Productivity impacts of broadband

Ipsos UK was commissioned by Building Digital UK (BDUK), an Executive Agency of the Department for Science, Innovation and Technology (DSIT)[1] in October 2021 to undertake an evaluation of the Superfast Broadband Programme. The Superfast Broadband Programme was announced in 2010 in response to concerns that the commercial deployment of superfast broadband infrastructure would fail to reach many parts of the UK. This document is a part of the wider evaluation, and sets out the results of an analysis exploring the productivity impacts of broadband availability using Ofcom Connected Nations data and the Annual Business Survey (ABS) available in the ONS Secure Research Service (SRS). The methodology for the analysis is an enhancement of the analysis undertaken for a previous evaluation of the Superfast Broadband Programme.[2]

1.1 Aims of the research

The aim of the analysis set out in this paper was to estimate the productivity gains associated with making faster broader connectivity available for the purposes of economic appraisal and forecasting the benefits of future public support for network investment. The results of the modelling exercise will be used to calibrate the BDUK 'Benefits Model' to support the development of future Business Cases.

1.2 Model

Econometric modelling of the productivity gains associated with enhanced connectivity should (in principle) allow for the following:

- Faster available broadband speeds would be expected to raise the productivity of businesses.
- Diminishing marginal returns - in any given period, the productivity gains associated with faster speeds would be expected to get smaller as speeds rise.

These principles can be summarised in the following equation:

$$y_{it} = \alpha {L_{it}}^{\beta} {K_{it}}^{\gamma} {B_{it}}^{\delta}$$

Where y represents the output of firm i in period t, B is the speed available to the firm via broadband networks, and L and K represent the firms use of labour and capital respectively. The key parameter of interest is δ - the elasticity of output to broadband speeds. If δ is less than unity, then there are diminishing marginal returns (i.e. a doubling of broadband speeds will lead to less than a doubling of output, if labour and capital inputs are held constant).

This model can be rewritten as follows (which can be estimated with econometric methods):

$$\ln y_{it} = \ln \alpha + \beta \ln L_{it} + \gamma \ln K_{it} + \delta \ln B_{it}$$

[1] BDUK is formerly an Executive Agency of the Department for Digital, Culture, Media and Sport (DCMS)

[2] Department for Science, Innovation and Technology and Department for Digital, Culture, Media and Sport (2018) Evaluation of the Economic Impact and Public Value of the Superfast Broadband Programme Available at: https://www.gov.uk/government/publications/evaluation-of-the-economic-impact-and-public-value-of-the-superfast-broadband-programme

1.3 Data

Econometric estimation of this model requires longitudinal data on the output of individual firms (GVA), their number of employees, their capital stocks, and broadband speeds taken or available to the firm.

Firm GVA, employment, and capital stocks

Two data sources are available within the ONS Secure Research Service that provide the data on firm performance needed: the Annual Business Survey and the Business Structure Database.

Annual Business Survey

The ONS Annual Business Survey is a census of large firms and a random probability survey of SMEs, providing approximately 62,000 observations annually. It captures information on firm level output (GVA) and employment (taken from the parallel Business Register of Employment Survey), as well information on capital expenditures and disposals. Financial data is reported at the Reporting Unit level (the smallest combination of legal units within an enterprise group with autonomy[3]) while employment is reported at the Local Unit level (i.e. branch sites of multi-plant enterprises). Data was available to 2021 at the time of analysis.

The Annual Business Survey has no data on capital stocks but does capture information on capital expenditures and disposals. This was used to derive estimates of each firm's capital stock using the Perpetual Inventory Method, following ONS methodologies[4].

While the ABS provides all firm level measures needed to implement the analysis, several issues need to be considered:

- **SMEs versus large firms:** The ABS provides annual data for large firms (those with 250 employees or more) while SMEs are sampled less regularly. Consequently, the sample is dominated by large companies that are most likely to obtain broadband services via leased lines and whose efficiency is least likely to be influenced by public investments in broadband networks. To address this, a separate set of analyses were restricted to the sample of SMEs. Given the resampling rules for the ABS, it was not possible to construct a balanced panel of SMEs, however an unbalanced panel was used for the analysis on the basis that the sampling procedures meant that missing data was random in nature.

- **Apportionment of financial variables to spatially stable Local Units:** The analysis seeks to establish the effect of improvements in broadband connectivity (which is experienced locally) on output and productivity (which is observed at the level of the overall enterprise). For multi-plant firms, financial variables were apportioned to local units based on each Local Unit's share of the enterprise's employment. The robustness of this approach was tested by limiting the sample to firms with a single site.

Business Structure Database

The Business Structure Database (BSD) is an annual snapshot of the Interdepartmental Business Register. It provides annual observations of employment and turnover for all firms registered for VAT and

[3] This is typically the overall enterprise except for a minority of the largest businesses with complex structures.
[4] See http://doc.ukdataservice.ac.uk/doc/6698/mrdoc/pdf/6698userguide.pdf

PAYE. Observations are drawn from a combination of administrative sources (e.g. VAT and PAYE returns) and surveys (e.g. the Business Register of Employment Survey). As with the ABS, information on turnover is available at the enterprise level, while employment is available at the level of the Local Unit.

The BSD offers some advantages over the ABS in that it provides near complete coverage of the business population. However, it has limitations in that it provides information on turnover rather than GVA. This can only be used to generate a proxy measure of productivity (turnover per worker). Additionally, as it only provides information on one factor of production (labour), it cannot be used to generate multi-factor estimates of productivity. However, it could be used if the ABS data proves unsuitable for the purposes of the exercise or undertaking robustness checks on ABS results taking advantage of the larger sample sizes.

Broadband speeds

Data on broadband availability and take-up at a postcode level was available from the Connected Nations dataset published annually by Ofcom and was used to generate an estimate of broadband speeds available to businesses.

The nature of the data created some challenges in estimating available speeds:

- **Measures reported:** Connected Nations does not provide any measure of the average speed available on a given postcodes (it only provides the average speed of connections). However, between 2016 and 2022 it has provided the following measures that might be used to construct an approximation:
  - The percentage of premises unable to receive 2Mbit/s, 5Mbit/s, 10Mbit/s, and 30Mbit/s.
  - The percentage of premises able to receive superfast and ultrafast broadband services (defined as 30Mbit/s and 300Mbit/s or greater). In later years, the data also reports premises with gigabit availability (premises with coverage from a gigabit capable service from fixed broadband).

  Average available speeds were approximated by making assumptions regarding the available speeds for each of these groups of premises. The mid-point for each group of premises with sub-superfast speeds was used for speeds below 30Mbit/s and it was assumed that premises with superfast availability could obtain speeds of 80Mbit/s. Finally, premises with ultrafast availability were assumed to be able to obtain 1000Mbit/s (on the assumption that most ultrafast connectivity will be delivered via FTTP).

  Owing to the limited resolution of the data, some caution is needed in relation to inferences at the fastest available speeds.

- **Speeds available to businesses:** Connected Nations does not distinguish between residential and non-residential connections, and it was necessary to assume that businesses and households were equally likely to benefit from improvements in available broadband speeds. Additionally, while data on broadband is available at the postcode level, it is only possible to identify the Output Area in which businesses are located (a small area with an average population of 310 residents). As such, postcode level data on broadband availability was aggregated to the Output Area before input into the SRS in order to estimate the model described below.

These challenges weaken the precision with which broadband speeds available to individual firms are measured (i.e. productivity will be linked to general improvements in broadband speeds in the area rather than the speeds specifically available to the firm).

1.4 Econometric model

The main challenge estimating the model outlined above are issues relating to endogeneity. If areas receive faster broadband connectivity because local firms are expected to become more productive in the future (and therefore more willing to pay), then the model will overstate the impact of broadband speeds on productivity.

To mitigate these concerns, models were implemented to control for (a) firm fixed effects (θ^i), (b) time specific shocks affecting all firms (θ^t), and (c) unobserved trends at the sector and local authority level (tA^i, tS^i) as follows:

$$\ln y_{it} = \ln \alpha + \beta \ln L_{it} + \gamma \ln K_{it} + \delta \ln B_{it} + \theta^i + \theta^t + tA^i + tS^i + \varepsilon_{it}$$

The analysis could potentially be adjusted to examine either effects by sectors of the economy or types of area. Specific breakdowns of interest will be discussed with BDUK. Analysis was restricted to the 2016 to 2021 period given data availability of ABS releases and Connected Nations variables.

1.5 Results

The table below outlines the main results of the initial analysis. The analysis showed that:

- **Elasticity of output to broadband availability:** The base model resulted in an estimated elasticity of output to availability of 0.019 percent. This indicates that a 1 percent increase in broadband speed led to a 0.019 percent increase in GVA. Robustness checks focussed on SMEs led to a higher estimate for this type of firms at 0.026 percent. Analysis focussed solely on firms with a single site (to assess the extent to which the overall results may be affected by the apportionment of financial variables to local units) estimated a similar elasticity of output to broadband availability as that for SMEs at 0.027 percent.

- **Sector differences:** The tourism and agriculture sectors were highlighted as sectors of interest and were explored in models restricted to just firms active within these sectors (using SIC 2007 codes). Note that the ABS data does not include data on the majority of agriculture firms and only includes agricultural support services, hunting, forestry and fishing. The sector results imply a higher elasticity of output to broadband availability for tourism sector firms at 0.024 percent and a lower elasticity for agriculture firms of just 0.006 percent.

- **Area differences:** Comparisons can also be made by the rural/urban nature of areas. Using the ONS classification codes, areas were divided into urban or rural in nature. Estimated elasticities across both were similar to the overall models with elasticities for firms in urban areas 0.019 percent. The estimated elasticity for firms in rural areas was slightly higher at 0.023 percent.

Table 1.1: Estimates of output elasticities – base, sector and area models

Model (firms/areas included)	Elasticity of output to: Labour	Capital	Broadband
Base models			
Overall	0.937***	0.094***	0.019***
SMEs	1.025***	0.365***	0.026***
Single site	0.984***	0.262***	0.027***
Sector			
Tourism sector	0.964***	0.118***	0.024**
Agriculture	0.913***	0.326**	0.006*
Rural/urban areas			
Rural	0.964***	0.095***	0.023***
Urban	0.900***	0.093***	0.019***

Source: Ipsos analysis. ***, **, and * indicate that the estimated coefficient was significant at the 99%, 95%, and 90% level of confidence respectively. All models were estimated with fixed effects and unobserved time specific shocks.

A set of further analyses were completed to explore the elasticity of output to broadband availability at different starting points. For this analysis the year before and the year after a change in broadband speed occurred were isolated and the regression model outlined above was applied. The table below outlines the results:

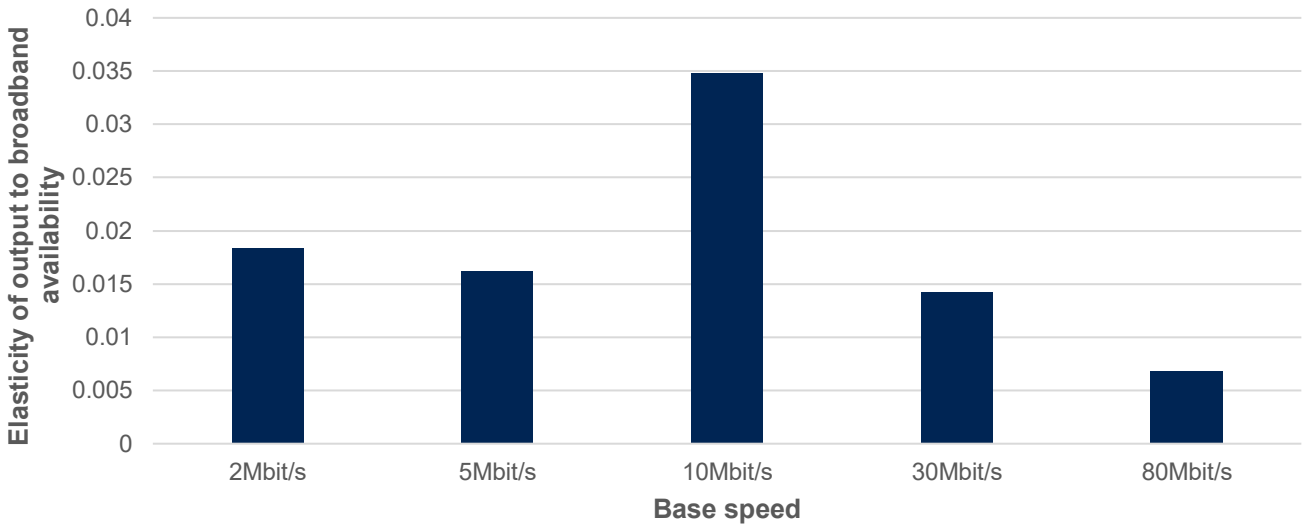
- **Upgrades from basic broadband:** Base speeds of below 10 Mbit/s were associated with elasticities of between 0.016 and 0.035 percent. The higher range was obtained where areas had a base speed of under 10Mbit/s but higher than 5 Mbit/s. These upgrades would have been to at least superfast or ultrafast speeds and suggests that improvements from a low baseline such as this have a much greater impact on output.
- **Upgrades from superfast to ultrafast:** Estimated elasticities for upgrades above superfast were smaller and imply that improvements from superfast to ultrafast had a lower impact on output than changes from basic broadband.

Table 1.2: Estimates of output elasticities – by base speed

Speed category before upgrade	Elasticity of output to: Labour	Capital	Broadband
2Mbit/s	0.964***	0.104***	0.018*
5Mbit/s	0.959***	0.113***	0.016**
10Mbit/s	0.972***	0.100***	0.035***
30Mbit/s	0.949***	0.110***	0.014***
80Mbit/s	0.962***	0.170***	0.007*

Source: Ipsos analysis. ***, **, and * indicate that the estimated coefficient was significant at the 99%, 95%, and 90% level of confidence respectively. All models were estimated with fixed effects and unobserved time specific shocks.

Figure 1.1: Output elasticities by base speed



Source: Ipsos analysis.

It should be noted that this analysis has weaknesses in terms of the limitations imposed on the years included (just those before and after a change in speed) and alternative ways to estimate differences by base speed will be explored. Note that the base model in table 1.1. does indicate diminishing returns to scale and in itself implies that changes in output are smaller as speed increases (as the coefficients are less than unity).