Local Full Fibre Network (LFFN) wave one: Programme evaluation

Technical Annex

Ipsos

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1 Introduction

Ipsos UK was commissioned by Building Digital UK (BDUK) in May 2018 to undertake an evaluation of the wave one projects funded through the Local Full Fibre Network (LFFN). This report is the technical annex for the final evaluation report, providing details of econometric research undertaken.

1.1 Description of the programme

The LFFN Programme was launched by BDUK in 2017 with £200 million funding. The aims of the programme were to accelerate and de-risk the deployment of the next generation of digital infrastructure, create UK digital leadership and drive productivity and growth. The programme provided funding to local bodies to achieve these aims. There were three delivery models from which local bodies can choose to apply and deliver locally:

- **Public-Sector Anchor Tenancy (PSAT):** Bringing together local public sector customers, to create enough broadband demand to reduce the financial risk of building new full-fibre networks;
- **Public-Sector Building Upgrades (PSBU):** Directly connecting public sector buildings, such as schools and hospitals; and
- **Public-Sector Asset Re-use (PSAR):** Opening up public sector assets, such as existing ducts, to allow fibre to be laid more cheaply.

A Gigabit Voucher Scheme offering full-fibre broadband connection vouchers for businesses, to increase take-up of services is operating in parallel to the three delivery models above. However, the Gigabit Voucher Scheme is subject to a separate evaluation, and is therefore not covered in this scoping study.

Wave one of the LFFN programme comprised of a selection of pilot projects for the wider LFFN programme, which aimed to demonstrate how the interventions can operate and provide learning for the remaining LFFN projects. These projects were:

- **The PSAR 'Thin Layer Model' Tameside project.** This project seeks to demonstrate how far it is feasible to deploy assets owned by the public sector to stimulate the market to increase the supply of Fibre-to-the-Premises (FTTP) connectivity.
- **The West Sussex PSAT project (otherwise known as the West Sussex Gigabit project).** This project provides public sector buildings with gigabit capable connections and seeks to use these connections as long-term tenants.
- **The Trans Pennine Initiative project.** This project also aims to demonstrate how far it is feasible to deploy assets owned by the public sector to stimulate the market to increase the supply of Fibre-to-the-Premises (FTTP) connectivity.
- **The PSBU Schools project.** This project has been delivered in partnership with Department for Education (DfE). This project aims to provide connectivity to schools, and allow operators to deliver further commercial build after the initial fibre connection to the schools.

1.2 Study aims

The key research questions for the evaluation of the LFFN wave one projects, as defined in the Invitation to Tender, are set out in the table below. These broad questions were further refined as part of an initial planning stage that was completed in May 2019, which involved the agreement of bespoke evaluation questions for each of the projects and evaluation approach. This report builds on a baseline, process and early impacts assessment that was completed in July 2019 and the interim evaluations which took place in 2020-2022.

In the summer of 2022, a series of workshops were undertaken, involving key stakeholders from BDUK and the LFFN wave one project leads. These workshops were used to focus the final evaluation on the shorter-term outputs and outcomes that were emerging from each project, including unanticipated outcomes. This was to compliment the assessment of the connectivity and socio-economic impacts that the projects were anticipated to generate as a result of the infrastructure build in the longer-term. The three key aims of the workshops were to:

- Agree what success looked like for each project in the shorter-term;
- Identify how these shorter-term outcomes could be evidenced; and
- Discuss areas of focus for the final evaluation activity to add most value.

The workshops led to minor amendments being made to the project level Theories of Change, identified topics to be explored in primary research and stakeholders to consult.

This evaluation report focuses on both the short-term outcomes around coverage and connectivity, alongside the longer-term outcomes and impacts relating to public sector service provision and economic and social outcomes.

Table 1.1: Key evaluation questions

Question area	Sub-questions
What outcomes can be attributed and were they as intended?	What is the range of local level outcomes from LFFN?
	What local level changes made a difference, were there other explanations?
	What, if any, were the wider benefits of LFFN?
	Were there any unintended outcomes?
How has LFFN achieved these outcomes?	To what extent is this affected by context or circumstance?
	How can LFFN achievements be enhanced?
What can we learn to improve future policy designs and implementation?	LFFN Programme
	Other Government broadband infrastructure policy or programmes
	Other Government future telecommunications infrastructure policy or programmes (including 5G)
	Demand-led delivery approaches

Source: BDUK Invitation to Tender

1.3 Structure of this report

The remaining sections of this Annex are structured as follows:

- Section 2 provides an overview of the methodological approach for the econometric analysis;
- Section 3 presents details of the approach used for West Sussex;

- Section 4 presents details of the approach used for Tameside;
- Section 5 presents details of the approach used for the Trans Pennine Initiative; and
- Section 6 presents details of the approach used for the Schools PSBU project.

2 Methodological approach

This section provides an overview of the overarching analytical approach which has been used to assess the impact of the LFFN projects on coverage, take-up, connection speeds and economic outcomes.

2.1 Selection of counterfactual groups

The evaluation scoping for the LFFN wave one projects established that it would be feasible to undertake quantitative quasi-experimental methods to assess the impacts of the projects.

The projects were able to provide, or the research team were able to identify shapefiles which presented the location of the LFFN funded network build for each of the projects. This allowed the research team to identify all postcodes which were within certain distances of the LFFN activity. This was undertaken at multiple levels, but all postcodes within 1km of the build were identified.

The evaluation scoping identified two potential approaches to identifying a counterfactual case for each of the projects. These were:

- Using comparisons to **matched** areas forming the focus **of unfunded and funded** schemes in **waves two and three** of the programme.
- Using comparisons to **matched** areas **not part of wave two or three applications.**

However, following an initial assessment of the wave two and wave three projects, and discussions with BDUK, the first option was deemed infeasible. This was because:

- There were significant differences between the projects funded in wave one and the subsequent waves, which made identifying counterfactual cases challenging; and
- The wave two and wave three projects had already started their build activity, and there was no assurance that the wave one projects would complete a significant period of time in advance of the wave two and three projects, which would render the comparator groups inappropriate.

Therefore, it was decided between the research team and BDUK that the second option was the most appropriate to develop counterfactual cases for the four wave one projects.

The next stage of identifying comparator areas involved the research team undertaking desk research to find areas of the UK that were similar to the intervention areas. This was a desk-based exercise, which aimed to identify high level geographic areas (such as local authorities, transport routes or groups of public sector buildings) which shared similarities to the LFFN wave one project areas. This included looking at geographic routes and information (for example whether rail routes passed through urban and rural areas, typological similarities between areas etc), connectivity data (the level of superfast, ultrafast and gigabit capable network coverage in 2016, 2017 and 2018), economic data (employment, sectors, earnings etc.) and examining potential similarities in these data sets between the LFFN wave one areas and areas not included in the LFFN programme.

The research team developed a long list of potential comparator areas based on this desk-based review. These were presented to BDUK, to collect additional insight into the potential comparator areas. For example, whether there were other publicly funded interventions that were taking place in the comparator areas, and insight into expected commercial roll out plans. This process ruled out some of the potential comparator areas.

The final stage was a discussion between the research team and BDUK about which area would be most appropriate to use. BDUK and the research team agreed on the locations to use.

2.2 Matching

Following the identification of a suitable comparator area, the research team undertook a matching exercise. This was undertaken to match the local areas where the projects have been delivered to more comparable locations within the comparator areas in year (2018) before the LFFN projects were completed.

A propensity score matching (PSM) approach was selected over other approaches to maximise the number of observations in the treatment and comparator area groups. A PSM approach generates scores of how likely a particular postcode (or output area) was included in the treatment area given its characteristics. This is done by applying a probit model to the dataset which provides a score for each postcode. Postcodes in the treatment and comparator areas are matched based on their score, with those postcodes which cannot be matched based on their score excluded from the subsequent analysis.

The research team took the following steps to create a matched comparator group:

- Collect postcode level (and output area level) data for the agreed comparator area.
- Try different specifications of the PSM model to improve the quality of the matching between the treatment and comparator groups. This was done by introducing new variables into the probit model from an original basic model (using a small number of variables).
- Select the most appropriate PSM specification, based on the quality of the match between groups and the number of observations remaining for analysis.

2.3 Regression analysis

This following fixed effects model was used to explore the impact of the LFFN wave one projects:

$$X_{it} = \beta_0 + \beta_1 P_i + \theta t + \alpha_i + \gamma_t + \epsilon_i$$

Here, the outcome variable X (for example gigabit capable coverage) for postcode i in year t is the connectivity or economic outcome. A dummy variable P_i was used to identify whether the postcode was within 1km of the LFFN build and whether the time period is before or after the LFFN intervention. This means that the effect the programme has had on gigabit capable availability (for example) is estimated by β_1.

This model allows for the inclusion of both entity fixed effects ($\boldsymbol{\alpha_i}$) which account for any time invariant observed and unobserved characteristics of postcodes. It also accounts for time fixed effects (γ_t) that account for any time specific shocks influencing connectivity across all areas. In addition, the equation includes time trends (a series of dummy variables for time periods) at the national level (t), with the coefficients θ indicating the effect of the year on the outcome.

2.4 Limitations

There are several limitations to the methodological approach described above. These are:

- **Connected Nations discontinuity:** The results make extensive use of the Ofcom Connected Nations datasets. The Connected Nations dataset is the most comprehensive dataset which provides data on broadband coverage and usage. Therefore, it has been used extensively in this research. Although Ofcom aims to ensure that each report and dataset is as accurate as possible at a point in time, the nature of the way in which data is collected makes it very difficult to ensure consistency over time. This is in part due to:

  - The suppliers who report to Connected Nations changes each year. For example, the list of suppliers who provided data to Connected Nations 2022 includes 14 suppliers who did not provide data to Connected Nations 2021 and omits four suppliers who did.

  - There may also be errors or missing data in the detailed local data provided by these suppliers at different points in time which are difficult for Ofcom to detect.

  - There may have been a delay reporting when an area received coverage.

  - Between September 2020 and January 2022, Virgin Media made a technological upgrade which meant all premises on its network (15.5 million premises) were able to access gigabit-capable broadband. This made a substantial contribution to the large increase in the proportion of premises that can access gigabit-capable broadband over this period, from 25 percent in September 2020 to 65 percent in January 2022 that did not relate to the deployment of new infrastructure and served only to move previously ultrafast only premises to gigabit capability.

  - Changes in the methodology used by Ofcom to identify premises, with the addition of more premises in areas diluting coverage in some places. This means that it is not possible to clearly separate the impact of changes in the data to those coverage driven by LFFN.

  These data issues may not be important if undertaking longitudinal analysis for large areas with thousands of properties, however they become a much greater issue when carrying out longitudinal analysis for small areas such as postcode areas. These challenges should be considered when interpreting the results presented.

- **Challenges with approach to measure impact:** The approach to measure the impact of the four projects, has some limitations. The first of these is that the geographic boundary to measure the impact of the project has been selected at 1km away from the network build. However, some of the projects aimed to provide greater gigabit connectivity to a wider region. The geographic area was selected as the areas closer to the network build were anticipated to be the most likely to benefit from the project, and measuring the impact at a wider geographic area would be difficult (at a larger geographic level the impact would need to be much larger to be detectable in the analytical framework). Therefore, the analysis focuses on a smaller geographic area for practical reasons, while it should be acknowledged that some impacts of the project may be overlooked. A second limitation is the selection of a comparator area, which has been selected to closely match the characteristics of the project area. However, it was not possible to know at the point of selection what network provider commercial roll out plans were, which could mean that there were unobservable differences between the project and comparator areas. The research team attempted to account for these unobservable differences via qualitative information collected during discussions with BDUK, but this may not have accounted for all differences between the groups.

- **Limitations given progress of projects:** The completion of three of the four LFFN wave one projects were slightly slower than anticipated. There were a variety of reasons for the slow progress which are discussed in this report. A challenge for the evaluation of these projects is that, because of these delays, there are fewer years between the project completion and the final evaluation research than expected, meaning outcomes have had less time to materialise. Therefore, it is still possible that some of the longer-term outcomes and impacts for the projects could be realised in the future and it is still early to form conclusions about the wider impact of some projects. For example, take-up and economic impacts could be expected to be achieved four to five years post completion, meaning these would not have been fully achieved or be observable in the data at this stage. The initial evaluation plan, developed in 2018, did not account for these delays and also anticipated that the longer-term impacts of the programme may materialise sooner than has proved to be the case. Therefore, economic impacts should not be expected to be observed in this evaluation, but the assessment has been undertaken to provide a complete assessment of potential impacts of the intervention. The framework used here could be utilised in the future to investigate if the longer-term impacts are realised in future years. Further, the investment in the LFFN wave one projects in local areas is relatively modest to produce a transformative economic impact. Therefore, as well as the impacts being longer-term, it would also be expected that any impacts would be relatively small. Table 2.1 below presents the time period when projects were completed and the time between project completion and the final evaluation activity.

Table 2.1: Progress of projects

Project	Baseline (prior to build activity)	Project completed	Interim evaluation research	Years post network build / connections completion for final evaluation fieldwork
West Sussex	2017	2019 – 2020 (all buildings connected by Q3 2020/21)	Late 2020	2
Schools	2017	2018 – 2020 (most schools connected in 2019)	Early 2022	1.5 to 2.5
TPI	2017	2019	Late 2020	3
Tameside	2017	2018	Early 2020	4

- Limitations of matching approach: Undertaking a PSM to improve the comparability of the treatment and comparator areas has some limitations. These are that the approach is data intensive, it discards observations in both the treatment and comparator areas that are not matched. A reduction in the number of observations reduces the statistical power of the regression models, despite increasing the comparability of the two areas. Therefore, large samples are needed, and the LFFN projects were delivered in relatively small local areas, meaning that the statistical power of the models is low. Secondly, the matching between treatment and comparator areas can only use variables where data exists, but there are factors which could influence broadband rollout and economic performance where data does not exist (such as broadband rollout plans). Therefore, the matching can only be as good as data availability.

2.5 Primary research

Alongside the statistical analysis described above, the research team undertook primary research to collect evidence of the outputs and outcomes achieved by the LFFN wave one projects. The primary research was undertaken as semi-structured, qualitative interviews. These were undertaken via Microsoft Teams. The list of individuals selected to participate in the primary research was developed collaboratively between BDUK, the research team and the project leads. The interviewees included:

- Local project leads;
- BDUK officers responsible for the projects;
- Stakeholders in organisations that have benefitted from the project network build;
- Network providers responsible for delivering the civil works as part of the projects;
- Wider local stakeholders with knowledge of the area / project and its outcomes; and
- Network providers not involved in the delivery of any LFFN project.

The semi-structured qualitative interviews covered topics including the progress the projects had made towards achieving their stated objectives, any challenges they faced and how these were overcome, lessons learned from the delivery of the project, outputs and outcomes achieved, factors contributing to the achievement of outputs and outcomes and how the projects can contribute to longer-term ambitions.

The findings from the qualitative interviews were analysed thematically. A matrix was developed which highlighted key themes to analyse, and the findings from each interview entered into the matrix. The matrix was analysed to identify common themes across the interviews.

3 West Sussex

This section provides details of the econometric analysis undertaken for the West Sussex Gigabit project. It provides an initial description of the areas considered for the comparator group, and then presents the results of the matching exercise and regression analysis.

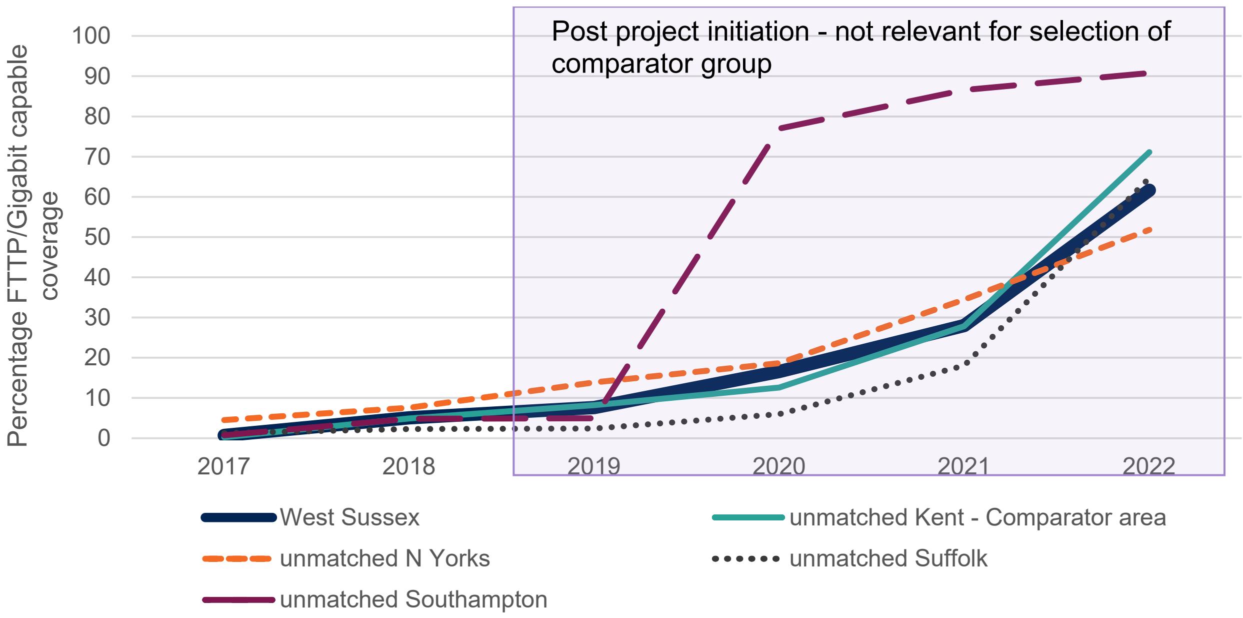
3.1 Areas considered for comparator group

Following the initial desk research phase to identify potential comparator areas, the following areas were proposed for discussion between BDUK and the research team:

- Kent (selected as the comparator area)
- Southampton
- Suffolk
- North Yorkshire

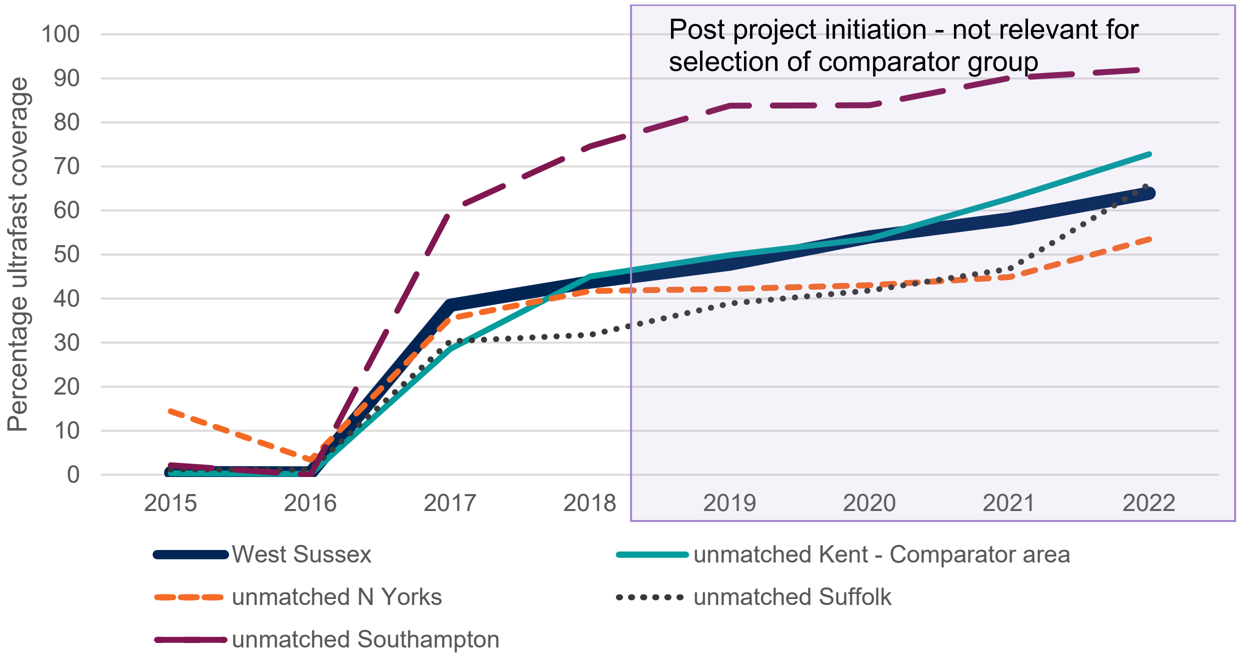
The figures below present the trend in ultrafast and gigabit capable coverage in the West Sussex area and the potential comparator areas from the Connected Nations dataset. This shows that in 2019, all the areas except for Southampton had potential as a comparator area. Areas of Southampton were materially different from West Sussex due to differences in the trends of ultrafast broadband coverage between Southampton and West Sussex from 2017 onwards, and was therefore excluded as a potential comparator area. Areas of Kent were selected following the discussions with BDUK.

Figure 3.1: FTTP/Gigabit capable coverage in West Sussex and all potential comparator areas, 2017-2022



Source: Ofcom Connected Nations

Figure 3.2: Ultrafast broadband coverage in West Sussex and all potential comparator areas, 2017-2022



Source: Ofcom Connected Nations

Following the West Sussex project initiation, there has been a further divergence in the gigabit capable coverage and ultrafast coverage in Southampton compared to all the other potential comparator areas and West Sussex. The commonality in trends across Kent, North Yorkshire and Suffolk suggests all three could have been a reasonable comparator group, as it strongly suggests what would have happened in the absence of the project. Therefore, the use of Kent as a comparator group appears valid.

3.2 Propensity Score Matching

The results of the probit models associated with the matching models are set out in the table below. Prior to the matching exercise, postcodes that had received Gigabit vouchers were removed from both the treatment and comparator population. The table shows that there was limited variation in connectivity indicators, rural urban indicators and population density prior to the matching exercise. The differences prior to matching were around digital employment and jobs density which were both narrowed in the matching exercise.

The table shows that there were six indicators where the matching exercise led to an increase in bias: average data use in 2018, the number of residential delivery points, line length, population and premise density and the hamlet category of rural urban classification. Some of these variables showed particularly large increases in bias, for example a 95 percent increase for line length. However, all of these indicators had a relatively low level of initial bias (initially under four percent difference). Therefore, the increase in bias still leaves a relatively small difference between the treatment and comparator group. Many more of the indicators have seen a reduction in bias of over 80 percent (for example distance from the exchange and digital employment). Overall, there has been a reduction in the bias between the two samples, with a median reduction in bias of 35.7 percent. As the initial samples displayed a high level of similarity, therefore the matching exercise would be expected to have a relatively small impact on bias.

Table 3.1: Propensity Score Matching variable results for West Sussex and Kent

Variable		Mean		% bias	Reduction in bias	t-test	p>|t|
		Treatment (West Sussex)	Comparator (Kent)				
Superfast Broadband coverage 2018	Unmatched	98.81	98.65	1.7		1.10	0.27
	Matched	98.78	98.92	-1.5	11.1	-1.12	0.26
Ultrafast Broadband coverage 2018	Unmatched	43.83	45.19	-2.8		-1.78	0.08
	Matched	43.88	44.51	-1.3	54.1	-0.89	0.37
FTTP coverage 2018	Unmatched	4.99	4.89	0.5		0.34	0.74
	Matched	5.01	5.17	-0.8	-46.1	-0.53	0.60
Median download speed 2018	Unmatched	42.30	41.39	3.2		2.09	0.04
	Matched	42.16	42.55	-1.4	56.6	-0.88	0.38
Median upload speed 2018	Unmatched	6.08	5.98	2.6		1.68	0.09
	Matched	6.05	6.12	-1.8	32.4	-1.23	0.22
Average data usage 2018	Unmatched	238.59	243.47	-2.9		-1.81	0.07
	Matched	236.71	242.61	-3.5	-20.8	-2.85	0.00
Residential delivery points	Unmatched	20.49	20.54	-0.4		-0.27	0.79
	Matched	20.50	20.44	0.4	-3.0	0.30	0.77
Non-residential delivery points	Unmatched	0.80	0.86	-2.1		-1.34	0.18
	Matched	0.80	0.86	-2.0	2.7	-1.45	0.15
Distance from exchange	Unmatched	1193.80	1233.70	-5.5		-3.58	0.00
	Matched	1187.20	1181.90	0.7	86.6	0.52	0.61
Distance from cabinet	Unmatched	187.32	193.92	-4.3		-2.77	0.01
	Matched	187.71	188.73	-0.7	84.6	-0.48	0.63
Exchange delivery points	Unmatched	1177.90	1219.20	-5.7		-3.71	0.00
	Matched	1171.20	1164.40	0.9	83.6	0.66	0.51
Exchange cabinet distance	Unmatched	1821.10	1883.40	-6.2		-4.01	0.00
	Matched	1812.50	1804.70	0.8	87.6	0.54	0.59
Line length	Unmatched	19735.00	19411.00	3.6		2.29	0.02
	Matched	19737.00	20371.00	-7.0	-95.1	-4.90	0.00
Cabinet delivery points	Unmatched	405.29	411.73	-4.1		-2.63	0.01
	Matched	404.73	398.78	3.8	7.7	2.61	0.01
Exchange only lines	Unmatched	0.25	0.21	1.9		1.22	0.22

Variable		Mean		% bias	Reduction in bias	t-test	p>|t|
		Treatment (West Sussex)	Comparator (Kent)				
	Matched	0.24	0.27	-1.2	39.0	-0.76	0.45
Virginmedia coverage	Unmatched	0.43	0.41	5.1		3.24	0.00
	Matched	0.43	0.42	2.7	47.4	1.86	0.06
Population density	Unmatched	4281.30	4250.90	1.1		0.72	0.47
	Matched	4285.00	4327.40	-1.5	-39.5	-1.05	0.29
Premise density	Unmatched	2546.40	2526.20	1.1		0.72	0.47
	Matched	2550.70	2582.80	-1.8	-58.7	-1.20	0.23
Digital employment	Unmatched	0.88	0.59	20.8		12.67	0.00
	Matched	0.70	0.75	-3.3	84.0	-3.15	0.00
Jobs density	Unmatched	1909.70	1634.30	9.5		6.05	0.00
	Matched	1929.70	1983.00	-1.8	80.6	-1.15	0.25
City / town category	Unmatched	0.98	0.97	4.8		3.14	0.00
	Matched	0.98	0.97	2.3	52.6	1.65	0.10
Town fringe category	Unmatched	0.02	0.02	-3.5		-2.29	0.02
	Matched	0.02	0.02	-0.7	81.3	-0.48	0.63
Village Category	Unmatched	0.00	0.00	-2.6		-1.71	0.09
	Matched	0.00	0.00	-2.1	18.4	-1.50	0.13
Hamlet category	Unmatched	0.00	0.00	-2.6		-1.72	0.09
	Matched	0.00	0.00	-3.4	-32.1	-2.34	0.02

3.3 Regression results

The tables below present the results from the econometric analysis described above. As presented in the main report, this suggests that the West Sussex PSAT project may have led to a decrease in the speed of gigabit capable networks in the area immediately surrounding the LFFN project network build. The median upload and download speeds will have been affected by lower speed contracts or fewer high speed contracts taken up by customers on the networks available in both West Sussex and comparison postcodes. All of the regression models show statistically significant (mainly) positive coefficients for the years included in the model. This indicates that there are factors in each year which have had a positive impact on the outcome (for example coverage, download and upload speed) influence for each year one baseline year) across both the treatment and comparator areas when compared to the first year in the model (usually 2015). For example, the models indicate that across both areas, ultrafast coverage was 71 percent higher in 2022 than in 2015. The year coefficients for the coverage models (Model 1 and 2) for the West Sussex PSAT project are broadly in line with the Tameside PSAR project, which would be expected as both projects are targeted in built up areas. The year coefficients are slightly higher than for the Trans Pennine Initiative, which has a combination of urban and rural locations, and the LFFN PSBU Schools project, which is targeted at more rural areas.

Table 3.2: West Sussex Broadband coverage regression results

Variable	Model 1: Gigabit capable coverage	Model 2: Ultrafast coverage	Model 3: Median download speed	Model 4: Median upload speed	Model 5: Maximum download speed	Model 6: Maximum upload speed
LFFN impact	-0.847*	-4.172***	-0.125	-0.314***	-11.40***	-0.0341
2016		-0.169***	6.681***	0.524***	20.84***	-1.524***
2017		35.30***	14.23***	3.047***	30.65***	2.259***
2018	4.858***	43.84***	19.40***	3.937***	31.99***	3.027***
2019	7.588***	52.41***	14.30***	3.205***	80.04***	3.335***
2020	14.27***	57.31***	38.35***	9.680***	109.7***	9.791***
2021	27.37***	63.19***	41.59***	11.17***	180.9***	20.73***
2022	67.68***	70.98***	48.79***	13.02***	325.8***	45.42***
Constant	0.234	0.362	23.28***	2.158***	90.28***	14.27***
Observations	84,974	113,316	107,940	107,940	106,982	106,958
R squared	0.471	0.463	0.475	0.182	0.395	0.071
Number of postcodes	14,172					

*Source: Ofcom Connected Nations, LFFN Management Information, Ipsos analysis; *** represents differences significant at 99 percent, ** at 95 percent and * at 90 percent*

Table 3.3: West Sussex Broadband usage regression results

Variable	Model 7: Average data usage	Model 8: Ultrafast broadband

		connections
LFFN impact	-15.15***	-0.0638***
2016		0.00585***
2017	52.45***	0.0310***
2018	100.1***	0.00677***
2019	188.3***	0.0670***
2020	-135.5***	0.570***
2021	340.9***	0.905***
2022	357.4***	1.508***
Constant	141.8***	0.00185
Observations	93,188	106,982
R squared	0.380	0.296
Number of postcodes	14,172	

*Source: Ofcom Connected Nations, LFFN Management Information, Ipsos analysis; *** represents differences significant at 99 percent, ** at 95 percent and * at 90 percent*

The level of explanatory power of the models is approximated by the goodness of fit, or R squared of the model, and the level of statistical significance of the coefficients. There are differences between the level of fit the models display in estimating the effect the LFFN project has had. Most display a reasonable level of fit (between 30 and 48 percent), and the findings can be viewed with a degree of confidence. However, the level of fit for the model estimating the effect on upload speeds, both median and maximum, is lower than for the other models and display low levels of fit (with R squared values of 18 percent and seven percent respectively). Given that for both of these models the variables included are all statistically significant, the models for these outcomes either contain data with a lot of variance for the postcodes covered or there are other factors which are driving the changes in the outcome which have not been included in this model specification. The findings from these models should be seen as less robust than the findings of the other outcomes.

4 Tameside

This section provides details of the econometric analysis undertaken for the Tameside PSAR project. It provides an initial description of the areas considered for the comparator group, and then presents the results of the matching exercise and regression analysis.

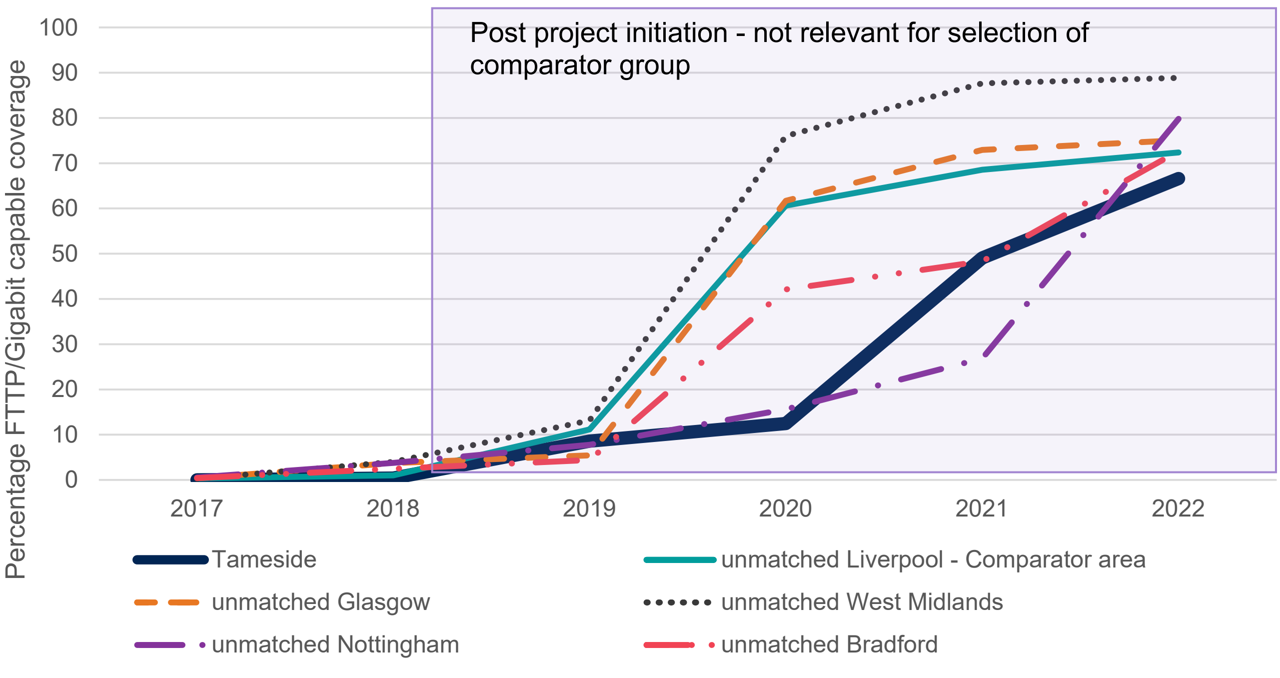
4.1 Areas considered for comparator group

Following the initial desk research phase to identify potential comparator areas, the following areas were proposed for discussion between BDUK and the research team:

- Bradford and Calderdale
- Glasgow
- Liverpool (selected as the comparator area)
- Nottingham
- West Midlands

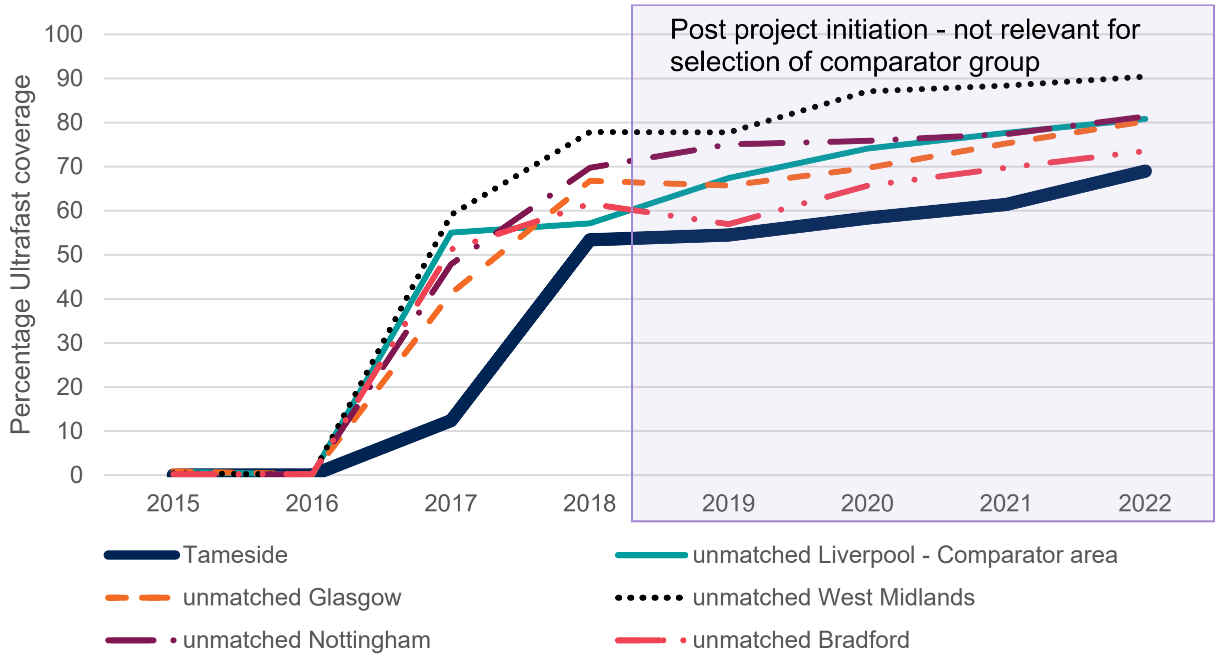
The figures below present the trend in ultrafast and gigabit capable coverage in the West Sussex area and the potential comparator areas from the Connected Nations dataset. This shows that in 2019, all the areas had potential as a comparator area. There were differences in ultrafast coverage between Tameside and all other potential comparator areas, with all the potential comparator areas following the same trend, and these were moving in the same direction and potential differences could be accounted for in a matching exercise. The level of gigabit capable coverage was comparable. Areas of Liverpool were selected following the discussions with BDUK.

Figure 4.1: FTTP/Gigabit capable coverage in Tameside and all potential comparator areas, 2017-2022



Source: Ofcom Connected Nations

Figure 4.2: Ultrafast broadband coverage in Tameside and all potential comparator areas, 2017-2022



Source: Ofcom Connected Nations

Following the Tameside project initiation, there has been a divergence in the gigabit capable coverage between Tameside and all the potential comparator groups, with the exception of Nottingham. The commonality in trends in these four areas on the outskirts of cities provides confidence that the use of Liverpool as a comparator group is valid, as the changes in Liverpool are not localised.

4.2 Propensity Score Matching

The results of the probit models associated with the matching models are set out in the table below. Prior to the matching exercise, postcodes that had received Gigabit vouchers were removed from both the treatment and comparator population. The table shows that prior to matching there were large differences between the treatment and comparator areas in ultrafast coverage, download speeds, distance from the exchange and jobs density, and these were reduced by the matching exercise.

The table shows that there was only a single indicator where the matching exercise led to an increase in bias: superfast broadband coverage in 2018, with the change in bias being nearly -96 percent. However, the initial difference between the treatment and comparator areas was small at just over two percent, and the increase in bias still leaves a relatively small difference of 4.5 percent between the treatment and comparator group. Many more of the indicators have seen a reduction in bias of close to 100 percent (for example FTTP coverage and median download speeds). Overall, there has been a reduction in the bias between the two samples, with a median reduction in bias of 84.9 percent, demonstrating that the matching exercise has been successful in making the treatment and comparator groups more comparable.

Table 4.1: Propensity Score Matching variable results for Tameside and Liverpool

Variable		Mean		% bias	Reduction in bias	t-test	p>|t|
		Treatment (Tameside)	Comparator (Liverpool)				
Superfast Broadband coverage 2018	Unmatched	98.27	98.53	-2.3		-1.30	0.19
	Matched	98.26	97.76	4.5	-95.6	1.69	0.09
Ultrafast Broadband coverage 2018	Unmatched	53.40	59.10	-11.6		-6.43	0.00
	Matched	53.25	53.63	-0.8	93.3	-0.32	0.75
FTTP coverage 2018	Unmatched	0.38	1.10	-9.2		-4.47	0.00
	Matched	0.39	0.38	0.1	98.7	0.07	0.95
Median download speed 2018	Unmatched	36.69	45.87	-39.9		-20.62	0.00
	Matched	36.70	36.82	-0.5	98.7	-0.25	0.80
Median upload speed 2018	Unmatched	5.09	5.05	1.3		0.78	0.44
	Matched	5.08	5.09	-0.3	75.3	-0.12	0.90
Average data usage 2018	Unmatched	277.04	259.79	10.5		5.61	0.00
	Matched	277.41	274.90	1.5	85.5	0.55	0.58
Residential delivery points	Unmatched	21.30	22.19	-6.5		-3.64	0.00
	Matched	21.36	21.52	-1.2	82.0	-0.47	0.64
Non-residential delivery points	Unmatched	0.84	0.67	6.2		3.67	0.00
	Matched	0.83	0.72	4.0	36.6	1.70	0.09
Distance from exchange	Unmatched	1100.30	1438.80	-49.3		-23.53	0.00
	Matched	1103.50	1086.80	2.4	95.1	1.20	0.23
Distance from cabinet	Unmatched	162.79	180.26	-14.1		-7.24	0.00
	Matched	163.08	169.35	-5.1	64.1	-2.37	0.02
Exchange delivery points	Unmatched	1074.80	1396.70	-45.8		-21.89	0.00
	Matched	1077.70	1061.40	2.3	94.9	1.15	0.25
Exchange cabinet distance	Unmatched	1665.70	2133.30	-49.8		-23.90	0.00
	Matched	1670.00	1656.50	1.4	97.1	0.72	0.47
Line length	Unmatched	20670.00	20233.00	5.7		2.70	0.01
	Matched	20648.00	20717.00	-0.9	84.3	-0.37	0.71
Cabinet delivery points	Unmatched	431.27	436.78	-3.1		-1.68	0.09
	Matched	432.11	431.80	0.2	94.3	0.07	0.94

Variable		Mean		% bias	Reduction in bias	t-test	p>|t|
		Treatment (Tameside)	Comparator (Liverpool)				
Exchange only lines	Unmatched	0.70	1.17	-9.6		-4.73	0.00
	Matched	0.70	0.60	2.2	77.4	1.21	0.23
Virginmedia coverage	Unmatched	0.47	0.72	-52.4		-30.04	0.00
	Matched	0.47	0.49	-2.7	94.9	-1.06	0.29
Population density	Unmatched	4512.90	4715.90	-7.1		-3.68	0.00
	Matched	4524.00	4479.90	1.5	78.3	0.66	0.51
Premise density	Unmatched	2777.90	2723.90	3.0		1.60	0.11
	Matched	2778.40	2730.80	2.7	11.8	1.07	0.29
Digital employment	Unmatched	0.37	0.31	6.9		4.21	0.00
	Matched	0.37	0.40	-3.4	50.2	-1.30	0.19
Jobs density	Unmatched	1481.90	1142.90	20.5		11.30	0.00
	Matched	1458.30	1424.80	2.0	90.1	0.75	0.45

4.3 Regression results

The tables below present the results from the econometric analysis described above. As presented in the main report, this suggests that the Tameside PSAR project may have led to a decrease in the speed of gigabit capable networks in the area immediately surrounding the LFFN project network build. However, it also suggests that the project may have led to improvements in ultrafast broadband coverage and increases in the median upload speeds in the area. All of the regression models show statistically significant (mainly) positive coefficients for the years included in the model. This indicates that there are factors in each year which have had a positive impact on the outcome (for example coverage, download and upload speed) influence for each year one baseline year) across both the treatment and comparator areas when compared to the first year in the model (usually 2015). For example, the models indicate that across both areas, ultrafast coverage was 74 percent higher in 2022 than in 2015. The year coefficients for the coverage models (Model 1 and 2) for the Tameside PSAR project are broadly in line with the West Sussex PSAT project, which would be expected as both projects are targeted in built up areas. The year coefficients are slightly higher than for the Trans Pennine Initiative, which has a combination of urban and rural locations, and the LFFN PSBU Schools project, which is targeted at more rural areas.

Table 4.2: Tameside Broadband coverage regression results

Variable	Model 1: Gigabit capable coverage	Model 2: Ultrafast coverage	Model 3: Median download speed	Model 4: Median upload speed	Model 5: Maximum download speed	Model 6: Maximum upload speed
LFFN impact	-14.48***	6.696***	-1.616***	0.347***	-21.97***	-4.609***
2016		-0.281***	4.768***	0.295***	18.90***	-0.773***
2017		25.68***	11.59***	1.952***	31.69***	2.592***
2018	0.284***	53.15***	17.14***	3.463***	33.50***	4.174***
2019	19.81***	55.29***	12.40***	1.778***	90.85***	6.818***
2020	43.83***	62.38***	41.21***	9.245***	132.6***	14.61***
2021	68.69***	66.80***	46.47***	10.88***	231.8***	20.60***
2022	80.59***	74.48***	55.41***	12.95***	373.9***	29.59***
Constant	0.0968	0.298	19.79***	1.626***	90.01***	12.11***
Observations	37,914	50,553	47,927	47,927	47,596	47,594
R squared	0.547	0.542	0.622	0.739	0.442	0.256
Number of postcodes	6,323					

*Source: Ofcom Connected Nations, LFFN Management Information, Ipsos analysis; *** represents differences significant at 99 percent, ** at 95 percent and * at 90 percent*

Table 4.3: Tameside Broadband usage regression results

Variable	Model 7: Average data usage	Model 8: Ultrafast broadband

		connections
LFFN impact	2.660	-0.117***
2016		-0.000517
2017	82.57***	0.0129***
2018	139.4***	0.00509***
2019	228.7***	0.0843***
2020	-144.3***	0.647***
2021	381.8***	1.022***
2022	405.4***	1.631***
Constant	140.4***	0.00105
Observations	41,521	47,596
R squared	0.273	0.344
Number of postcodes	6,323	

*Source: Ofcom Connected Nations, LFFN Management Information, Ipsos analysis; *** represents differences significant at 99 percent, ** at 95 percent and * at 90 percent*

The level of explanatory power of the models is approximated by the goodness of fit, or R squared of the model, and the level of statistical significance of the coefficients. The statistical models used to estimate the effects of the LFFN project display a reasonable to good level of fit across all models, with the models estimating median download and upload speeds displaying good levels of fit (with R squared values of 62 percent to 74 percent). The remaining models all display reasonable levels of fit of between 26 percent and 55 percent. This, coupled with the almost all variables within the model (with the exception of the LFFN variable) being estimated as statistically significant provides confidence that the findings are robust.

5 Trans Pennine Initiative

This section provides details of the econometric analysis undertaken for the Trans Pennine Initiative. It provides an initial description of the areas considered for the comparator group, and then presents the results of the matching exercise and regression analysis.

5.1 Areas considered for comparator group

An initial phase of desk-based research identified multiple potential rail routes which could be used as a comparator group for the Trans Pennine Initiative project. Many of these were not appropriate due to other commercial and publicly funded roll out plans, like the Glasgow to Edinburgh rail route. A final potential list of comparator groups discussed by BDUK and the research team, and these were:

- Reading to Bristol (selected as the comparator area)
- Brighton to Southampton
- Milton Keynes to Birmingham
- Leicester to Sheffield
- Durham to Edinburgh

Following discussions with BDUK, it was decided that the Reading to Bristol rail route should be used as the comparator group for the Trans Pennine Initiative project.

5.2 Propensity Score Matching

The results of the probit models associated with the matching models are set out in the table below. Prior to the matching exercise, postcodes that had received Gigabit vouchers were removed from both the treatment and comparator population. The table shows that prior to the matching, there were large differences between the treatment and comparator areas in FTTP coverage, download speeds, data usage, jobs density, digital employment, population and premise density. These differences were significantly reduced during the matching process.

The table shows that there were three indicators where the matching exercise led to an increase in bias: ultrafast broadband coverage in 2018, residential delivery points and distance from the cabinet. For ultrafast broadband coverage in 2018, this is potentially concerning, given this is a key outcome measure. Some of these variables showed particularly large increases in bias, for example a 236 percent for residential delivery points and 115 percent for distance from the cabinet. However, it should be noted that increases in bias do not have an upper limit, and can extend beyond 100 percent, whereas decreases in bias are limited to 100 percent. For the indicators with large increases in bias, they demonstrated an initial small difference between the treatment and comparator group (under one percent for residential delivery points and three percent for distance from the cabinet). Therefore, the increase in bias still leaves a relatively small difference between the treatment and comparator group (of under one percent for residential delivery points and under seven percent for distance from the exchange). Many indicators have displayed large reductions in bias, for example close to 100 percent for FTTP coverage, premise and population density and line length. Overall, there has been a reduction in the bias between the two samples, with a median reduction in bias of 86.1 percent, demonstrating that the matching exercise has been successful in making the treatment and comparator groups more comparable.

Table 5.1: Propensity Score Matching variable results for the Trans Pennine Initiative and Reading to Bristol rail routes

Variable		Mean		% bias	Reduction in bias	t-test	p>|t|
		Treatment (Trans Pennine route)	Comparator (reading – Bristol route)				
Superfast Broadband coverage 2018	Unmatched	92.25	94.39	-9.3		-3.26	0.00
	Matched	91.37	90.46	4.0	57.4	0.81	0.42
Ultrafast Broadband coverage 2018	Unmatched	56.47	57.65	-2.4		-0.81	0.42
	Matched	51.55	52.88	-2.8	-13.2	-0.65	0.51
FTTP coverage 2018	Unmatched	28.46	8.37	57.1		23.15	0.00
	Matched	19.52	19.85	-1.0	98.3	-0.21	0.83
Median download speed 2018	Unmatched	30.83	41.64	-50.8		-15.39	0.00
	Matched	31.54	30.76	3.7	92.7	1.00	0.32
Median upload speed 2018	Unmatched	5.09	5.27	-4.3		-1.47	0.14
	Matched	5.10	5.08	0.3	92.5	0.07	0.94
Average data usage 2018	Unmatched	197.73	228.78	-15.3		-5.24	0.00
	Matched	203.34	204.18	-0.4	97.3	-0.11	0.91
Residential delivery points	Unmatched	20.67	20.65	0.2		0.06	0.95
	Matched	20.33	20.23	0.6	-236.4	0.14	0.89
Non-residential delivery points	Unmatched	0.82	1.10	-9.4		-2.95	0.00
	Matched	0.93	1.07	-4.8	48.2	-1.08	0.28
Distance from exchange	Unmatched	1463.70	1259.90	21.1		7.53	0.00
	Matched	1398.10	1314.20	8.7	58.9	2.11	0.04
Distance from cabinet	Unmatched	205.20	214.97	-3.1		-0.93	0.35
	Matched	216.70	195.75	6.7	-114.6	2.00	0.05
Exchange delivery points	Unmatched	1362.50	1173.90	19.5		7.08	0.00
	Matched	1298.80	1212.80	8.9	54.4	2.14	0.03
Exchange cabinet distance	Unmatched	2174.50	1929.70	18.0		6.36	0.00
	Matched	2100.40	1969.80	9.6	46.7	2.36	0.02
Line length	Unmatched	15074.00	21602.00	-53.5		-15.72	0.00
	Matched	15874.00	15757.00	1.0	98.2	0.24	0.81
Cabinet delivery points	Unmatched	335.22	370.70	-19.4		-6.12	0.00

Variable		Mean		% bias	Reduction in bias	t-test	p>|t|
		Treatment (Trans Pennine route)	Comparator (reading – Bristol route)				
	Matched	337.23	309.05	15.4	20.6	3.77	0.00
Exchange only lines	Unmatched	2.49	1.68	11.1		4.04	0.00
	Matched	1.90	2.03	-1.8	84.2	-0.44	0.66
Virginmedia coverage	Unmatched	0.21	0.49	-61.4		-19.06	0.00
	Matched	0.25	0.24	1.2	98.1	0.29	0.77
Population density	Unmatched	3318.80	4372.90	-29.8		-9.51	0.00
	Matched	3407.90	3386.70	0.6	98.0	0.14	0.89
Premise density	Unmatched	1995.30	2595.50	-27.4		-9.06	0.00
	Matched	2074.40	2081.30	-0.3	98.8	-0.07	0.94
Digital employment	Unmatched	0.51	1.27	-65.9		-18.16	0.00
	Matched	0.55	0.61	-4.8	92.7	-1.92	0.05
Jobs density	Unmatched	1859.10	3647.20	-28.2		-8.36	0.00
	Matched	2100.40	2229.30	-2.0	92.8	-0.59	0.56
City / town category	Unmatched	0.74	0.91	-44.7		-17.12	0.00
	Matched	0.78	0.80	-6.0	86.6	-1.30	0.19
Town fringe category	Unmatched	0.18	0.06	36.4		14.29	0.00
	Matched	0.13	0.11	5.3	85.3	1.24	0.22
Village Category	Unmatched	0.05	0.02	16.4		6.36	0.00
	Matched	0.06	0.05	2.4	85.5	0.47	0.64
Hamlet category	Unmatched	0.03	0.01	13.6		5.32	0.00
	Matched	0.04	0.04	0.6	95.7	0.11	0.91

5.3 Regression results

The tables below present the results from the econometric analysis described above. As presented in the main report, this suggests that the Trans Pennine Initiative may have had a positive effect in the areas surrounding the network build on gigabit capable coverage, maximum download and upload speeds. However, it may also have contributed to a decrease in the speed of rollout of ultrafast broadband coverage. All of the regression models show statistically significant (mainly) positive coefficients for the years included in the model. This indicates that there are factors in each year which have had a positive impact on the outcome (for example coverage, download and upload speed) influence for each year one baseline year) across both the treatment and comparator areas when compared to the first year in the model (usually 2015). For example, the models indicate that across both areas, ultrafast coverage was 62 percent higher in 2022 than in 2015. The year coefficients for the coverage models (Model 1 and 2) for the Trans Pennine Initiative project are slightly lower than the Tameside PSAR and West Sussex PSAT project, which would be expected as both projects are targeted in built up areas, whereas the Trans Pennine Initiative includes both urban and rural areas. The year coefficients are higher than for the LFFN PSBU Schools project, which is targeted at more rural areas.

Table 5.2: Trans Pennine Initiative Broadband coverage regression results

Variable	Model 1: Gigabit capable coverage	Model 2: Ultrafast coverage	Model 3: Median download speed	Model 4: Median upload speed	Model 5: Maximum download speed	Model 6: Maximum upload speed
LFFN impact	7.175***	-4.021***	3.038*	2.235*	65.49***	135.3***
2016		-1.183***	4.147***	0.252*	11.82***	-0.991**
2017		22.60***	9.144***	1.856***	22.77***	3.499***
2018	14.05***	46.78***	13.18***	3.069***	26.30***	3.473***
2019	23.17***	49.29***	7.617***	0.733	33.34***	-65.25***
2020	27.07***	52.22***	37.14***	9.219***	140.1***	41.77***
2021	36.64***	55.31***	44.90***	12.30***	210.9***	48.90***
2022	55.33***	62.36***	54.44***	15.09***	293.3***	69.16***
Constant	5.646***	5.443***	18.26***	2.032***	69.60***	11.86***
Observations	11,767	15,693	14,699	14,699	14,506	14,505
R squared	0.336	0.429	0.312	0.067	0.385	0.198
Number of postcodes	1,963					

*Source: Ofcom Connected Nations, LFFN Management Information, Ipsos analysis; *** represents differences significant at 99 percent, ** at 95 percent and * at 90 percent*

Table 5.3: Trans Pennine Initiative Broadband usage regression results

Variable	Model 7: Average data usage	Model 8: Ultrafast broadband

		connections
LFFN impact	-1.777	0.487***
2016		-0.00225
2017	47.90***	0.0162***
2018	90.96***	0.00212
2019	165.8***	-0.250***
2020	-117.1***	0.649***
2021	277.8***	1.042***
2022	305.8***	1.480***
Constant	116.3***	0.00550
Observations	12,614	14,506
R squared	0.317	0.236
Number of postcodes	1,963	

*Source: Ofcom Connected Nations, LFFN Management Information, Ipsos analysis; *** represents differences significant at 99 percent, ** at 95 percent and * at 90 percent*

The level of explanatory power of the models is approximated by the goodness of fit, or R squared of the model, and the level of statistical significance of the coefficients. Most of the models display a reasonable model fit (R^2 of 20 percent to 42 percent), particularly given the relatively low number of postcodes on which the model is based (under 2,000 postcodes). Most of the variables are statistically significant, and this points to the findings being robust.

6 Schools PSBU

This section provides details of the econometric analysis undertaken for the Schools PSBU project. It provides an initial description of the areas considered for the comparator group, and then presents the results of the matching exercise and regression analysis.

6.1 Areas considered for comparator group

Due to the dispersed nature of the Schools PSBU project, it was challenging to select a list of potential areas for a comparator group. The only realistic option to use as a counterfactual group were schools that also did not have good quality broadband connections when the LFFN programme was launched. Fortunately, the Rural Gigabit Connectivity programme, which followed on from the LFFN programme, also provided enhanced connectivity to schools, and these schools were to be upgraded after the LFFN project had completed. Therefore, these schools were selected as a comparator group.

Some schools in the LFFN schools PSBU project were completed in 2020, later than anticipated. As a result, a small number of Rural Gigabit Connectivity schools were also connected in the same year. These Rural Gigabit Connectivity schools were excluded from the comparator group.

6.2 Propensity Score Matching

The results of the probit models associated with the matching models are set out in the table below. Prior to the matching exercise, postcodes that had received Gigabit vouchers were removed from both the treatment and comparator population. The table shows that there were large differences between the treatment and comparator groups in ultrafast coverage, data usage, distance from exchanges, premise density and rural urban categorisation. These differences were narrowed significantly by the matching process.

The table shows that there were three indicators where the matching exercise led to an increase in bias: superfast broadband coverage in 2018, median download speeds 2018 and digital employment. Some of these variables showed particularly large increases in bias, for example a 335 percent for median download speeds and 280 percent for digital employment. However, it should be noted that increases in bias do not have an upper limit, and can extend beyond 100 percent, whereas decreases in bias are limited to 100 percent. For the indicators with large increases in bias, they demonstrated an initial small difference between the treatment and comparator group (five percent for median download speeds and 13 percent for digital employment). The increases in bias for median download speeds leads to a difference of 19 percent that is in line with some other variables. The increase in bias for digital employment to over 50 percent suggests there is a lack of comparability for this variable, however the research team feel this variable is less important for matching than the other variables included in the specification. Many indicators have displayed large reductions in bias, for example close to 100 percent for ultrafast coverage, premise density and village population. Overall, there has been a reduction in the bias between the two samples, with a median reduction in bias of 85.2 percent, demonstrating that the matching exercise has been successful in making the treatment and comparator groups more comparable.

Table 6.1: Propensity Score Matching variable results for LFFN and Rural Gigabit Connectivity schools

Variable		Mean		% bias	Reduction in bias	t-test	p>|t|
		Treatment (LFFN schools)	Comparator (RGC schools)				
Superfast Broadband coverage 2018	Unmatched	92.70	90.57	8.6		6.23	0.00
	Matched	92.30	88.47	15.4	-79.1	8.08	0.00
Ultrafast Broadband coverage 2018	Unmatched	24.33	4.97	58.6		45.37	0.00
	Matched	20.57	20.34	0.7	98.8	0.33	0.74
FTTP coverage 2018	Unmatched	6.10	2.29	20.2		15.39	0.00
	Matched	3.62	5.22	-8.5	57.8	-4.66	0.00
Median download speed 2018	Unmatched	31.25	30.37	5.0		3.73	0.00
	Matched	31.62	27.78	21.8	-335.1	12.16	0.00
Median upload speed 2018	Unmatched	5.11	5.97	-18.9		-13.67	0.00
	Matched	5.40	4.88	11.4	40.0	6.87	0.00
Average data usage 2018	Unmatched	221.90	196.44	16.8		12.17	0.00
	Matched	216.96	214.54	1.6	90.5	0.97	0.33
Residential delivery points	Unmatched	19.46	17.88	11.9		8.71	0.00
	Matched	19.22	20.16	-7.0	41.0	-3.83	0.00
Non-residential delivery points	Unmatched	0.97	0.63	13.1		9.86	0.00
	Matched	0.64	0.44	7.6	42.0	5.44	0.00
Distance from exchange	Unmatched	1252.80	1686.50	-35.9		-25.12	0.00
	Matched	1352.50	1337.90	1.2	96.6	0.88	0.38
Distance from cabinet	Unmatched	230.11	313.59	-14.3		-9.91	0.00
	Matched	253.05	329.87	-13.1	8.0	-8.00	0.00
Exchange delivery points	Unmatched	1200.40	1574.50	-32.7		-22.96	0.00
	Matched	1289.40	1234.10	4.8	85.2	3.58	0.00
Exchange cabinet distance	Unmatched	1954.60	2605.70	-37.2		-26.08	0.00
	Matched	2109.40	2134.80	-1.4	96.1	-1.01	0.31
Line length	Unmatched	15025.00	4971.60	122.7		95.03	0.00
	Matched	12008.00	11072.00	11.4	90.7	6.75	0.00
Cabinet delivery points	Unmatched	360.65	312.52	26.4		19.35	0.00
	Matched	364.02	401.87	-20.8	21.3	-11.24	0.00

Variable		Mean		% bias	Reduction in bias	t-test	p>|t|
		Treatment (LFFN schools)	Comparator (RGC schools)				
Exchange only lines	Unmatched	1.52	2.23	-11.0		-7.87	0.00
	Matched	1.60	1.22	5.8	47.4	3.77	0.00
Virginmedia coverage	Unmatched	0.15	0.02	50.8		40.09	0.00
	Matched	0.13	0.14	-1.2	97.7	-0.51	0.61
Population density	Unmatched	3059.90	1423.60	78.9		59.84	0.00
	Matched	2641.30	2557.90	4.0	94.9	2.20	0.03
Premise density	Unmatched	1874.20	849.39	78.8		59.89	0.00
	Matched	1554.30	1540.70	1.0	98.7	0.56	0.58
Digital employment	Unmatched	0.59	0.56	3.5		2.62	0.01
	Matched	0.60	0.47	13.3	-280.2	7.31	0.00
Jobs density	Unmatched	1438.80	202.43	57.6		46.45	0.00
	Matched	470.99	334.69	6.4	89.0	12.94	0.00
Major conurbation category	Unmatched	0.03	0.01	11.1		8.43	0.00
	Matched	0.03	0.02	6.0	46.6	3.28	0.00
City / town category	Unmatched	0.74	0.03	210.9		165.09	0.00
	Matched	0.66	0.67	-3.1	98.5	-1.26	0.21
Town fringe category	Unmatched	0.13	0.57	-101.2		-71.51	0.00
	Matched	0.19	0.19	-1.6	98.5	-0.96	0.34
Village Category	Unmatched	0.06	0.30	-64.3		-44.65	0.00
	Matched	0.09	0.09	-0.3	99.5	-0.25	0.81
Hamlet category	Unmatched	0.03	0.09	-23.7		-16.60	0.00
	Matched	0.04	0.03	4.2	82.2	2.95	0.00

6.3 Regression results

The tables below present the results from the econometric analysis described above. As presented in the main report, the modelling does not indicate that the Schools PSBU project has contributed towards any changes in broadband coverage or take-up. All of the regression models show statistically significant (mainly) positive coefficients for the years included in the model. This indicates that there are factors in each year which have had a positive impact on the outcome (for example coverage, download and upload speed) influence for each year one baseline year) across both the treatment and comparator areas when compared to the first year in the model (usually 2015). For example, the models indicate that across both areas, ultrafast coverage was 34 percent higher in 2022 than in 2015. The year coefficients for the Schools PSBU project are lower than for the other three LFFN wave one projects, and one reason for this could be the more rural nature of the LFFN schools and the schools in the comparator group, as the other projects are targeted at more built up areas.

Table 6.2: Schools PSBU Broadband coverage regression results

Variable	Model 1: Gigabit capable coverage	Model 2: Ultrafast coverage	Model 3: Median download speed	Model 4: Median upload speed	Model 5: Maximum download speed	Model 6: Maximum upload speed
LFFN impact	0.0899	2.907**	1.659***	0.241	0.572	-2.890
2016		-1.000***	4.577***	0.555***	11.48***	-0.453**
2017		6.762***	10.18***	2.254***	18.51***	2.653***
2018	2.132***	17.72***	14.13***	3.525***	22.95***	23.56
2019	2.897***	18.70***	9.602***	2.170***	37.37***	5.860***
2020	9.381***	20.51***	29.79***	8.421***	63.87***	11.69***
2021	15.76***	25.94***	34.50***	9.813***	106.4***	16.82***
2022	35.15***	33.90***	38.92***	11.52***	173.9***	26.48***
Constant	2.289***	2.709***	15.89***	1.636***	58.74***	11.15***
Observations	52,414	69,897	65,717	65,717	65,052	65,045
R squared	0.244	0.231	0.551	0.285	0.222	0.000
Number of postcodes	8,744					

*Source: Ofcom Connected Nations, LFFN Management Information, Ipsos analysis; *** represents differences significant at 99 percent, ** at 95 percent and * at 90 percent*

Table 6.3: Schools PSBU Broadband usage regression results

Variable	Model 7: Average data usage	Model 8: Ultrafast broadband

		connections
LFFN impact	3.884	0.0151
2016		-0.00448
2017	55.86***	0.000692
2018	101.7***	-0.00261
2019	178.6***	0.00925
2020	-123.1***	0.229***
2021	315.5***	0.444***
2022	351.6***	0.693***
Constant	118.8***	0.00580
Observations	56,673	65,052
R squared	0.479	0.135
Number of postcodes	8,744	

*Source: Ofcom Connected Nations, LFFN Management Information, Ipsos analysis; *** represents differences significant at 99 percent, ** at 95 percent and * at 90 percent*

The level of explanatory power of the models is approximated by the goodness of fit, or R squared of the model, and the level of statistical significance of the coefficients. There are differences between the level of fit the models display in estimating the effect the LFFN project has had. Most display a reasonable level of fit (between 20 and 55 percent). However, the level of fit for the model estimating the effect on take-up of ultrafast broadband connections is lower at 14 percent, potentially explained by the only years in the model with statistically significant effects being 2020 onwards. The R squared value for maximum upload speeds is poor, especially given the statistically significant results for the year variables. This suggests that there may be a lot of variance in the underlying data for take-up in the postcodes covered by the analysis, or that the model specification does not include factors which are driving changes in the outcome variable. The findings from these models should be seen as less robust than the findings of the other outcomes.

Annex

Ofcom Connected Nations data changes

Ipsos have compared the 2019 Ofcom Connected Nations data to that of 2018. Having completed further analysis on the LFFN wave one project areas, there are definite differences in terms of ultrafast availability.

Across the whole Connected Nations dataset, the number of postcodes across both years were very similar. There were just 57,568 postcodes included in the 2019 which were not in the 2018 dataset. A further 6,141 were in 2018 but not 2019 and 1,619,056 were in both.

However, when comparing the key availability figures there were decreases in superfast, ultrafast and FTTP coverage. In the case of the LFFN wave one projects where ultrafast and FTTP coverage is of more interest there seems to be significant changes. Therefore, comparisons between 2018 and 2019 should be treated with caution, and the use of a comparator area or national averages are used alongside time trends to account for this data inconsistency.

The tables below show the proportion with increasing, decreasing and stationary availability:

Table A.1: Change 2018 to 2019 data

	Superfast	**Ultrafast**	**FTTP**
Down	5.2%	12.2%	1.4%
Same	85.4%	74.9%	88.8%
Up	9.4%	12.9%	9.8%

Table A.2: Summary statistics for change variables

Variable	**Observations**	**Mean**	**Std. Dev.**	**Min**	**Max**
Change in Superfast availability (%)	1,615,668	1.102826	14.59872	-100	100.1
Change in Ultrafast availability (%)	1,615,668	2.705448	28.1401	-100	100
Change in FTTP availability (%)	1,615,668	3.724803	19.47962	-100	100
Change in Ultrafast connections (#)	1,171,617	0.062637	2.653258	-2600	79
Change in Superfast connections (#)	1,171,617	1.653238	4.126515	-2588	74

The 2019 Methodology report (see historic changes on page 10) cites a change in approach which may be the cause of decreases observed. The comparisons Ofcom ran using the new approach on the 2018 data showed that the 2018 coverage figures on aggregate would be lower with this new approach (reflected in some changes in 2018 figures in this report compared with the Baseline report submitted last year).

Ipsos understands the new approach (Service Delivery Address or SDA) creates a premise base using addresses that more accurately constitute those that a service could be delivered to. The result is a larger overall premise base than the Delivery Point Address approach they used previously. In short, Ofcom have identified further eligible addresses, and if these are without availability but within a postcode in Connected Nations for 2018 then it is feasible for availability to drop. At the root, this seems to stem from the use of premise data by Ofcom but the lowest level of aggregation available publicly being at postcode level.

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