Media at a postcode could reduce the likelihood that it was included in local schemes signalling the presence of a competitor and reducing the commercial benefits associated with providing upgraded services. However, when comparing white postcodes, where Virgin Media may have had no immediate plans to roll out superfast broadband services, competing providers may see an attraction in providing superfast to the postcodes to enable them to gain a competitive advantage, increasing the likelihood that the postcode was included in the build plans for local schemes.
- Estimated cost to upgrade the serving cabinet or exchange only lines: BDUK developed estimates of the cost of upgrading the cabinets or exchange only lines in 2013 to support the resource allocation process. The expectation was that those cabinets with higher predicted upgrade costs (or higher upgrade costs per premises upgraded) would be less likely to be included within the build plans for local schemes (or at least those that involved higher upgrade costs per premises upgraded).
- Population density: The likelihood that a postcode was upgraded was also thought to be linked to the density of the local population, with denser eligible areas the most likely to be included within the build plans of local schemes. This was measured using information from the 2011 Census describing the size of the resident population at an Output Area level.
- Age of population: The size of the resident population of working age and aged 65 and over was included to provide measures of overall potential demand for superfast broadband services.
- Other factors influencing demand: Demand for superfast broadband services was also assumed to be linked to the characteristics of the local economy. Information on gross weekly earnings, employment rates and unemployment rates was included to provide these types of measure.
- GBVS and LFFN: A supplementary set of analyses were also undertaken to control for the delivery of parallel programmes that may have also contributed to changes in connectivity locally. This included controls for the number of GBVS vouchers awarded to upgrade other premises in the relevant output area to FTTP, and proximity to the fibre rings or public sector buildings upgraded by Wave One LFFN pilot projects²⁷. It should be noted that there are other BDUK (e.g. Wave 2 and 3 LFFN pilots) and locally funded programmes (e.g. broadband voucher schemes administered by Local Enterprise Partnerships) that could produce similar results to the Superfast Broadband programme. Data on the delivery of these schemes could not be compiled for the purposes of this study (and as such, there is a residual risk that some outcomes attributed to the Superfast Broadband programme were the results of parallel programmes).

²⁷ These controls took the form of dummy variables denoting whether or not a postcode was located within 50m, 100m, 500m or 1km of a GBVS voucher or an LFFN intervention area (in turn defined as a postcode within 1km of planned LFFN build).

4.4.2 Results

The results using a regression approach are presented in Table 4.3 below. The results of models without control variables were identical to those obtained using simple differences-in-differences. Controlling for the pre-programme characteristics of postcodes led to smaller estimates of the impact of the programme, suggesting that the results of the simple difference-in-difference analyses were biased upwards (as expected):

- Coverage on postcodes benefitting from subsidised upgrades: The results suggested that the Phase 3 schemes increased the share of premises covered by NGA, superfast and FTTP by 2.6, 10.4, and 24.4 percentage points respectively (in those postcodes benefitting from subsidised upgrades by September 2019). These results indicate the programme has increased superfast coverage in some areas and had an important effect on the quality of infrastructure in others the results imply 13 percent²⁸ of premises would have otherwise received superfast made available through inferior technologies to FTTP.
- Coverage on all postcodes in the build plans of Phase 3 SCTs: The findings also indicated that the programme had a negative overall effect on NGA and superfast coverage across all postcodes in the build plans of Phase 3 SCTs. This would indicate that the programme has worked to delay superfast coverage in some areas included in the scope of Phase 3 schemes.
- Competition: The models were consistent in suggesting that the programme had a positive effect on the number of network providers operating in the postcodes of interest. The results indicated that that the network providers increased by 0.1 to 0.2 on average (depending on whether the focus is on postcodes benefitting from subsidised upgrades or all postcodes in the build plans of Phase 3 schemes). This indicates that Phase 3 has worked to promote greater levels of competition.
- Speeds and take-up: However, the results indicated that the programme had a negative impact on take-up of superfast connections (regardless of whether the focus is on postcodes benefitting from subsidised upgrades or all postcodes in the build plans of Phase 3 schemes). This could be explained by the delays with the delivery of the programme. Subsidised superfast coverage has not come forward as rapidly as originally anticipated. This may have delayed access to superfast services for those consumers that would have benefitted from superfast coverage in the absence of the programme.

The addition of controls for the GBVS and LFFN did not materially alter the estimated impacts, indicating that the estimated impacts are not confounded by the delivery of parallel schemes. Additionally, most models were estimated using Ordinary Least Squares. This could produce biased results for those outcomes that were bounded at zero and one (e.g. NGA availability cannot exceed 100 percent and cannot fall below zero percent). Robustness checks were completed by estimating models (Model 4 and Model 8) with a Tobit specification that allowed for censoring at 0 and 100. Results from these models did not suggest that OLS was biased in this case. The following table summarises the results of these analyses. The full results of the regressions (including coefficients associated with control variables) are provided in the statistical annex (Annex D).

²⁸ I.e. 24.4 minus 10.4.

Outcome	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Treatment postcodes	Postc	odes deliver	ed to by Sep.	2019	All postcodes in Phase 3 build plans			
Modelling approach	OLS	OLS	OLS	Tobit	OLS	OLS	OLS	Tobit
Postcode controls	No	Yes	Yes	Yes	No	Yes	Yes	Yes
LFFN/GBVS controls	No	No	Yes	Yes	No	No	Yes	Yes
Number of observations	60,597	21,479	21,479	21,479	118,454	109,964	109,964	109,964
Adjusted R-squared	0.0108	0.7014	0.7016	0.5742	0.0020	0.6092	0.6094	0.4962
		Cover	age outcor	nes				
NGA availability (% of premises)	10.7	2.6	2.6	2.1	3.1	-1.8	-1.8	-1.9
Superfast availability (% of premises)	25.2	10.4	10.5	10.2	6.1	-3.2	-3.1	-3.4
FTTP availability (% of premises)	28.7	24.1	24.4	24.3	3.5	1.6	1.6	1.4
Number of network providers	0.2	0.2	0.2	n/a	0.0	0.1	0.1	n/a
		Take-	up outcom	ies				
Average download speeds of connections (Mbps)	-2.1	-1.4	-1.5	n/a	-4.6	-2.0	-2.0	n/a
Maximum download speeds of connections (Mbps)	16.9	6.2	6.2	n/a	-10.9	-4.0	-4.1	n/a
Average upload speeds of connections (Mbps)	3.9	0.9	0.9	n/a	0.4	-0.2*	-0.2*	n/a
Number of connections with download speed of 30Mbps+	-2.4	-1.1	-1.1	n/a	-1.6	-0.9	-0.9	n/a

Table 4.4: Estimated impact of Phase 3 schemes on coverage and take-up, regression based difference-in-difference results

Source: Ipsos MORI analysis; All coefficients significant at the 99% confidence level unless marked with *.

4.5 Difference-in-difference with matched samples

The preceding set of analyses controlled for observable differences between the areas benefitting from the programme. These analyses were refined further by selecting a comparison group of white postcodes that were observationally equivalent to those included in the build plans of Phase 3 schemes. This was achieved using a propensity score matching (PSM) matching approach. This involved matching postcodes in the treatment and control groups based upon their characteristics in the years before 2016. This was implemented by:

- Developing statistical models that compared the characteristics of white postcodes that were and were not included in the build plans of local schemes and predict the likelihood that each postcode was included in a scheme.
- White postcodes that were not included in the build plans of Phase 3 schemes but shared a similar predicted likelihood of being included to those postcodes that were addressed by those build plans
 were considered to be 'matched' and formed part of the comparison group.
- Postcodes that did not feature in the build plans of local schemes and did not share a similar likelihood of inclusion within the build plan of a local scheme were dropped from the sample, and did not form part of the comparison group.

4.5.1 Control variables

This approach offers an unbiased estimate of the impact of the programme if it is possible to control for all factors that influenced the inclusion of a postcode within the build plan of a Phase 3 scheme. Postcodes were matched on the same vector of control variables described in subsection 4.4.1.

As noted, a matching approach will only be effective in providing an unbiased assessment of the impact of the programme if these characteristics described above capture all factors that could influence both the selection of postcodes into BDUK funded schemes and the likelihood that they will receive enhanced broadband connectivity. There also will be other factors influencing the cost of installation that are not captured in the above, e.g. local topography. Additionally, there are potentially unobserved features of postcodes that may be correlated with both their inclusion in the programme and the likelihood that superfast broadband coverage would have come forward without public subsidy.

4.5.2 Matching models

Propensity scores were generated by applying a probit model that sought to explain the likelihood a given postcode was included in the build plan of a Phase 3 scheme on the vector of control variables described in subsection 4.4.1 above²⁹. These models were estimated with and without controls for the average and maximum downloads speeds of connections (owing to the large amount of missing data on these variables for 2012 and 2013).

The results of the probit models associated with the two selected matching models are set out in Table 7.4 in Annex B and largely confirmed expectations regarding how the observable characteristics of postcodes would influence their inclusion within local schemes. There was a relatively high degree of consistency in the direction and size of the estimated coefficients when information on historic average download speeds was also included as a matching variable.

However, the available data did not explain a high share of the variance in the decisions made by tenderers to include postcodes in the build plans of Phase 3 schemes (9 to 13 percent). This rose to 18 and 20 percent when restricting the analysis to those postcodes benefitting from subsidised upgrades by September 2019. This does indicate there may be unobserved factors (e.g. topography or planning constraints) that have influenced suppliers' decisions on which postcodes to target. The degree to which this is consequential will depend on how far those factors are correlated with the outcomes of interest.

4.5.3 Quality of the matched sample

Matching was completed using a nearest neighbour technique in which each postcode in the build plans of Phase 3 schemes were matched to the postcode in the comparison sample with the closest propensity score³⁰. Common support was imposed by dropping any postcode from the comparison sample that had a propensity score that was higher than the highest – or lower than the lowest – propensity score associated with postcodes included within the build plans of Phase 3 schemes. Individual postcodes in the comparison sample could form a match with multiple postcodes that received BDUK subsidies.

An overview of the resultant matched samples is provided in Table 4.4 below. The matching approach reduced the mean standardised bias (the average percentage differences in the characteristics of the treatment and the comparison sample) to between 1.4 and 4.2 percent (from between 11.4 and 30.2).

²⁹ The model took the form: $\Delta outcome_i = \beta_0 + \beta_1 TD + \beta x_i + \epsilon_i$

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

There were limited significant differences between the treatment and comparison samples on most characteristics included in the matching models, however the models were not fully effective in eliminating all observable differences between the treatment and comparison samples. The models tended to produce a comparison sample with a larger number of delivery points in the serving exchange and in the serving cabinet.

As illustrated in the table below, there were very few postcodes dropped from the matching implying that the postcodes within each of the groups were relatively similar overall. The models including take-up and speed outcomes as controls performed more effectively with fewer dropped postcodes in the treatment group. The figure below uses the matched samples produced from the first model in Table 4.4 below to plot the evolution in superfast availability in matched areas over time. This indicates an apparent delaying effect in the programme area between 2016 and 2018 relative to the comparison area, though with a substantial increase in coverage in 2019 (correlating with the increase in the delivery of Phase 3 observed in Section 3).

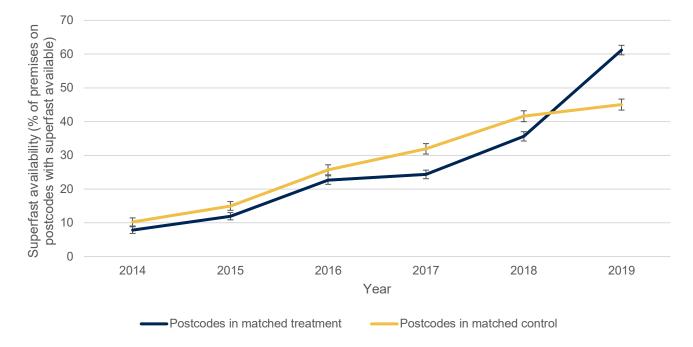


Figure 4.1: Evolution of superfast availability, matched samples 2014 to 2019

Source: Ipsos MORI analysis

Table 4.5: Overview of Characteristics of Matched Samples

Treatment group	Postcodes delivered to by September 2019					Postcodes in the build plans of Phase 3 schemes							
Controls included	No	speed contr	ols	Speed controls included			No speed controls			Speed controls included			
No. of treated postcodes in matched sample		8,832		3,578			62,627				25,117		
Number of unmatched postcodes		73			39			160			84		
Mean standardized bias (pre-match)		30.2			20.6			23.3			11.4		
Mean standardized bias (post-match)		4.2			3.1			1.5			1.4		
Variable	Treated	Control	Sig.	Treated	Control	Sig.	Treated	Control	Sig.	Treated	Control	Sig.	
Number of suppliers in postcode (2012)	2.14	2.18	*	2.25	2.28		2.37	2.39	**	2.41	2.43	**	
Number of suppliers in postcode (2016)	2.35	2.38	*	2.44	2.46		2.43	2.43		2.47	2.47		
Superfast % of premises (2014)	7.85	7.99		6.60	6.50		11.57	11.05	**	9.68	9.28	*	
Superfast % of premises (2015)	11.97	12.92	*	12.90	12.29		18.50	17.27	***	20.56	19.23	***	
Superfast % of premises (2016)	22.67	25.90	***	25.23	24.42		28.40	27.47	***	33.34	32.15	**	
NGA % or premises (2012)	0.16	0.17	**	0.14	0.15		0.16	0.16	*	0.12	0.12		
NGA % or premises (2013)	0.25	0.30	**	0.23	0.27	***	0.25	0.26	***	0.20	0.21	**	
NGA % or premises (2014)	0.33	0.37	***	0.32	0.36	***	0.34	0.34	*	0.31	0.32	*	
NGA % or premises (2015)	0.59	0.61	***	0.60	0.60		0.65	0.66	**	0.66	0.67	*	
NGA % or premises (2016)	0.70	0.73	**	0.70	0.72	*	0.74	0.74		0.75	0.75		
% of postcodes in LA with NGA, (2013)	0.39	0.40	***	0.40	0.40		0.41	0.41	*	0.40	0.40		
% of postcodes in LSOA with NGA, (2013)	0.28	0.31	***	0.27	0.30	**	0.27	0.28	**	0.23	0.24	*	
Line Length (m)	7.98	7.98		7.90	7.94	*	7.92	7.91		7.78	7.80		
Final speed	6.47	6.34		6.88	6.86		6.72	6.87	***	7.26	7.35	*	
Premises with EO lines 2013	2.27	2.21		3.64	3.40		2.25	2.35	*	3.75	3.81		
Delivery points at serving exchange	6655.10	7615.50	***	6643.20	7496.20	***	6412.70	6505.70	*	6005.40	6127.20		
Delivery points at serving cabinet	215.91	227.50	***	233.75	251.44	***	249.81	250.56		267.63	269.02		
Virgin Media availability	0.00	0.00		0.00	0.00		0.01	0.01	*	0.00	0.00		
Estimated Upgrade Cost (£)	65519	66026		67349	68004		67571	67281	*	68993	68599		
Cost Per Premises Upgraded	351.57	341.75		327.02	309.84	*	333.43	331.48		284.93	275.31	**	
Working Age Population	198.07	201.21	**	198.10	204.02	**	176.86	179.97	***	176.25	180.44	***	
Population Aged 65 and Over	65.15	67.02	***	65.72	65.40		57.49	58.23	***	58.55	59.93	***	
(Log) Population Density	4.30	4.36	*	4.66	4.66		4.53	4.54		4.99	4.98		
(Log) Premises Density	3.73	3.81	*	4.07	4.08		3.98	3.99		4.42	4.42		

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496.17	492.14	***	500.52	498.95		503.69	502.96	*	502.94	500.61	**
74.60	74.52		74.64	74.55		74.23	74.33	**	73.95	74.10	**
6.16	6.00	***	6.14	6.01	*	6.38	6.30	***	6.45	6.39	*
1.64	1.60	***	1.50	1.46		2.55	2.42	**	2.32	2.24	
2.32	2.33		2.96	2.85		3.79	3.52	***	4.97	4.75	
3.87	4.05		5.48	5.18		5.42	5.21	**	7.77	7.58	
			1.12	0.98	*				1.63	1.60	*
			0.64	0.59					0.92	0.91	
			0.23	0.23					0.29	0.29	
			5.09	5.10					5.56	5.54	
			8.29	8.22					8.97	8.98	
			5.64	5.67					6.23	6.23	
			9.78	9.95					10.47	10.58	*
			6.86	6.91					7.66	7.69	
			14.19	14.54					15.70	15.92	
			8.40	8.30					9.58	9.59	
			18.72	18.54					22.06	22.08	
			10.86	10.39	**				12.82	12.83	
			24.86	23.74					30.25	30.38	
			0.87	0.85					0.95	0.95	
			0.87	0.85					0.95	0.95	
			1.52	1.50					1.77	1.73	**
	74.60 6.16 1.64 2.32	74.6074.526.166.001.641.602.322.33	430.17 432.14 74.60 74.52 6.16 6.00 *** 1.64 1.60 *** 2.32 2.33	430.17 432.14 300.32 74.60 74.52 74.64 6.16 6.00 *** 6.14 1.60 *** 1.64 1.60 *** 2.32 2.33 2.96 3.87 4.05 5.48 1.12 0.64 0.23 5.09 8.29 5.64 9.78 6.86 14.19 8.40 18.72 10.86 24.86 0.87 0.87 0.87	430.17 432.14 300.32 430.33 74.60 74.52 74.64 74.55 6.16 6.00 *** 6.14 6.01 1.64 1.60 *** 1.50 1.46 2.32 2.33 2.96 2.85 3.87 4.05 5.48 5.18 1.12 0.98 0.64 0.59 0.23 0.23 0.23 0.23 0.23 0.23 5.09 5.10 8.29 8.22 5.64 5.67 9.78 9.95 6.86 6.91 14.19 14.54 8.40 8.30 18.72 18.54 10.86 10.39 24.86 23.74 0.87 0.85 0.87 0.85	430.17 432.14 300.22 430.33 74.60 74.52 74.64 74.55 6.16 6.00 *** 6.14 6.01 * 1.64 1.60 *** 1.50 1.46 2.32 2.33 2.96 2.85 3.87 4.05 5.48 5.18 1.12 0.98 * 0.64 0.59 0.23 0.23 0.23 5.09 5.10 8.29 8.22 5.64 5.67 9.78 9.95 6.86 6.91 14.19 14.54 8.40 8.30 18.72 18.54 10.86 10.39 24.86 23.74 0.87 0.85	430.17 432.14 300.32 430.35 303.03 74.60 74.52 74.64 74.55 74.23 6.16 6.00 *** 6.14 6.01 * 1.64 1.60 *** 1.50 1.46 2.55 2.32 2.33 2.96 2.85 3.79 3.87 4.05 5.48 5.18 5.42 1.12 0.98 * 0.64 0.59 0.23 0.23 5.09 5.10 8.29 8.22 5.64 5.67 9.78 9.95 6.86 6.91 14.19 14.54 8.40 8.30 18.72 18.54 10.86 10.39 ** 24.86 23.74 0.87 0.85	430.17 432.14 300.32 430.33 503.39 302.30 74.60 74.52 74.64 74.55 74.23 74.33 6.16 6.00 *** 6.14 6.01 * 6.38 6.30 1.64 1.60 *** 1.50 1.46 2.55 2.42 2.32 2.33 2.96 2.85 3.79 3.52 3.87 4.05 5.48 5.18 5.42 5.21 1.12 0.98 * 0.64 0.59 0.23 0.23 0.23 0.23 0.23 0.23 5.09 5.10 8.29 8.22 5.64 5.67 9.78 9.95 6.86 6.91 14.19 14.54 8.40 8.30 18.72 18.54 10.39 ** 24.86 23.74 0.87 0.85 0.87 0.85 0.87 0.85	430.17432.14 300.32 430.33 300.39 302.30 74.6074.5274.6474.5574.2374.33**6.166.00***6.146.01*6.386.30***1.641.60***1.501.462.552.42**2.322.332.962.853.793.52***3.874.055.485.185.425.21**1.120.98*0.640.59****0.640.595.095.10******8.298.225.645.679.789.95**6.866.9114.1914.54******18.7218.5410.8610.39****24.8623.740.870.850.870.85	430.11432.14300.32430.33 303.32 303.32 303.32 303.32 303.32 303.32 302.34 74.6074.5274.6474.5574.2374.33**73.956.166.00***6.146.01*6.386.30***6.451.641.60***1.501.462.552.42**2.322.322.332.962.853.793.52***4.973.874.055.485.185.425.21**7.771.120.98*1.630.920.920.230.230.230.295.568.298.228.975.568.995.645.676.239.789.9510.476.866.917.6614.1914.5415.708.408.309.589.589.589.5818.7218.5422.0610.860.9310.8610.39**12.8224.8623.7430.250.870.850.950.870.850.95	74.60 74.52 74.64 74.55 74.23 74.33 $**$ 73.95 74.10 6.16 6.00 *** 6.14 6.01 * 6.38 6.30 *** 6.45 6.39 1.64 1.60 *** 1.50 1.46 2.55 2.42 ** 2.32 2.24 2.32 2.33 2.96 2.85 3.79 3.52 *** 4.97 4.75 3.87 4.05 5.48 5.18 5.42 5.21 ** 7.77 7.58 1.12 0.98 * 1.64 0.59 0.92 0.91 0.23 0.23 0.23 0.23 0.29 0.29 0.64 0.59 0.29 0.29 0.29 0.23 0.23 0.23 0.23 0.23 0.78 9.95 5.10 5.56 5.54 8.29 8.22 8.97 8.98 5.64 5.67 6.23 6.23 9.78 9.95 10.47 10.58 9.78 9.95 10.47 10.58 9.78 9.95 10.47 15.92 8.40 8.30 9.58 9.59 18.72 18.54 22.06 22.08 0.87 0.85 0.95 0.95 0.87 0.85 0.95 0.95

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

4.5.4 Results

As noted above, the results of matching models are only robust to the degree that that can account for all observable factors that influenced the selection of postcodes into the build plans of Phase 3 schemes. To account for unobserved (but time invariant) differences between the matched treatment and comparison group, the matched samples generated above were used to implement the difference-in-difference models described in subsection 4.3. The key results are set out in Table 4.5 below (full regression tables are provided in Annex E). However, there was very little difference in the estimated results to those associated with the difference-in-difference models described above.

	Model 9	Model 10
Treatment postcodes	Postcodes delivered to by September 2019	Postcodes in the build plans of Phase 3 schemes
Model specification	OLS	OLS
Postcode Controls	Yes	Yes
LFFN/GBVS Controls	Yes	Yes
Matched Sample	Yes	Yes
Number of observations	5,980 to 14,851	34,073 to 87,110
Adjusted R-squared	0.014 to 0.352	0.001 to 0.597
	Coverage outcomes	
NGA availability (% of premises)	2.7	-1.9
Superfast availability (% of premises)	10.6	-3.2
FTTP availability (% of premises)	25.0	1.7
Number of network providers	0.2	0.1
	Take-up outcomes	
Average download speeds of connections (Mbps)	-1.2	-2.0
Maximum download speeds of connections (Mbps)	7.7	-4.3
Average upload speeds of connections (Mbps)	1.0	-0.1*
Number of connections with download speed of 30Mbps+	-1.3	-0.8

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

Source: Ipsos MORI analysis; All coefficients significant at 99 percent confidence level unless marked *

4.6 Longitudinal panel models

The difference-in-difference models outlined in subsections 4.4 and 4.5 account for observed differences between postcodes included in the build plans of Phase 3 schemes and the comparison group of other white postcodes. The models also account for unobserved but time invariant differences between the two groups. A final set of supplementary set of analyses were developed to probe the robustness of the results further by accounting for unobserved but time specific shocks that could affect all areas (the COVID-19 pandemic could be an example of this, if it prompted consumers to upgrade their connections to enable remote working).

This was achieved by exploiting the longitudinal nature of the data available using the following panel model specification:

$$putcome_{it} = \beta_0 + \beta_1 CP_{it} + \theta t + \alpha_i + \gamma_t + \epsilon_i$$

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 (α_i) which account for any time invariant observed and unobserved characteristics of postcodes as well as time fixed effects (γ_t) that account for any time specific shocks influencing connectivity or take-up across all areas. In addition, the equation includes time trends at the national level (t).

The specification of these models captures the relationship between the timing of subsidised upgrades and changes in coverage. As such, the results can be compared to those preceding analyses focusing on areas that benefitted from subsidised coverage but not to those that explore the impact of the programme on all postcodes included in the build plans of Phase 3 schemes. The apparent effects of Phase 3 in delaying the availability of superfast coverage for some premises is explored in more detail in the following chapter.

The comparison group for these analyses comprises of postcodes that were eligible for Phase 3 funding but weren't upgraded by September 2019. In addition, postcodes updated in later years form a part of the control group for those upgraded in earlier years with them switching to the treatment group in the year the postcode was upgraded.

4.6.1 Results

Table 4.6 below outlines the findings of the analyses. The definition of the treatment variable differs to those employed in the preceding analyses (which used a dummy variable classifying whether the postcode was upgraded or not). As results, the regression coefficients are not directly comparable – effects are expressed as the average effect per premises upgraded per postcode. The findings indicated:

- NGA, superfast and FTTP availability: As with other models, the panel models showed that NGA, superfast and FTTP increased in response to the delivery of subsidised coverage. For each premises upgraded, the number of premises with NGA, superfast and FTTP availability rose by 0.41, 0.49 and 0.39 respectively. These results did not vary substantially when models were augmented to control for time-specific shocks affecting all areas, national trends and the delivery of parallel programmes. The findings can be interpreted as a direct measure of additionality (i.e. the share of premises upgraded that would not have had enhanced coverage in the absence of the programme).
- Number of network providers: The panel models found that for each premises upgraded an additional 0.02 suppliers were operating on the postcode implying an increase in local competition. These findings were again robust to time-specific shocks affecting all areas, national trends and the delivery of parallel programmes.
- Take-up: The results showed a similar pattern of findings for take-up measures as preceding analyses. These findings indicated that the programme had a small negative effect on the number of superfast connections (-0.01 per premises upgraded). However, for each premise upgraded on a postcode, average speeds taken up increase by a negligible amount whilst maximum speeds rose between 1.3 and 2.5 Mbps.

Outcome	Model 11	Model 12	Model 13	Model 14	Model 15				
Туре	FE	FE	FE	FE	Tobit				
Postcodes included		A	ll white postcode	S					
Time fixed effects	No	Yes	Yes	Yes	Yes				
Time trends	No	No	Yes	Yes	Yes				
GBVS controls	No	No	No	Yes	Yes				
Number of observations	355,008 to 947,672								
Adjusted R-squared	0.029 to 0.121	0.805 to 0.244	0.105 to 0.244	0.081 to 0.243	0.101 to 0.347				
Coverage outcomes (effects per premise upgraded per postcode)									
Number of premises with NGA access	0.41	0.25	0.25	0.26	0.21				
Number of premises with superfast access	0.49	0.38	0.38	0.38	0.37				
Number of premises with FTTP availability	0.39	0.37	0.37	0.37	0.35				
Number of network providers	0.02	0.02	0.02	0.02	0.02				
Take-up outcon	nes (effects per	premise upgrad	ded per postcoo	de)					
Average download speed of connections (Mbps)	0.58	0.06	0.06	0.06	0.06				
Maximum available speed of connections (Mbps)	2.52	1.47	1.47	1.47	1.45				
Average upload speeds of connections (Mbps)	0.34	0.22	0.22	0.22	-				
Number of superfast connections	0.09	-0.01	-0.01	-0.01	-0.01				

Table 4.7: Estimated impact of subsidised coverage on superfast availability and take-up – Phase 3 2016 to 2019

Source: Ipsos MORI analysis; All coefficients significant at 99 percent

4.7 Control group regression to predict counterfactual treatment group coverage

The second approach outlined in the state aid evaluation plan involves the application of regression techniques to the control group. This regression took the following form:

$$outcome2019_i = \beta_0 + \beta x_i + \epsilon_i$$

Where, the i subscript denotes observation number i, β_0 is a constant, x_i is a vector of explanatory variables which are believed to influence the outcomes in an area, β is a vector of the regression coefficients for those explanatory variables, and ϵ_i is an error term. A logistic regression function was used for NGA availability whilst tobit models were used for outcomes bounded by 0 and 100 (the percentage of premises with superfast or FTTP coverage). A negative binomial function was utilised for the number of suppliers.

Details of the regression models are set out in the annex C. The fits of the models did vary with some models able to account for larger proportions of the variation in the outcomes than others. The models performed better at predicting the number of suppliers and the number of superfast enabled premises with high R squared statistics at 0.91 and 0.83 respectively (implying the models accounted for 91 percent and 83 percent of the variation in these outcomes). In terms of speed outcomes, the model predicting the maximum available speed for a postcode accounted for 70 percent of the variation. However, the remainder of the models had R squared statistics (or pseudo R squared) between 30 and 55 percent and

would suggest that these models did not capture all the relevant independent variables required to predict the outcomes.

The regression coefficients are then applied to the treatment group postcodes to estimate what would have happened in the absence of the scheme (counterfactual). The difference between this estimated outcome and the actual observed outcome is then taken for the areas in the control group giving another estimate of the causal effect of the programme on the outcomes of interest.

4.7.1 Results

Application of the control group regression approach found largely similar results to the difference-indifference with some exceptions where the treatment group comprised of only built to postcodes:

- NGA, Superfast & FTTP % availability: These results were very close to those presented in the difference in difference regression analysis above for these outcomes. The change in NGA coverage was marginally higher here at 3.5 percentage points compared to 2.7 whilst the change in superfast coverage was slightly lower at 9.9 percentage points compared to 10.6. Results for FTTP using this approach showed an additional 25.2 percentage points in FTTP coverage attributable to the programme in line with the DiD findings above.
- **Number of suppliers:** This approach also found that treatment postcodes had on average 0.2 more suppliers operating in them which is again consistent with prior findings presented above using a difference-in-difference approach.
- **Take-up outcomes:** Application of the control group regression approach identified similar effects on both maximum speeds and the number of superfast connections but found a small positive impact on the average speed of connections within treated postcodes³¹.

The findings on both the percentage of premises on postcodes with superfast and FTTP availability outcomes in this approach are not consistent to the results directly exploring the number of premises superfast and FTTP enabled respectively. This is a weakness of this approach. Using all postcodes in build plans:

- NGA, Superfast & FTTP % availability: These results found negative levels of additionality for NGA
 and superfast coverage implying crowding out (and supporting the hypothesis that many of these
 postcodes would have seen some coverage come forward in the absence of the programme with
 this potentially delayed). The estimated level of additionality for FTTP delivery was also very low
 potentially reflecting the lack of delivery brought forward through Phase 3 to date.
- **Number of suppliers:** This approach found no significant differences between the estimated counterfactual number of suppliers in 2020 and actuals.
- **Take-up outcomes:** Differences were much smaller in this case compared to the models including only built to areas but still positive in terms of speeds taken.

³¹ These results are contradictory to those obtained through difference-in-difference analysis and it is not clear why. These control group models should however be considered less robust in comparison to the panel models presented in subsection 5.6.

	Counterfactual	Actual	Difference	Counterfactual	Actual	Difference		
Treated postcodes	Delivere	d as of Sep 2	019	All in build plans				
Coverage outcomes:								
Change in % NGA availability	87.6	91.1	3.5***	90.1	87.3	-2.8**		
Change in % SFB availability	50.8	60.7	9.9***	55.2	44.9	-10.3***		
Change in % FTTP availability	10.2	35.4	25.2***	9.0	9.8	0.7*		
Change in number of suppliers	2.4	2.6	0.2*	2.5	2.5	0.0		
Change in superfast enabled premises	10.4	8.4	-2.1**	11.8	7.7	-4.1***		
Change in FTTP enabled premises	2.6	4.1	1.5**	1.9	1.2	-0.7**		
Take-up outcomes:								
Change in average download speed (Mbps)	24.8	27.0	2.2*	25.3	26.1	0.7*		
Change in max download speed (Mbps)	69.5	76.5	7.0***	57.1	57.8	0.7		
Change in average upload speed (Mbps)	10.9	7.5	3.4***	6.3	6.8	-0.5**		
Change in number of superfast connections (Mbps)	4.8	3.7	-1.2**	5.5	4.8	-0.7*		

Table 4.8: Control group coverage regression results – Phase 3 in 2019

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

4.8 Overview of findings

4.8.1 Overview of results

The table below provides a summary of the estimated impact of the programme on areas benefitting from subsidised coverage under Phase 3 of the programme by September 2019 (note that these do not include the results of the panel models as these provide a direct estimate of additionality as discussed below). The models provided a consistent view on the effects of the programme:

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

- Competition: The results consistently suggest that the programme has promoted additional competition and has increased the number of network providers offering broadband services in the target area (by around 0.2 providers on average). The areas benefitting from the programme were less well served by fewer broadband suppliers than other areas of the UK, and this may bring benefits to consumers in the longer-term (e.g. in the form of lower prices or wider choice).
- Impact on take-up: Subsidised coverage has reduced the share of households and businesses that have a superfast connection and the average download speeds of connections. This may be explained by the relatively early stage at which the impacts have been estimated. Only seventeen percent of the contracted premises upgraded had been delivered over the period covered by this analysis (and most these in the final year covered by this analysis). Take-up typically lags availability it took six years for take-up to reach 60 percent of premises upgraded through Phase 1. As such, it is premature to consider the impact of the programme on take-up. However, the observation of negative effects on the number of premises with superfast connection indicates that for some households or businesses, the programme made superfast services available at a later date than they would have otherwise been received (an issue considered in more depth below).

Table 4.9: Estimated impact of Phase 3 on areas benefitting from subsidised coverage by September 2019

Outcome	Difference-in-Differences	Propensity Score Matching with Difference in Differences	Control group regression
NGA availability (% of premises)	2.1 to 10.7	2.7	3.5
Superfast availability (% of premises)	10.2 to 25.2	10.6	9.9
FTTP availability (% of premises)/	24.3 to 27.8	25.0	25.2
Number of network providers	0.2 to 0.2	0.2	0.2
Average download speeds of connections (Mbps)	-2.1 to -1.5	-1.2	2.2
Maximum download speeds of connections (Mbps)	6.2 to 16.9	7.7	7.0
Average upload speeds of connections (Mbps)	0.9 to 3.9	1.0	3.4
Number of connections with download speed of 30Mbps+	-2.4 to -1.1	-1.3	-1.2

Source: Ipsos MORI analysis^{/.}

4.8.2 Additionality of subsidised broadband infrastructure

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

 NGA coverage: The programme is estimated to have led to 2,300 to 16,600 additional premises with NGA coverage. Additionality (i.e. the share of premises benefitting from superfast coverage that would not have in the absence of the programme) is estimated at between 3 and 20 percent, with the most estimates towards the lower end of this range.

- **Superfast availability:** The programme is estimated to have increased the number of premises that can access superfast broadband services (30Mbps or above) by 10,800 to 29,300 by the end of September 2019. The associated rate of additionality ranges from 14 percent to 37 percent.
- **FTTP coverage:** Subsidised coverage is estimated to have led to 19,000 to 30,300 additional premises with FTTP coverage. The rate of additionality ranges from 35 percent to 55 percent (with most estimates in the region of 50 percent).

	Impact on outcome	Number of premises on postcodes	Number of premises upgraded	Premises enabled attributable to programme	Implied additionality					
		NGA availability	/							
Simple DiD	10.7	108,814	79,100	11,643	14.7%					
DiD regression with controls	2.1	108,814	79,100	2,285	2.9%					
Matched sample regression	2.7	108,814	79,100	2,938	3.7%					
Control group regression	3.5	108,814	79,100	3,808	4.8%					
Panel models	-	108,814	79,100	16,611	21.0%					
Superfast availability										
Simple DiD	25.2	108,814	79,100	27,421	34.7%					
DiD regression with controls	10.2	108,814	79,100	11,099	14.0%					
Matched sample regression	10.6	108,814	79,100	11,534	14.6%					
Control group regression	9.9	108,814	79,100	10,773	13.6%					
Panel models	-	108,814	79,100	29,267	37.0%					
		FTTP availability								
Simple DiD	27.8	108,814	55,000	30,250	55.0%					
DiD regression with controls	24.3	108,814	55,000	26,442	48.1%					
Matched sample regression	25	108,814	55,000	27,204	49.5%					
Control group regression	25.2	108,814	55,000	27,421	49.9%					
Panel models	-	108,814	55,000	19,250	35.0%					
	1									

Table 4.10: Estimated additionality of NGA coverage across methods

Source: Ipsos MORI analysis

4.8.3 Impacts on the programme area

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

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

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Table 4.11: Estimated impact of Phase 3 on all postcodes in the build plans of Phase 3 s	schemes
by September 2019	

Outcome	Difference-in-Differences	Propensity Score Matching with Difference in Differences	Control group regression
NGA availability (% of premises)	-1.8 to 3.1	-1.9	-2.8
Superfast availability (% of premises)	-3.4 to 6.1	-3.2	-10.3
FTTP availability (% of premises)/	1.4 to 3.5	1.7	0.7
Number of network providers	0.0 to 0.1	0.1	-
Average download speeds of connections (Mbps)	-4.6 to -0.2	-2.0	0.7
Maximum download speeds of connections (Mbps)	-10.9 to -4.1	-4.3	-
Average upload speeds of connections (Mbps)	0.4 to -	-0.1	-0.5
Number of connections with download speed of 30Mbps+	-1.6 to -0.9	-1.3	-0.7

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

5 Programme Connectivity Impacts

This section presents the results of the analysis undertaken to explore the impacts of the whole programme to date including Phase 1, 2 and 3 delivery. This analysis was completed to explore the effects and additionality of subsidised coverage over time to support a broader assessment of the costs and benefits of the programme and its cost-effectiveness in bringing forward coverage.

5.1 Data

The data utilised in the analysis set out in this section is the same as that described in the previous chapter. A more detailed review, covering the processing steps and issues relating to comprehensiveness and quality, is provided in Annex A.

5.2 Evaluation design issues

5.2.1 Defining the population of white postcodes

Phase 3 of the programme extends the Superfast Broadband Programme to new areas that were previously designated as 'white' in Phases 1 and 2 of the programme. This reduced the size of the population of white postcodes that can potentially provide comparators for the programme as a whole. The definition of comparator groups for each phase are presented below:

- **Phase 1:** The comparator group for Phase 1 is defined as postcodes designated as white in the Phase 1 OMRs that were not included in the build plans of Phase 1, Phase 2, or Phase 3 schemes.
- **Phase 2:** The comparator group for Phase 2 is defined as postcodes designated as white in the Phase 2 OMRs that were not included in the build plans of Phase 2 or Phase 3 schemes.
- **Phase 3:** The comparator group for Phase 3 is defined as postcodes with premises that were designated as white in the Phase 3 OMRs, where no premises were included in the build plans of Phase 3 schemes.

Postcodes or premises were defined as being in the build plans of schemes (i.e. members of the treatment group) if they were either marked in the build plans of the scheme as described in the Speed and Coverage Template (SCT) or if the C3 reports indicated the postcode received subsidised coverage. This latter step accounts for small differences that arise between the SCT and the delivery of the scheme. This might occur – for example – if a planned upgrade was not feasible (e.g. for planning reasons), and the suppliers moved on to upgrade a nearby cabinet that was not in the original build plan.

5.3 Matching models

The first approach to assess the whole programme impact was to select a comparison sample of postcodes that did not receive BDUK investment but shared similar observable characteristics to those that did before the programme began. This was achieved by applying a propensity score matching (PSM) approach similar to that described in subsection 4.5 to:

• Compare the characteristics of postcodes that were and were not included in the build plans of local schemes, and predict the likelihood that each postcode was included in a scheme.

- Using these results, postcodes that were not included in the build plans of local schemes but shared a similar predicted probability of being included those postcodes that were - were considered to be 'matched' and formed part of the comparison group.
- Postcodes that did not feature in the build plans of local schemes and did not share a similar likelihood of inclusion within the build plan of a local scheme were dropped from the sample and did not form part of the comparison group.

5.3.1 Control variables

This approach offers an unbiased estimate of the impact of the programme if it is possible to control for all factors that influenced the inclusion of a postcode within the build plan of a Phase 3 scheme. Postcodes were matched on the same vector of control variables described in subsection 4.4.1.

5.3.2 Matching models

The propensity score matching was completed using nearest neighbour techniques in which each postcode within the build plans of funded schemes was matched to the postcode in the comparison sample with the closest propensity score. Common support was imposed by dropping any postcode from the comparison sample that had a propensity score that was higher than the highest – or lower than the lowest – propensity score associated with postcodes included within the build plans of funded schemes. Individual postcodes in the comparison sample were allowed to form a match with multiple postcodes that received BDUK subsidies. The results of the initial probit models associated with a sample of matching models are set out in the appendix³². It illustrates:

- The matching models largely confirmed expectations regarding how the observable characteristics
 of postcodes would influence their inclusion within local schemes. There was a relatively high degree
 of consistency in the direction and size of the estimated coefficients when information on average
 download speeds in 2013 were included as a matching variable in comparable models.
- However, the available data did not explain a high share of the variance in the decisions made by tenderers to include postcodes in the build plans of Phase 1, 2 and 3 schemes (15 to 49 percent). Including additional information on average download speeds did increase explanatory power, but only at the margin.

There is a risk that unobserved factors influenced the decision to include postcodes within the scope of local schemes. The degree to which this is consequential will depend on how far those factors are correlated with the outcomes of interest.

An overview of the resultant matched samples is provided below. The matching models reduced the level of mean standardised bias, i.e. the average percentage differences in the characteristics of the treatment and the comparison sample, to between 3.2 and 5.8 percent. The models were not fully effective in eliminating all observable differences between the treatment and comparison samples. In general, the models generated matched samples in which the treatment group typically contained postcodes with longer line lengths to the nearest exchange.

³² Draft Note: Will be added following submission of state aid report

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

Table 5.1: Comparison of matched samples (whole programme)

	Mod	el 1	Mod	el 2	Mod	el 3	Mod	el 4	Mod	el 5	Mod	el 6
Mean standardized bias	3.	2	5.	8	5.3	3	5.	7	4.	0	3.	5
Variable	Treated	Control										
NGA access in 2012	0.18	0.16	0.15	0.14	0.09	0.10	0.26	0.23	0.10	0.10	0.33	0.34
NGA access in 2013	0.22	0.20	0.20	0.20	0.13	0.14	0.33	0.29	0.12	0.12	0.43	0.44
% of postcodes in LA with NGA, 13	0.50	0.51	0.50	0.51	0.45	0.48	0.62	0.60	0.44	0.45	0.64	0.64
% of postcodes in LSOA with NGA, 13	0.28	0.27	0.28	0.29	0.22	0.24	0.40	0.38	0.15	0.15	0.57	0.58
Line Length (m) / Log Line Length	2595.00	2525.80	7.55	7.62	7.34	7.18	7.70	7.73	7.52	7.57	7.25	7.27
Final speed / Log Line Length	9444.20	9710.40	7.44	6.86	8.01	7.79	6.87	7.22	7.34	6.62	9.22	9.14
Premises with EO lines 2013	3.77	3.83	2.64	2.68	2.99	2.95	2.69	2.89	3.41	3.35	4.46	4.39
Delivery points at serving exchange	6762.7	7550.6	6632.0	6791.7	6289.9	7657.5	7526.6	8193.7	3255.7	3497.9	14092.0	14362.0
Delivery points at serving cabinet	256.73	254.55	239.05	207.93	242.56	250.03	226.06	200.20	263.67	252.71	243.03	248.51
Virgin Media availability	0.06	0.06	0.04	0.04	0.04	0.04	0.06	0.08	0.01	0.01	0.17	0.17
Estimated Upgrade Cost (£)	66213	66838	66153	66564	65468	69618	65983	62526	68522	69637	61317	62369
Cost Per Premises Upgraded	281.73	311.85	331.20	380.52	295.46	323.77	374.82	406.49	283.98	368.74	272.74	291.42
Working Age Population	183.51	187.01	185.38	189.97	172.21	169.46	220.24	212.94	183.07	190.63	184.62	183.66
Population Aged 65 and Above	56.82	56.66	56.86	56.45	55.48	51.27	61.13	59.65	60.55	61.33	49.08	49.13
Population Density (log)	6.12	6.11	5.59	5.17	6.06	6.06	5.30	5.12	5.45	5.14	7.54	7.49
Premises Density (log)	5.59	5.58	5.06	4.65	5.56	5.57	4.73	4.58	4.87	4.55	7.08	7.06
Gross Weekly Wages (in LA)	511.31	512.79	511.25	509.46	510.83	509.84	516.29	514.57	514.53	512.03	504.82	502.93
Employment Rate (in LA)	73.12	72.86	73.27	73.03	73.45	73.11	72.94	72.83	73.85	73.72	71.60	71.58
Unemployment Rate (in LA)	6.95	7.00	6.89	6.80	6.80	6.86	7.12	7.13	6.50	6.31	7.91	7.75
Average Download Speeds 2014							9.84	9.53				
Maximum Download Speeds 2014							20.84	20.58				
% of premises with Superfast access 2014							13.64	13.07				
% of premises with NGA access in 2014							0.30	0.27				

Source: Ipsos MORI analysis

5.3.3 Results

Comparisons between the matched treatment and comparison groups from the analyses above were used to estimate the effect of the Superfast Broadband programme on NGA access, maximum available download speeds, the percent of premises with superfast (30Mbps) availability, and average download speeds. It should be noted that Connected Nations provides a measure of the share of premises on a postcode with superfast availability, but comparisons could produce misleading results if the programme had differential effects on postcodes with larger or smaller numbers of premises. To address this difficulty, an estimate of the number of premises with superfast availability on each postcode was derived by combining measures of the share of premises with superfast availability with estimates of the number of delivery points (as modelled by BDUK).

Table 5.1 and 5.2 below provides these results and includes the findings associated with model variants, illustrating the sensitivity of the results to:

- Inclusion of speed outcomes as outcome variables of interest (Models 2b, 3b, 4b and 7b) as postcodes for which data on these metrics are excluded, this reduces the available sample sizes for the analysis.
- Inclusion of average download speeds in 2013 as a matching variable (Models 2c and 3c) again, as this was unobserved for a non-trivial number of postcodes, this also reduced the available sample sizes for analysis.

These results present a complex picture of the impacts of the Superfast Broadband programme which vary both with time and the Phase of the programme³³:

- Impacts on NGA coverage: The results indicated that the Superfast Broadband programme increased the share of premises in the programme area with NGA availability by almost 25 percentage points. The impacts of the programme on NGA coverage appear to have peaked in 2018. This suggests that postcodes that have not benefitted from the programme have started receive commercial deployment of NGA coverage (suggesting that in part, one of the effects of the programme is to accelerate the availability of enhanced infrastructure).
- Impact on superfast broadband availability: The impact of the programme on superfast broadband availability continued to rise by 34 percentage points on postcodes in the build plans of local schemes by 2019. The effects of the programme on superfast availability were larger than for NGA, and the results do not suggest that these impacts have begun to decay. This would indicate that while some areas benefitting from the programme may have received NGA coverage in the absence of the programme, these technologies would not necessarily have delivered superfast speeds (in common with the findings set out in the preceding section).
- Phase 1: The impact of Phase 1 schemes peaked in 2016. Differences between NGA and superfast broadband coverage on postcodes in the build-plans of Phase 1 schemes and the comparison group got smaller in 2018 and 2019. This suggests these earlier schemes had a significant effect in accelerating access to superfast broadband coverage, although some premises would have otherwise benefitted from upgrades at a later point in time.

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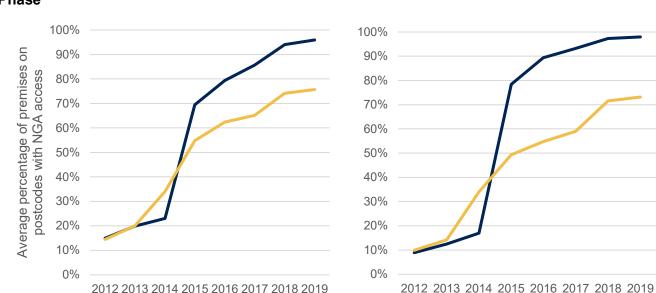
³³ Phase 3 charts below differ from those presented in Section 4 as the matching models used in that analysis incorporated additional years of connectivity data.

Overall

Overall - comparison

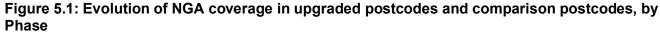
Take-up: Using the matching approach, the impact on take-up (as visible in the maximum and average speed of connections) has increased with time, suggesting (as might be expected) that effects on take-up have lagged effects on coverage. More recent editions of Connected Nations include measures of the number of connections taken at superfast speeds. For Phase 2 and Phase 3 analysis, the timing of delivery allows for the analysis to control for baseline take-up levels, with take-up of superfast broadband connections in 2014 used for Phase 2 and take-up in each year from 2014 to 2017 used in the matching approach for Phase 3. The results illustrate the lagged effect with take-up rising slowly over time. There were 3.6 extra connections taken up per postcode delivered to through Phase 2 delivery by 2019.

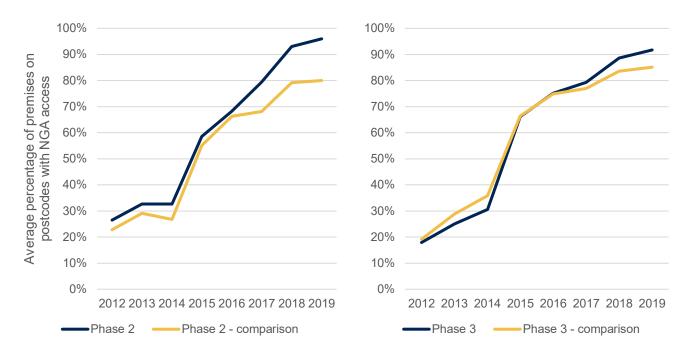
In the below tables for NGA coverage, the trends for areas within build plans and the comparison areas clearly diverges in 2014 for Phase 1, 2017 for Phase 2 and 2018 for Phase 3. Similar trends are observed for superfast coverage, particularly for Phase 2 and 3 in 2017 and 2018 respectively.



Phase 1

-Phase 1 - comparison





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

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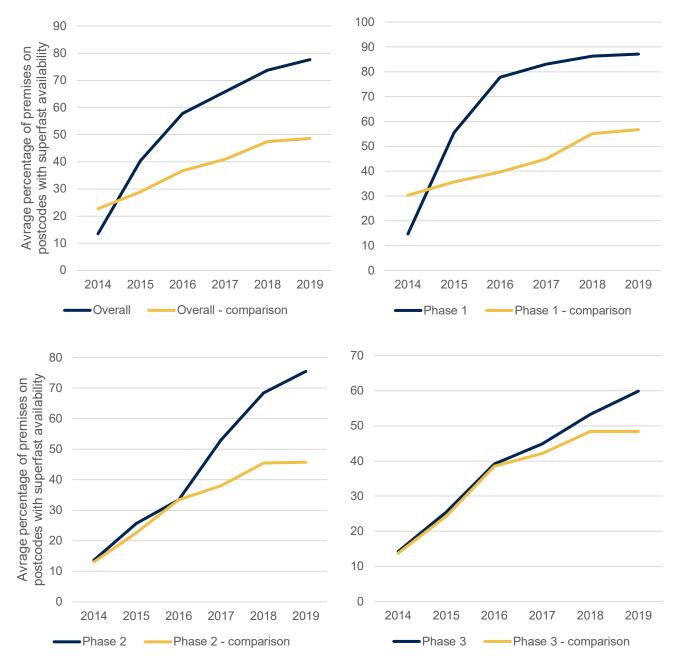


Figure 5.2: Evolution of superfast broadband coverage in upgraded postcodes and comparison postcodes, by Phase

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

Table 5.2: PSM model results - NGA and superfast broadband availability

	% of post	codes wit overage	h NGA	Superfast availability as % of premises			Average number of premises with superfast availability			
Effects as of [year]:	2016	2018	2019	2016	2018	2019	2016	2018	2019	
Model 2	17.2	23.3	23.6	24.4	31.3	34.1	3.0	4.0	4.3	
Model 2b (speed outcomes included)	21.2	24.6	24.2	26.3	32.4	34.6	4.6	5.9	6.3	
Model 2c (speeds included as controls)	20.7	24.2	24.1	26.3	32.6	35.1	3.9	5.0	5.3	
Phase 1										
Model 3	32.5	27.9	27.4	37.3	34.4	34.4	4.9	4.5	4.5	
Model 3b (speed outcomes included)	37.5	32.0	30.9	42.1	38.6	38.2	7.2	6.5	6.5	
Model 3c (speeds included as controls)	35.9	29.7	28.8	41.0	36.5	36.3	7.0	6.1	6.1	
			Pha	se 2						
Model 4	2.0	17.7	20.8	4.5	27.3	36.1	1.8	4.6	5.9	
Model 4b (speed outcomes included)	0.0	17.4	20.3	4.4	27.7	36.1	1.9	6.0	7.6	
			Pha	se 3						
Model 7	-	5.0	6.6	-	4.9	8.8	-	1.8	2.4	
Model 7b (speed outcomes included)	-	5.2	6.9	-	5.7	9.7	-	1.7	2.4	
		Ur	ban and	rural split						
Model 5 (Rural)	19.8	23.2	22.5	22.7	28.8	30.9	3.2	4.2	4.6	
Model 6 (Urban)	9.6	12.3	13.1	11.0	13.9	15.8	1.9	2.8	3.1	
Model 1 (all areas as control)	7.5	11.1	10.0	5.4	11.3	12.4	1.3	2.4	2.5	

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

Table 5.3: PSM model results - Download s	speeds (n	naximum a	and average)
	, oood (ii	maximani c	ina avoiago,

		ilable dov eds (Mbps			ge downl eds (Mbp		Average number o superfast broadbar connections		and
Effects as of [year]:	2016	2018	2019	2016	2018	2019	2016	2018	2019
Model 2	-	-	-	-	-	-	-	-	-
Model 2b (speed outcomes included)	-0.5	3.3	11.8	-0.9	2.8	9.3	-	-	-
Model 2c (speeds included as controls)	-1.5	2.2	9.4	-1.1	2.5	9.1	-	-	-
			Phase	1					
Model 3	-	-	-	-	-	-	-	-	-
Model 3b (speed outcomes included)	4.6	3.7	9.0	0.8	4.7	10.5	-	-	-
Model 3c (speeds included as controls)	-2.5	-5.7	-1.2	-1.5	1.0	7.5	-	-	-
			Phase	2					
Model 4	-	-	-	-	-	-	0.3	2.0	3.6
Model 4b (speed outcomes included)	3.0	12.9	16.0	1.1	5.2	9.1	0.3	2.0	3.5
			Phase	3					
Model 7	-	-	-	-	-	-	-	0.2	0.3*
Model 7b (speed outcomes included)	-	13.8	18.3	-	5.4	7.5	-	0.2	0.2*
		U	rban / rur	al split					
Model 5 (Rural)	-4.1	0.6	3.5	-2.0	2.4	7.4	-	-	-
Model 6 (Urban)	1.8	5.0	8.1	-0.8	2.6	5.4	-	-	-

Source: Ipsos MORI analysis; BDUK C3 reports & Ofcom Connected Nations; * indicates not statistically significant

5.3.4 Additionality of subsidised coverage

Aggregating the estimated effects on average number of premises with superfast broadband coverage to estimate the total number of additional premises with superfast broadband coverage by 2019 suggests that between 1.6m and 2.3m additional premises benefitted from superfast broadband coverage that would not have done without the programme by 2019. This implies an overall rate of additionality at between 39 and 57 percent.

Note that the results for Phase 3 in these analyses differ to those presented in Section 4. The differencein-difference approach used in that section is considered more robust given that it uses a matched sample from which a DiD approach is implemented on whereas the effects visible here are based upon comparisons of the treatment and control means. However, this does illustrate a significant degree of uncertainty with respect to the additionality level of Phase 3 delivery which should be viewed with caution. Table 5.4: Estimated Additionality – share of premises receiving subsidised coverage that would not have received superfast broadband coverage without the programme (PSM Models)

Number of Postcodes		Total number of delivery points on	Estimated effect on the average number of premises with superfast broadband coverage by 2019		Estimated number of additional premises with superfast broadband coverage by 2019		No. of premises No. of receiving premises subsidised receiving superfast subsidised broadband coverage by		Estimated Additionality (%)	
		postcodes	Low	High	Low		coverage by	Sep 2019	Low	High
Postcodes in build plans of Phase 1, 2 & 3 schemes	367,091	5,327,795	4.4	6.4	1,615,200	2,349,382	4,149,850	4,298,160	39%	57%
Postcodes in build plans of Phase 1 schemes	291,223	4,297,449	4.4	6.5	1,281,381	1,892,950	3,570,399	3,706,292	36%	53%
Postcodes in build plans of Phase 2 schemes	82,488	1,119,286	5.6	6.9	461,933	569,167	793,956	821,558	58%	72%
Postcodes in build plans of Phase 3 schemes	9,266	108,514	1.7	2.4	15,752	22,238	60,095	79,100	26%	37%

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

5.4 Longitudinal panel models

Further modelling was completed to examine the relationship between the number of premises with superfast broadband availability and the number of premises with upgraded connections (at the Output Area level).³⁴ These analyses were restricted to those areas that were eligible for the programme (i.e. with postcodes or premises identified as white in the OMR). The longitudinal nature of the data allowed the analysis to accommodate for unobserved differences between areas that do not change with time, giving more robust findings than the matching models described above. These results are comparable to the Difference-in-Difference analyses put forward in the State Aid evaluation plan (which envisages the analyses being completed at the premise/postcode level, examining overall changes in coverage between 2016 and 2020 rather than annual variation). This was implemented using the estimation of the following econometric model describing the relationship between the number of premises receiving subsidised superfast coverage through the programme and the outcomes of interest:

$$outcome_{it} = \alpha + \beta X_{i,2013/16} + \gamma C_{it} + \theta t + \alpha^{i} + \alpha^{L} t + \alpha^{T} + \alpha^{L} \alpha^{t} + \varepsilon_{it}$$

This model describes the number of premises with the outcome in area i in period t (outcomeit) as a function of a set of observable characteristics of an area before the programme began (*Xi*,2013/16) and the cumulative number of premises receiving subsidised coverage within the area in the period (*Cit*). The model also allows for national trends that might influence the outcomes across all areas (t). The model also allows for unobserved differences between areas that do not change over time (αi), unobserved but time-specific shocks that affect all areas (αT), unobserved trends at the local authority level ($\alpha L \alpha t$). The parameter γ gives a direct measure of the additionality associated with the programme, i.e. the proportion of premises receiving subsidised coverage that would not have received NGA/superfast/FTTP coverage in the absence of the programme. To facilitate the estimation of the model, the equation above was specified in first-differences as specified below:

$$\Delta outcome_{it} = \gamma \Delta C_{it} + \theta \Delta t + \alpha^{L} \Delta t + \alpha^{T} + \alpha^{L} \alpha^{T} + \varepsilon_{it}$$

This transformation relates the change in the outcome to the number of premises receiving subsidised coverage within the year. The transformation also results in fixed characteristics of areas being dropping out of the model - including the pre-treatment characteristics of the model – but importantly, differencing in this way means that the results will not be biased because of their omission. However, in some models, these controls were reintroduced to explicitly capture any unobserved trend effects affecting areas with different pre-programme characteristics.

These results could still be biased by unobserved differences between areas that change with time. Given the time frame over which the analysis has been conducted, this is a heightened risk. For example, Openreach's Physical Infrastructure Access (PIA) product has become more accessible during the period of analysis and interviews with suppliers have suggested that this has made some areas commercially viable that previously were not. If this improvement in commercial viability was more significant in areas benefitting from subsidised coverage, then these results could overstate additionality in the longer-term.

5.4.1 Results

The findings of these analyses are presented in the two tables below. In table 5.4:

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³⁴ An Output Area is small area covering around 10-12 postcodes.

- Model 1 presents a simple first difference model produce an estimated increase in NGA coverage of 0.75 premises for each premise receiving subsidised coverage through the programme by 2016, i.e. 77 percent additionality. This declines to 0.71 and 0.70 by 2018 and 2019 respectively.
- Models 2 and 3 exclude those output areas reaching 100 percent NGA coverage and ineligible areas. This reduces the size of the estimated impacts.
- Models 4 and 5 allow for unobserved local authority level trends, time-specific shocks affecting all areas, and time-specific shocks at a local authority level. Adding these further controls further reduces the estimated impacts of the programme (with an implied additionality rates of 60 percent).
- Model 6 uses model 5 but allows for differing effects by Phase. Here, Phase 1 additionality was estimated at 61 percent, Phase 2 at 60 percent and Phase 3 at 19 percent by 2019.

Table 5.5: Longitudinal panel models – estimated impacts

Areas reaching 100% NGA coverage excluded?NoYesYesYesYesYesYesYesEligible areas excluded?NoNoNoYesYesYesFixed effectsNoNoNoNoYesYes2013 Output Area controlsNoNoNoNoYesYesEffects up to 2016EEStatistical Coverage premises per premises receiving subsidised coverage under Phase 10.75***0.71***0.70***0.62***0.61***0.62***Change in NGA covered premises per premises receiving subsidised coverage under Phase 10.52***Change in NGA covered premises per premises receiving subsidised coverage under Phase 20.2261.688261.688250.899Change in NGA covered premises per premises receiving subsidised coverage under Phase 20.71***0.69***0.61***0.61***Change in NGA covered premises per premises receiving subsidised coverage0.71***0.69***0.61***0.61***Change in NGA covered premises per premises receiving subsidised coverage under Phase 20.61***Change in NGA covered premises per premises receiving subsidised coverage under Phase 20.60***Change in NGA covered premises per premises receiving subsidised coverage under Phase 30.240.230.260.380.30***Change in NGA covered premises per premises receiving subsidised coverage under Phase 30.60****Chan		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
No No<	Areas reaching 100% NGA coverage excluded?	No	Yes	Yes	Yes	Yes	Yes
2013 Output Area controls No No No No No Yes Effects up to 2016 Change in NGA covered premises per premises receiving subsidised coverage under Phase 1 0.75*** 0.71*** 0.70*** 0.62*** 0.61*** - Change in NGA covered premises per premises receiving subsidised coverage under Phase 2 - - - 0.52*** Observations 857.784 292.785 261.688 261.688 250.889 250.889 Adjusted R-Squared 0.24 0.23 0.25 0.36 0.40 0.38 Effects up to 2018 Change in NGA covered premises per premises receiving subsidised coverage under Phase 1 - - - 0.61*** Change in NGA covered premises per premises receiving subsidised coverage under Phase 1 - - - 0.61*** Change in NGA covered premises per premises receiving subsidised coverage under Phase 3 - - - 0.61*** Change in NGA covered premises per premises receiving subsidised coverage under Phase 3 - - - 0.61*** Change in NGA covered premises per premises receiving subsidised coverage under Phas	Eligible areas excluded?	No	No	Yes	Yes	Yes	Yes
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Change in NGA covered premises per premises receiving subsidised coverage0.70***0.69***0.69***0.61***0.60***-Change in NGA covered premises per premises receiving subsidised coverage under Phase 10.61***Change in NGA covered premises per premises receiving subsidised coverage under Phase 20.60***Change in NGA covered premises per premises receiving subsidised coverage under Phase 20.60***Change in NGA covered premises per premises receiving subsidised coverage under Phase 30.60***Change in NGA covered premises per premises receiving subsidised coverage under Phase 30.60***Change in NGA covered premises per premises receiving subsidised coverage under Phase 30.60***Observations1,501,122365,370321,421321,421308,101308,101	Adjusted R-Squared	0.24	0.22	0.25	0.36	0.39	0.39
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receiving subsidised coverage under Phase 3 0.19 ^{4AA} Observations 1,501,122 365,370 321,421 308,101 308,101	a 1 1 1	-	-	-	-	-	0.60***
		-	-	-	-	-	0.19***
Adjusted R-Squared 0.24 0.22 0.25 0.37 0.40 0.39	Observations	1,501,122	365,370	321,421	321,421	308,101	308,101
	Adjusted R-Squared	0.24	0.22	0.25	0.37	0.40	0.39

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

5.4.2 Additionality over time

The results above only compare changes in NGA coverage and premises receiving subsidised coverage within the same year. This may provide a misleading representation of impact for the following reasons:

- Delayed coverage for areas likely to receive enhanced connectivity anyway: The matching
 models above pointed to a possible effect whereby the programme may have delayed investment in
 superfast coverage in those postcodes that would have been likely to receive enhanced that
 investment anyway. Failing to allow for this possible effect could cause estimates of impact to be
 overstated.
- Lagged effects: Additionally, there may be recording lags in the data (with increases in maximum download speeds visible in the Connected Nations data up to 1 year following the installation of the technology). Failing to allow for these lagged effects would cause estimates of impact to be understated.
- Acceleration effects: There is also a possibility that part of the effect of the programme is to accelerate an area's access to faster broadband speeds, rather than enabling the area to access faster speeds on a permanent basis. This would imply higher rates of additionality in the short-term and lower rates of additionality in the longer-term.

These hypotheses were explored by introducing forward and backward lags of the treatment variable into the model as follows (the panel data only included five years so it was not possible to include more lags within the models to explore longer-term effects):

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

The results are set out in the table below and suggest that the scheme did have a negative effect on NGA availability in the year before premises received subsidised coverage (equivalent to nine premises per 100 connections). This implies a small degree of initial localised crowding out. However, the estimates suggested that in the year following the delivery of subsidised coverage, 0.57 additional premises received NGA coverage per premises upgraded (57 percent additionality). The results also suggested that 5 percent of premises receiving subsidised connections would have received NGA coverage anyway but two years later. This gives overall additionality of 59 percent over the four-year period, which is consistent with the estimates of the matching models.

The pattern remains consistent across phases in the below. This also allows for the plotting of additionality over time. The results shown in table 5.5 and the figure below imply a slowly decreasing level of additionality over time, up to five years after delivery in the overall results. This implies that the likelihood of an area being upgraded in the absence of the programme increases as time passes, albeit at a slow rate. The analysis illustrates an overall level of additionality after four years of 40 percent, which compares to 60 percent after one year. This is illustrated in the figure below.

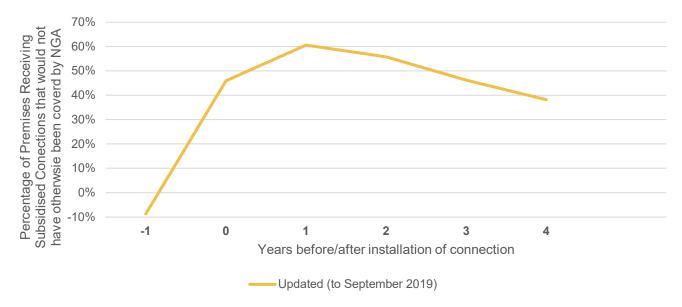


Figure 5.3: Estimates of additionality of NGA Coverage over time

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

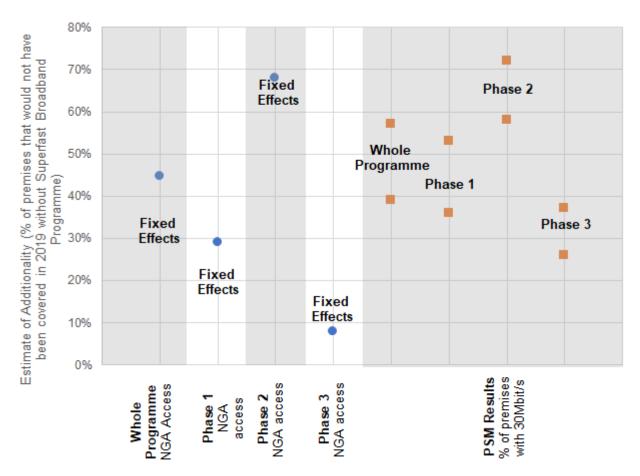
Table 5.6: Estimated Additionality Over Time – Longitudinal Panel Models

	Overall	Phase 1	Phase 2	Phase 3	Overall
Areas reaching 100% NGA coverage excluded?	Yes	Yes	Yes	Yes	Yes
Eligible areas excluded?	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes
2013 Output Area controls	Yes	Yes	Yes	Yes	Yes
Up to 2019					
Change in NGA covered premises per premises receiving subsidised coverage (T+1)	-0.09***	-0.09***	-0.07***	-0.04*	-0.09***
Change in NGA covered premises per premises receiving subsidised coverage (T)	0.57***	0.57***	0.57***	0.08**	0.55***
Change in NGA covered premises per premises receiving subsidised coverage (T-1)	0.16***	0.16***	0.18***	-	0.15***
Change in NGA covered premises per premises receiving subsidised coverage (T-2)	-0.05***	-0.05***	-0.01	-	-0.05***
Change in NGA covered premises per premises receiving subsidised coverage (T-3)					-0.10***
Change in NGA covered premises per premises receiving subsidised coverage (T-4)					-0.08***
Total effect 2/5 years post delivery	0.59	0.59	0.69	0.04	0.38
Observations	209,18	2	209,182	7	79,471
Adjusted R-Squared	0.45		0.46		0.40

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

5.4.3 Summary of findings

The figure below summarises the estimates of additionality across the methods implemented above for the whole programme analysis.





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

5.5 Crowding Out

The programme could have negative effects elsewhere if its delivery diverted scarce resources – such as skilled labour or capital – away from areas in which providers planned to install enhanced infrastructure without subsidy. However, positive effects (crowding-in) are also possible if the process of demand and cost recovery supported by the programme encouraged providers to make further or bring forward investments in superfast broadband infrastructure.

The level of crowding in or out was explored by assuming any effects of this nature were likely to occur at the local level. While telecoms operate national supply chains, the delivery of construction activity tends to be by local contractors (motivating this assumption). Additionally, it was assumed that the size of these effects would be linked to the volume of delivery in nearby white postcodes. This was operationalised using the following econometric model (a non-parametric distance-decay model):

$$NGA_{jt} = \alpha + \sum_{k=1}^{5} \gamma_k C_{kt} + \theta t + \alpha_i + \alpha_L t + \alpha_L \alpha_t + \varepsilon_{it}$$

This model relates the number of premises covered by NGA on grey, black and otherwise ineligible postcodes in output area j in period t (NGA_{jt}) to the cumulative number of premises receiving subsidised coverage within distance bands (k) of increasing distance from area j (C_{kt}). Five distance bands were adopted for the purposes of the analysis at 10km intervals from the centroid point of the relevant LSOA³⁵ (0 to 10km, 10km to 20km, 20km to 30km, 30km to 40km, and 40km to 50km). The parameter γ_k captures the effect of each premises covered delivered in distance band k in period t on the number of premises on grey, black, and other ineligible postcodes covered by NGA. A positive coefficient is a signal of crowding-in and a negative coefficient is a signal of crowding out. The parameter θt accounts for time trends t the national level.

The model also allows for unobserved differences between areas that do not change over time (α_i) , unobserved but time-specific shocks that affect all areas (α_t) , unobserved trends at the local authority level $(\alpha^L t)$ and unobserved and time-specific shocks at the local authority level $(\alpha_L \alpha_t)$. As before, the model was specified in first differences removing the influence of any time invariant factors that might be correlated with the outcome:

$$\Delta NGA_{jt} = \sum_{k=1}^{5} \gamma_k \Delta C_{kt} + \theta \Delta t + \alpha_L t + \alpha_t + \alpha_L \alpha_t + \varepsilon_{it}$$

Any LSOAs without any grey, black, or otherwise ineligible postcodes were removed from the sample. Additionally, if NGA coverage reached 100 percent on all relevant postcodes within the Output Area, subsequent observations were removed from the sample from the following year (as by assumption there can be no crowding in or crowding out effects once 100 percent coverage is achieved).

5.5.1 Results

Overall, the analysis suggested the delivery of subsidised coverage led to a small reduction in NGA coverage in nearby areas in of crowding out in the 0 to 10km distance but also a small degree 10km to 20km and 20 to 30km away in the year of delivery. One year after, the opposite is true for areas 10 to

³⁵ Distances were calculated at an LSOA rather than a postcodes level to reduce the number of distances between pairs of areas that required calculation to produce the dataset needed for this analysis.

20km away and 20km to 30km. The level of crowding out estimated overall is negligible in these models however.

Table 5.7: Estimated	Level of Crowdi	ng Out – up to 2019
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	Model 26	Mod	el 27
	No lagged effects	Effect in year t	Effect in year t+1
0 to 10km	-0.0004***	-0.0004***	0.0002
10 to 20km	-0.0001	-0.0002*	0.0002*
20 to 30km	-0.0001*	-0.0003***	0.0004***
30 to 40km	0.0002***	0.0002***	0.0000
40 to 50km	0.0000	0.0000	0.0001
Total effect	-0.0003	-0.0	001
R-squared	0.2620	0.2	620
Observations	101,022	101,	.022

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

6 Cost effectiveness

This final section of the technical appendix sets out a cost-effectiveness analysis of the Superfast Broadband programme using the impacts estimated across the whole programme as presented in section five. The analysis relates the expected net subsidy associated with the programme to the number of additional connections delivered.

6.1 Costs

Data on the costs of delivering the Superfast Broadband programme have been drawn from BDUK monitoring data and the outputs of an extensive modelling exercise. Details of these can be found in Appendix 2.

6.2 Cost-effectiveness of public sector funding

6.2.1 Contracted cost per premises passed

Data on the costs of delivering the Superfast Broadband programme have been drawn from BDUK monitoring data and the outputs of the modelling exercise described in Section 5 of Technical Appendix 2. A total of £1.9bn of public sector funding (in nominal terms³⁶) was committed across Phase 1, 2 and 3 contracts with a total of 5.5 million contracted premises passed. This equates to an ex-ante gross cost per premise passed of £342. There was significant variation across the various phases. Phase 1 had the lowest gross public sector cost per premises passed of £266. Phase 3 had the highest public sector cost per premise at over £1,216. This is expected given the proportion of FTTP build expected in Phase 3 delivery which was expected to come at a higher cost.

	Contracted public sector cost ³⁷ (£m)	Contracted premises passed	Gross public subsidy per gross premises passed (£)
Phase 1	1169,1	4,388,618	266.39
Phase 2	332.6	830,654	400.39
Phase 3	391.9	322,242	1,216.29
Overall	1893.6	5,541,514	341.72

Table 6.1: Contracted gross public sector cost per premises passed over Phases 1, 2 and 3

Source: Ipsos MORI analysis; CORA; BDUK

6.2.2 Expected cost per premises passed by March 2019

The table below provides estimates of the current expected public sector cost per premises passed by March 2019 (following the approach outlined in Technical Appendix 3). As highlighted, current expectations of public spending (before implementation and take-up clawback) differs significantly to the contracted costs outlined above (primarily driven by underspend on Phase 1 contracts). The expected gross public spend per premises passed was lower overall at £268. and the expected gross public spend per premises passed fell from £1,216 to just above £497 (primarily due to expected underspend, though note that these projections are highly uncertain at this stage).

Factoring in the likelihood that some of those premises passed to date would otherwise have received coverage through commercial deployments, the table below also includes the estimated number of

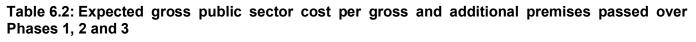
65

³⁶ The time profile associated with these contracts was not available, so this is presented in nominal terms on an undiscounted basis.

³⁷ In nominal terms, not in present value terms. Taken from CORA management extract

additional premises passed. This applies estimated additionality over the first three years following delivery (to align with the period covered by the OMR process) of 56 percent. The gross public sector cost (i.e. before clawback) per additional premises passed over three years was £460 (in 2019 prices).

The table below provides estimates of the expected public sector cost per premises passed by March 2017. Expected Phase 3 costs were scaled down to 17 percent of the total to reflect the amount of delivery by March 2019. These costs were calculated in present value terms and in 2019 prices.



	Expected public sector cost (£m)	Premises passed to date	Additional premises passed to date	Expected Gross public subsidy per gross premises passed (£)	Expected Gross public subsidy per additional premises passed (£)
Phase 3	25	51,285	28,720	490	880
Overall	1353	5,268,398	2,950,303	260	460

Source: BDUK, Ipsos MORI analysis

6.2.3 Net public cost per additional premises upgraded over three years

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

	Net public sector cost (£m)	Additional premises upgraded to date	Net public subsidy per additional premise upgraded (£)
Phase 1	429.8	2818651.0	152
Phase 2	274.3	500273.0	548
Phase 3	22.6	28720.0	788
Overall	726.7	3353638.0	217

Table 6.3: Net public sector cost per additional premises passed over Phases 1, 2 and 3

Source: BDUK, Ipsos MORI analysis

6.2.4 Cost per connection

Finally, as highlighted in Section 4, a total of 15,369 connections were made to infrastructure subsidised through Phase 3 of the programme. Combining this with the estimated costs of delivery to this point gives an estimated gross cost per connection of £1,642 before clawback and £1,472 after clawback. However, the findings of the analysis indicated that Phase 3 of the programme had no net effect on the number of superfast connections over the relatively short time-frame for the analysis.

6.3 Benchmarking

Whilst an attempt has been made to compare the costs per connection outlined for the programme above, there remains little evidence on comparable interventions. There are very few studies that have sought to examine the cost-effectiveness of broadband programmes. This may in part be because of a relative lack of public programmes on the same scale as the Superfast Programme and a consequent lack of published evaluative work.

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

Annex A: Datasets used in the analysis

This Annex provides an overview of the data available for the analyses reported in this Appendix, highlighting issues relating to comprehensiveness or quality, and any implications for the findings.

Connected Nations

Ofcom's Connection Nations report provided the evidence on the key outcomes of interest for the analysis - including NGA availability, available speeds, and the speeds of connections (which gives an indication of take-up) between 2012 and 2019. The data provided a snapshot of local connectivity in June of each year up to and including the 2016 release. The 2017 release provided a snapshot in May of that year and the 2018 and 2019 releases gave a snapshot for September.

The number of postcodes included in the report has changed from year-to-year, and in compiling the data any postcode with missing data for one or more years was dropped from the analysis. This gave a sample of 1.54m postcodes which excluded any new postcodes that may have emerged as result of new housing or commercial developments on greenfield sites. The following analyses should be reviewed bearing in mind the following limitations of the data:

- Coverage of suppliers: The number of suppliers providing data to Ofcom for the Connected Nations output has increased with time. In 2019, the data incorporated information provided by 24 fixed network suppliers covering all such Superfast suppliers with one exception³⁸ as well as data from Airband, a wireless internet service provider and Superfast supplier. The data also includes returns from 12 other wireless ISPs. The 2017 and 2018 data included information from fewer fixed network suppliers but still included all Superfast suppliers with the above exception. Smaller suppliers were less likely to be included in earlier years of the data. Between 2012 and 2014 only coverage from the major providers (BT, Virgin Media and KCOM) was reported with Sky and TalkTalk added in 2015. In 2016, a further five alt-net providers were added including B4RN, Gigaclear and Hyperoptic.
- Measures of superfast and FTTP availability: The Connected Nations data has increased in resolution over time with a greater number of variables included in the dataset in each year. In 2012 and 2013, the dataset only gave a binary measure of whether a postcode has Next Generation Access (NGA)³⁹ access or not⁴⁰. From 2014 onwards the data described the percentage of premises with NGA and superfast access. It was only possible to construct a consistent measure of superfast availability across the 2012 to 2019 period by converting post 2014 measures of NGA access into a binary measure. This was achieved by assuming a postcode had NGA access if more than 50 percent of the premises on the postcode had NGA access. This measure more closely tracked aggregate changes⁴¹ in NGA access than the available alternatives⁴² but is likely to overstate NGA coverage in earlier years (potentially leading to an understatement of the impact of the programme. NGA access is positively correlated with the availability of superfast broadband, with a Pearson's correlation coefficient of 0.7⁴³. However, it is not a strong predictor in some cases, for example where the distance of premises from the serving cabinet is large. As such, a focus on NGA access will

⁴² Such as assuming a postcode has NGA coverage if at least one premises was covered by NGA.

³⁸ UKB have not been included in the Connected Nations data for any year but delivered the Phase 2 contract in Swindon.

³⁹ Defined by Ofcom as: New or upgraded access networks that will allow substantial improvements in broadband speeds and quality of service. Can be based on a number of technologies including cable, fixed wireless and mobile. Most often used to refer to networks using fibre optic technology.

⁴⁰ The 2012 and 2013 OfCom datasets will have systematically overstated NGA coverage for the analytical purposes of this paper, as a postcode qualified as being passed by NGA if just one premise was enabled with NGA.

⁴¹ I.e. the share of premises with NGA coverage, which is measured directly in the Connected Nations dataset between 2014 and 2016.

⁴³ This was calculated based on the relationship between share of premises with NGA coverage and the share of premises with superfast (30 Mbit/s) coverage at a postcode level, as captured in the 2016 to 2019 Connected Nations datasets.

overstate superfast availability. In addition, NGA access was excluded from the 2017 release and has been imputed using both NGA availability in 2016 and superfast availability in 2017. Where a postcode had NGA availability in 2016 it was assumed this remained the case in 2017 whilst any postcodes that did not have NGA available in 2016 but had more than 50 percent of premises with superfast available in 2017 were also assumed to have NGA available in 2017. Superfast availability itself appears in the data from 2014 onwards, while observations of FTTP coverage are available from 2017.

- Definition of superfast: There were differences in the definition of superfast employed by the programme in Phase 1 and Phase 2 (>24Mbps) and the Connected Nations data (>30Mbps). In these cases, analyses will understate the effect of the programme on superfast availability where subsidised coverage has delivered speeds of between 24 and 30 Mbps. The definition of superfast in Phase 3 aligns with Connected Nations.
- Missing data: The Connected Nations data describes the average and maximum download speeds of connections. Average and maximum download speeds are missing for a meaningful share of postcodes in early years, particularly 2012 and 2013 but to a lesser extent throughout, due to insufficient numbers of premises or missing data. This is primarily an issue for the long-term assessment of the impacts of the programme. Restricting the sample to postcodes where speed data is available in all years between 2016 and 2019 reduces the sample size to 1.2m postcodes, though data on NGA access is available for all postcodes. Clearly, there are questions as to how far there are systematic differences between those postcodes for which speed data is and is not available, and the analysis has sought to explore the effect of including and excluding these postcodes on the estimated impact of the programme.
- Truncated data: Observations of low and high download speeds are truncated in the 2012 and 2013 Connected Nations data. Speeds of less than 4Mbps are recorded as '<4Mbps' and speeds greater than 30MBits/s are recorded as '30Mbps' – and as such cannot be included as a control variable without further reducing the size of the available sample. Again, this limitation is only of relevance to the longer-term assessment of the programme's impacts.
- Change in methodology to derive the premise base: In 2019, Ofcom altered the derivation of the premise base used to allocate supplier provided data returns to coverage of postcodes across the UK⁴⁴. The result of this methodological change is that some postcodes saw reported falls in superfast and FTTP coverage between 2018 and 2019. The code used to produce the premise base for the 2019 release is available in the methodology report and was used to provide revised measures of the premises base for 2019 whilst Ofcom provided the code to generate the premise base for all years prior. The percentage of premises with superfast, NGA and FTTP availability in 2019 was multiplied by the 2019 premise base for each postcode to generate the number of premises with such availability in 2019. This was then divided by the 2018 premise base to construct a revised measure of availability for 2019.

ThinkBroadband

ThinkBroadband is an independent organisation which collects information about broadband coverage in the UK. ThinkBroadband made data available on broadband coverage by infrastructure provider by

⁴⁴ See <u>https://www.ofcom.org.uk/___data/assets/pdf_file/0021/186411/connected-nations-2019-methodology.pdf</u>

postcode for the years 2012, 2016, and 2020. This enabled the construction of postcode level measures of the number of network providers.

The data covered the estimated footprints of 60 network providers⁴⁵ offering broadband coverage (superfast or below). The data also includes the type of technology used to provide these broadband services. This data has been collected in three main ways:

- **Desk research of the Openreach network:** Identifying the location of Openreach cabinets and the postcodes they serve, the technology used in the cabinet and when this was upgraded.
- Press releases and network provider engagement: ThinkBroadband staff monitor press releases issued by network providers that state where they have built networks and where they are planning to build networks in the future. Additionally, network providers engage with ThinkBroadband directly, informing them of their footprints of their existing networks and are going to build networks. The information received from network providers and press releases is validated by ThinkBroadband staff, who check that broadband coverage is available from the network provider in the postcodes they claim to cover.
- Cross reference with speed test data: Individuals undertaking speed tests on the ThinkBroadband website are asked to provide their Internet Service Provider (ISP). The data generated by the Speed Tests is checked against the coverage data collected by ThinkBroadband. Where a speed test flags that a network provider (through providing access to ISPs) has coverage in an area that the coverage data states the network provider does not, this area is validated. If the network provider does have coverage in the area highlighted in the speed test, this is added to the coverage database.

This data covered a total of 1.7m postcodes in 2020 and 2016 and 1.6m in 2012. These matched in to the majority of postcodes used in the Phase 3 analysis with 99 percent of each cross section successfully linked.

Speed and Coverage Templates

Details of eligible ('white') postcodes and the postcodes included in the build plans of local schemes are generally captured within Speed and Coverage Templates (SCTs) that are completed by providers as part of the tendering exercise. BDUK supplied Ipsos MORI with all available SCTs, which covered almost all local schemes that had been contracted under Phase 1, 2 and 3 by September 2019⁴⁶. Postcode level data in Phase 1 and 2 SCTs and premise level data in Phase 3 SCTs were aggregated and matched to the Connected Nations datasets. Any postcodes that did not match were dropped from the analysis. Table 1.1 provides a breakdown of the postcodes available by their status as defined in the SCTs. In summary:

- White postcodes: There were 348,480 'white' postcodes eligible for BDUK subsidies (23 percent of postcodes in the UK) under Phase 1 of the programme, 173,014 postcodes eligible for BDUK subsidies under Phase 2 of the programme (11 percent of postcodes in the UK) and 118,460 eligible postcodes in Phase 3 (eight percent of UK postcodes).
- **Postcodes included in build plans:** The build plans associated with local schemes covered 248,521 postcodes (16 percent of postcodes in the UK) in Phase 1, 95,266 postcodes in Phase 2 (6

⁴⁵ Data covered suppliers that owned and operated their own networks and did not cover ISPs in this analysis

⁴⁶ Two SCTs from Phase 2 and a further three from Phase 3 were not used in the analysis as they did not contain the necessary information and were in different formats.

percent of postcodes in the UK) and 66,926 postcodes in Phase 3 (4 percent of UK postcodes). These figures exclude any postcodes that were included in build plans for non-superfast delivery.

- Grey or Black Postcodes: For Phase 1, a total of 524,124 postcodes were deemed as 'grey' or 'black' in the SCT template, and therefore ineligible for BDUK subsidies (around 34 percent of postcodes in the UK). The number of ineligible postcodes rose to 744,233 in Phase 2 (48 percent of the UK) and then fell to just 39,472 for Phase 3.⁴⁷
- Descoped and ineligible LAs: A further 227-232,000 postcodes were ineligible for BDUK subsidies because they were 'de-scoped' by the Local Authority or Devolved Administration or were located in Local Authorities deemed outside the scope of the programme by BDUK because commercial deployments were expected to be extensive (or Local Authorities voluntarily declared themselves ineligible). The ineligible local authorities were Birmingham, Bristol, Kingston-Upon-Hull, Manchester and Salford and the 33 Boroughs of London while Coventry, Portsmouth and Southampton did not take part. This was equivalent to just under 15 percent of the postcodes in the UK.
- Postcodes not present in SCT or areas without schemes: The SCTs prepared by local bodies did not always provide full coverage of the postcodes within their area. This was particularly the case for Phase 3 where SCTs predominantly included just those premises that were eligible for subsidy. Additionally, some local bodies eligible for BDUK subsidies did not come forward with a scheme (e.g. Luton). It is unknown if these postcodes were 'white,' 'grey' or 'black'. This accounted for 19 percent of postcodes in the UK under Phase 1, and 22 percent under Phase 2 and 75 percent in Phase 3. In Phase 3, large numbers of ineligible premises were not included in the SCTs (explaining the high share of postcodes falling in this category).
- Area excluded from the analysis: SCT templates were not available for a small number of local areas (Gloucestershire & Herefordshire and North Yorkshire) who contracted their programmes via an OJEU process rather than using the BDUK Framework Agreement in Phase One. Additionally, there was no SCT template available for Wales. No information is available on the postcodes included within the build plan of these schemes or those that were eligible and these areas have been dropped from most analyses provided in this report. Additionally, a prior evaluation scoping study prepared for BDUK recommended the exclusion of Cornwall owing to the contaminating effect of the broadband coverage subsidised through the EU Convergence programme. On this basis, Cornwall has also been excluded in the following analyses⁴⁸. Phase 3 schemes did not cover these areas and no areas were excluded.

⁴⁷ Note that for Phase 3, most SCTs only included premises that were eligible for subsidy.

⁴⁸ It is understood that a similar issue applies in Northern Ireland with EU funded programmes bringing superfast coverage to towns and villages. However, prior programmes were planned - and to a large extent delivered - before the Superfast Broadband programme. Their effects on coverage would have been captured through the Open Market Review process, enabling these external factors to be controlled for in the analysis.

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	Table 1.1. Overview of opeca and ooverage reinplates, r hase 1, 2 and 0								
Status	Ph	ase 1	Pha	se 2	Pha	Phase 3			
	Number	Percentage	Number	Percentage	Number	Percentage			
White postcode within build plan defined in SCT	248,521	16.18	95,266	6.2	66,926	4.36			
White postcode out of build plan defined in SCT	99,959	6.51	77,748	5.06	51,534	3.35			
Grey or Black postcode in SCT	524,124	34.11	744,233	48.44	39,472	2.57			
De-scoped postcode or 'ineligible' LA	227,214	14.79	227,450	14.8	231,894	15.09			
Postcodes not present in SCT or in areas with no scheme	290,082	18.88	264,371	17.21	1,146,567	74.63			
Area excluded from analysis	146,493	9.53	127,325	8.29	-	-			
Total	1,536,393	100	1,536,393	100.0	1,536,393	100.0			

Table 1.1: Overview of Speed and Coverage Templates, Phase 1, 2 and 3

Source: SCT templates, Ipsos MORI analysis

C3 reports

Claimed delivery of premises upgraded are reported to BDUK by contractors in a 'C3 report.' The C3 report captures the address of each premise the contractor claimed they had upgraded, and provides predicted download and upload speeds. C3 reports to September 2019 were used to support the analyses reported below and elsewhere in this evaluation. These provided details of 6.3m premises that were claimed to have been upgraded by providers. Not all of these premises would have received coverage subsidised by BDUK, and a number of steps were taken to refine this dataset:

- Predicted speeds: Around 608,500 premises (in 101,768 postcodes) were claimed to have been
 upgraded to an available download speed of less than 24Mbps⁴⁹. This might occur, for example, if
 the premise was too far from the serving exchange or cabinet, and includes delivery of basic
 broadband funded by BDUK but is treated as out of scope of the evaluation.
- Dates: A further 4,984 premises upgraded were dropped from the dataset because the reported date
 of the upgrade occurred before the programme began or was not clear (e.g. the quarter quoted was
 larger than 4). It is assumed that these represent data entry errors, and account for a negligible share
 of the overall number of premises upgraded.
- Matching to Connected Nations: Finally, 33,222 premises upgraded were associated with postcodes that were not present in the Connected Nations dataset. These were also excluded from the analysis as there were no observations of the outcomes of interest.
- Allocation to delivery years: Allocation of delivery to specific years was complicated by the changing times across years from which the Connected Nations snapshots were taken (as described above). To address this issue, delivery between July 2016 and April 2017 were assigned to 2017 (a

⁴⁹ 30Mbit/s was the threshold applied for Phase 3.

period of 10 months), and delivery between May 2017 and August 2018 were assigned to 2018 (a period of 16 months).

The table overleaf maps the resultant sample of upgraded premises to the status of areas described in Table 1.1. Sixty four percent of claimed delivery under Phase 1 and 91 percent under Phase 2 was reported in postcodes included in the build plans of local schemes defined in the SCT. A large share of this apparent discrepancy for Phase 1 and 2 is accounted for by delivery recorded in those areas that have been excluded from the analysis (20 percent under Phase 1 and one percent under Phase 2).

The data also points to a level of claimed delivery in areas that were outside the build plan:

- Delivery in other white postcodes: Just over 400,000 premises upgraded in Phase 1 were claimed on white postcodes outside of the build plan defined in the SCT. This fell to 29,000 for Phase 2 and 868 for Phase 3. Discussions with BDUK suggested that this would occur primarily where the engineers reached a cabinet and found that they could not upgrade, e.g. for technical reasons or if there was a planning constraint. In this case, the engineers may move on to the next eligible postcode. In principle, these changes should have been captured in the SCT via a change request, though in practice the SCTs do not provide a perfect record. Reinvestments also may not have been fully captured in change requests. These postcodes were reallocated to the set of postcodes benefitting from BDUK subsidies.
- Delivery in ineligible areas: Only a small fraction of premises upgraded located in ineligible areas, i.e. the grey, black, and de-scoped postcodes or postcodes in ineligible local authorities. Discussions with BDUK suggested that this would primarily occur because the serving cabinets upgraded would simultaneously serve premises on white and ineligible postcodes, and providers would report the full set of premises upgraded. In the analysis, these postcodes were not reallocated to the set of postcodes considered to have benefitted from BDUK investment as suppliers did not receive a subsidy to upgrades these premises.
- Delivery on postcodes not included in the SCT: In Phase 3, 88 percent of claimed delivery was on postcodes that included in the build plans of Phase 3 contracts. However, 10 percent of claimed delivery was claimed for premises upgraded on postcodes that were not included in the SCTs. These premises were discounted from the analysis and are suspected to be premises bordering ineligible areas.

Status	Phase	e 1	Phas	e 2	Phase 3			
	Number of Premises Claimed	Percentage	Number of Premises Claimed	Percentage	Number of Premises Claimed	Percentage		
White postcode within build plan defined in SCT	2,949,323	64%	805,211	93%	78,232	88%		
White postcode out of build plan defined in SCT	400,744	9%	29,372	3%	868	1%		
Grey or Black postcode in SCT	319	0%	22,950	3%	564	1%		
De-scoped postcode or 'ineligible' LA	6,104	0%	0	0%	0	0%		
Postcodes not present in SCT or in areas with no scheme	350,622	8%	0	0%	8,781	10%		
Area excluded from analysis	925,677	20%	12,763	1%	0	0%		
Total	4,632,789	100%	870,296	100%	88,445	100%		

Table 1.2: Claimed Number of Premises Upgraded, 2013 to 2019

Source: C3 Reports, Ipsos MORI analysis.

Infrastructure data

BDUK supplied a range of other data describing the pre-programme characteristics of postcodes in the UK. These served as control variables for the analysis. These primarily described the characteristics of local networks in 2013⁵⁰ in terms of factors likely to influence the costs of upgrading serving cabinets or the final speeds attained. These variables included:

- Modelled length of the line from the serving exchange to the serving cabinet to the premise;
- Modelled length of the line from the serving cabinet to the premise;
- Modelled share of exchange only lines;
- Modelled number of delivery points at the serving exchange;
- Modelled number of delivery points at the serving cabinet (equalling zero for postcodes served by Exchange Only lines);
- Whether the postcode was within the Virgin Media or K-COM footprint in 2013;
- Number of residential and non-residential delivery points on the postcode in 2013.

Some postcodes were served by more than one cabinet. In these cases, the variables above were calculated as a weighted average across the cabinets serving the postcodes, with the share of delivery points served by each cabinet providing the weights. The available data did not capture all factors likely to influence installation costs, such as topography or local planning constraints.

Area characteristics

A further set of control variables were collected describing the characteristics of the resident population before the programme was delivered. These included measures of the size of the working age population

⁵⁰ The modelling has not been updated since 2013 and therefore no more recent data was available to update this.

and population aged 65 plus at the output area level derived from the 2011 Census that were also used to calculate measures of population density. An indicator of whether a postcode was located within rural or urban areas was derived from the ONS Postcode Lookup table. Finally, measures of the economic performance of areas in 2013 were derived from the Annual Survey Hours and Earnings and the Annual Population Survey respectively, including gross weekly earnings, and unemployment and employment rates. The latter were observed at the level of the local authority district.

LFFN and Gigabit Connectivity Voucher Scheme

Finally, BDUK supplied the postcodes associated with premises that had received a Gigabit Connectivity Voucher to control for their possible influence over the outcomes of interest. These entitle recipients to a subsidy towards a gigabit capable connection (typically FTTP) which would lead to similar outcomes as those expected through the Superfast Programme. There were 2,135 vouchers issued in 2018 and 11,901 in 2019. These were spread across 1,018 postcodes in 2018 and 6,102 in 2019. In total 6,833 postcodes benefitted from at least one voucher.

The postcodes within 1km of Wave One Local Full Fibre Networks Programme (LFFN) areas were also matched into the data with FTTP rollout targeted in these areas as part of the LFFN. These encompassed 64,863 postcodes in total in areas of West Sussex, Tameside, across the Pennines (Trans-Pennine Initiative (TPI) areas) and around schools in rural areas benefitting from the Public Sector Building Upgrades scheme. In total, 7,400 postcodes and 106,401 premises delivered to through the Superfast programme were within 1km of FTTP coverage or connections brought forward with support from LFFN. Details of Wave Two and Wave Three schemes were unavailable.

Annex B: First probit progressions – propensity score matching models (Phase 3)

Table 6.4: PSM probit regression outputs

Treatment group	D	elivered as	of Sep 2019		All in build plans					
Controls included	No speed co	ntrols	Speed controls	included	No speed cor	ntrols	Speed controls	included		
Variable	Coef	P>z	Coef	P>z	Coef	P>z	Coef	P>z		
Number of suppliers in postcode (2012)	-1.36	0.00	-1.36	0.00	-0.70	0.00	-0.01	0.05		
Number of suppliers in postcode (2016)	1.18	0.00	1.22	0.00	0.73	0.00	0.02	0.00		
Superfast % of premises (2014)	0.00	0.00	0.00	0.07	0.00	0.00	-0.02	0.06		
Superfast % of premises (2015)	-0.01	0.00	-0.01	0.00	0.00	0.00	0.00	0.89		
Superfast % of premises (2016)	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.07		
NGA % or premises (2012)	-0.07	0.02	-0.07	0.19	-0.15	0.00	-0.01	0.08		
NGA % or premises (2013)	-0.09	0.01	-0.18	0.00	-0.04	0.05	0.01	0.00		
NGA % or premises (2014)	0.48	0.00	0.48	0.00	0.31	0.00	-0.01	0.15		
NGA % or premises (2015)	-0.08	0.00	-0.01	0.86	0.08	0.00	0.00	0.11		
NGA % or premises (2016)	0.00	0.97	0.08	0.05	-0.01	0.41	-0.01	0.05		
% of postcodes in LA with NGA, (2013)	-0.41	0.00	-0.47	0.00	-0.44	0.00	0.00	0.67		
% of postcodes in LSOA with NGA, (2013)	0.25	0.00	0.33	0.00	-0.02	0.21	0.00	0.06		
Line Length (m)	0.01	0.19	-0.01	0.22	0.00	0.72	0.00	0.00		
Final speed	0.01	0.00	0.00	0.83	0.01	0.00	-0.83	0.00		
Premises with EO lines 2013	0.00	0.60	0.00	0.84	0.00	0.00	0.83	0.00		
Delivery points at serving exchange	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05		
Delivery points at serving cabinet	0.00	0.00	0.00	0.03	0.00	0.01	0.00	0.00		
Virgin Media availability	-1.19	0.00	-1.26	0.02	-0.97	0.00	0.00	0.00		

Estimated Upgrade Cost (£)	0.00	0.10	0.00	0.46	0.00	0.00	-0.09	0.00
Cost Per Premises Upgraded	0.00	0.20	0.00	0.06	0.00	0.99	-0.13	0.00
Working Age Population	0.00	0.03	0.00	0.50	0.00	0.00	0.24	0.00
Population Aged 65 and Over	0.00	0.00	0.00	0.04	0.00	0.00	0.12	0.00
(Log) Population Density	0.18	0.00	0.19	0.00	0.07	0.00	0.10	0.00
(Log) Premises Density	-0.12	0.00	-0.16	0.01	-0.03	0.04	-0.47	0.00
Gross Weekly Wages (in LA)	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.29
Employment Rate (in LA)	0.08	0.00	0.08	0.00	0.08	0.00	-0.01	0.06
Unemployment Rate (in LA)	0.06	0.00	0.05	0.00	0.05	0.00	0.01	0.00
Number of premises with superfast available (2014)	0.00	0.17	-0.01	0.08	0.00	0.08	0.00	0.00
Number of premises with superfast available (2015)	0.01	0.04	0.00	0.19	0.00	0.09	0.00	0.00
Number of premises with superfast available (2016)	0.00	0.36	0.00	0.60	0.00	0.93	-0.69	0.00
Number of superfast connections (2016)			-0.02	0.02			0.00	0.39
Number of superfast connections (2015)			0.03	0.05			0.00	0.00
Number of superfast connections (2014)			0.02	0.38			0.00	0.00
Average Download Speeds (2012)			0.02	0.02			0.18	0.00
Maximum Download Speeds (2012)			0.00	0.95			-0.14	0.00
Average Download Speeds (2013)			-0.03	0.01			0.00	0.00
Maximum Download Speeds (2013)			0.02	0.00			0.07	0.00
Average Download Speeds (2014)			-0.03	0.00			0.05	0.00
Maximum Download Speeds (2014)			0.01	0.00			-0.03	0.00
Average Download Speeds (2015)			0.00	0.90			0.00	0.94
Maximum Download Speeds (2015)			0.00	0.67			0.00	0.11
Average Download Speeds (2016)			0.00	0.30			0.00	0.01

Maximum Download Speeds (2016)			0.00	0.00			-3.52	0.00
Average Upload Speeds (2014)			0.01	0.80			0.00	0.91
Average Upload Speeds (2015)			-	-			-	-
Average Upload Speeds (2016)			0.01	0.31			0.02	0.01
Constant	-5.49	0.00	-5.14	0.00	-4.46	0.00	0.00	0.00

Annex C: Control group regression results

Table 6.5: State aid control group approach predictive regression results

	Model 1	Model 2	Model 3	Model 4
Model	Logit	OLS	OLS	OLS
Outcome	NGA availability in 2019	Superfast availability in 2019	FTTP availability in 2019	Number of suppliers in 2020
Number of suppliers in 2012	0.102	3.934***	-7.13***	0.077***
Number of suppliers in 2016	-0.094	-2.141***	7.538***	0.879***
Superfast access in 2014	-0.019***	-0.012***	-0.079***	0*
Superfast access in 2015	-0.014***	0.006**	0.185***	0***
Superfast access in 2016	0.019***	0.546***	-0.14***	0***
NGA access in 2012	0.694***	-0.845***	-1.644***	-0.014***
NGA access in 2013	-0.252***	0.448***	0.692***	0.015***
NGA access in 2014	0.738***	-2.154***	-2.861***	0.009***
NGA access in 2015	1.084***	4.452***	3.074***	-0.016***
NGA access in 2016	3.033***	-19.738***	-3.067***	0.011***
% of postcodes in LA with NGA, 13	0.434***	7.592***	8.957***	0.096***
% of postcodes in LSOA with NGA, 13	-0.231***	-3.032***	2.087***	0.019***
Line Length (m) / Log Line Length	0.032***	-0.925***	-0.08***	0.004***
Final speed / Log Line Length	0.031***	0.435***	0.059***	0.001***
Premises with EO lines 2013	0.002***	0.034***	-0.037***	-0.001***
Delivery points at serving exchange	0**	0***	0***	0***
Delivery points at serving cabinet	0.002*	-0.001***	-0.002***	0***
Virgin Media availability	1.323***	-1.88***	-6.607***	0.018***
Estimated Upgrade Cost (£)	0***	0***	0*	0**
Cost Per Premises Upgraded	0***	0***	0.001***	0***
Working Age Population	0***	0.011***	0.014***	0***
Population Aged 65 and Above	-0.001	0.029***	-0.017***	0***
Population Density (log)	0.049***	-2.932***	-6.231***	-0.019***
Premises Density (log)	0.056	5.602***	6.331***	0.032***
Gross Weekly Wages (in LA)	0.004*	0.024***	-0.007***	0***
Employment Rate (in LA)	0.007***	0.168***	-0.221***	0.004***
Unemployment Rate (in LA)	0.077***	0.56***	-0.493***	0.001***
FTTP availability 2017 / number of premises	0.107***	0.193***	1.745***	0.003***
Superfast availability 2014 / number of premises	0.041***	-0.041***	0.139***	0
Superfast availability 2015 / number of premises	0.013***	0.002	-0.263***	0***
Superfast availability 2016 / number of premises	-0.006***	0.011**	0.044***	0.001***
Constant	-4.105***	4.283***	31.443***	-0.253***

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Observations	699,153	699,153	699,153	699,153
R Squared	0.484	0.541	0.306	0.916

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

Annex D: Regression based difference-in-difference tables

Figure 6.1: Regression based DiD results part 1 (treatment postcodes include those upgraded by Sep 2019)

Outcome	(Change in NGA	A	(Change in SFE	3	Change in FTTP			Change in <u>number of</u> suppliers		
		Postcode			Postcode			Postcode			Postcode	
Controls included Treatment (upgraded	No Controls	Controls	All Controls	No Controls	Controls	All Controls	No Controls	Controls	All Controls	No Controls	Controls	All Controls
by Sep 2019) Total GBVS vouchers	0.107***	0.0265***	0.0265***	25.21***	10.51***	10.64***	28.69***	23.48***	23.85***	0.202***	0.205***	0.208***
in postcode Total GBVS vouchers			-0.00205			0.606*			-1.047***			-0.00569
in OA Total GBVS vouchers			0.00999***			0.282			1.808***			0.0183***
in LSOA PSBU school within			-0.00218***			0.178*			0.168**			0.000517
100m PSBU school within			-0.00619			-9.631*			-3.521			0.175**
500m			0.0524**			4.778			0.00856			-0.133***
PSBU school within 1000m			-0.00483			-5.174**			-13.02***			-0.0318
Number of suppliers present in 2012		-0.0124***	-0.0126***		-4.747***	-4.730***		-20.64***	-20.55***		0.0870***	0.0877***
Number of suppliers present in 2016		0.0241***	0.0244***		6.893***	6.895***		21.56***	21.53***		-0.123***	-0.124***
Superfast coverage (2014)		0.000154**	0.000156**		-0.0415***	-0.0410***		-0.0551***	-0.0543***		0.000264**	0.000277**
Superfast coverage (2015)		- 0.000600***	- 0.000596***		0.0202**	0.0202**		0.0141*	0.0135*		- 0.000536***	- 0.000544***
Superfast coverage (2016)		0.000139***	0.000135**		-0.490***	-0.490***		-0.0662***	-0.0658***		0.000338***	0.000342***
NGA coverage (2012)		-0.00946***	-0.00961***		-1.312***	-1.284***		0.0773	0.192		-0.00982*	-0.00897
NGA coverage (2013)		0.00338	0.00361		0.255	0.315		2.237***	2.303***		0.0269***	0.0278***
NGA coverage (2014)		-0.0297***	-0.0298***		0.0678	-0.00643		-0.635	-0.807		-0.0276***	-0.0295***
NGA coverage (2015)		0.0448***	0.0449***		4.093***	4.158***		1.867***	2.022***		-0.0361***	-0.0343***
NGA coverage (2016) NGA coverage in LA		-0.745***	-0.744***		-18.03***	-17.99***		-1.047**	-1.003**		0.0149**	0.0153**
(2016) NGA coverage in		0.0497***	0.0497***		11.83***	11.66***		14.14***	13.68***		0.0531***	0.0496***
LSOA (2016)		-0.0139***	-0.0141***		-1.935***	-1.979***		0.613	0.535		0.00813	0.00699
Line length (log)		-0.000590	-0.000632		-0.980***	-0.995***		0.0888	0.0607		0.00481***	0.00466***
Line speed (log)		0.00265***	0.00265***		0.456***	0.454***		0.151***	0.150***		0.000663	0.000663
Exchange only lines Exchange delivery		6.93e-05	7.25e-05		0.0615*** -4.96e-	0.0617*** -4.90e-		0.0319** -9.50e-	0.0326*** -9.32e-		- 0.000812***	- 0.000799***
points		-2.00e-07**	-2.00e-07**		05***	05***		05***	05***		5.56e-07*** -3.70e-	5.61e-07*** -3.49e-
Cabinet delivery points		2.56e-05***	2.58e-05***		-0.000494	-0.000408		-0.000958	-0.000758		05***	05***

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Virgin Media coverage		-0.0118***	-0.0119***		-2.576***	-2.564***		-5.923***	-5.910***		0.0436***	0.0436***	
Total cost to upgrade cabinet in 2013		3.17e-07***	3.15e-07***		7.91e-05***	7.91e-05***		2.32e-06	2.24e-06		-1.09e-07	-1.12e-07	
Cost per premise to													
upgrade cabinet in 2013		-2.90e-07	-3.19e-07		0.000380***	0.000375***		0.000728***	0.000725***		6.56e-06***	6.54e-06***	
Working age		-2.900-07	-3.196-07		0.000380	0.000375		0.000728	0.000725		0.508-00	0.540-00	
population		3.52e-06	1.65e-06		0.00599***	0.00593***		0.00675***	0.00687***		6.98e-05***	6.99e-05***	
Population 66+		8.04e-05***	8.49e-05***		0.0212***	0.0216***		-0.0220***	-0.0221***		- 0.000398***	- 0.000396***	
Population density		0.040 00	0.400 00		0.0212	0.0210		0.0220	0.0221		0.000000	0.000000	
(log)		-0.00411	-0.00341		-1.906***	-1.810***		-6.413***	-6.228***		-0.0308***	-0.0291***	
Premises density (log)		0.0121***	0.0114***		4.601***	4.515***		6.145***	5.995***		0.0326***	0.0312***	
Weekly wages		0.000243***	0.000245***		0.0350***	0.0349***		0.0208***	0.0203***		0.000200***	0.000197***	
Employment rate		-0.000484**	-0.000525**		-0.0922***	-0.0953***		-0.437***	-0.442***		0.00463***	0.00455***	
Unemployment rate		0.00195***	0.00193***		0.0372	0.0484		-0.412***	-0.383***		0.00374***	0.00394***	
FTTP premises (2017)		0.000994***	0.000998***		0.106***	0.107***		-0.474***	-0.471***		0.00354***	0.00356***	
SFB premises (2014)		-0.000262*	-0.000271*		-0.0443**	-0.0455**		-0.00425	-0.00493		-0.000109	-0.000118	
SFB premises (2015)		0.00106***	0.00105***		0.0219	0.0215		0.102***	0.102***		0.000707**	0.000706**	
		-	-		0.00000	0.00040		0.0000***	0.0002***		0.000007	0.000000	
SFB premises (2016)		0.000959***	0.000950***		-0.00282	-0.00210		-0.0880***	-0.0883***		-0.000237	-0.000238	
Constant	0.111***	0.494***	0.495***	13.79***	19.18***	19.29***	4.775***	27.99***	28.21***	0.0766***	-0.331***	-0.329***	
Observations	60,597	56,085	56,085	60,597	56,085	56,085	60,579	56,085	56,085	60,540	56,085	56,085	
R-squared	0.011	0.685	0.686	0.057	0.481	0.482	0.138	0.229	0.234	0.034	0.056	0.058	1

Figure 6.2: Regression based DiD results part 2 (treatment postcodes include all in build plans)

Outcome	(Change in NG	A	(Change in SFE	3	Change in FTTP			Change in number of suppliers		
Cutoonic		Postcode			Postcode			Postcode		Change	Postcode	
Controls included	No Controls	Controls	All Controls	No Controls	Controls	All Controls	No Controls	Controls	All Controls	No Controls	Controls	All Controls
Treatment (all in build plan) Total GBVS vouchers	0.328***	0.0314***	-0.0182***	-0.0180***	6.059***	-3.164***	-3.131***	3.535***	1.571***	1.637***	0.0486***	0.0539***
in postcode Total GBVS vouchers				-0.00273			0.505			-0.570**		
in OA Total GBVS vouchers				0.0120***			0.572**			1.652***		
in LSOA West Sussex LFFN				-0.00358***			-0.0112			0.102*		
west Sussex LFFN within 500m West Sussex LFFN				-0.0101			-30.75			-13.55		
within 1000m PSBU school within				0.0289			1.579			8.971		
100m PSBU school within				0.00538			-2.634			-1.321		
500m PSBU school within				0.0893***			8.125***			-0.511		
1000m				-0.0636***			-4.354**			-3.337**		
TPI within 100m				-0.0251			-26.37			10.21		
TPI within 500m				0.00504			20.68			0.324		
TPI within 1000m				0.0475			-8.184			-6.590		
Number of suppliers present in 2012			-0.0232***	-0.0232***		-8.595***	-8.606***		-18.60***	-18.62***		0.0312***
Number of suppliers present in 2016			0.0294***	0.0295***		8.996***	9.014***		18.74***	18.78***		-0.0612***
Superfast coverage (2014)			0.000198***	0.000199***		-0.00113	-0.000850		-0.0398***	-0.0394***		-1.00e-05
Superfast coverage (2015) Superfast coverage			- 0.000442***	- 0.000441***		0.0357***	0.0360***		0.0295***	0.0297***		0.000479***
(2016)			2.59e-05	2.37e-05		-0.478***	-0.478***		-0.0738***	-0.0740***		0.000104
NGA coverage (2012)			-0.00251	-0.00246		-0.804**	-0.802**		-0.698***	-0.670***		-0.00923**
NGA coverage (2013)			0.00939***	0.00951***		0.653	0.676*		1.328***	1.359***		0.0157***
NGA coverage (2014)			-0.0266***	-0.0267***		-2.427***	-2.443***		0.164	0.122		-0.00388
NGA coverage (2015)			0.0717***	0.0716***		5.525***	5.538***		0.0317	0.0936		-0.0622***
NGA coverage (2016) NGA coverage in LA			-0.717***	-0.717***		-16.92***	-16.88***		-1.216***	-1.173***		0.0179***
(2016) NGA coverage in			0.0241***	0.0240***		7.582***	7.534***		8.196***	8.042***		0.0255***
LSOA (2016)			-0.0292***	-0.0294***		-2.183***	-2.199***		2.333***	2.300***		0.00775
Line length (log)			-0.00149**	-0.00152**		-1.023***	-1.027***		-0.00438	-0.0155		0.00387***
Line speed (log)			0.00195***	0.00195***		0.253***	0.253***		0.0897***	0.0889***		0.00134***
Exchange only lines			0.000255***	0.000259***		0.0505***	0.0508***		-0.0247***	-0.0237***		0.000758***

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Exchange delivery		L	1			1		I	i i			
points			-2.25e-07**	-2.19e-07**		-1.50e-05	-1.47e-05		-7.00e-06	-6.16e-06		1.66e-06*** -4.87e-
Cabinet delivery points			6.38e-05***	6.42e-05***		0.000530	0.000569		-0.00262***	-0.00250***		05***
Virgin Media coverage			-0.00941***	-0.00924***		-1.777***	-1.761***		-5.436***	-5.419***		0.0423***
Total cost to upgrade cabinet in 2013			4.26e-07***	4.25e-07***		9.06e-05***	9.05e-05***		-7.51e-06**	-7.92e-06**		7.36e-08
Cost per premise to												
upgrade cabinet in 2013			7.87e-07	7.68e-07		0.000223***	0.000221***		0.000294***	0.000293***		1.49e-06
Working age population			-4.16e- 05***	-4.23e- 05***		0.0164***	0.0163***		0.0141***	0.0140***		0.000136***
												-
Population 66+ Population density			0.000105***	0.000107***		0.0405***	0.0407***		-0.00245	-0.00212		0.000119***
(log)			0.00284	0.00360		-3.388***	-3.314***		-4.065***	-3.955***		0.00486
Premises density (log)			0.00238	0.00165		6.267***	6.196***		3.978***	3.877***		-0.00137
Weekly wages			0.000139***	0.000139***		0.00924***	0.00925***		0.00252*	0.00239*		0.000328***
Employment rate			0.000435**	0.000422**		0.0428	0.0414		-0.262***	-0.264***		0.00373***
Unemployment rate			0.00358***	0.00358***		0.166***	0.168***		-0.254***	-0.247***		0.000775
FTTP premises (2017)			0.000903***	0.000908***		0.0997***	0.100***		-0.525***	-0.524***		0.00299***
SFB premises (2014)			-0.000223*	-0.000228*		-0.0555***	-0.0566***		0.000665	-0.000182		0.000418*
SFB premises (2015)			0.000498***	0.000500***		-0.0463**	-0.0465**		0.0252	0.0247		0.000430
SFB premises (2016)			0.000408***	0.000409***		0.0783***	0.0791***		-0.00836	-0.00760		-0.000353*
Constant	-2.012***	0.111***	0.460***	0.461***	13.79***	21.15***	21.14***	4.775***	25.66***	25.64***	0.0766***	-0.353***
Observations	1,599,664	118,454	109,964	109,964	118,454	109,964	109,964	118,422	109,964	109,964	118,333	109,964
R-squared		0.002	0.609	0.610	0.007	0.358	0.359	0.006	0.082	0.085	0.004	0.028

Annex E: Regression based difference-in-difference tables with matched sample

Figure 6.3: Regression based DiD results with matched sample part 1 (treatment postcodes include those upgraded by Sep 2019)

Outcome	(Change in NGA	4		Change in SFE			Change in FTT	P	Change in number of suppliers			
Controls included	No Controls	Postcode Controls	All Controls	No Controls	Postcode Controls	All Controls	No Controls	Postcode Controls	All Controls	No Controls	Postcode Controls	All Controls	
Treatment (upgraded by Sep 2019) Total GBVS vouchers	0.0508***	0.0329***	0.0323***	16.02***	11.09***	11.17***	26.08***	23.07***	23.43***	0.166***	0.189***	0.194***	
in postcode			-0.0130			0.747			-0.675			0.0218	
Total GBVS vouchers in OA Total GBVS vouchers			0.0167***			0.179			1.288*			-0.00315	
in LSOA PSBU school within			-0.00401**			0.202			0.428*			0.00451	
100m PSBU school within			-0.0304			-15.58*			-2.579			-0.0490	
500m			0.0627*			5.790			-1.990			-0.110	
PSBU school within 1000m Number of suppliers			0.00773			-2.148			-10.74***			-0.155***	
present in 2012 Number of suppliers		-0.0182***	-0.0186***		-5.904***	-5.921***		-20.52***	-20.48***		0.191***	0.191***	
present in 2016 Superfast coverage		0.0331***	0.0335***		8.846***	8.868***		23.03***	23.02***		-0.177***	-0.178***	
(2014)		-1.15e-05	-1.56e-05		-0.104***	-0.106***		-0.133***	-0.135***		6.42e-05	5.36e-05	
Superfast coverage (2015) Superfast coverage		-5.05e-05	-3.93e-05		0.0488**	0.0497**		-0.0555**	-0.0556**		-0.00172***	-0.00174***	
(2016)		-0.000258**	-0.000263**		-0.564***	-0.563***		0.0243	0.0256*		0.00206***	0.00209***	
NGA coverage (2012)		-0.0350***	-0.0359***		-1.279	-1.266		4.393***	4.706***		-0.00919	-0.00393	
NGA coverage (2013)		0.00732	0.00707		-0.421	-0.387		4.821***	4.934***		0.0422**	0.0440**	
NGA coverage (2014)		-0.0568***	-0.0561***		1.297	1.331		4.473***	4.264***		-0.0589***	-0.0630***	
NGA coverage (2015)		0.0614***	0.0606***		5.527***	5.510***		-0.837	-0.653		-0.0758***	-0.0719***	
NGA coverage (2016)		-0.752***	-0.751***		-14.39***	-14.34***		-0.226	-0.228		0.0224	0.0208	
NGA coverage in LA (2016) NGA coverage in		0.104***	0.107***		25.32***	25.24***		33.48***	32.47***		-0.118***	-0.134***	
LSOA (2016)		-0.00183	-0.00138		-1.048	-1.136		-0.209	-0.400		0.0385*	0.0360*	
Line length (log)		-0.00441**	-0.00450**		-1.304***	-1.309***		0.0352	0.0341		0.00402	0.00410	
Line speed (log)		0.00143***	0.00140***		0.434***	0.431***		0.256***	0.256***		-0.000577	-0.000529	
Exchange only lines Exchange delivery		0.000620***	0.000611***		0.187*** -	0.187*** -		0.217*** -	0.221*** -		-0.00114** -2.42e-	-0.00108** -2.24e-	
points		-2.60e-07	-2.83e-07		0.000145***	0.000143***		0.000580***	0.000568***		06***	06***	
Cabinet delivery points		5.54e-05***	5.60e-05***		0.00134	0.00144		-0.00726***	-0.00715***		- 0.000163***	- 0.000164***	

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Virgin Media coverage		-0.00888	-0.00907		-1.792	-1.852		2.047	1.926		0.322***	0.321***
Total cost to upgrade cabinet in 2013		2.59e-07***	2.47e-07***		9.27e-05***	9.15e-05***		5.14e-05***	5.22e-05***		-1.34e-07	-9.34e-08
Cost per premise to upgrade cabinet in 2013 Working age		4.01e-06**	3.99e-06**		0.00106***	0.00105***		0.00132***	0.00131***		3.26e-06	2.95e-06
population		1.85e-06	-2.14e-07		-0.00426	-0.00443		0.00337	0.00394		-0.000139**	-0.000131**
Population 66+ Population density		0.000127*	0.000136**		-0.00796	-0.00719		-0.0609***	-0.0618***		- 0.000599***	- 0.000626***
(log)		0.0120	0.0122		1.582	1.691		-9.736***	-9.656***		-0.0468***	-0.0452***
Premises density (log)		-0.00238	-0.00275		1.612	1.513		8.258***	8.249***		0.0198	0.0193
Weekly wages		0.000455***	0.000457***		0.0647***	0.0649***		0.0667***	0.0660***		0.00117***	0.00116***
Employment rate		-0.00183***	-0.00195***		-0.594***	-0.602***		-1.081***	-1.064***		0.00689***	0.00736***
Unemployment rate		-0.000857	-0.00105		-1.166***	-1.166***		-1.303***	-1.246***		0.00234	0.00334
FTTP premises (2017)		0.00122**	0.00121**		0.265***	0.268***		-1.235***	-1.226***		0.00501***	0.00515***
SFB premises (2014)		0.000501	0.000474		0.0222	0.0243		-0.191**	-0.182**		-0.00337***	-0.00321***
SFB premises (2015)		2.30e-06	-6.60e-06		-0.00345	-0.00236		0.356***	0.357***		0.00627***	0.00633***
SFB premises (2016)		-0.000630*	-0.000620*		-0.0472	-0.0508		-0.201***	-0.208***		-0.00180**	-0.00193***
Constant Observations	0.166*** 14,851	0.488*** 14,851	0.498*** 14,851	22.91*** 14,851	40.34*** 14,851	40.80*** 14,851	7.210*** 14,851	56.11*** 14,851	54.39*** 14,851	0.0931*** 14,851	-0.744*** 14,851	-0.785*** 14,851
R-squared	0.004	0.695	0.695	0.034	0.450	0.451	0.109	0.320	0.323	0.024	0.098	0.101

Figure 6.4: Regression based DiD results with matched sample part 2 (treatment postcodes include all in build plans)

Outcome		Change in NG/	\	Change in SFB				Change in FTTP			Change in number of suppliers			
		Postcode		Postcode		Postcode			onunge					
Controls included	No Controls	Controls	All Controls	No Controls	Controls	All Controls	No Controls	Controls	All Controls	No Controls	Controls	All Controls		
Treatment (all in build plan) Total GBVS vouchers	-0.00708**	-0.0190***	-0.0187***	0.855***	-3.217***	-3.169***	2.398***	1.602***	1.687***	0.0494***	0.0517***	0.0528***		
in postcode Total GBVS vouchers			-0.00270			0.548			-0.745**			-0.00197		
in OA Total GBVS vouchers			0.0139***			0.638**			1.661***			0.00899**		
in LSOA West Sussex LFFN			-0.00415***			-0.0494			0.0972			0.00825***		
within 500m West Sussex LFFN			-0.00955			-30.78			-13.81			-0.0362		
within 1000m PSBU school within			0.0328			1.917			8.908			-0.142		
100m PSBU school within			-0.0120			-5.722			-1.693			0.0109		
500m PSBU school within			0.114***			9.794***			-1.281			-0.301***		
1000m			-0.0851***			-4.681**			-2.471			0.179***		
TPI within 100m			-0.0272			-26.19			10.71			0.0236		
TPI within 500m			0.00947			20.82			0.244			-0.0257		
TPI within 1000m			0.0478			-8.222			-6.807			-0.174		
Number of suppliers present in 2012		-0.0340***	-0.0340***		-9.927***	-9.936***		-20.44***	-20.46***		0.0368***	0.0364***		
Number of suppliers present in 2016		0.0390***	0.0390***		9.950***	9.966***		20.54***	20.58***		-0.0578***	-0.0570***		
Superfast coverage (2014) Superfast coverage		0.000274***	0.000274***		0.00488	0.00524		-0.0479***	-0.0474***		-0.000216*	-0.000200*		
(2015) Superfast coverage		0.000426***	0.000425***		0.0381***	0.0384***		0.0343***	0.0347***		0.000534***	0.000531***		
(2016)		-1.22e-05	-1.41e-05		-0.483***	-0.484***		-0.0705***	-0.0709***		0.000215***	0.000209**		
NGA coverage (2012)		-0.00225	-0.00220		-0.806**	-0.808**		-0.577*	-0.554*		-0.0165***	-0.0163***		
NGA coverage (2013)		0.00972***	0.00991***		0.806*	0.835*		1.072***	1.116***		0.0208***	0.0216***		
NGA coverage (2014)		-0.0304***	-0.0306***		-2.795***	-2.814***		0.850**	0.807**		-0.00691	-0.00734		
NGA coverage (2015)		0.0783***	0.0781***		6.032***	6.043***		-0.533*	-0.473*		-0.0693***	-0.0675***		
NGA coverage (2016) NGA coverage in LA		-0.719***	-0.718***		-16.91***	-16.87***		-1.024***	-0.978***		0.0154***	0.0156***		
(2016) NGA coverage in		0.0240***	0.0236***		8.009***	7.966***		8.387***	8.235***		-0.0208***	-0.0225***		
LSOA (2016)		-0.0318***	-0.0320***		-2.356***	-2.373***		2.945***	2.902***		0.00849	0.00771		
Line length (log)		-0.00209***	-0.00214***		-1.106***	-1.110***		-0.0531	-0.0607		0.00455***	0.00450***		
Line speed (log)		0.00171***	0.00172***		0.202***	0.202***		0.0899***	0.0904***		0.00139***	0.00137***		
Exchange only lines		0.000327***	0.000332***		0.0465***	0.0469***		-0.0318***	-0.0306***		0.000615***	0.000594***		

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Exchange delivery			4 45 97		0.77.00	0.50.00			0.50.05**			1.07.00***	
points		-1.54e-07	-1.45e-07		-3.77e-06	-3.53e-06		-2.68e-05**	-2.56e-05**		1.97e-06*** -4.81e-	1.97e-06*** -4.75e-	
Cabinet delivery points		8.32e-05***	8.39e-05***		0.00108	0.00112		-0.00350***	-0.00340***		05***	05***	
Virgin Media coverage		-0.00749	-0.00737		-0.693	-0.686		-3.706***	-3.737***		0.0344***	0.0337***	
Total cost to upgrade cabinet in 2013		4.66e-07***	4.65e-07***		9.62e-05***	9.60e-05***		-1.67e-06	-2.13e-06		1.28e-07**	1.21e-07*	
Cost per premise to													
upgrade cabinet in 2013		9.12e-07	8.87e-07		0.000197**	0.000195**		0.000315***	0.000314***		7.57e-07	7.73e-07	
Working age		-5.54e-	-5.63e-										
population		05***	05***		0.0198***	0.0197***		0.0163***	0.0163***		0.000151***	0.000151***	
Population 66+ Population density		0.000125***	0.000128***		0.0414***	0.0418***		-0.00478*	-0.00447*		-5.00e-05	-4.62e-05	
(log)		0.00405	0.00497		-3.486***	-3.401***		-3.825***	-3.721***		0.0163***	0.0169***	
Premises density (log)		0.000926	2.88e-05		6.566***	6.483***		3.674***	3.579***		-0.0153***	-0.0158***	
Weekly wages		0.000125***	0.000125***		0.00666***	0.00669***		-0.000877	-0.000999		0.000453***	0.000452***	
Employment rate		0.000570**	0.000566**		-0.00889	-0.00991		-0.310***	-0.310***		0.00446***	0.00445***	
Unemployment rate		0.00391***	0.00390***		0.0993*	0.100*		-0.306***	-0.299***		0.000562	0.000721	
FTTP premises (2017)		0.000858***	0.000869***		0.159***	0.160***		-0.797***	-0.795***		0.00248***	0.00249***	
SFB premises (2014)		-0.000203	-0.000210		-0.0566**	-0.0581***		0.0149	0.0139		0.000909***	0.000886***	
SFB premises (2015)		0.000487***	0.000493***		-0.0550**	-0.0552**		-0.0244	-0.0252		0.000464	0.000440	
SFB premises (2016)		- 0.000376***	- 0.000381***		0.0919***	0.0929***		0.0236*	0.0246*		-0.000540**	-0.000503**	
Constant	0.148***	0.456***	0.456***	19.09***	26.00***	25.93***	5.972***	31.26***	31.01***	0.0764***	-0.474***	-0.477***	
Observations	87,110	87,110	87,110	87,110	87,110	87,110	87,110	87,110	87,110	87,110	87,110	87,110	
R-squared	0.000	0.597	0.597	0.000	0.329	0.329	0.002	0.084	0.087	0.003	0.029	0.033	

al Appendix 1 – Reducing the Digital Divide

For more information

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