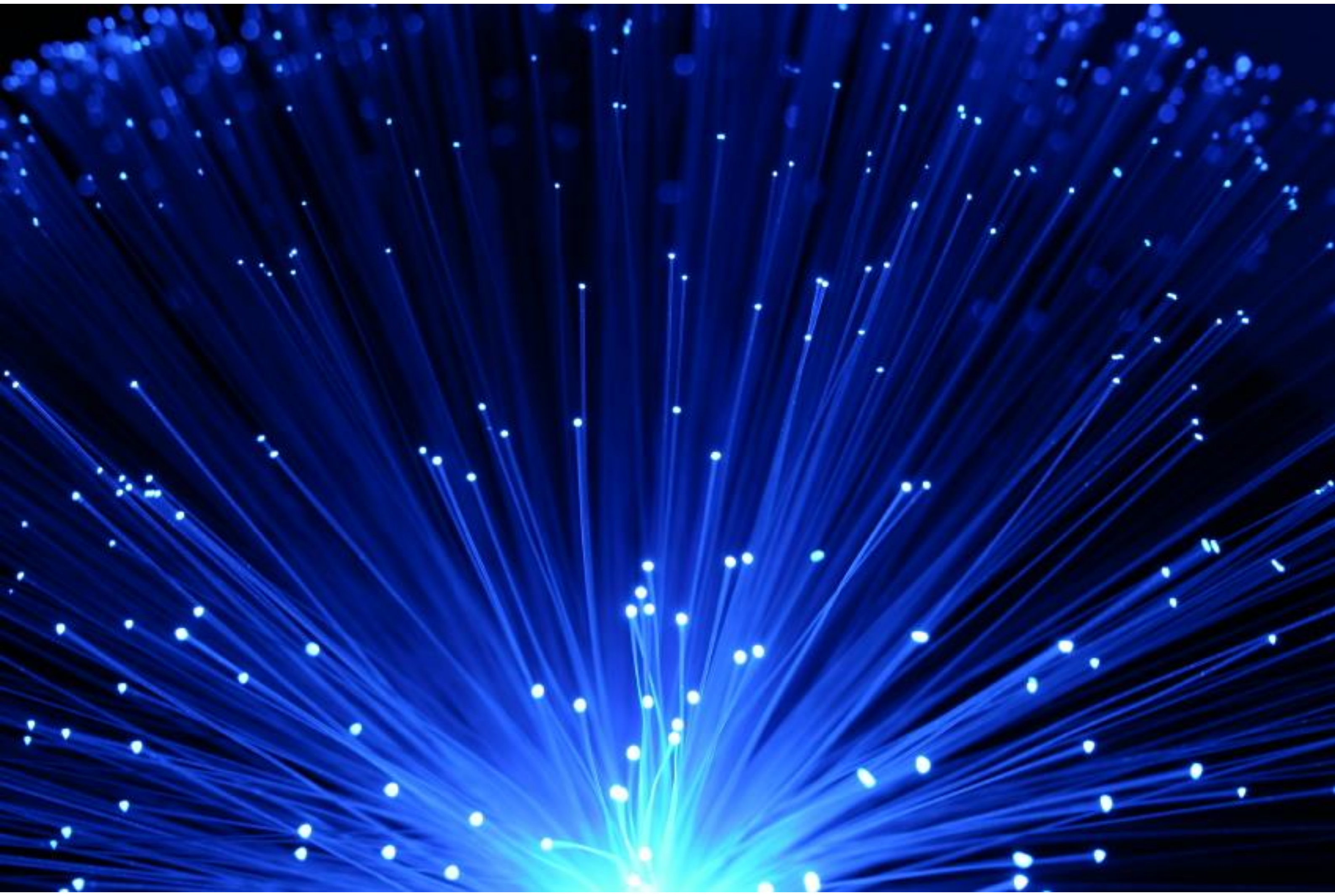
UK Broadband Impact Study

Impact Report

November 2013



SQW

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Foreword

There can be few areas of modern life which are not touched somehow by broadband connectivity – whether it's supporting how we work, how we learn, how we communicate with friends and family, or how we entertain ourselves.

But how much will we benefit from *improvements* in broadband performance? And what return will we see from the substantial public funds going into upgrading the UK's broadband infrastructure?

This report, commissioned by the Department for Culture, Media & Sport, addresses these questions by assessing the economic, social and environmental impacts for the UK from faster broadband, and from publicly funded intervention.

While recognising that there are still gaps in the empirical evidence base, and that the future is inherently uncertain, the study's projections are the outputs from a rigorous and detailed analysis which draws on the best data currently available. Our report has relevance for decision-making in a variety of policy areas, at national and local levels. We hope you find it interesting and useful.

Chris Green

CEO, SQW Group

Executive Summary

With the need to stimulate strong and sustainable growth and to ensure that the UK can succeed in the global economy, it is vital to ensure that there is a good understanding of the impacts of publicly funded interventions. Further improving our understanding can inform future funding decisions and help maximise the value for money of these investments.

Upgrading the UK's broadband infrastructure is one area into which substantial public funds are being invested. The Department for Culture, Media & Sport has therefore initiated the first phase of the UK Broadband Impact Study, to build further insights into the impacts of faster broadband. The study has been undertaken by a consortium led by SQW, in partnership with Cambridge Econometrics and Dr Pantelis Koutroumpis.

Central to this phase of the study has been the development of an integrated model of the projected economic, social and environmental impacts associated with faster broadband (i.e. increased broadband speeds since a baseline year of 2008), and of those impacts attributable to the current set of publicly funded interventions to improve broadband quality and coverage[1]. This has been informed by an extensive literature review[2], published in February 2013.

While acknowledging that there remain many uncertainties, the output from this work is the most in-depth and rigorous forward-looking quantification of broadband impacts developed to date in the UK.

Note that we do not, in this report, include any impacts associated with further interventions resulting from the Government's announcements[3] in July 2013 on extending superfast broadband to 95% of premises by 2017.

Economic impacts

Regarding the economic impacts, we estimate that the availability and take-up of faster broadband speeds will add about **£17 billion** to the UK's annual Gross Value Added[4] (GVA) by 2024. This level of uplift contributes an average of 0.07 percentage points to real annual GVA growth over this period.

The GVA impacts attributable to the current set of publicly funded interventions rise to about **£6.3 billion** p.a. by 2024, which is equivalent to an uplift of 0.03 percentage points on the UK's real annual GVA growth.

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[1] Note that the scope of this study focuses on *fixed* broadband connectivity to business premises and homes. The impacts associated with *mobile* broadband connectivity are not addressed here.

[2] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/85961/UK_Broadband_Impact_Study_-_Literature_Review_-_Final_-_February_2013.pdf

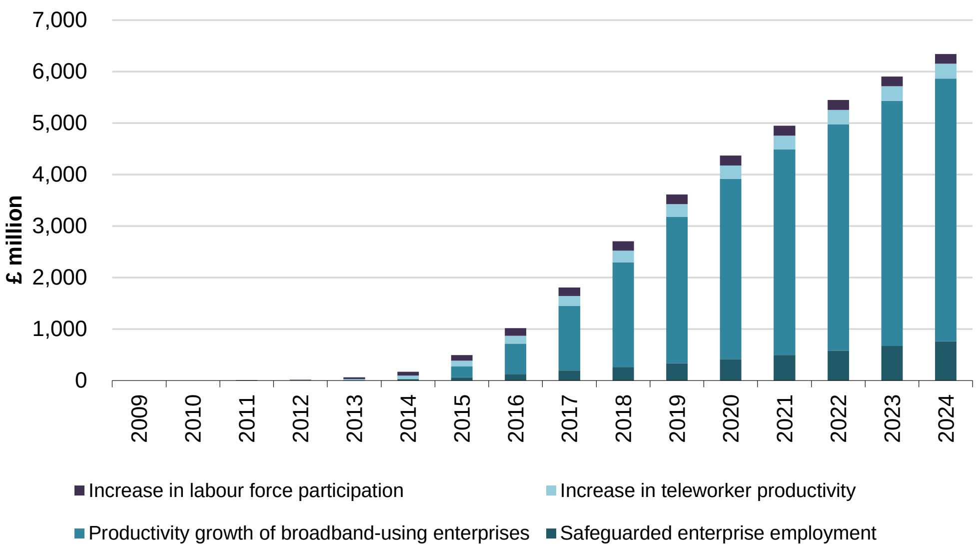
[3] http://www.broadbanduk.org/2013/07/30/dcms-publish-policy-paper-connectivity-content-and-consumers-britains-digital-platform-for-growth/

[4] Gross Value Added is a measure of economic output. It is closely linked to Gross Domestic Product, as follows: GVA + taxes on products - subsidies on products = GDP

Over our modelling period (to 2024), these interventions are projected to return approximately **£20 in net economic impact for every £1 of public investment**. This is an unusually high level of return for public funding, but we consider it to be realistic, given that broadband is a General Purpose Technology which has an increasingly critical role in the day-to-day operations of the majority of UK businesses. The Government's interventions are substantially improving the quality of this technology across a significant proportion of the UK, which, in the long term, will benefit hundreds of thousands of businesses, employing millions of people.

The bulk of this economic impact comes from improvements in the productivity of broadband-using firms, as illustrated in the chart below, but there are also significant benefits from safeguarding employment in areas which would otherwise be at an unfair disadvantage, from productivity-enhancing time-savings for teleworkers, and from increased participation in the labour force. The total net employment impacts from faster broadband rise to about 56,000 jobs at the UK level by 2024, and about **20,000 jobs** are attributable to the publicly funded intervention.

Figure 1: Total net annual GVA impact attributable to intervention – by type of impact (£ million, 2013 prices)



Source: UK Broadband Impact Model, SQW 2013

In addition (and excluded from the Benefit Cost Ratio cited above), the work involved in constructing the subsidised networks, including multiplier effects, is expected to account for a short-term total gross GVA impact of about £1.5 billion, with approximately 35,000 job-years created or safeguarded over the period to 2016.

Social impacts

Beyond its economic impacts, broadband has, of course, become an integral part of modern life, affecting various aspects of our day-to-day activities as individuals, families and communities.

The Government's Universal Service Commitment for everyone to have access to at least basic broadband (2Mbps+) will help to ensure that no areas are excluded from the benefits of broadband and the internet.

However, as bandwidths available in urban areas have continued to advance rapidly, there has been growing concern over the extent to which a new 'digital divide' is emerging, to the disadvantage of those communities left with relatively poor levels of broadband service.

Our analysis confirms that the interventions currently underway will have a material impact on reducing the digital divide for both households and businesses.

In particular, the introduction of 'FTTP on demand' throughout BT's FTTC footprint[5] (which will be substantially increased through the Rural Programme intervention) should have an important and sustained impact in putting the UK's rural areas onto a 'more level playing field' as far as business connectivity is concerned.

For households, the *current* set of interventions goes a long way to addressing the digital divide. However, as urban bandwidths continue to advance over time, including through improvements in Virgin Media's offerings and through new entrant FTTP providers, households in the least densely populated areas could fall further behind in relative terms.

This situation will be further addressed, however, following the Government's announcement in July 2013 to extend its target to 95% of premises having access to superfast broadband by 2017, and to explore the measures needed to reach at least 99% by 2018.

Besides the digital divide issue, there are many other potential social impacts associated with the availability and usage of faster broadband – as discussed in our literature review. The complex and changing nature of the interactions between people and technology mean that many of these social impacts are impossible to forecast with any degree of confidence.

However, we have quantified some social impacts associated with changes in teleworking. We estimate that the increase in teleworking facilitated by faster broadband will save about 60 million hours of leisure time per annum in the UK by 2024 (of which about 10 million hours are attributable to publicly funded intervention). By avoiding commuting costs, the additional teleworking enabled by faster broadband will lead to total household savings rising to £270 million p.a. by 2024 (£45 million of which are attributable to intervention).

Environmental impacts

The availability and use of faster broadband will also have significant environmental impacts. We estimate that, by 2024, it will save a total of:

[5] FTTP=Fibre to the Premises; FTTC=Fibre to the Cabinet. Note that 'FTTP on demand' is a service which will be offered in FTTC-enabled areas. Its pricing differs from that of the mass market FTTP services offered in areas enabled for FTTP.

- 2.3 billion kms in annual commuting, predominantly in car usage, through enabling increased telework for a proportion of the workforce. This is in the order of 2% of the current total annual UK commuting distance.
- 5.3 billion kms in annual business travel, predominantly in car usage, through the increased use of video and online collaboration tools by broadband-using firms. This is in the order of 9% of the current total annual UK business travel distance.
- 1 billion kWh of electricity usage p.a., through broadband-using firms shifting part of their server capacity onto (more energy-efficient) public cloud platforms.

Allowing for rebound effects (in particular, teleworkers needing to heat their homes in the winter), we estimate that faster broadband will account for about **1.6 million tonnes of carbon dioxide equivalent (CO2e) savings per annum**, by 2024. This is equivalent to about 0.3% of the UK's current greenhouse gas emissions. Of these CO2e savings, publicly funded intervention in faster broadband will account for approximately **0.4 million tonnes p.a.** by 2024.

1. Introduction

Context

In recognition of broadband's role as a key enabler for the nation's socio-economic development, the Government intends to establish world-class connectivity throughout the UK.

To help achieve this goal, Broadband Delivery UK (BDUK) has put in place a number of initiatives to improve broadband quality and coverage, in areas where there is an insufficient case for operators to do so on a commercial basis, and to stimulate take-up. These include the Rural Programme, the Rural Community Broadband Fund, and the Urban Broadband Fund.

Including matched funding from local authorities, devolved administrations and European sources as well as central government funds, these interventions represent a very substantial public investment in improving the UK's broadband infrastructure: £1.6 billion of public funds have been committed to date[6].

The UK Broadband Impact Study

With the need to stimulate strong and sustainable economic growth, it is vital to ensure that there is a good understanding of the impacts of publicly funded broadband interventions, in order to inform future funding decisions and to help maximise the value for money of these investments.

The Department for Culture, Media & Sport (DCMS) therefore initiated the UK Broadband Impact Study in November 2012, commissioning a consortium led by SQW (with Cambridge Econometrics and Dr Pantelis Koutroumpis) to undertake the first phase of the work.

Our study has developed an integrated model of the projected economic, social and environmental impacts associated with faster broadband[7] (i.e. increased broadband speeds since the baseline year of 2008), and with publicly funded intervention in improving broadband quality and coverage. This has been informed by an extensive review of the available literature, the report of which[8] was published in February 2013.

The model

As well as drawing on findings reported in the academic literature, the model developed for this study has been informed by a review undertaken by Cambridge

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[6] See DCMS. 2013. "Connectivity, Content and Consumers: Britain's digital platform for growth"

[7] Note that the impacts of *mobile* broadband, and of BDUK's Mobile Infrastructure Project are not within the scope of this study.

[8] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/85961/UK_Broadband_Impact_Study_-_Literature_Review_-_Final_-_February_2013.pdf

Econometrics of broadband impact studies previously carried out for local authorities and devolved administrations across the UK. The design of our model has sought to expand on the best aspects of these previous approaches, while excluding some mooted routes to impact which as yet appear to be too speculative, or unsupported by the available evidence, in the study team's opinion. We consider the resulting analysis to be the most in-depth and rigorous forward-looking quantification of broadband impacts developed to date in the UK – while recognising the uncertainties inherent in this task.

Our model covers the period from 2008 to 2024 inclusive[9]. Impacts are estimated for three different domains:

- economic (in terms of net employment and net Gross Value Added impacts).
- social (in terms of digital divide measures, and value to households from teleworking)
- environmental (in terms of net carbon dioxide equivalent - CO2e – emissions saved).

For each of these, there are two types of impact:

- the impact attributable to faster broadband speeds being available since the baseline year, 2008
- the impact attributable to the public sector interventions currently underway on broadband (via the Rural Programme, Rural Community Broadband Fund, and the Urban Broadband Fund).

Understanding the *spatial* aspects of broadband has been critical for our study: broadband speeds vary by location, and the profile of broadband users also vary by geography (in particular, in terms of the distribution of different sizes/sectors of businesses). The choice of geographic unit for our analysis has therefore been important. Too large a unit would obscure important differences through 'averaging out' effects, while too small a unit would become unmanageable.

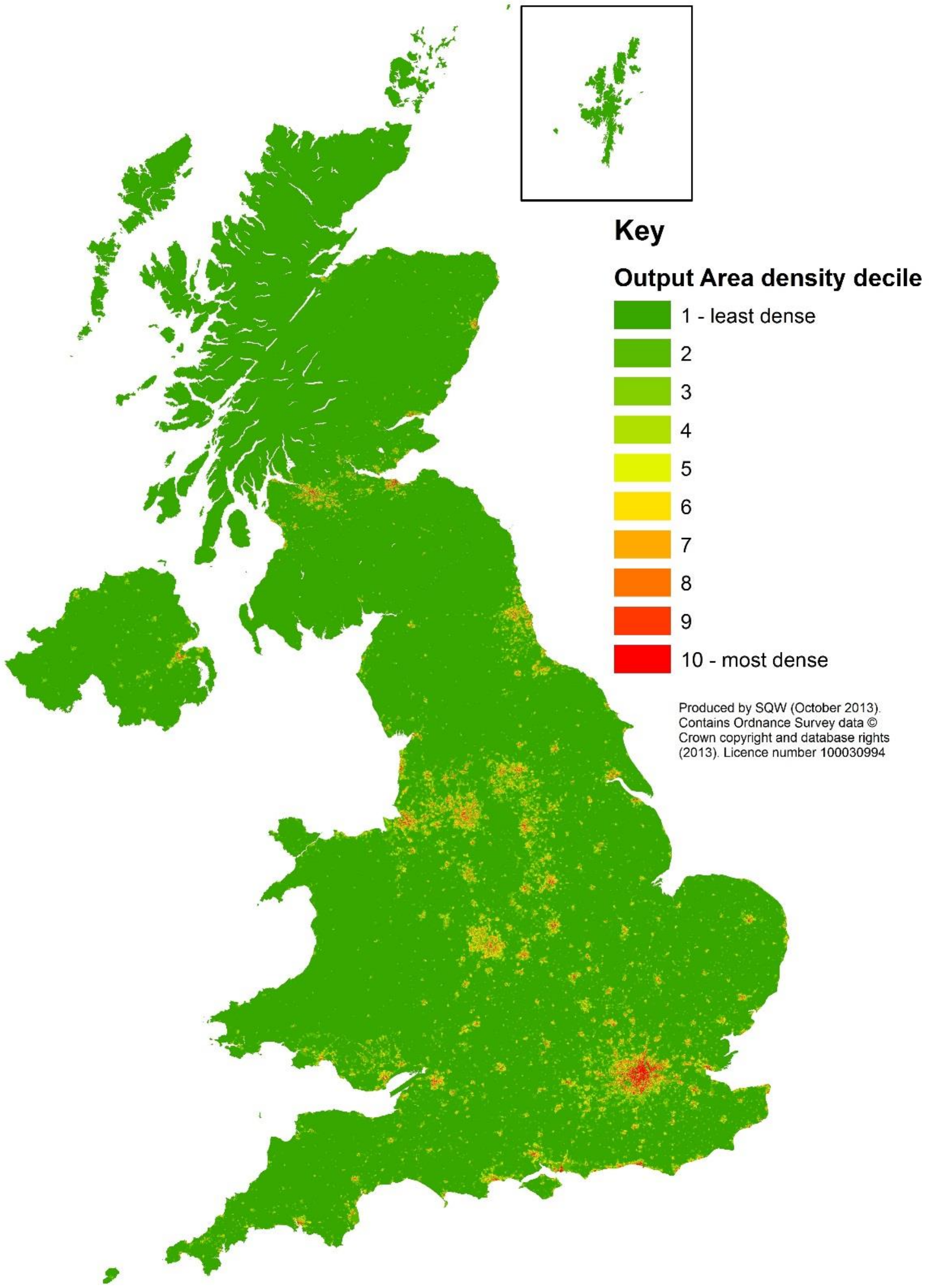
The approach chosen was to divide the UK into ten 'density deciles', ranging from the 10% of Census output areas[10] with the fewest premises per square kilometre (sq km), to the 10% of Census output areas with the most premises per sq km. Both residential and business premises are included in this calculation. In broad terms, this is designed to align with the commercial drivers for broadband roll-out: operators tend to provide upgraded services to the most densely populated areas first, where they have the lowest unit costs, and to the least densely populated areas last, where they have the highest unit costs. This therefore allows us to analyse

[9] 2008 was chosen as the baseline year, as superfast broadband services first became available in the UK at the end of that year, with the launch of Virgin Media's 50Mbps service.
[10] There are about 220,000 output areas in the UK. They are designed to cover roughly similar populations, and therefore vary in area: from less than 0.001 sq km in some city neighbourhoods to 200 sq km + in the most rural areas.

geographic differences in broadband speed, and so understand the geographic differences in impacts.

These density deciles are illustrated in the map below, which shows the least dense areas in dark green, and the densest areas in red. While it is striking that the least dense decile covers the vast majority of the UK's land mass, it should be remembered that it only accounts for about 10% of premises.

Figure 1-1: Map of the UK by the 'density deciles' of Census Output Areas (1= the 10% of UK Output Areas with fewest premises per sq km, in dark green)



Source: SQW analysis

Links from speeds to impacts

The underlying hypothesis for our model is that *speed matters*: faster broadband will enable businesses and individuals to change the way they do things. Moreover, the last decade has seen significant improvements in the broadband speeds available in the UK, and we envisage that this trend will continue throughout our modelling period – driven by competition between operators, technological improvements in the capabilities and costs of network equipment, and by the adoption of increasingly bandwidth-hungry applications, notwithstanding improvements in data compression techniques.

In order to capture the effect of continuing improvements in broadband speed over time, we have incorporated explicit links between the projected broadband speeds *available*, the projected speeds *used*, and their projected net impacts. For some impacts, it is the *relative* broadband speed (i.e. the speed available in an area compared with the national average) that is the key driver, rather than the absolute speed.

Given that *upstream* speeds are important, as well as *downstream* speeds, (e.g. for cloud computing and video applications), we have reflected this in the model by combining the two into a notional 'total speed'.

Inputs and assumptions

A list of the model's inputs and assumptions is provided in Annex A. Each of these has been calibrated using the best information currently available, and the rationale and/or source for each input/assumption has been set out within the model.

It is recognised, however, that there are currently considerable uncertainties inherent in many of the assumptions. For the purposes of this study, we have used what we consider to be conservative assumptions in these cases, and the model has been designed so that such inputs can be updated as and when better information becomes available.

Displacement and multipliers

Impacts for direct beneficiaries of faster broadband can have knock-on effects in the wider economy. Where appropriate, the model therefore includes assumptions on 'displacement' and 'multiplier' effects, in calculating the net economic impacts for the UK:

- Displacement captures the effect of increased growth in directly affected businesses being at the expense, to some extent, of lower growth for their competitors elsewhere in the UK.
- Multipliers capture the effect of increased growth in directly affected businesses leading to indirect benefits (in their supply chains), and to 'induced' benefits (though their employees spending wages in the economy).

Monte Carlo simulation

We have incorporated Monte Carlo simulation functionality in the model, in order to explore the probability distributions of inputs and outputs. Model inputs/assumptions to which Monte Carlo distributions have been applied are highlighted in bold in Annex A.

Testing

The model has been developed by SQW, with advice from Dr Koutroumpis on certain assumptions, and subjected to independent testing by Cambridge Econometrics, to verify its correct working, logical consistency, usability, and fitness for purpose.

This report

Our report takes each domain in turn: economic impacts (section 2), social impacts (section 3) and environmental impacts (section 4). Not all potential impacts have been quantified in our model, and where appropriate we briefly discuss other types of impacts in qualitative terms.

Unless otherwise specified, all £ values are in 2013 prices.

2. Economic impacts

Routes to economic impact

The key modelled routes to economic impact are: productivity growth of broadband-using enterprises; safeguarding of local enterprise employment; improved teleworker productivity; and increased labour force participation

There are various mechanisms through which faster broadband, and publicly funded investment into faster broadband, can lead to economic impacts for the UK. As an infrastructure investment, broadband network deployment produces spillover effects to all sectors of the national economy. The adoption of faster broadband by firms stimulates further investment in wider Information and Communications Technology (ICT) systems and applications taking advantage of the improved connectivity, and results in business process restructuring, more informed decision making, and productivity gains. Faster broadband also helps to support the creation of new businesses, and the easier access to market information helps to reduce barriers to entry – though this may be at the expense of the decline of more traditional businesses in sectors which are disrupted by the new technology. Continual improvements in broadband service offerings, for both business and consumer markets, stimulate innovation in business models, and this serves to improve overall productivity levels in the economy. Outsourcing of processes and operations is made easier for small businesses, which helps them focus on improving their core strengths while reducing operational costs.

The 'routes to impact' which we have modelled are as follows:

- **Productivity growth of broadband-using enterprises**. It is now widely accepted that the availability and adoption of affordable broadband plays an important role in increasing productivity in national economies – through, for example, supporting the development of new, more efficient, business models, enabling business process re-engineering to improve the efficiency and management of labour intensive jobs, and enabling increased international trade and collaborative innovation. Our model includes estimates of the average increase in the broadband speeds used by businesses each year (by industry group, size band and density decile), and the extent of the associated productivity benefits.

- **Safeguarding of local enterprise employment**. Broadband – and faster broadband in particular – has a complex relationship with employment creation *at a national level*. There appears to be a 'creative destruction' effect at work, in which employment growth may be suppressed to some extent by improvements in business process efficiency (businesses doing more with less), while the better connectivity also leads to employment growth opportunities through new business models and emerging sectors. There is more consensus in the literature, however, that the relative availability and quality of broadband has a significant impact on employment growth at a *local level*: areas with poor broadband lose out to areas with better connectivity. Our model assumes that if there were a persistent and widening digital divide, then this local effect would lead to adverse national level impacts over time, as jobs lost or foregone in areas with poor broadband (which might, for example, also have advantages in other respects, such as relatively low accommodation costs or labour costs) would not be entirely replaced by jobs created in areas with good connectivity. Publicly funded intervention, to reduce the digital divide, can therefore help safeguard net employment and the associated GVA at the UK level, as well as at local levels.

- **Teleworker productivity**. As levels of connectivity at home improve, this will tend to encourage higher levels of working from home – the majority of which will be people working a few days per month from home, rather than teleworking full-time. While some have argued that employees can be inherently more productive when working at home, our model takes a relatively conservative view, assuming that a certain proportion of the time saved by not commuting on a telework-day is spent on work: i.e. adding to the employee's productive hours per day, rather than making those hours more efficient.

- **Labour force participation**. The ability to work from home, using improved levels of connectivity, also reduces the barriers to employment for certain parts of the working age population. In particular, we have assumed that a proportion of carers (i.e. people who are economically inactive, because they are looking after the home or family members) would be willing and able to take up part-time employment based at home, and that the prevalence of this will increase as levels of home connectivity improve over time. Similarly, we have assumed that a proportion of unemployed disabled people would find it easier to find and retain suitable work if this were based at their own homes (levels of unemployment for disabled people have historically been persistently significantly higher than those for the workforce as a whole) – and again, that the prevalence of this will increase as levels of home connectivity improve over time.

Network construction impacts have been calculated, but are not included in our value for money assessment

- **Network construction impacts**. The investment of public funds into faster broadband infrastructure, together with the leveraged private sector investment, itself creates (or safeguards) economic activity in the relevant telcos and their supply chains in the construction phase: e.g. in manufacturing the required additional equipment, undertaking civil engineering for new ducts, installing new fibre cable and cabinets etc. Our model generates estimates for the gross employment and GVA effects associated with this activity – though we have *excluded* this in our assessment of the value for money of the intervention, as we have assumed that the public funds could otherwise be used for other construction projects (i.e. there would be 100% 'deadweight' on the construction impacts).

We have not assumed any impacts on public sector GVA, nor included any consumer surplus

Our focus is on the net Gross Value Added impact for the UK – i.e. how much higher the UK's GVA may be, as a result of faster broadband, and as a result of publicly funded intervention. We have therefore *excluded* the following from our analysis:

- Changes in the GVA associated with the *public sector* itself (which would largely consist of the employment costs associated with public sector employees). Public sector GVA will be constrained by national budgets for public expenditure, and we have not assumed that the advent of faster broadband will lead to an increase in public expenditure in the foreseeable future, given the need for deficit reduction (this is not to say that faster broadband will have no productivity benefits for the public sector; it *will*, in terms of improved service delivery, and being able to do more with less).

- Any measures of 'consumer surplus'. Some studies have estimated the consumer surplus associated with faster broadband (that is, the aggregated difference between what consumers would be willing to pay for faster broadband and its market price). While this is a valid theoretical approach (if problematic for forward-looking studies, given the rapid changes in quality and price), consumer surplus makes no contribution to the UK's GVA, and we have therefore not included it in our economic impact assessment.

Economic impacts for the UK of faster broadband

First we report our findings on the economic impacts for the UK of faster broadband: i.e. the impacts attributable to the availability and use of speeds faster[11] than those available in our baseline year of 2008, over the period 2009 to 2024.

Productivity of broadband-using firms

In estimating the productivity impacts of faster broadband, we have taken into account the following considerations:

- **The distribution of businesses varies by geography**. We have used data for 2008 provided by the Office for National Statistics (ONS), on the count of private sector 'local units' and employment for each of six broad industry groups[12], in four size bands[13], at detailed levels of geography[14], and derived estimates of the associated counts and employment for each of our density deciles.

- **Not all businesses will be using (mass market) broadband for their primary connectivity**. Our study is focused on the impacts of mass market broadband services – i.e. 'affordable broadband' for SMEs and households. More expensive business connectivity services – such as traditional leased lines, and the newer Ethernet leased lines – are not included in our analysis. Hence only a proportion of each size band's businesses are assumed to be

[11] Note that this uses the 'with intervention' scenario
[12] The six broad industry groupings, using SIC2007 sections, are: A (Agriculture, forestry and fishing); B,D&E (Mining and quarrying; Electricity, gas, steam and air conditioning supply; Water supply; sewerage, waste management and remediation activities); C&F (Manufacturing; Construction); G,H&I (Wholesale and retail trade, repair of motor vehicles and motor cycles; Transport and storage; Accommodation and food service activities); J,K,L,M&N (Information and communication; Financial and insurance activities; Real estate activities; Professional, scientific and technical activities; Administrative and support service activities); P,Q,R&S (Education; Human health and social work activities; Arts, entertainment and recreation; Other service activities)
[13] Employment levels of: 1 to 9; 10 to 49; 50 to 199; and 200+
[14] Middle-layer Super Output Area in England & Wales, Super Output Area in Northern Ireland, and Datazone in Scotland

'broadband-using' (a much lower proportion for large businesses than for micro businesses).

- **The broadband speeds available to businesses vary by geography, and will continue to change over time**. We have analysed postcode-level data provided by BDUK (based on information provided by operators) on the current coverage of different technologies, and developed our own estimates of the additional coverage through intervention. This has been combined with projections as to how the availability and speeds of various technologies may continue to increase over time, in order to derive estimates of the coverage and speeds available to businesses, by density decile, and by year over the modelling period. See Figure 3-4 in the next section for the resulting modelled speeds available to businesses by density decile.

- **There are lags associated with businesses taking up the newly available speeds**. It takes time for increases in speed to be taken up across the business base, hence the average used speeds will be considerably lower than the maximum available speeds; we have assumed lags dependent on the size of business – up to ten years for each year's increase in available speed to diffuse, in the case of the smallest firms (employing 1 to 9 people).

- **There are further lags associated with businesses realising productivity impacts from their improved connectivity**. An improvement in a firm's connectivity does not lead to an immediate step-change in productivity. It takes time to implement process changes – potentially involving other complementary investments in systems and training – in order to realise the productivity benefits. We have assumed that it takes three years for the productivity shock associated with each year's increase in used speed to be fully realised.

- **The productivity impacts of increased speeds are, as yet, highly uncertain.** Our model uses a curve describing the average productivity shock associated with varying levels of in-year speed increase, ranging from 0% (at a speed increase of 0%) up towards a defined maximum towards which the curve asymptotes. The shape of the curve is principally driven by an assumption on the impact of a doubling of speed, for which our central estimate is 0.3% (i.e. an increase of 100% in the used speed in a year will lead to a 0.3% uplift in productivity, over the following three year period; the incremental benefits of greater speed increases progressively decline until the impact curve 'saturates'). As superfast broadband has only been introduced relatively recently, evidence of the relationship between broadband speed and productivity has yet to be fully addressed in the academic literature. However, we have drawn on some recent research findings that help approach the issue from a different angle. Using quality-adjusted deflators for telecommunications equipment prices, researchers from Imperial College and the Bank of England estimated the recent impact of telecommunications on UK productivity growth through capital deepening and spillovers[15]. By applying our own estimates of the time taken for broadband speeds to double, and of the share for broadband connectivity of this overall impact of telecommunications, we have derived the above estimate of the productivity impact associated with a doubling of speeds. It also aligns (if we assume no significant net employment effect) with research by Chalmers University of Technology[16], which found that a doubling of speed is associated with a 0.3 percentage point increase in GDP growth, using a macroeconomic framework for OECD countries. As this is a particularly important - but uncertain - assumption in our model, we have applied a Monte Carlo probability distribution (using a triangular distribution ranging from 0.19% to 0.44%), such that the effects of this uncertainty are reflected in the outputs from the Monte Carlo simulations.

- **The productivity impacts of increased speeds will vary by sector**. The productivity performance of some sectors is much more dependent on ICT, including connectivity, than that of others. We have used estimates from Cambridge Econometrics of the average GVA per employee, as of 2008, in each of our six broad industry groups, and varied the above average productivity effects depending on their relative ICT intensity, based on information from the EU KLEMS database on the consumption of ICT fixed capital vs the total consumption of fixed capital in the year 2007, by sector.

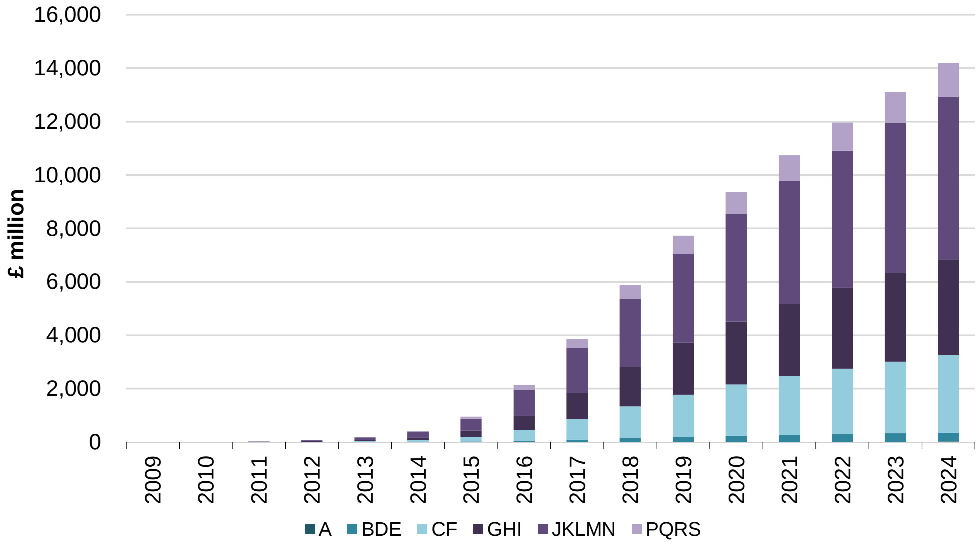
The results of our analysis of the enterprise productivity impacts attributable to faster broadband are illustrated in Figure 2-1 and Figure 2-2 below, showing the breakdown by industry group, and by size of firm respectively.

Annual enterprise productivity impacts rise to £14 billion by 2024

Overall, we estimate that the availability and exploitation of faster broadband will lead to a net annual GVA impact of about £14 billion by 2024, through enhancing the productivity of broadband-using firms. The largest shares of this are for the JKLM&N industry group[17] (which is the most ICT-intensive), and for the 1 to 9 employment size band (which is the most dependent on this mass market broadband connectivity).

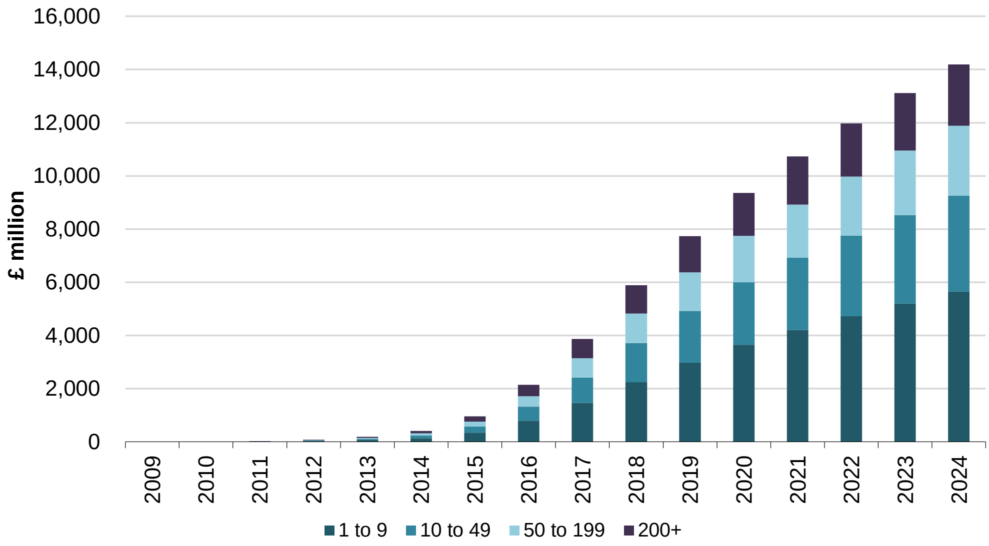
[15] Goodridge, Peter, Jonathan Haskel, and Gavin Wallis. 2013. "The 'C' in ICT : Communications Capital, Spillovers and UK Growth."
[16] Rohman, Ibrahim Kholilul, and Erik Bohlin. 2012. "Does Broadband Speed Really Matter for Driving Economic Growth? Investigating OECD Countries."
[17] Information and communication; Financial and insurance activities; Real estate activities; Professional, scientific and technical activities; and Administrative and support service activities

Figure 2-1: Net annual GVA impact from productivity growth for broadband-using firms, attributable to faster speeds since 2008 – by industry groups[18]



Source: UK Broadband Impact Model, SQW 2013.

Figure 2-2: Net annual GVA impact from productivity growth for broadband-using firms, attributable to faster speeds since 2008 – by size of firm (employment)



Source: UK Broadband Impact Model, SQW 2013

[18] Key: A (Agriculture, forestry and fishing); B,D&E (Mining and quarrying; Electricity, gas, steam and air conditioning supply; Water supply; sewerage, waste management and remediation activities); C&F (Manufacturing; Construction); G,H&I (Wholesale and retail trade, repair of motor vehicles and motor cycles; Transport and storage; Accommodation and food service activities); J,K,L,M&N (Information and communication; Financial and insurance activities; Real estate activities; Professional, scientific and technical activities; Administrative and support service activities); P,Q,R&S (Education; Human health and social work activities; Arts, entertainment and recreation; Other service activities)

Teleworker productivity

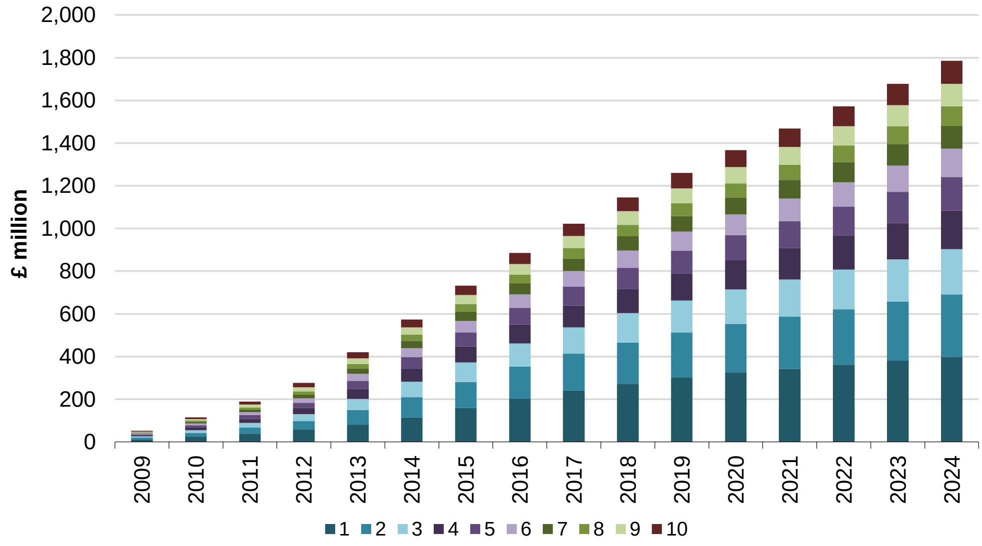
We have assumed that teleworker productivity impacts are additional to the enterprise-level productivity impacts estimated above, because the teleworker impacts will accrue to firms which are not 'broadband-using' (e.g. large corporates with teleworking employees) as well as those firms using mass market broadband. Our analysis combines assumptions and data on the following:

- The proportion of employed people who are 'telework-eligible' varying by Standard Occupational Classification (averaging 48% of all employed people); the distribution of occupations by density decile, using census data; and estimates of the proportion of telework-eligible employees who do telework to some extent, by year – rising from 40% in 2008 to 72% in 2024. Of these, only the proportion employed in the private sector are assumed to contribute to a net GVA effect.
- A curve estimating the relationship between days per year teleworked and the average used household speed (including a saturation level), and estimates of the relative propensity to telework by density decile, derived from an analysis of census data on those working mainly at or from home.
- The average duration of a two-way commute, by density decile, using data from the census and from the National Travel Survey (44 to 78 minutes); the proportion of saved time used for work (we have assumed 60%, based on a previous Cisco survey); and the average GVA per hour worked.
- Displacement and multiplier assumptions.

Annual teleworker productivity impacts reach £1.8 billion by 2024

As shown in Figure 2-3, the net GVA impact from the teleworker productivity effect rises to £1.8 billion p.a. by 2024. Roughly half is from teleworkers living in the three least dense deciles – which have above-average proportions of telework-eligible employees, where people have the longest average commutes, and where there is the highest propensity to telework.

Figure 2-3: Net annual GVA impact from increased teleworker productivity, attributable to faster speeds since 2008 – by density decile of their home area (1=least dense)



Source: UK Broadband Impact Model, SQW 2013

Labour force participation

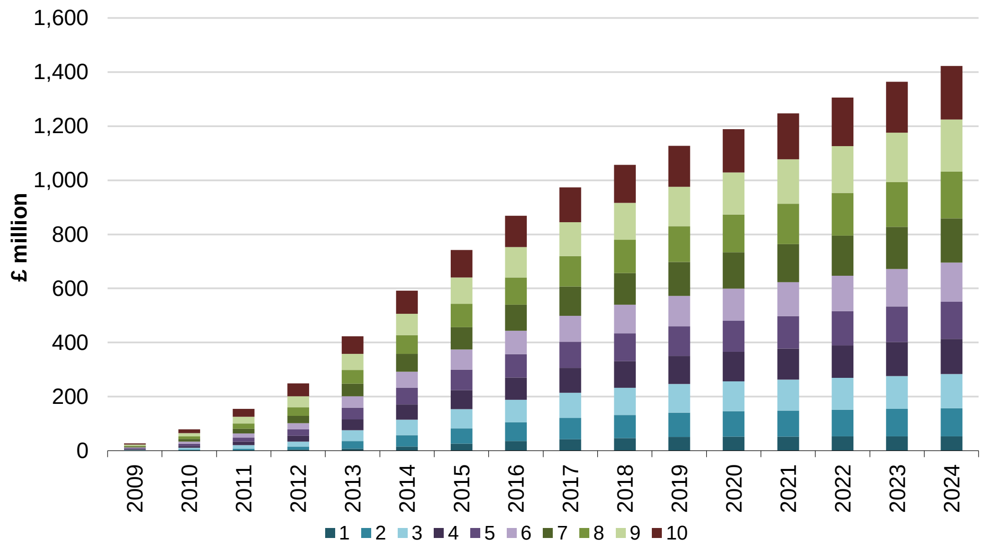
We assume that improved home connectivity will help to expand the UK's labour capacity, through increased participation of carers and disabled people. Our estimates combine data and assumptions on the following:

- The numbers of working age people who are economically inactive due to looking after the home or family members, by density decile; the proportion of these who would like a job; and proportion of these who would be telework-eligible.
- The number of unemployed disabled people, by density decile, and the proportion of these who would be telework eligible.
- Curves estimating the proportions of telework-eligible carers and unemployed disabled people gaining home-based employment, as functions of the average used household speed (including saturation levels).
- GVA per additional worker (assumed to be full-time for disabled people, and part-time for carers).
- Displacement and multiplier assumptions.

Annual impacts from increased labour force participation rise to £1.4 billion by 2024

The resulting net GVA impacts from increased labour force participation rise to about £1.4 billion p.a. by 2024 (Figure 2-4). In this case, there are more impacts for denser areas than for the less dense areas – partly due to the distribution of potential beneficiaries (e.g. in 2008 there were more than twice as many unemployed disabled people in density decile 10 than in decile 1), and partly due to the higher speeds available in urban areas.

Figure 2-4: Net annual GVA impact from increased participation of carers and disabled people, attributable to faster speeds since 2008 – by density decile of their home area (1=least dense)



Source: UK Broadband Impact Model, SQW 2013

Total economic impacts

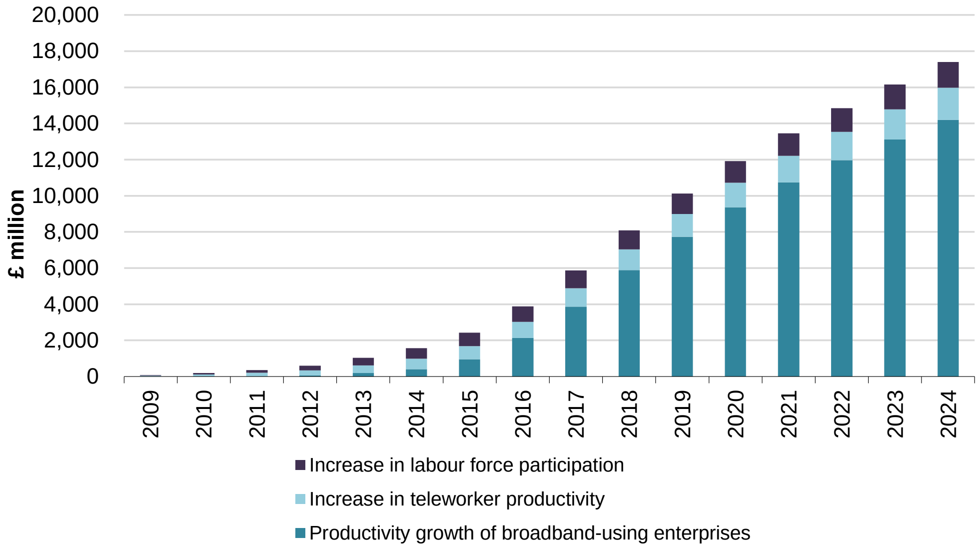
Total annual net GVA impacts rise to £17 billion by 2024.

In total then, we estimate that the net annual GVA impacts for the UK, attributable to faster broadband speeds since 2008, will rise to about £17 billion by 2024 (Figure 2-5). Of this, approximately £4.6 billion will accrue to 'rural' areas (where 'rural' means those Census Output Areas not flagged as being in towns and cities with resident populations of more than 10,000, which accounts for about 22% of UK premises).

This is equivalent to a contribution of 0.074 percentage points to the UK's real annual GVA growth over the period

To put this into context, the UK's total GVA in 2008 was £1.44 trillion in 2013 prices (£1.29 trillion in 2008 prices). So this level of uplift would correspond to an average contribution from faster broadband of about 0.074 percentage points (pp) to real annual GVA growth over the period 2009 to 2024 (cf the current Office of Budget Responsibility forecast of real GDP growth rising to 2.8% p.a. by 2017). Given that broadband is a General Purpose Technology which has an increasingly critical role in the day-to-day operations of the majority of UK businesses, this estimated level of uplift does not seem unreasonable.

Figure 2-5: Total net annual GVA impact, attributable to faster speeds since 2008 – by type of impact



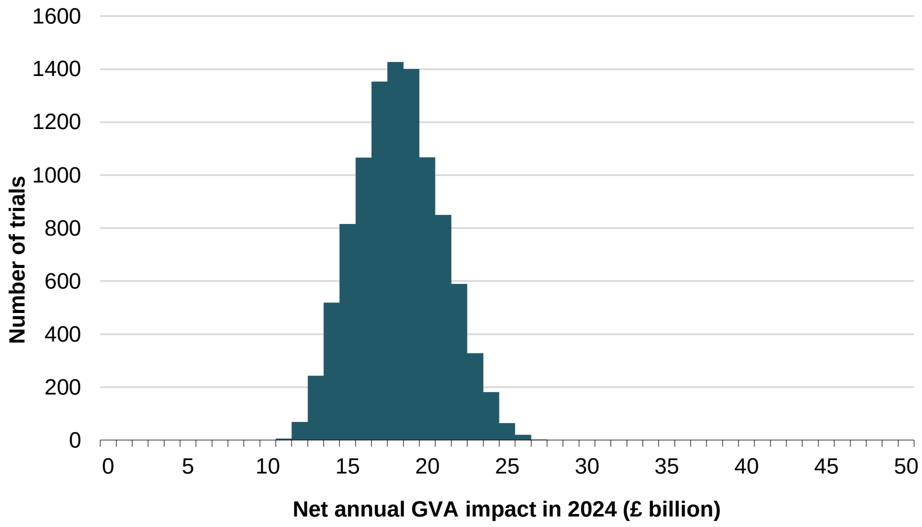
Source: UK Broadband Impact Model, SQW 2013

There are, however, many uncertainties inherent in the assumptions which combine to generate this estimate. We have assigned probability distributions to the assumptions which we consider to be most uncertain, with ranges around our 'most likely' estimate for each[19].

The resulting range of values for the net annual GVA impact in 2024 is illustrated in the chart below, from a Monte Carlo simulation using 10,000 trials, 90% of which return values between £14 billion and £23 billion (equivalent to a contribution to real annual GVA growth over the period of between 0.060pp and 0.099pp).

[19] For simplicity, and to avoid spurious accuracy, we have applied triangular distributions, rising from 0% probability at the lower bound to a peak probability at the most likely value, then falling again to 0% probability at the upper bound.

Figure 2-6: Monte Carlo distribution for the net annual GVA impact (£ billion) in the year 2024, attributable to faster speeds since 2008 (10,000 trial simulation)

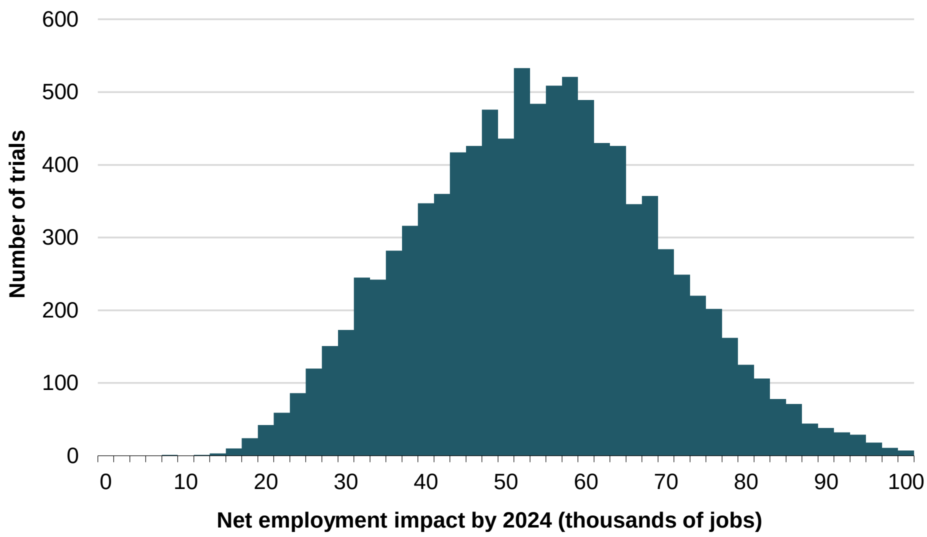


Source: UK Broadband Impact Model, SQW 2013

Net employment impacts rise to about 54,000 jobs by 2024

The total net employment impacts rise to about 56,000 jobs by 2024 – consisting of 40,000 from the participation of carers, and 16,000 from (otherwise unemployed) disabled people. As illustrated in the Monte Carlo chart below, there is a relatively high degree of uncertainty around this employment impact estimate – with 90% of the trials returning results between 30,000 and 80,000 jobs.

Figure 2-7: Monte Carlo distribution of the net employment impact by the year 2024, attributable to faster speeds since 2008 (10,000 trial simulation)



Source: UK Broadband Impact Model, SQW 2013

Economic impacts of public sector intervention

In order to assess the economic impacts attributable to *public sector intervention*, our model includes estimates of the 'with intervention' and 'without intervention' scenarios. The economic impact associated with intervention is simply the difference between the two net GVA impact time series.

The with-intervention scenario includes the current Rural Programme, RCBF and UBF initiatives

The with-intervention scenario incorporates:

- additional coverage of primarily FTTC-based services through the current Rural Programme (including the pre-BDUK projects in Northern Ireland and Cornwall) – and the associated availability of 'FTTP on demand' across BT's FTTC footprint from 2014 (which we have assumed will be affordable for businesses, though not for households)
- additional coverage of faster broadband services through the Rural Community Broadband Fund; in the absence of information yet being available on the specific implementations, we have assumed[20] a mix of FTTC and FTTP for these projects, covering additional premises – predominantly in the least dense deciles
- an acceleration in the business take-up of higher speeds, through the Urban Broadband Fund's voucher scheme, which we have assumed will reach about 35,000 businesses over the period 2013 to 2015 in urban areas.

Note that we do not, in this report, include any impacts associated with further interventions resulting from the Government's announcements[21] in July 2013 on extending superfast broadband to 95% of premises by 2017, and exploring the measures needed to reach at least 99% by 2018.

Safeguarding of local enterprise employment

Without intervention, we assume that the least densely populated areas of the UK would increasingly suffer significant losses of enterprises and employment, as a result of businesses having broadband connectivity which falls further and further behind that available to competitors in urban areas (in the UK and overseas). While a majority of these lost jobs would probably be displaced into the UK's urban areas (through business re-locations, or through urban competitors growing faster at the expense of their rural competitors), a proportion would not – bearing in mind that the rural locations may have other factors contributing to business competitiveness such as lower accommodation costs, and/or lower labour costs, and remembering that small businesses are increasingly accessing global markets through e-commerce, in which they are competing more with overseas firms than with UK firms.

[20] We have had to make some assumption on the mix of RCBF technologies for modelling purposes. This is not intended to be a prediction of the outcomes of the projects' procurement decisions.
[21] http://www.broadbanduk.org/2013/07/30/dcms-publish-policy-paper-connectivity-content-and-consumers-britains-digital-platform-for-growth/

Hence, by mitigating the digital divide in the geographic coverage of faster broadband, public sector intervention has an economic impact through safeguarding employment, and the associated GVA, that would otherwise be lost to the UK.

In developing estimates of these impacts, our model uses a concept of 'Relative Broadband Quality' (RBQ), which is the indicative speed available in each decile divided by the national average[22]. The densely populated areas of the UK typically therefore have an RBQ of greater than 1.0, while the least dense deciles typically have an RBQ of less than 1.0, though the values change over time.

We have constructed curves which estimate the annual growth of enterprises and employment in an area as a function of Relative Broadband Quality in that year. The shapes of these curves have been informed by an analysis of the differences between the years 2008 and 2012 in the number of business sites and employment in each density decile, using data from ONS. This analysis found no convincing growth trends across density deciles for 10+ employment size bands, but there was a modest positive trend for higher growth with increasing density for the count of 1 to 9 employment firms[23]. Adjusting for the proportion of this trend that can be attributed to changes in RBQ[24], our curve for the 1 to 9 employment size band results in annual growth rates of, for example, -0.05% at an RBQ of 0.5, and +0.03% at an RBQ of 1.5. The curves for 10+ employment size bands have been 'zeroed out', as no clear relationship was observed in the historic data. That is, the safeguarding employment impact is effectively only assumed to be relevant to the 1 to 9 employment size band.

By 2024, net annual GVA impacts attributable to intervention include: £0.8 billion from safeguarding local enterprise employment…

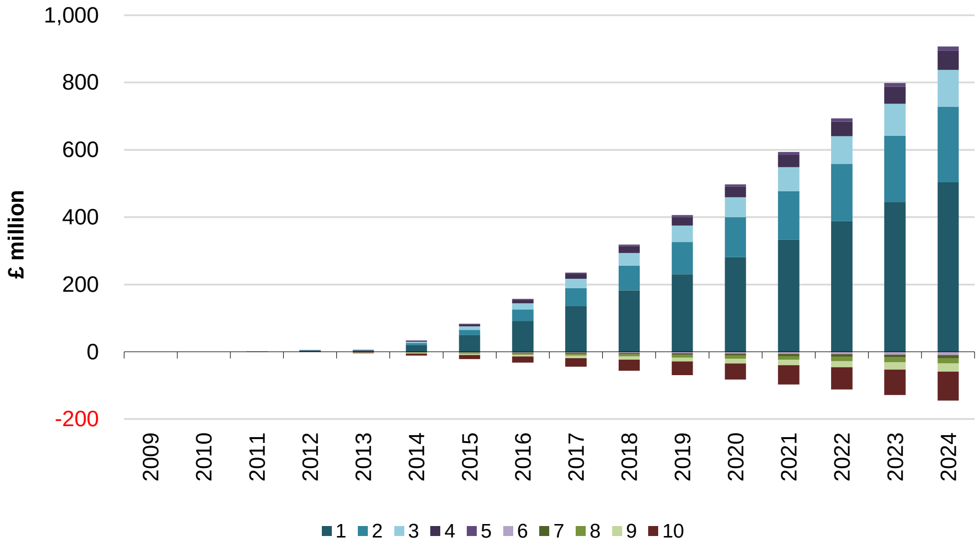
The net annual GVA impact from this effect, attributable to intervention, is estimated to rise to about £0.8 billion by 2024. As shown in Figure 2-8, the benefits to the least dense areas are offset to some extent by modest negative net impacts for the most dense areas (as the cities, in the absence of the Government's interventions, would have otherwise grown at the expense of the less connected rural areas).

[22] For these impacts, it is the speed available to businesses (rather than to households) which is used. 'The 'national average' is taken to be the mean of the speeds available in the 5th and 6th density deciles.

[23] For this size band, between 2008 and 2012, growth in the count of local units was -1.9% in decile 1, vs +1% in decile 10, corresponding to annual growth rates of -0.5% and +0.2%.

[24] Using the R-squared value of 0.25 found for the correlation between local unit count growth and RBQ, for this size band

Figure 2-8: Net annual GVA impact from safeguarded employment in local enterprises, attributable to intervention – by density decile



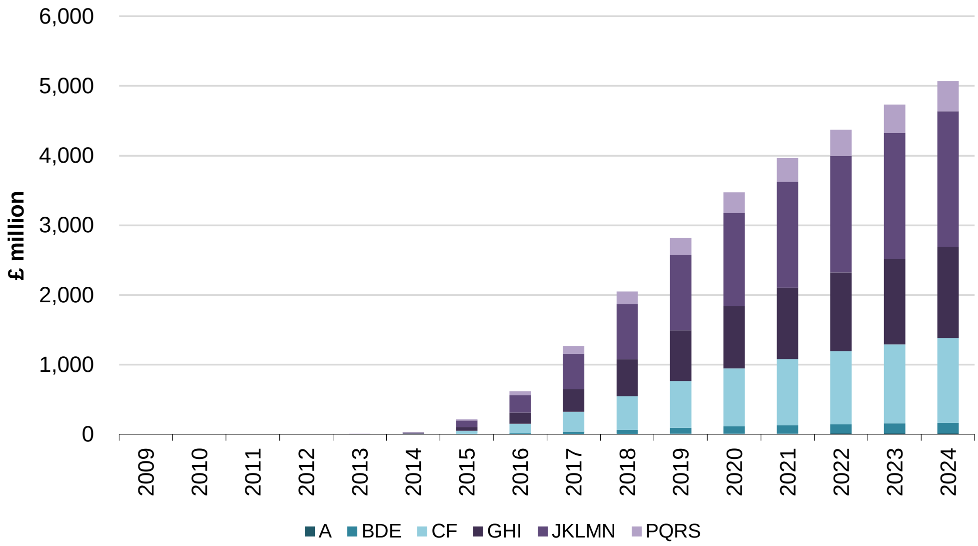
Source: UK Broadband Impact Model, SQW 2013

Productivity growth of broadband-using firms

…£5 billion from productivity growth for broadband-using firms…

Comparing the two scenarios, we find that about £5 billion in net annual GVA impacts are attributable to intervention by 2024. As with the overall impacts of faster broadband, the largest contributions to this come from the JKLM&N industry group[25] (Figure 2-9) and the 1 to 9 employment band (Figure 2-10).

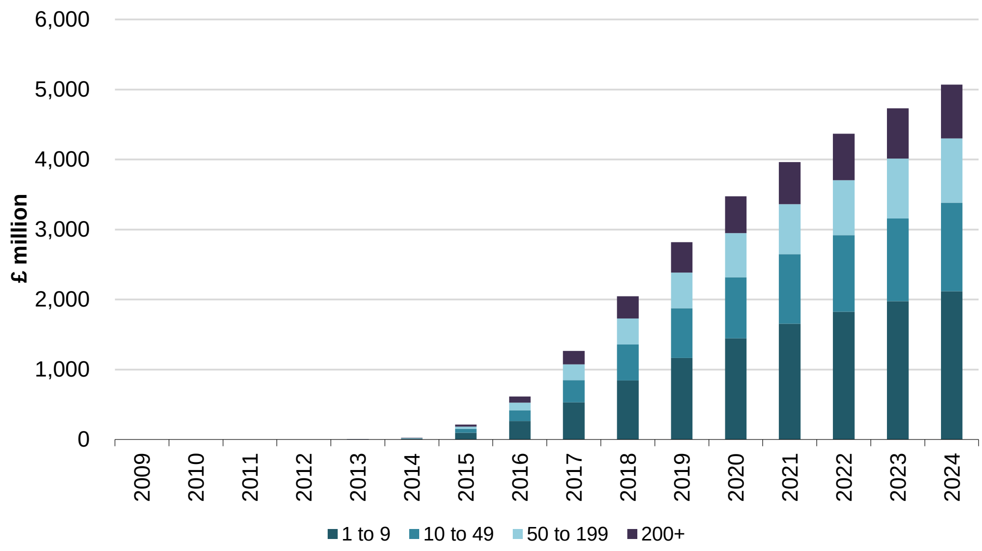
Figure 2-9: Net annual GVA impact from productivity growth for broadband-using firms, attributable to intervention – by industry groups



Source: UK Broadband Impact Model, SQW 2013

[25] Information and communication; Financial and insurance activities; Real estate activities; Professional, scientific and technical activities; and Administrative and support service activities

Figure 2-10: Net annual GVA impact from productivity growth for broadband-using firms, attributable to intervention – by size of firm (employment)



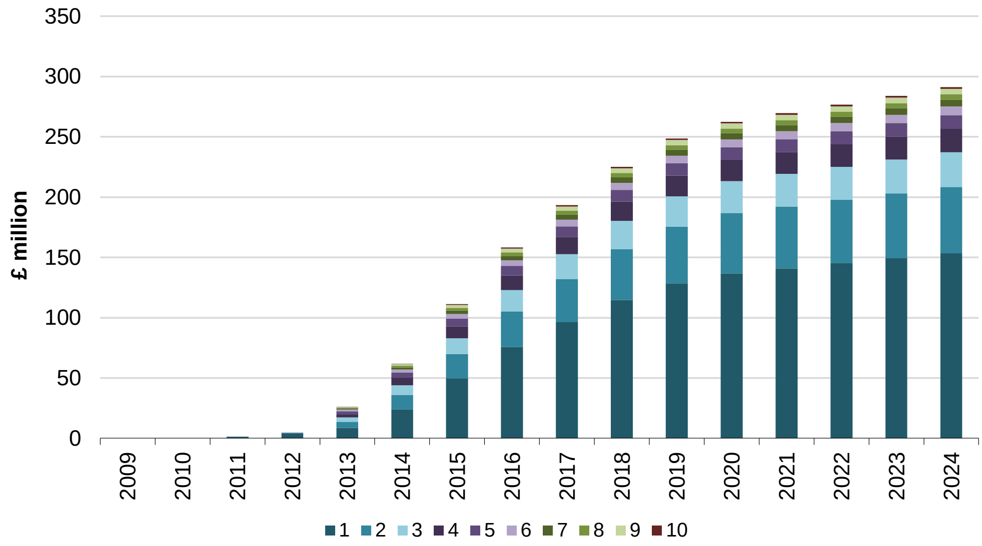
Source: UK Broadband Impact Model, SQW 2013

Teleworker productivity

…£0.3 billion from improved teleworker productivity…

The net annual GVA impacts attributable to intervention from improved teleworker productivity reach almost £0.3 billion by 2024 (Figure 2-11), with the bulk of these impacts in the three least dense deciles of the UK (where there are most teleworkers, and where the bulk of the intervention investment is focused).

Figure 2-11: Net annual GVA impact from increased teleworker productivity, attributable to intervention – by density decile of their home area (1=least dense)



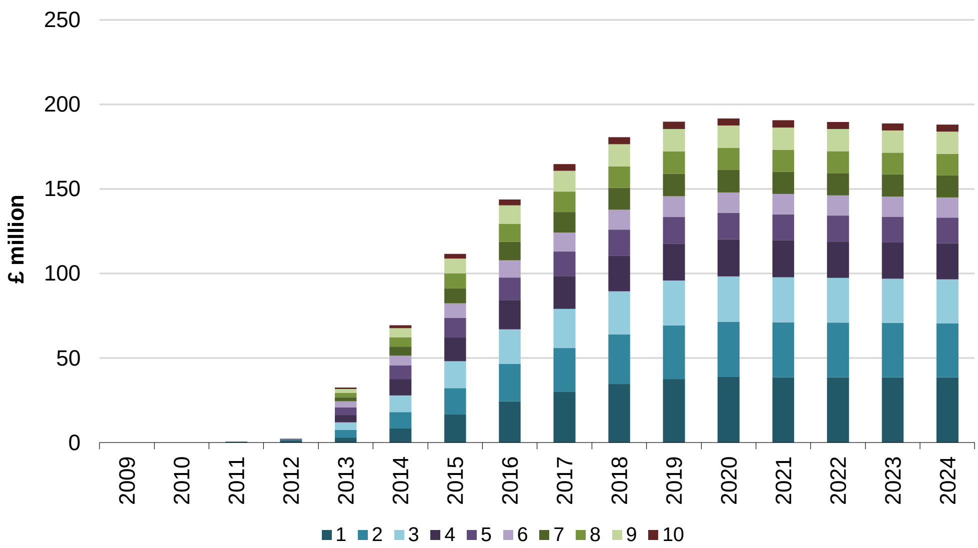
Source: UK Broadband Impact Model, SQW 2013

Labour force participation

…and £0.2 billion from increased labour force participation

Net annual GVA impacts attributable to intervention from improved participation of carers and disabled people reach almost £0.2 billion by 2024 (Figure 2-11). This equates to about 5,000 additional carers and about 1,900 additional disabled people gaining employment through telework, who would not have been able to do so in the absence of the Government's intervention in faster broadband.

Figure 2-12: Net annual GVA impact from increased participation of carers and disabled people, attributable to intervention – by density decile of their home area (1=least dense)



Source: UK Broadband Impact Model, SQW 2013

Network construction impacts

Drawing on data provided by BDUK, we calculate that the total capital expenditure – including both public and private sector funding – associated with the current set of interventions will amount to approximately £1.7 billion. This is spread over the period 2009 to 2016, with the expenditures up to 2012 predominantly associated with the pre-BDUK projects in Northern Ireland and Cornwall.

Network construction accounts for 35,000 job-years…

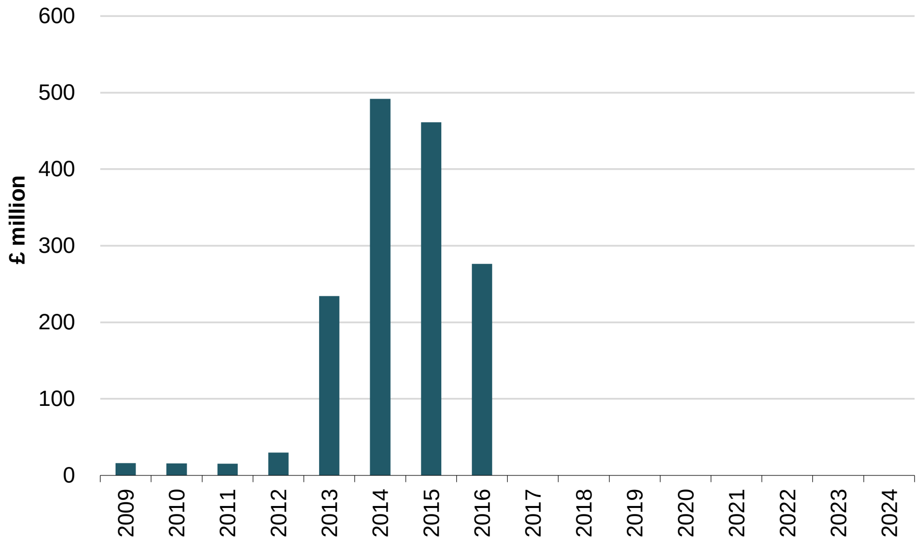
Assuming a type 2 employment effect[26] of 20 job-years per £1 million of investment, this suggests that the network construction accounts for a total of about 35,000 job-years in the UK economy over the 2009 to 2016 period, peaking at about 11,000 jobs in 2014.

…and the gross annual GVA impacts peak at about £0.5 billion in 2014

Using a type 2 'GVA effect'[27] of 0.9, we estimate that the gross GVA impact will total about £1.5 billion over the period, with the annual impact peaking at about £0.5 billion in 2014, as shown in Figure 2-13.

[26] This is informed by OffPAT guidance from 2009. Type 2' captures both the indirect effects associated with the supply chain, and the induced effects associated with employees spending their wages in the economy.
[27] This uses the value from the Scottish Input-Output tables for specialised construction in 2009. 'A GVA effect of 0.9 means that each £1m of additional expenditure results in £0.9m in GVA.

Figure 2-13: Gross annual GVA impacts associated with network construction for broadband interventions



Source: UK Broadband Impact Model, SQW 2013

As previously noted, however, we have not incorporated these network construction effects into our assessment below of the total economic impacts or the value for money of the interventions, as they are gross rather than net impacts. We effectively assume that the 'deadweight' for these effects is 100%; i.e. if the public funds were not used for this construction project, they could be used for an alternative construction project, with similar short term effects.

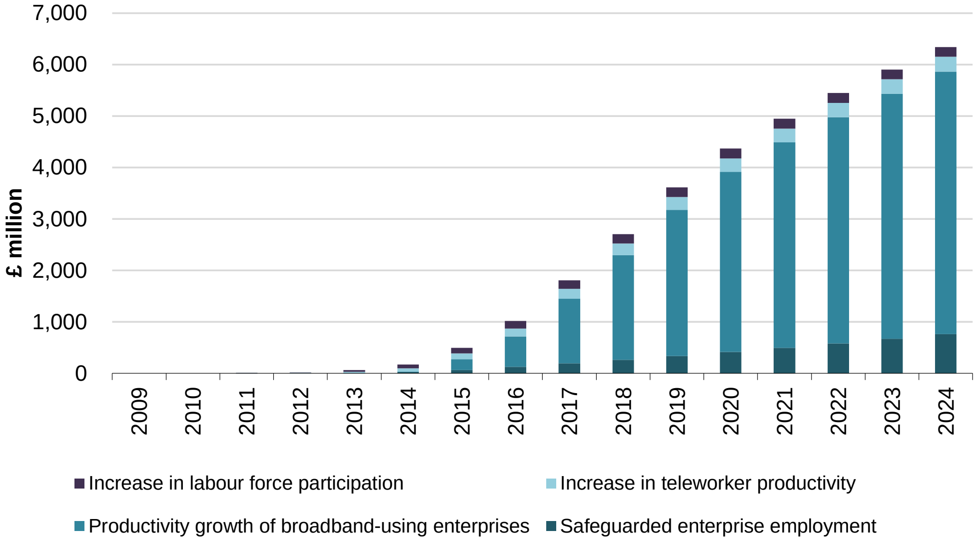
Total economic impacts

Total annual net GVA impacts of intervention rise to £6.3 billion by 2024…

…equivalent to an uplift of 0.027 percentage points in the UK's real annual GVA growth

Bringing together the various sources of economic impact, we estimate that the total net annual GVA impacts attributable to intervention rise to about £6.3 billion by 2024, the bulk of which comes from improvements in the productivity of broadband-using firms (Figure 2-14). This is equivalent to an average uplift of 0.027 percentage points for the UK's real annual GVA growth over the modelling period.

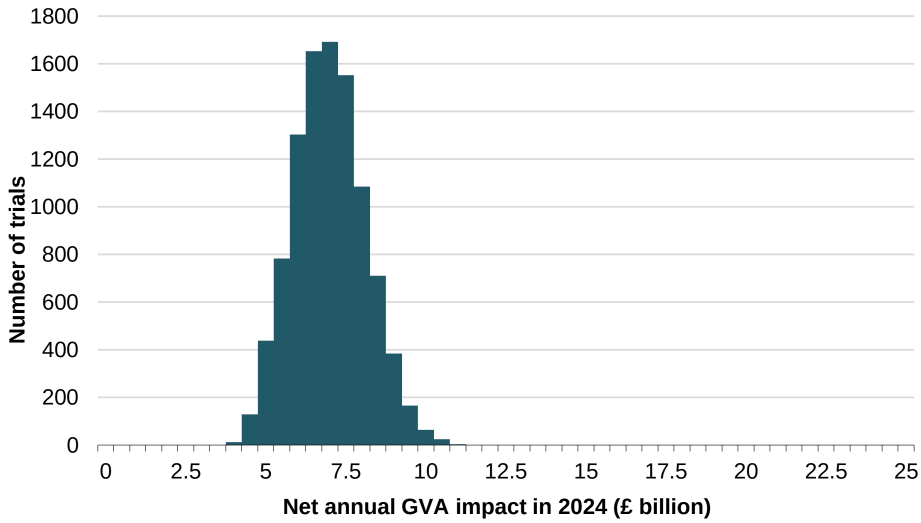
Figure 2-14: Total net annual GVA impact, attributable to intervention – by type of impact



Source: UK Broadband Impact Model, SQW 2013

In the Monte Carlo simulation, 90% of trials returned results between £5.5 billion and £9.0 billion for the net annual GVA impact attributable to intervention in 2024 (Figure 2-15) – equivalent to a range of 0.024pp and 0.039pp for the uplift to the UK's real annual GVA growth.

Figure 2-15: Monte Carlo distribution for the net annual GVA impact (£ billion) in the year 2024, attributable to intervention (10,000 trial simulation)



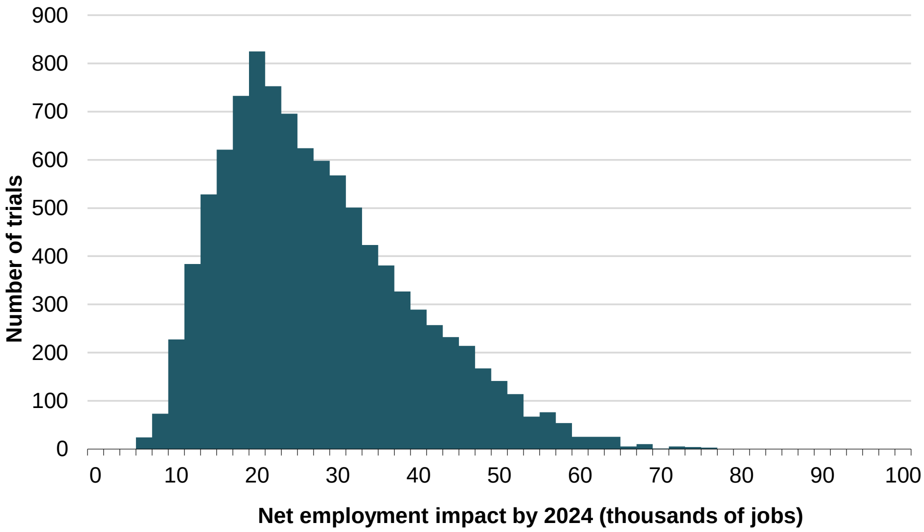
Source: UK Broadband Impact Model, SQW 2013

Of the net GVA impacts from intervention in 2024, approximately £3.3 billion will accrue to 'rural' areas (where 'rural' means those Census Output Areas not flagged as being in towns and cities with resident populations of more than 10,000), and about £3 billion to 'urban' areas.

We estimate that approximately 89% of the benefits of the current set of interventions will accrue to areas of the UK other than London and the South East of England[28] – thereby helping the spatial rebalancing of our economy.

The net employment impacts from the intervention rise to about 20,000 jobs, at the UK level, by 2024. The Monte Carlo simulation for this (Figure 2-16) is skewed towards the left, as these impacts are predominantly associated with the safeguarding of local employment effect, for which our 'most likely' assumption has been set towards the lower end of the range of feasible values; 90% of trials returned results between 12,000 and 52,000 jobs by 2024.

Figure 2-16: Monte Carlo distribution for the net employment impact by the year 2024, attributable to intervention (10,000 trial simulation)



Source: UK Broadband Impact Model, SQW 2013

Value for money assessment

Over the 2009 to 2024 period, the interventions are projected to return approximately £20 in net economic impact for every £1 of public investment

Discounting the real values for the total public expenditure and the net GVA impacts attributable to intervention at 3.5%, as per Treasury Green Book guidance, and using 2009 as year zero, we find that the Benefit Cost Ratio[29] (BCR) rises to about 20 by 2024 (Figure 2-17). That is, over the 2009 to 2024 period, the interventions are projected to return approximately £20 in net economic impact for every £1 of public investment.

[28] For comparison, the current split of population is 27% in London and the South East, and 73% in the rest of the UK.

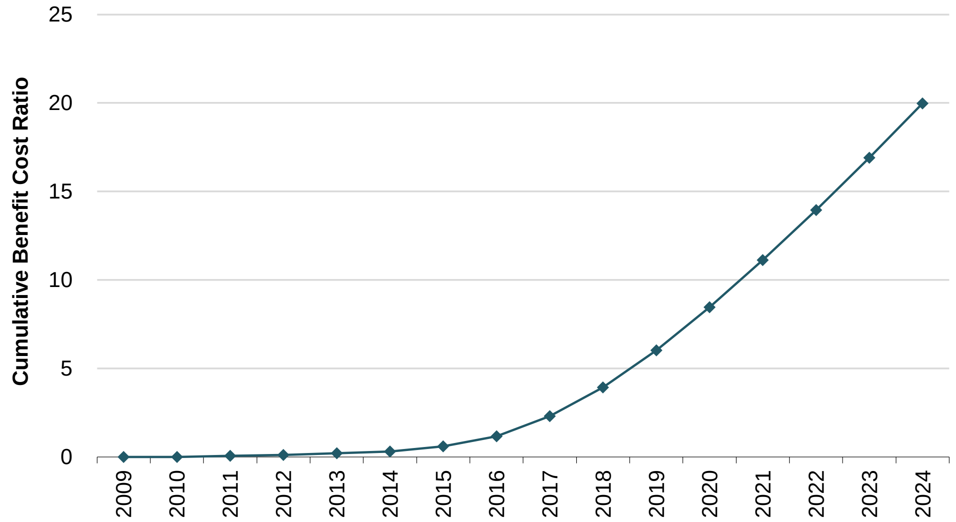
[29] The BCR is the cumulative Present Value of the net GVA impacts over the period, divided by the cumulative Present Value of the public funding (including both the capital expenditure and administration costs)

This ratio is unusually high for a public investment, but we consider that it is realistic, bearing in mind the following:

- The interventions are substantially improving the quality of a General Purpose Technology across a significant proportion of the UK, which, in the long term, will benefit hundreds of thousands of businesses, employing millions of people.
- It is now well accepted that ICT is one of the most important drivers of productivity growth, and broadband connectivity underpins most ICT applications.
- The 'deadweight' is very low over our modelling period: i.e. in the absence of the publicly funded interventions, there would be very little prospect of large-scale unsubsidised roll-outs of faster fixed broadband services in the areas addressed – whether by BT or other players – given the high unit costs of providing broadband services in relatively sparsely populated areas.
  - The costs of rolling out superfast broadband services are an order of magnitude higher than those of the original first generation broadband roll-out, because they involve extending fibre deeper into the access network. Although telecoms equipment prices can be expected to decrease over time, much of the costs associated with superfast broadband roll-outs are associated with civil engineering, and these are likely to increase rather than decrease over time.
  - BT forecasts that its payback on BDUK contracts will take 15 years (with subsidy), and with a lack of infrastructure-level competition in these areas there would otherwise appear to be little incentive for the operator to invest in costly upgrades to services where the vast majority of broadband customers will already be using BT's network.
  - While some unsubsidised community groups have taken matters into their own hands, and are creating community-owned fibre networks[30], we do not envisage that this would have become a common solution across large areas of the UK, within our modelling period, in the absence of intervention.
- The appraisal period is over 15 years (if we reduce this to 10 years, the BCR reduces to 6.0).

[30] For example, B4RN (b4rn.org.uk)

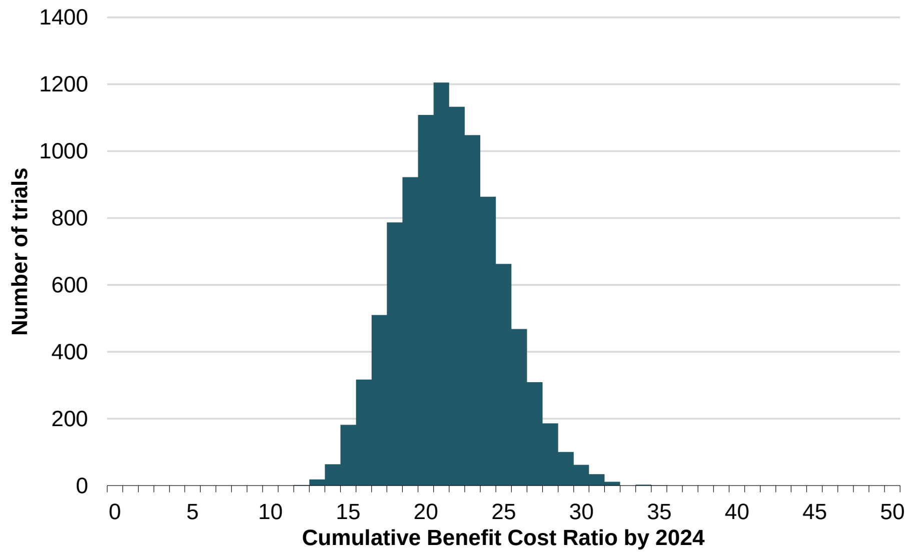
Figure 2-17: Cumulative Benefit Cost Ratio associated with interventions



Source: UK Broadband Impact Model, SQW 2013

Looking at the Monte Carlo simulation findings for the BCR by 2024 (Figure 2-17), we find that 90% of trials return results between 17 and 27.

Figure 2-18: Monte Carlo distribution of the cumulative Benefit Cost Ratio by 2024, associated with interventions (10,000 trial simulation)



Source: UK Broadband Impact Model, SQW 2013

3. Social impacts

Routes to social impact

Beyond its economic impacts, broadband has, of course, become an integral part of modern life, affecting various aspects of our day-to-day activities as individuals, families and communities.

Our model focuses on quantifying the following three areas of social impact:

- **The digital divide** – in terms of the differences in broadband speeds available to households and businesses in different parts of the UK.
- **The value of household savings associated with additional teleworking**. By enabling more efficient, more frequent teleworking, faster broadband will reduce the need for commuting, and hence lead to household savings on transport costs. Our model estimates these savings, but also the extent of costs incurred by households in additional space heating on telework-days.
- **The value of leisure time saved through increased teleworking**. Some of the time saved in commuting, through additional teleworking enabled by faster broadband, is likely to be spent on work (as assumed in the previous economic impacts section on teleworker productivity), and some will be taken as leisure time. Our model quantifies the potential additional leisure time saved, and the associated value of this time.

Various other social impacts are discussed in our study's literature review report[31], which examined the evidence for a wide range of potential social impacts associated with broadband, and with faster broadband in particular. A brief summary of these is provided in the table below.

Table 3-1: Other potential areas of social impact from faster broadband

Potential area of social impact	Comments
Change in consumption of video content	• Video is a bandwidth-hungry application, and a fast-growing source of internet traffic – fuelled by the increasing popularity of video on demand and by the introduction of high definition formats. One of the most significant social impacts of faster broadband is likely to be the increased consumption of video entertainment over broadband connections. • The latest Oxford Internet Survey[32] found that watching movies and videos had seen a substantial increase, from 39% of internet users in 2011 to 50% in 2013. Cisco forecasts[33] that the sum of all forms of video (TV, video on demand, internet video, and P2P) will be

[31] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/85961/UK_Broadband_Impact_Study_-_Literature_Review_-_Final_-_February_2013.pdf

[32] Dutton, W.H. and Blank, G., with Groselj, D. 2013. "Cultures of the Internet: The Internet in Britain. Oxford Internet Survey 2013". Oxford Internet Institute, University of Oxford.

[33] Cisco. 2013. "Cisco Visual Networking Index: Forecast and Methodology, 2012–2017"

Potential area of social impact	Comments
	approximately 80% to 90% of global consumer traffic by 2017. • This increased consumption of video may have both positive and negative aspects for consumers, families and society. We have not attempted to place a value on this impact of faster broadband.
Change in online gaming	• Some formats of online gaming will benefit from the lower latency - as well as the higher upstream and downstream bandwidths – typically associated with faster broadband services. • This is another application which has seen substantial growth in recent years, according to the Oxford Internet Survey: the proportion of internet users who use the internet for playing games has increased from 44% in 2009 to 52% in 2013. Another indicator of recent growth comes from Internet Service Provider Plusnet, which has seen a 50% increase in online gaming traffic over the last 12 months[34]. • As with video, this increased consumption of online gaming may have both positive and negative aspects for consumers, families and society, and we have not attempted to place a value on this impact of faster broadband.
Change in use of video communications	• The social use of video chat applications (such as Skype video, Google Talk and Apple's ichat) has become increasingly common over recent years. • In a survey of 610 US consumers by TokBox[35], 44% of people surveyed said that they use video calling/video chat. When asked what would make them use video communications more often, the most frequently cited response was higher quality - suggesting that the higher video quality enabled by faster broadband will help to stimulate growth in video calling.
Change in the quality of web browsing	• Many of the benefits of broadband are available through standard broadband, and do not necessarily require superfast broadband. However, it should be noted that the size of a typical web page is getting bigger: now about 1.6 Megabytes (MB) according to HTTP Archive (up from 1.3MB in December 2012). This growth has been fuelled by the increased use of images and JavaScript. • While websites can adapt to an extent to different connection speeds, the increasing size of web pages can have a material impact on the user experience for subscribers with relatively low broadband speeds. To fully load an average landing page for a website (1.5MB), it would take about: 24 seconds at 0.5Mbps, compared with 6 seconds at 2Mbps, 1.5 seconds at 8Mbps, and 0.4 seconds at 30Mbps. • This ongoing growth in page size means that users' web browsing experience will gradually deteriorate in areas poor broadband connectivity, relative to the experience of those able to access higher speeds.
Time savings from faster downloads	• As consumers can be doing other activities offline, or indeed using other applications on their internet-connected device while a large file download is going on in background mode, we have not attributed any value to any time savings associated with faster downloads of files.
Change in online shopping	• Online shopping has grown rapidly over the last several years, and this can save households money through getting better deals online. • However, as our literature review noted, given that e-commerce has already gained a very substantial share of the retail market in the UK (when the adoption of superfast broadband services is as yet rather

[34] http://community.plus.net/blog/2013/09/29/bandwidth-and-the-rise-of-online-gaming/
[35] TokBox. 2012. "A Video Chatterbox Nation; A report on live video communications today & tomorrow"

Potential area of social impact	Comments
	low), there is uncertainty over the extent to which *faster* broadband will serve to increase the sales through this channel, and an international comparison of relative levels of fibre broadband and of e-commerce levels also does not support the hypothesis. We have therefore assumed no additional impact on online shopping from faster broadband.
Change in adult skills development and employability	• The Oxford Internet Survey shows that the proportion of internet users using the internet for distance learning for an academic degree or job training has increased gradually over the last few years, from 24% in 2009 to 29% in 2013. • Many online learning resources are readily accessible through standard broadband – though faster broadband will improve the quality of video content/communications which is increasingly being integrated into e-learning packages. In particular, those with poor broadband speeds (sub 2Mbps) will be at a relative disadvantage in terms using video-rich online learning. • As yet, however, the evidence on the additional benefits of faster broadband speeds on adult skills development is rather sparse, and we have not included any values for this in our model.
Impact on house prices	• There is some emerging evidence that house prices may be influenced to some extent by the relative quality of broadband connectivity available in the area. For example, a survey conducted for Halifax[36] in December 2012 found that 30% of people said that access to good broadband was likely to affect their decision on whether to buy a home in a particular area; and 13% said they'd be prepared to pay up to 3% more for the same home if it had a good broadband signal. • Forthcoming academic research by Ahlfeldt, Koutroumpis and Valletti on the relationship between property prices and broadband availability and speeds appears to support the hypothesis that better broadband has a significant effect on house prices.
Increased access to and use of e-government services	• As the large majority of UK households now have access to broadband internet, this has presented opportunities for national and local government to offer online access to many public services, in order to improve the service to users, and to reduce transaction costs. • However, the most recent data suggest we may have reached something of plateau in the proportion of internet-using adults who are using the internet to find information about public services. • e-government services need to be designed to be as widely accessible as possible - i.e. bearing in mind the needs of households with slower connectivity. We have not attributed (to faster broadband) any benefits associated with increased penetration and usage of e-government services.
Change in civic participation	• There is mixed evidence as to broadband internet's impact on civic engagement. Some argue that the internet provides a platform for citizens to become more engaged in civic and political issues; but others maintain that the distractions and entertainment opportunities offered by surfing the internet lead to people engaging less in civic life. • We have not assumed any net benefits in terms of civic participation in our model of the impacts of faster broadband.
Impact on pupils'/students'	• While broadband at home and at school has clearly made it easier for learners to access a variety of learning resources, the evidence is

[36] http://www.lloydsbankinggroup.com/media1/press_releases/2013_press_releases/halifax/0802_Broadband.asp

Potential area of social impact	**Comments**
educational attainment	decidedly mixed as to the net impact of the use of computers and broadband internet on attainment. • Some studies suggest that the use of the internet by learners for *leisure* purposes (e.g. games, watching videos, social networking) can have a negative impact on attainment by displacing or disrupting study time, and this matches or even outweighs the positive impacts from learners using the internet for *educational* purposes. • In view of the likely growth in the availability of and attractiveness of video content and online gaming over faster broadband, this is an area which would warrant further primary research, in order to assess the extent to which faster broadband can aid – or hinder – improvements in learner attainment.
Change in public sector productivity in the delivery of health and social care services	• With increasing demands on the NHS and local authorities, there is substantial interest and activity in the development of telehealth and telecare applications to help these organisations meet the needs of an ageing population more cost-effectively. • Various studies have quantified projected benefits of such applications. For example, Access Economics[37] estimated the net benefits from widespread adoption of telehealth in Australia to be worth AUD2 billion to AUD4 billion per annum (approximately £1.1 - £2.3 billion). • However, it is worth noting some important barriers to realising health and social care benefits through broadband. Kenny and Kenny[38] note that telehealth is primarily for the elderly, and that this is one of the demographic groups least likely to be online. • Furthermore, as noted in a recent Economist Intelligence Unit report[39], many anticipated benefits of faster broadband in the provision of healthcare—for example, from telemedicine and remote diagnostics—are realistic but require wider reforms of the health system itself, together with substantial wider investments, before they can be realised. Broadband speed alone is not enough to effect a transformation, and attributing the full social benefits to faster broadband would not therefore be appropriate.
Impact on well-being	• While there are, of course, negative aspects to internet usage as well as positive benefits, the evidence suggests that the internet has made a net positive impact on wellbeing, as discussed in our literature review. • However, given the complex interactions between a wide range of potential impacts of faster broadband (e.g. on GDP growth, video consumption, teleworking, house prices), we have not attempted to predict the extent to which faster broadband will affect the UK's overall levels of wellbeing.

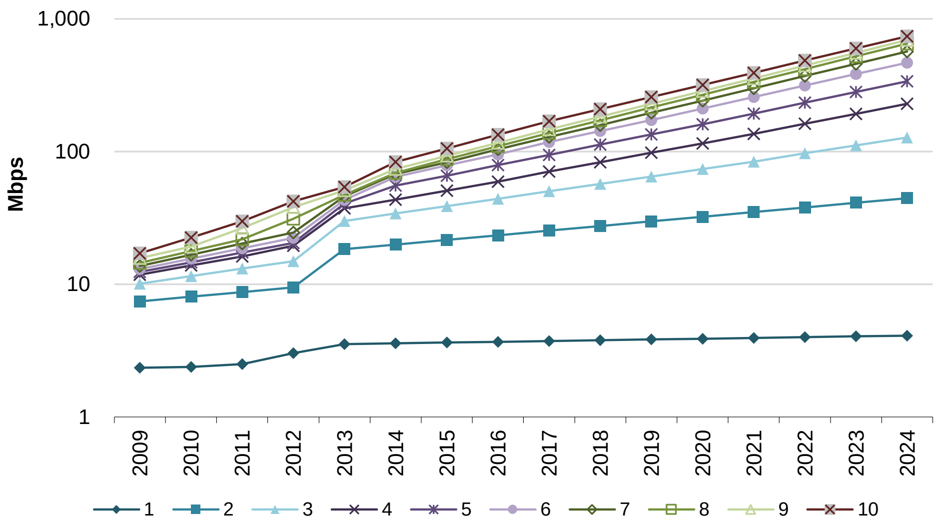
Source: SQW

[37] Access Economics. 2010. "Financial and Externality Impacts of High-speed Broadband for Telehealth."
[38] Kenny, Robert, and Charles Kenny. 2011. "Superfast Broadband: Is It Really Worth a Subsidy?" Info 13 (4) (June 28): 3–29. doi:10.1108/14636691111146127.
[39] Economist Intelligence Unit. 2012. "Superfast Britain? Myths and Realities About the UK ' s Broadband Future."

Digital divide

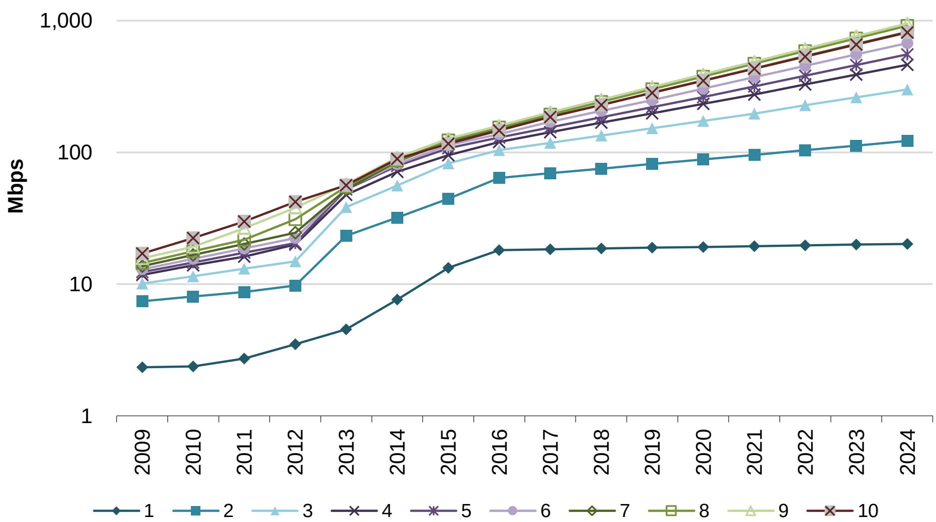
The previous section summarised our approach to deriving estimates of the coverage and speeds available to businesses, by density decile, and by year over the modelling period. The approach for households is identical, with one exception: we have assumed that 'FTTP on demand' will not typically be affordable to households. The indicative maximum total speeds (i.e. adding downstream and upstream) available to households in each density decile are shown below for the without-intervention (Figure 3-1) and with-intervention (Figure 3-2) scenarios. We use logarithmic y-axes in order to illustrate the trends and differences more clearly. Note that these are the maximum *available* speeds, rather than the average used speeds.

Figure 3-1: Indicative maximum total speeds (down + up) available to households, without intervention (Mbps), by density decile – note logarithmic y-axis



Source: UK Broadband Impact Model, SQW 2013

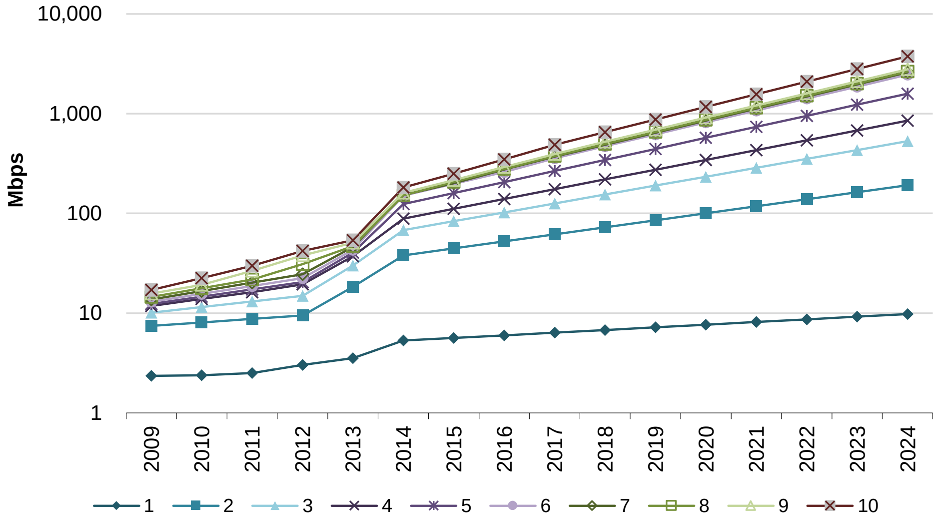
Figure 3-2: Indicative maximum total speeds (down + up) available to households, with intervention (Mbps), by density decile – note logarithmic y-axis



Source: UK Broadband Impact Model, SQW 2013

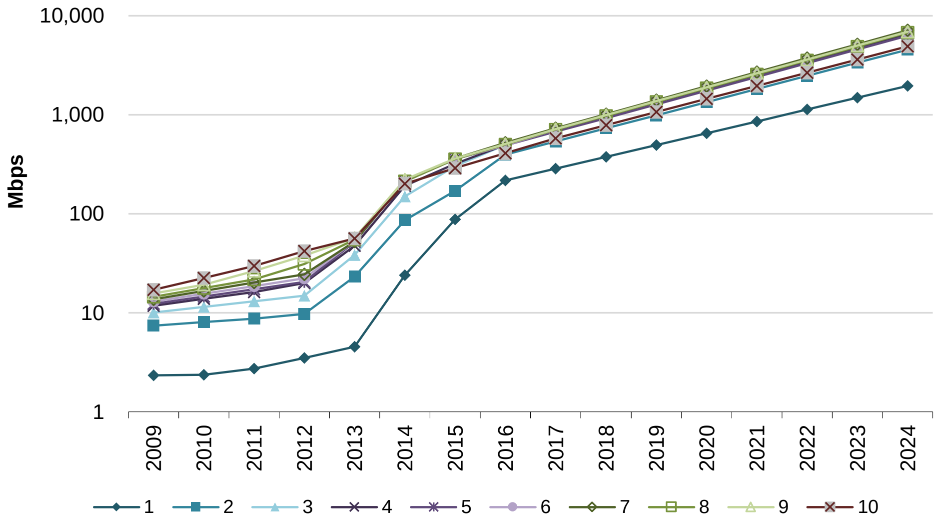
For businesses, the difference is in the availability of 'FTTP on demand' throughout BT's FTTC footprint from 2014, leading to a substantial increase in maximum speed[40] from that year. As the intervention substantially expands the FTTP on demand footprint (by expanding the FTTC footprint), the speeds available to businesses in the least dense deciles come much closer to those in urban areas, as they can mostly now access affordable FTTP (not typically the case for households in these deciles).

Figure 3-3: Indicative maximum total speeds (down + up) available to businesses, without intervention (Mbps), by density decile – note logarithmic y-axis



Source: UK Broadband Impact Model, SQW 2013

Figure 3-4: Indicative maximum total speeds (down + up) available to businesses, with intervention (Mbps), by density decile – note logarithmic y-axis



Source: UK Broadband Impact Model, SQW 2013

[40] Note that these indicative maximum total speeds are calculated from weighted geometric means, which take account of partial coverage levels within each decile of the various technologies, and avoid the overall indicative speed being unduly distorted by very high speeds for small percentages of premises in the decile (which would be the case with arithmetic means)

From the above charts we can see that the interventions currently underway will have a material impact on reducing the digital divide for both households and businesses.

The introduction of FTTP on demand throughout BT's FTTC footprint should have a particularly important and sustained impact in putting the UK's rural areas onto a 'more level playing field' as far as business connectivity is concerned.

For households, the *current* set of interventions goes a long way to addressing the digital divide in the UK, and the Universal Service Commitment will ensure everyone has access to basic broadband. However, as urban bandwidths continue to advance over time, including through improvements in Virgin Media's offerings and through new entrant FTTP providers, households in the least dense deciles will fall further behind in relative terms.

This situation will be further addressed, however, following the Government's announcement in July 2013 on extending its target to 95% of premises having access to superfast broadband by 2017, and exploring the measures needed to reach at least 99% by 2018.

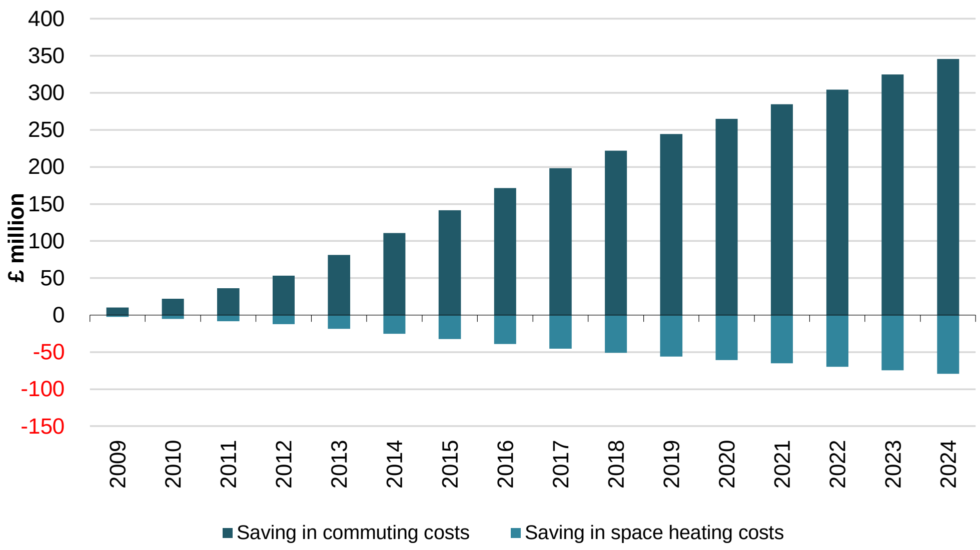
Household savings

Using the estimates derived for the environmental impacts of teleworking (see next section) on the total commuting distance saved per decile, and the modes of transport used per decile, we have developed estimates for the costs saved through reduced commuting by using data on the average cost per passenger km of different modes of transport. We have also applied unit energy costs to the additional usage of the various space heating fuels, in order to estimate the additional costs to households associated with heating the home on teleworked days.

Net household savings from increased teleworking rise to £270 million p.a. by 2024…

As shown in Figure 3-5, the total household savings due to increased teleworking, attributable to faster broadband, rise to £270 million by 2024, with commuting savings of £350 million in that year being offset by an additional £80 million in space heating costs.

Figure 3-5: Annual household savings due to increased teleworking, attributable to faster speeds since 2008



Source: UK Broadband Impact Model, SQW 2013

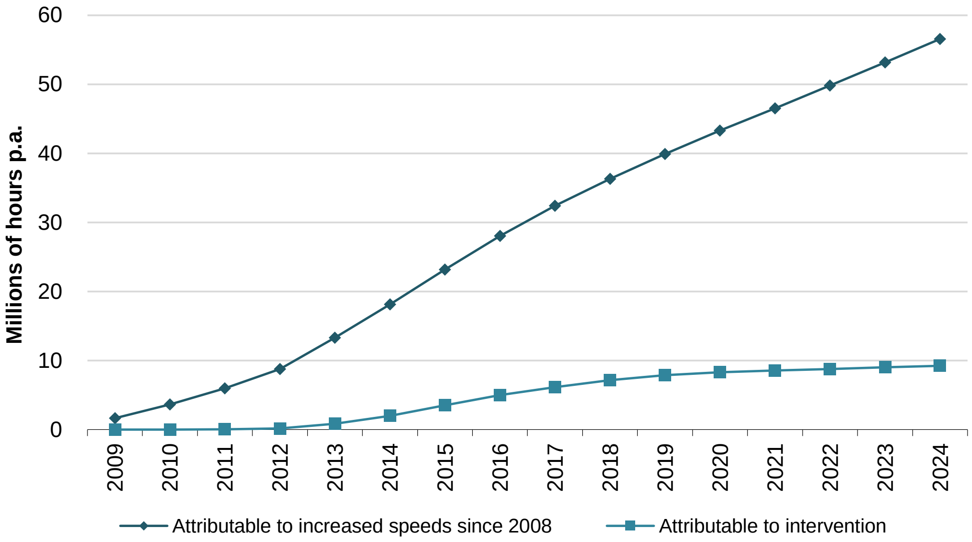
…of which the interventions account for about £45 million

For the impacts attributable to intervention, the net household savings reach £45 million by 2024.

Value of saved leisure time

We estimate that about 60 million hours of leisure time will be saved through increased teleworking attributable to faster broadband, by 2024, of which about 10 million hours will be attributable to publicly funded intervention (Figure 3-6).

Figure 3-6: Leisure time saved through increased teleworking (millions of hours p.a.)



Source: UK Broadband Impact Model, SQW 2013

The annual value of leisure time freed up by additional teleworking rises to £460 million by 2024, of which intervention accounts for about £75 million

Using values of leisure time from Department for Transport guidance, this equates to a value of approximately £460 million p.a. by 2024, attributable to faster broadband, of which £75 million is attributable to intervention.

4. Environmental impacts

Routes to environmental impact

Finally, we turn to the net *environmental* impacts of faster broadband, and of associated publicly funded interventions. For this we focus on the net savings in the annual tonnes of carbon dioxide equivalent (CO2e) greenhouse gas emissions.

The routes to impact which have been modelled are as follows:

- **Teleworking**. Probably the most frequently cited environmental benefit of better broadband is that it will encourage people to work from home more, thereby reducing carbon emissions associated with the daily commute. Our model develops estimates for this, but also includes 'rebound' effects, notably the extent to which some of the commuting miles saved will actually be travelled anyway for other purposes (such as shopping, or dropping children off at school, which may otherwise be done in the course of a commuting trip), and the extent to which people working from home leads to additional carbon emissions through domestic space heating.
- **Business travel**. Large corporates have made significant inroads over the last few years into reducing their travel costs (and emissions) by reducing the need for face-to-face meetings through the use of collaboration software and video-conferencing. With affordable faster broadband with low latency now widely available, we anticipate that the next few years will see this trend increasingly applying to smaller businesses.
- **Cloud computing**. UK businesses collectively use hundreds of thousands of servers, which are typically on for 24 hours per day, 365 days per year, and which are frequently operating at very low levels of utilisation. Although the trend towards virtualisation of on-premises servers is significantly improving utilisation levels (and hence carbon efficiency), the use of the 'public cloud' for a proportion of businesses' computing needs offers the prospect of substantial further environmental benefits. Our model estimates the extent to which business use of faster broadband will encourage a shift to the cloud, and the resulting net environmental impacts.

We consider these to be the most important environmental impacts of faster broadband, for which there are reasonably strong hypotheses. However, as with the social impacts, there are various others discussed in our study's literature review. A brief summary of these is provided in the table below.

Table 4-1: Other potential areas of environmental impact from faster broadband

Potential area of environmental impact	Comments
End user device emissions	• It could be argued that the availability of faster home broadband supports a proliferation in end user devices which use that connectivity (additional TVs, computers, tablets, smartphones, games consoles etc.). There will be carbon emissions associated with these devices, from their manufacture, distribution, usage and disposal. The *Powering the Nation* report[41], for example, estimates that 14% of domestic electricity use is now associated with consumer electronics, and a further 6% with ICT. However, a previous Energy Savings Trust report[42] noted that the pace of change makes it hard to predict future energy consumption for this area – with increased take-up and usage of devices being offset by significant improvements in their energy efficiency, and with a convergence of device functionality (e.g. internet-enabled TVs). The uncertainties around the extent to which faster broadband stimulates end user device adoption, together with the complexities of rapid changes in energy efficiency and device convergence, suggested that it would be impossible to derive a meaningful estimate of the net carbon impact of faster broadband in this area.
Changes in travel associated with e-commerce, telehealth, telecare etc.	• These applications have sometimes been cited as sources of carbon emission savings from broadband, through reducing the need for travel. • The recent growth in online shopping has coincided with a reduction in the average number of shopping trips per person per year – from 214 in 2002 to 189 in 2012, according to the National Travel Survey. As discussed in the previous section on social impacts, however, we have assumed no additional impact on e-commerce from *faster* broadband, given the available evidence. • Regarding telehealth, there may be some travel savings associated with reduced patient trips to GPs or hospitals, and/or reduced travel for healthcare workers to patients' homes. However, as noted in the section on social impacts, broadband speed alone is not enough to effect a transformation in the delivery of health and social care services, and attributing the full environmental benefits to faster broadband would not therefore be appropriate.
Network construction emissions	• There will be carbon emissions associated with the network construction itself – through the manufacture, distribution and installation of the additional equipment required. However, as with the GVA for network construction, these are gross rather than net impacts; in practice, the public funds may otherwise be used for other construction projects with similar, or potentially higher, levels of emissions.
Changes in energy consumption of the network	• A recent study[43], supported by Cisco, noted that "the majority of the energy used by the Internet today is consumed in the access network, and this will continue to be the case for the short-to mid-term future". The authors developed a model of the power consumption of various broadband access technologies, and found that FTTC and point-to-point FTTP technologies both had substantially high power consumptions per user, relative to ADSL technology, while the

[41] Energy Savings Trust, DECC and Defra. 2012. "Powering the nation - household electricity-using habits revealed"

[42] Energy Savings Trust. 2011. "The elephant in the living room: how our appliances and gadgets are trampling the green dream"

[43] Baliga, Jayant, Robert Ayre, Kerry Hinton, and Rodney S. Tucker. 2011. "Energy Consumption in Wired and Wireless Access Networks." IEEE Communications Magazine (June): 70–77

Potential area of environmental impact	Comments
	Passive Optical Network (PON) configuration for FTTP had lower power consumption per user than ADSL. However, the same study noted that the energy efficiency of the various technologies is improving rapidly over time. Given the pace of change in network equipment energy efficiency, we considered that it would be difficult or impossible to derive a meaningful estimate of the net change in network energy consumption (and emissions) associated with faster broadband. BT's reported carbon footprint[44] supports the view that the roll-out of fibre-delivered services does not appear to be driving any major adverse carbon impacts; the emissions associated with their purchased electricity (at grid average intensity factors) fell from 1,364 ktonnes in 2009/10 to 1,241 ktonnes in 2012/13.
Network maintenance emissions	• Some have argued that the implementation of fibre-delivered services will help to reduce the emissions associated with network maintenance, as the more reliable fibre technology reduces the need for 'truck-rolls'. With the UK's public sector intervention predominantly involving FTTC technology, we anticipate that any savings from reduced cable maintenance is likely to be substantially offset by additional maintenance associated with the new active cabinets. Again, the BT carbon footprint report does not appear to indicate a major impact on the overall emissions of their commercial fleet: which has been roughly constant at about 100 ktonnes p.a. between 2009/10 and 2012/13.
Smart metering	• While the introduction of smart metering is forecast to make a substantial impact on carbon emissions, the data rates required for this application are quite modest, and do not require bandwidths greater than 2008 levels. The impact of faster broadband on this application (and its associated carbon emission savings) is therefore considered to be negligible.

Source: SQW

[44] www.btplc.com/betterfuture/betterbusiness/betterfuturereport/data/ViewSpreadsheet.aspx?path=/betterfuture/betterbusiness/betterfuturereport/Section/Content/DataCentre/NetGood/Carbonemissions.html

Environmental impacts for the UK of faster broadband

Teleworking

In modelling the net carbon impacts associated with faster broadband, we have used the following assumptions:

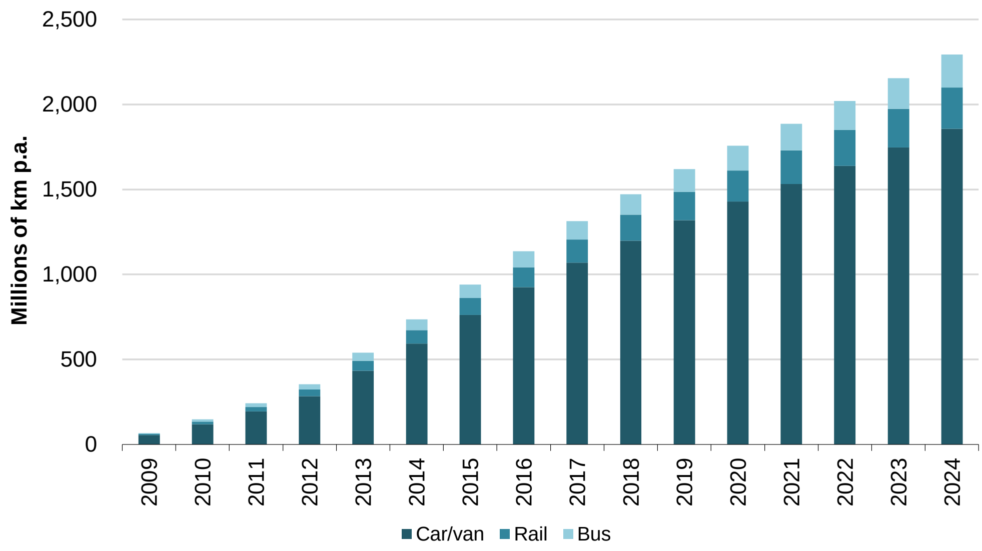
- The numbers of teleworkers each year, by density decile, and the days teleworked per year are taken from the analysis previously discussed in the economic impacts section. For the environmental impacts, though, we include public sector teleworkers, as well as private sector teleworkers.
- The average two-way commuting distance and the mix of transport modes used for the commute per decile, derived from census data.
- 'Rebound' assumptions for the saved commuting kms (due to trips being made anyway, which would otherwise be made in the course of a commuting trip, e.g. for shopping, or dropping children off at school). We have assumed 25% rebound for car commutes, and 10% for bus and rail commutes.
- Carbon emission factors per passenger km, taken from DECC/Defra guidance to companies on carbon reporting.
- Assumptions on the office energy usage avoided as a result of teleworking – varying by type of office (naturally ventilated cellular, naturally ventilated open-plan, air-conditioned, standard, and air-conditioned, prestige).
- The average domestic space heating energy per teleworked day, per density decile, taking into account differences in dwelling types (more detached homes and fewer flats in rural areas), and the relative space heating energy consumed per dwelling type.
- The mix of fuels used for space heating, by density decile (more use of heating oil and electricity for heating in rural areas, which are more likely to be off the gas grid), and the carbon emission factors of these fuels.
- The proportion of teleworkers living with an economically inactive or unemployed partner (where we assume that any heating would otherwise be on in the home anyway on teleworked days), and the proportion increase in daily space heating on teleworked days in those homes where the teleworker is not living with an economically inactive or unemployed partner (for which we estimate a 50% increase).

Faster broadband will reduce the UK's annual commuting distance by 2.3 billion kms by 2024, through increased teleworking

In total, we estimate that faster broadband will lead to a reduction in the UK's annual commuting distance[45] of about 2.3 billion kms by 2024 (Figure 4-1), predominantly in car usage. This is in the order of 2% of the current total annual UK commuting distance.

[45] In carbon-emitting modes of transport (i.e. excluding walking and bicycle).

Figure 4-1: Net annual commuting distance saved, attributable to faster speeds since 2008 (km millions p.a.) – by mode of transport

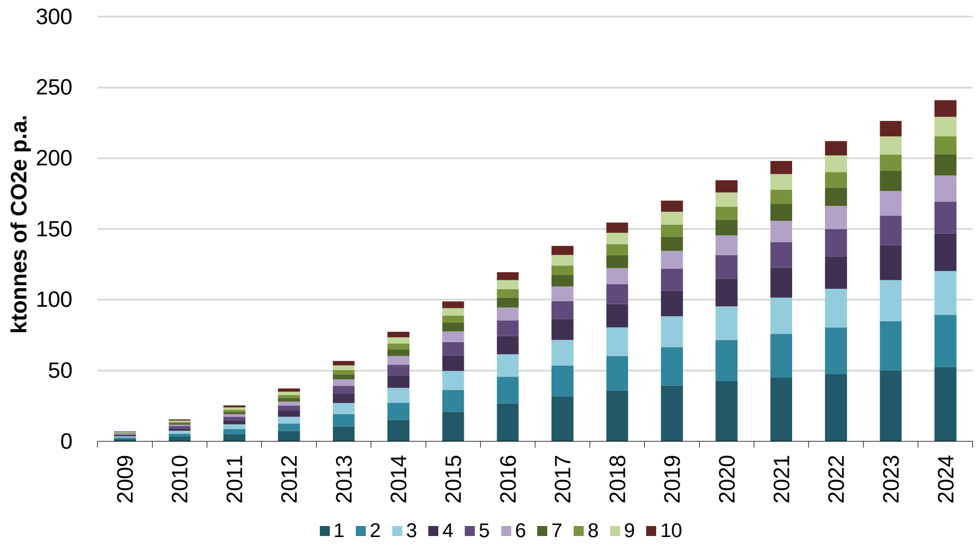


Source: UK Broadband Impact Model, SQW 2013

Annual net CO2e savings from increased teleworking, attributable to faster broadband, rise to 0.24 million tonnes by 2024

However, given that teleworking is most common in the least densely populated parts of the country (which tend to have larger dwellings, using more carbon-intensive fuels, as well as having the longest commutes), we estimate that more than half of the carbon savings from reduced commuting and office energy use will be offset by increased domestic space heating emissions. The resulting net annual saving in CO2e emissions through increased teleworking, attributable to faster broadband, rises to 0.24 million tonnes of CO2e by 2024, as shown in Figure 4-2.

Figure 4-2: Net annual saving in CO2e emissions through increased teleworking, attributable to faster speeds since 2008 (thousands of tonnes of CO2e p.a.) – by density decile of teleworker's home area



Source: UK Broadband Impact Model, SQW 2013

Business travel

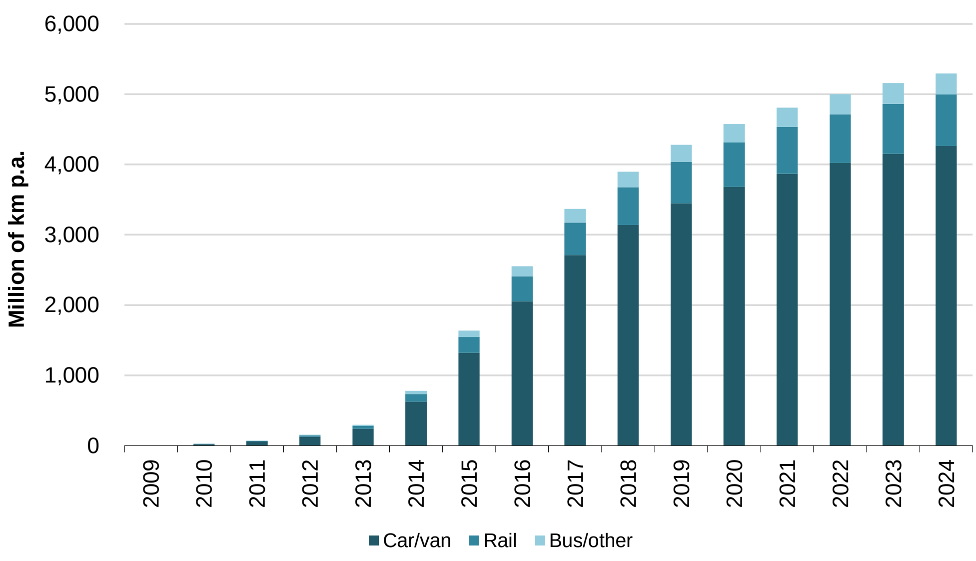
Our assessment of the potential impacts of faster broadband on business travel assumes the following:

- Data on business trip rates per head of population, from the National Travel Survey (NTS), which we have converted to an average number of trips p.a. per employed person, together with NTS data on average business trip distance and on total business trip miles by transport mode.
- A curve describing the proportion of business trips avoided, as a function of average business connectivity speed used.
- Unlike the case for teleworking/commuting, we do not assume any increase in space heating requirements associated with reduced business travel. Neither do we assume any rebound effects in terms of additional trips made for other purposes (e.g. shopping, or dropping children off at school).

Faster broadband will reduce the UK's business travel distance by 5.3 billion kms by 2024

In total, we estimate that faster broadband will lead to a reduction in the UK's annual business travel distance[46] of about 5.3 billion kms by 2024 (Figure 4-3), predominantly in car usage. This is in the order of 9% of the current total annual UK business travel distance. It would correspond to the number of annual business trips per head of population falling to 27 by 2024, which appears to be feasible given that this metric has reduced from 38 in 1995/97 to the current level of 31 (in 2012), according to the National Travel Survey.

Figure 4-3: Net annual business trip distance saved, attributable to faster speeds since 2008 (km millions p.a.) – by mode of transport



Source: UK Broadband Impact Model, SQW 2013

Annual net CO2e savings from reduced business travel, attributable to faster broadband, rise to 1.1 million tonnes by 2024

The net carbon impacts associated with this reduced level of business travel rise to 1.1 million tonnes of CO2e by 2024.

[46] Again, in carbon-emitting modes of transport (i.e. excluding walking and bicycle).

Cloud computing

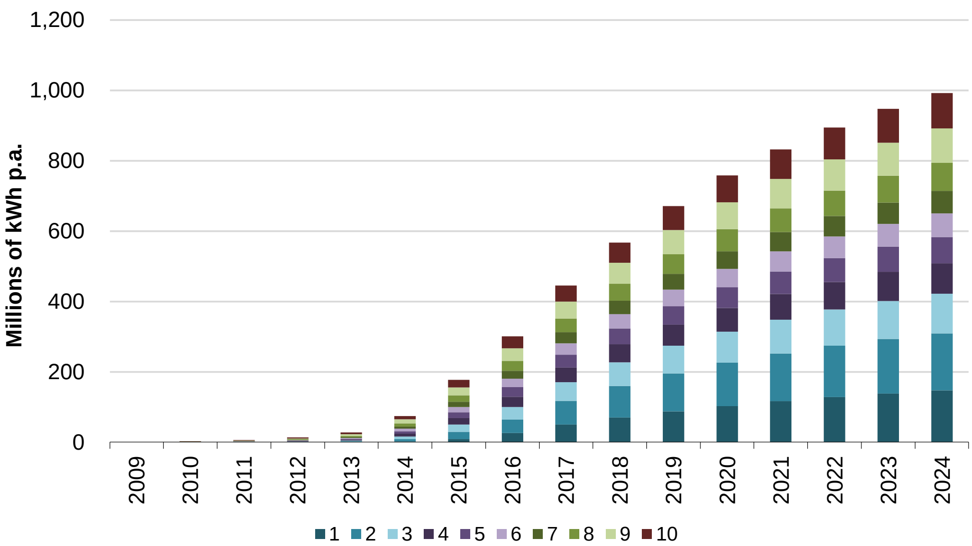
For the cloud computing impacts, we have used:

- Estimates on the electricity usage associated with servers per employee for the four different size bands (assuming fewer servers per employee for large businesses, on average), a Power Usage Effectiveness factor to account for the energy required for cooling infrastructure, and estimates on the employment in broadband-using enterprises, per size band and per density decile.
- A curve to describe the cumulative proportion of server capacity shifted to the public cloud as a function of average business speed used. We have assumed that this will saturate at about 50%, and that the rate of this shift will peak once used broadband speeds are in the order of 100Mbps (i.e. LAN-like speeds).
- Assumptions on the relative energy of public cloud versus on-premises servers. We have assumed that the public cloud can reduce emissions by about 70%, on average, versus virtualised on-premises servers.
- Time-varying carbon emission factors for long run marginal consumption of electricity, from the Supplementary Green Book Guidance on valuing energy use and greenhouse gas emissions – reflecting the projected decreasing carbon intensity of the UK's grid electricity over time.

Broadband-using enterprises shifting server capacity to the public cloud will save 1 billion kWh of electricity usage p.a., reducing annual CO2e emissions by 0.24 million tonnes p.a. by 2024

From this analysis, we estimate that approximately 1 billion kWh of electricity use will be avoided, per annum, through broadband-using enterprises shifting server capacity onto public cloud platforms by 2024 (Figure 4-4). The associated annual net carbon savings rise to 0.24 million tonnes of CO2e in that year.

Figure 4-4: Server electricity consumption avoided through shift of capacity to the public cloud by broadband-using enterprises, attributable to faster speeds since 2008 (millions of kWh p.a.) – by density decile



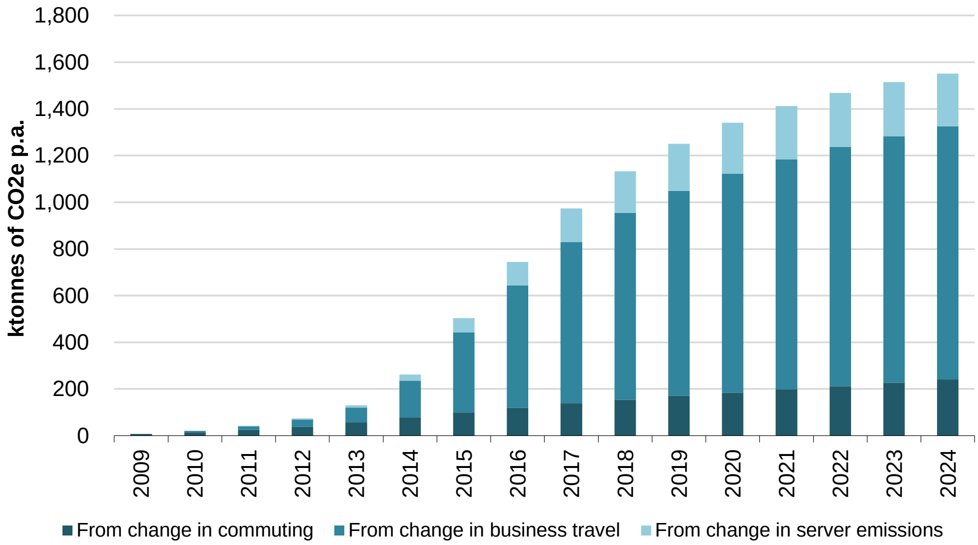
Source: UK Broadband Impact Model, SQW 2013

Total net carbon emission impacts

Total net carbon savings from faster broadband rise to 1.6 million tonnes of CO2e p.a. by 2024, which has a value of £100 million

In total, we estimate that faster broadband will account for about 1.6 million tonnes of CO2e savings per annum, by 2024 (Figure 4-5). This is equivalent to about 0.3% of the UK's current greenhouse gas emissions (572 million tonnes in 2012). Splitting these savings into 'traded' and 'non-traded' sectors, and applying the relevant carbon prices, this equates to a value of about £100 million p.a. by 2024.

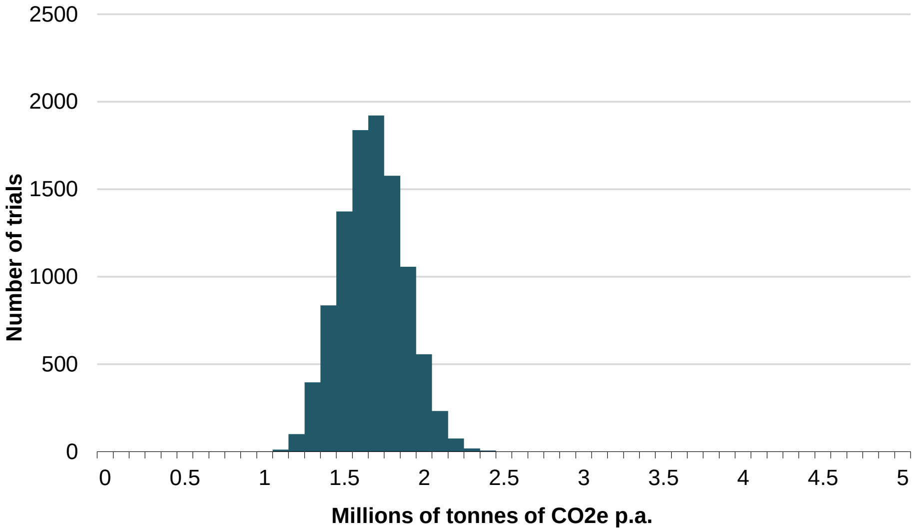
Figure 4-5: Total net CO2e emissions saved, attributable to faster speeds since 2008 (thousands of tonnes of CO2e p.a.) – by source of saving



Source: UK Broadband Impact Model, SQW 2013

The Monte Carlo simulation illustrates the relatively high degree of uncertainty over this estimate, with 90% of trials returning values of between 1.4 million tonnes and 2.0 million tonnes of CO2e p.a. by 2024 (Figure 4-6).

Figure 4-6: Monte Carlo distribution of the annual net CO2e emissions saved in the year 2024, attributable to faster speeds since 2008 (10,000 trial simulation)



Source: UK Broadband Impact Model, SQW 2013

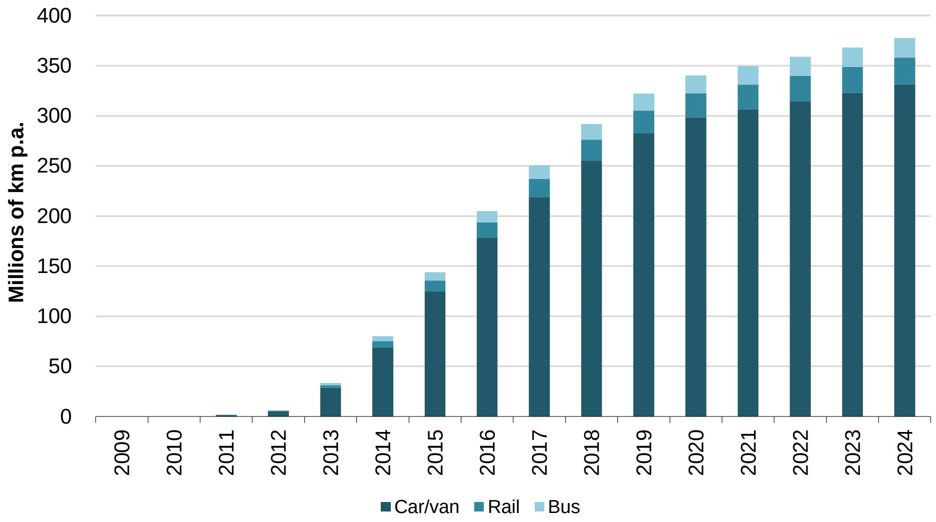
Environmental impacts of public sector intervention

Increased teleworking, attributable to intervention, reduces annual commuting distance by 0.35 billion p.a. by 2024…

Teleworking

Comparing the with-intervention and without-intervention scenarios, we find that the net annual commuting distance saved through increased teleworking, attributable to intervention, rises to about 0.35 billion km p.a. by 2024 (Figure 4-7).

Figure 4-7: Net annual commuting distance saved, attributable to intervention (km millions p.a.) – by mode of transport

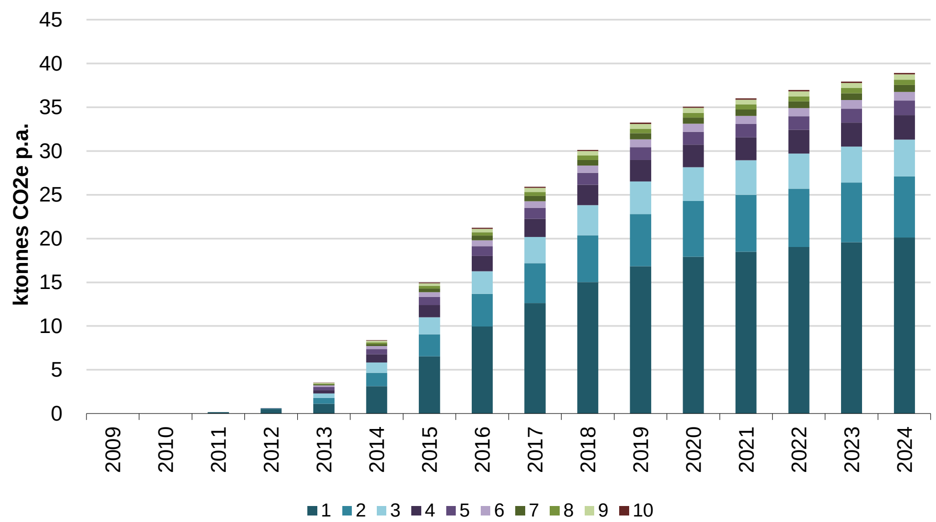


Source: UK Broadband Impact Model, SQW 2013

…and leads to 40 ktonnes of CO2e savings p.a. by 2024

The associated net annual carbon savings, after rebound effects, rise to about 40 ktonnes of CO2e by 2024 (Figure 4-8). The bulk of these carbon savings are in the three least dense deciles, where teleworking is most prevalent, and where the intervention funding is mostly targeted.

Figure 4-8: Net annual saving in CO2e emissions through increased teleworking, attributable to intervention (ktonnes of CO2e p.a.) – by density decile of home area



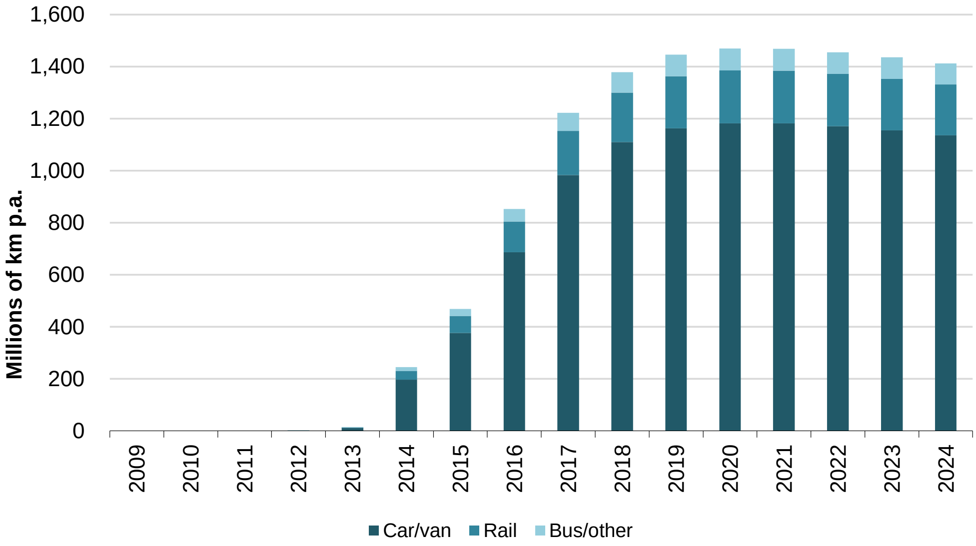
Source: UK Broadband Impact Model, SQW 2013

Business travel

Intervention accounts for a further 290 ktonnes of CO2e savings in 2024 through reduced business travel…

The net impacts of intervention account for about 1.4 billion km in reduced business travel p.a. by 2024 (Figure 4-9), and 290 ktonnes of CO2e savings in that year.

Figure 4-9: Net annual business trip distance saved, attributable to intervention (km millions p.a.) – by mode of transport



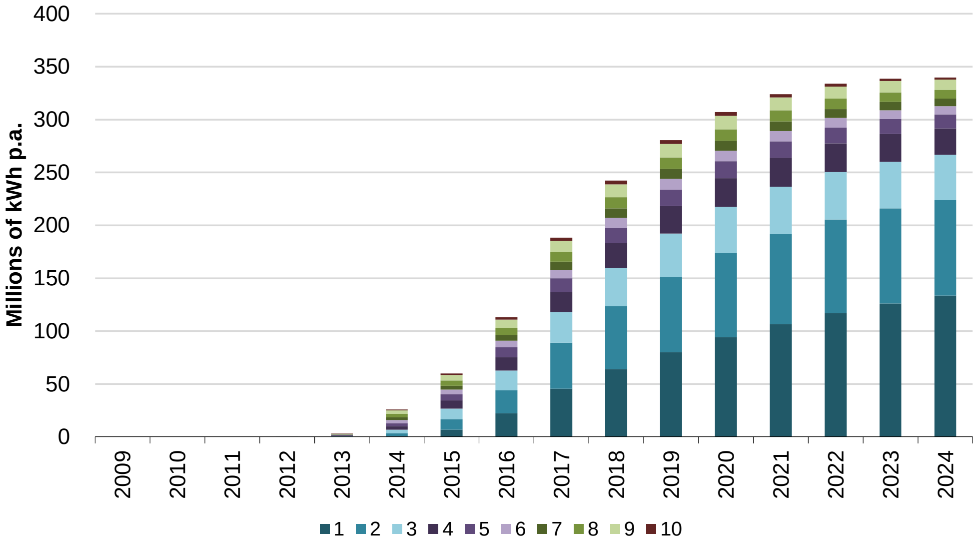
Source: UK Broadband Impact Model, SQW 2013

Cloud computing

…and 80 ktonnes through assisting the shift to cloud computing by broadband-using enterprises

By assisting a shift to cloud computing for broadband-using enterprises, intervention accounts for a saving in electricity usage of about 340 million kWh p.a. by 2024 (Figure 4-10), giving 80 ktonnes of CO2e savings in that year.

Figure 4-10: Server electricity consumption avoided through shift of capacity to the public cloud by broadband-using enterprises, attributable to intervention (millions of kWh p.a.) – by density decile



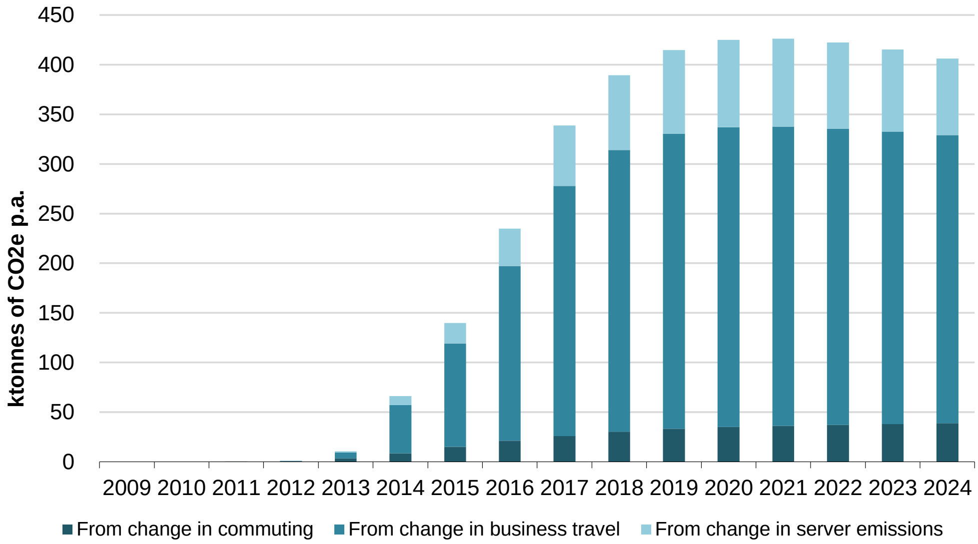
Source: UK Broadband Impact Model, SQW 2013

Total net carbon emission impacts

Total annual CO2e savings due to intervention are about 0.4 million tonnes p.a. by 2024

In total, we estimate that publicly funded intervention in faster broadband will account for approximately 0.4 million tonnes p.a. in CO2e savings by 2024 (Figure 4-11). Applying the relevant carbon prices, this has a value of about £26 million in that year.

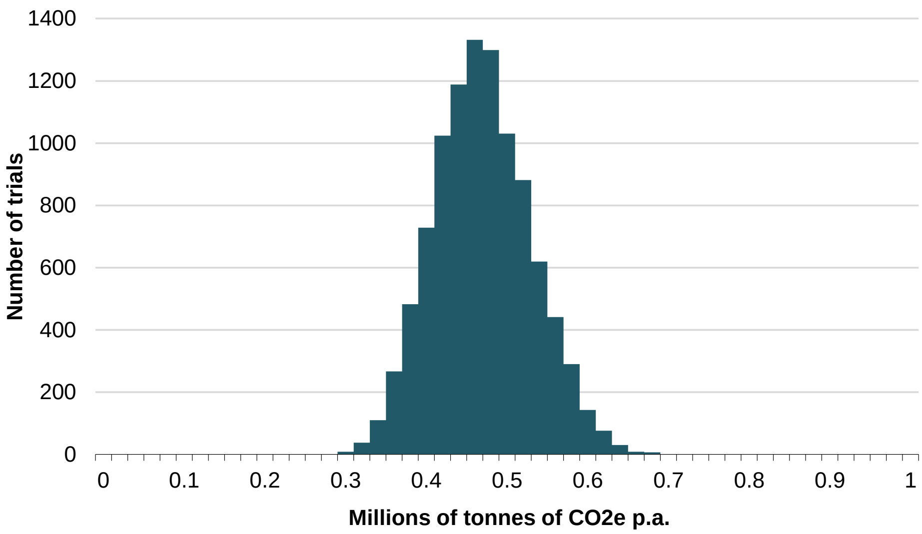
Figure 4-11: Total net CO2e emissions saved, attributable to intervention (thousands of tonnes of CO2e p.a.) – by source of saving



Source: UK Broadband Impact Model, SQW 2013

Our Monte Carlo simulation finds that 90% of trials return results between 0.38 million tonnes and 0.58 million tonnes of CO2e savings in the year 2024.

Figure 4-12: Monte Carlo distribution of the annual net CO2e emissions saved in the year 2024, attributable to intervention (10,000 trial simulation)



Source: UK Broadband Impact Model, SQW 2013

Annex A: List of model inputs/assumptions

Baseline assumptions and input data

- Discount rate
- Deflators
- Average unit price of commuting per mode (pence per km)
- Unit household costs of fuel for space heating (pence per kWh)
- Value of (commuting) non-working time (£ per hour)
- **Energy use associated with servers (2008)**[47]
- Relative energy efficiency of cloud versus on-premises servers
- Average annual business trips per person (2008)
- Average distance per business trip (miles)
- Mix of transport modes per business trip
- Transport modes used for commute
- **Commuting rebound kms**
- Average CO2e emissions per passenger km (kg per km)
- Office energy usage by type of office
- Proportion of teleworkers in each office type
- Workstation to employee ratio in each office type
- UK average energy consumption for domestic space heating
- Housing stock mix per decile
- Relative energy usage by different dwelling types
- Proportion of space heating by fuel type, per decile
- CO2e emissions per kWh, by fuel type
- Proportion of teleworking households with an unemployed/economically inactive partner
- Distribution of carers, by decile
- Numbers of UK carers wanting a job, by decile, 2008

[47] Monte Carlo distributions have been applied to the assumptions listed in bold

- Proportion of carers eligible for telework
- GVA per carer gaining employment through telework
- Distribution of unemployed disabled people, by decile
- Total UK disabled unemployed people, 2008
- Proportion of unemployed disabled people eligible for telework
- Distribution of employed people by occupation and density decile
- Total numbers of employed people in each occupation, as of 2008
- Proportion of employed people with jobs which could be undertaken, partly or wholly, from home, by occupation
- Proportion of eligible people who do telework
- Relative propensity to telework, by decile
- UK population (2008)
- Number of employed people at difference distance bands, by decile
- Assumed 1-way commuting distance per band (km)
- Average 1-way commuting trip time (minutes)
- Proportion of saved commuting time spent on work
- UK GVA in 2008 (£m, 2008 prices)
- UK total hours worked in 2008 (million hours)
- GVA per employee in 2008
- 2008 private sector business sites and employment, by density decile

Geographic data

- Total premises per local authority per density decile
- Total premises per nation per density decile
- Total premises per density decile by urban vs rural
- Total UK residential and non-residential premises per density decile
- Average distance from postcode centroids to serving exchange, per decile
- Average distance from postcode centroids to serving cabinet, per decile

Speed and take-up assumptions

- ADSL speeds by distance to the exchange
- ADSL2+ speeds by distance to the exchange
- FTTC speeds by distance to the cabinet
- **FTTP speeds**
- **Virgin Media cable speeds**
- Lag in households taking up in-year increases in speeds made available
- Typical speed used by households in 2008, by decile
- Lag in businesses taking up in-year increases in speeds made available, by employment sizeband - without intervention
- Cumulative proportion of firms using mass market broadband as their primary connection, by employment size band

Coverage without intervention assumptions

- ADSL2+ coverage per decile, without intervention
- Proportion of (current) non-EO premises enabled for FTTC, per decile, without intervention
- Proportion of (current) EO premises enabled for FTTC, per decile, without intervention
- Proportion of premises covered by FTTP (excl FTTP on demand) per decile, without intervention
- Virgin Media premises per decile
- Exchange Only premises per decile, as of May 2013
- Total EO premises per density decile, per nation, as of May 2013

Existing programme rollout assumptions

- Rural Programme investment
- RCBF investment
- UBF investment
- Cumulative total UBF voucher beneficiaries, by density decile
- Rural Programme Infill speed for those not served by superfast

- Cumulative additional proportion of total premises enabled for FTTC, through the Rural Programme intervention, per density decile
- Cumulative additional proportion of total premises enabled for FTTP (excl FTTP on demand), through Rural Programme intervention, per density decile
- Distribution of sample RCBF premises, by density decile
- Total cumulative additional premises covered by RCBF
- Split of FTTC vs FTTP for the RCBF

Impact assumptions

- **Displacement assumptions**
- Multiplier assumptions
- Type II employment effect of network investment (job-years per £1m investment)
- Type II GVA effect of network investment (£m of GVA per £1m investment)
- **Cumulative proportion of server capacity shifted to the public cloud as a function of typical business speed used**
- **Change in business trips per employed person, as a function of used broadband speed**
- **Proportion increase in daily domestic space heating per telework-day**
- **Cumulative proportion of telework-eligible carers gaining employment, as a function of typical household speed used**
- **Cumulative proportion of telework-eligible unemployed disabled people gaining employment, as a function of typical household speed used**
- **Average days per year teleworked from home, for those who telework and who live in the lowest density decile, as a function of typical household speed used**
- **Average productivity shock from doubling speed (100% increase)**
- **Ratio of maximum productivity shock to the shock from doubling speed**
- Relative productivity impact per industry, relative to private sector average
- Productivity shock lag assumptions
- **Assumed impact of Relative Broadband Quality on the annual local growth in the number of business sites**