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Fiber broadband, geography of work, and digital premium gaps: evidence from housing market responses

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Abstract

Using the universe of housing transactions in England and Wales between 2008 and 2017, we measure the perceived value of fiber broadband to homebuyers. We exploit the discontinuity across the boundary of areas that were fiber-enabled in different years and find a house price premium of 0.7 per cent. The effect is strongest in London and other major cities, particularly in high-income, high-skill areas. Within major cities, comparing areas that are in the same income tier, we find that areas with a higher proportion of skilled workers show a larger response to fiber.

Keywords: **fiber broadband; spatial discontinuity; house price; skill.**

JEL classifications: **J24, L86, O33, R21.**

1. Introduction

Data-intensive digital services and platforms have become an important part of modern life. Access to high-speed internet is a prerequisite for using these services that can transform the way we work, learn, or use health care. During the last decade, the rollout of fiber-optic broadband drove a major technological shift, offering faster, more reliable connections at an affordable cost.[1] While governments have prioritized universal access to fiber infrastructure and higher broadband speeds, relatively little is known about its perceived benefits to households.

This article makes two contributions to address this gap. First, we build a new dataset on the boundaries of fiber activation areas across England and Wales, which allows us to provide causal estimates of

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[1] Between 2014 and 2019, monthly fixed internet spending (per GB of data) declined by 80 per cent while monthly data usage has increased by 443 per cent for UK households (Ofcom Communication Market Report 2020).

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the housing market premium associated with fiber-to-the-cabinet (FTTC) broadband. Our findings contrast with earlier evidence from Ahlfeldt et al. (2017) showing diminishing returns to broadband speed improvements and negligible benefits beyond the maximum speeds (24 Mbps) offered by asymmetric digital subscriber line 2+ (Asymmetric Digital Subscriber Line (ADSL2+)). We show that even at higher speed levels associated with FTTC (30–50 Mbps), significant valuation effects persist. Second, the benefits of faster broadband are often attributed to their concentration in rich and dense areas.[2] Although we confirm that price capitalization of fiber infrastructure is indeed found in major cities and high-income areas, we find that the variation in local skill composition plays an important role in explaining the gains from faster broadband access.

To examine this issue empirically, we study the UK's transition from standard broadband to superfast fiber broadband. The transition was triggered by a nationwide rollout of FTTC infrastructure that began in 2009. By 2013 the majority of urban postcodes had access to the FTTC infrastructure. Still, the previous-generation ADSL broadband was the dominant technology in 2013, with more than 70 per cent of subscribers. Gradually, older connections were replaced by FTTC, which reached a 50 per cent market share by the end of 2019.

We examine how homebuyers respond to FTTC availability by measuring the price premium they are willing to pay for properties located in FTTC-enabled areas. To this end, we devise an empirical strategy that exploits the sharp discontinuity in high-speed broadband availability across neighboring postcodes that are connected to the FTTC infrastructure in different years. Our identification strategy requires a granular mapping of the FTTC network in the UK. To construct this mapping, we first collect FTTC activation dates for the universe of postcodes in the UK. We also collect information on the distribution points of FTTC broadband, commonly known as street cabinets, including their locations and the exact postcodes they serve. This detailed knowledge of FTTC infrastructure helps us in two ways. First, we join adjacent postcodes to construct areas that are activated in the same year. We then locate the boundary of these fiber activation areas and exploit the geographic discontinuities in FTTC availability across these boundaries. Second, we compute the distance between each postcode and the connecting cabinet, from which we deduce whether a postcode is well-situated to access the FTTC infrastructure.

To test the validity of our design, we examine the broadband speed across the boundaries of areas that got activated in different years. We find a sharp jump in download speeds when one side of the boundary line is activated while the other side remains inactive. We do not observe this speed gap in cases where neither side of the boundary line has been activated. We then proceed with our main estimation, which compares prices of the properties in these closely located postcodes that are connected to FTTC in different years. Specifically, we measure whether early FTTC activation and the proximity to FTTC infrastructure are capitalized in house prices, thereby estimating the digital premium of access to FTTC broadband.

Using this empirical design, we find a house price premium of 0.7 per cent caused by FTTC activation. Properties located within 200 meters of the cabinet get a premium of 1 per cent while those located farther away than 400 meters get no premium. The variation of premia by distance closely replicates the technical features of FTTC broadband, which delivers the greatest speed improvements closest to the cabinets. The magnitude of our estimate is roughly similar to the 1 per cent price effect reported by Ahlfeldt et al. (2017) for ADSL speed upgrade. However, it is noteworthy that our estimates apply to a higher speed range, suggesting that the ADSL-era diminishing returns to speed improvements might not be relevant over time.[3]

Next, we study the heterogeneity in the house price responses across urban geographies. We find that the digital premium for major cities is 2.4 per cent while the response for smaller cities and towns is

[2] See Ahlfeldt et al. (2017) for further details. In particular, they estimate the perceived value of broadband speed upgrades from ADSL (8 Mbps) to ADSL2+ (24 Mbps) in the UK using variation in house prices. Their heterogeneity analysis shows that the effect is concentrated in rich and dense areas.

[3] Not only FTTC offers a higher download speed (30–50 Mbps) compared to ADSL (maximum speed 24 Mbps), but also FTTC connections offer upload speeds that are eleven times faster than those of ADSL.

muted.[4] To understand what drives the strongest price responses in major cities, we examine variation in local characteristics such as income, skill, and population density. We estimate heterogeneous responses within different types of cities and towns by grouping middle layer super output areas (MSOAs) according to whether they fall above or below the national medians for each of these characteristics.[5] In major cities, high-income areas experience a 2.7 per cent higher response while high-skill areas have a 4.4 per cent higher capitalization effect. On the other hand, we do not find any different response for high-density areas. To ensure that these results are not driven by the disproportionate concentration of high-income and high-skill areas in London, we repeat the analysis focusing on cross-city differences in the distribution of these characteristics and find very similar results.

As income and skills are highly correlated, we carry out three separate exercises to test the relative importance of each component. First, we divide each major city into income tertiles and show that within these tertiles, variation in income does not significantly explain the variation in response to fiber broadband access. Second, we show that within the same income tertiles, where the income effect is muted, high-skill areas exhibit a 3.3 per cent larger response than low-skill areas. The estimate is smaller but not substantially different from our baseline skill effect of 4.4 per cent, which is obtained without restricting the analysis to areas within similar income groups. Third, we divide each major city into skill tertiles and find that, within each skill group, the difference in response between high- and low-income areas disappears.[6] Taken together, these results suggest that the geographic disparity in skills is a key factor in determining who benefits from fiber broadband.

This article contributes to several strands of literature. First, we design an empirical strategy that estimates the perceived value of access to fiber broadband. We follow the hedonic price approach, developed by Rosen (1974) and Roback (1982), which exploits rent and housing prices to infer the value of local (dis-)amenities, such as proximity to nuclear plants (Gamble and Downing 1982), school quality (Black 1999), air pollution (Chay and Greenstone 2005), transport access (Gibbons and Machin 2005), hazardous waste sites (Greenstone and Gallagher 2008), and crime risk (Linden and Rockoff 2008). We contribute to this literature by developing an empirical strategy to study the amenity of access to fiber broadband. The validity of hedonic price estimates often relies on careful empirical designs that isolate the quasi-exogenous variation in access to the amenities. To achieve this, we construct granular boundaries of fiber activation and study the changes in the prices of neighboring properties located across these boundaries in a difference-in-differences setup. The combination of narrow boundary discontinuity and temporal variation in fiber activation limits the impact of potential confounding factors that manifest themselves in cross-sectional setups (Black 1999; Gibbons and Machin 2005; Greenstone and Gallagher 2008).

Our results also contribute to the broader literature that examines the economic and social effects of broadband access. This includes studies on health outcomes (Amaral-Garcia et al. 2019; DiNardi et al. 2019), education (Dettling et al. 2018; Sanchis-Guarner et al. 2021), civic engagement and political participation (Falck et al. 2014; Gavazza et al. 2019; Geraci et al. 2022), labor market outcomes and productivity (Akerman et al. 2015; Hjort and Poulsen 2019), trade (Malgouyres et al. 2021), sex crime (Bhuller et al. 2013), and credit (D'Andrea and Limodio 2019). The closest work to our article is Ahlfeldt et al. (2017), which examines the effect of ADSL broadband on house prices between 1995 and 2010. What sets our article apart is our focus on next-generation broadband technologies delivered via fiber networks that began to take off after 2010. In particular, the static prediction in Ahlfeldt et al. (2017) suggests that demand

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[4] We use the words digital premium and FTTC premium interchangeably throughout the article.

[5] MSOAs are geographic areas used in England and Wales for statistical reporting, particularly for census data. MSOAs are built from groups of lower layer super output areas (OAs) and are designed to be medium-sized statistical units with populations ranging from 5,000 to 15,000 people.

[6] Note that in the first exercise, we compare high- and low-income areas within each income tertile, where areas are classified based on whether they fall above or below the median income within their respective tertile. Similarly, in the second exercise, high- and low-skill areas are defined using the median share of skilled residents within each income tertile. In the third exercise, we classify high- and low-income areas according to the median income within each skill group.

for higher speed above a certain threshold was expected to be zero during the first-generation broadband upgrades. In contrast, our article shows that the speed threshold has risen over time, making fiber broadband increasingly important for households, especially for households with specific characteristics, such as higher skills and incomes.

Our work is among the first to study the causal effect of a speed upgrade following the rollout of fiber broadband. DeStefano et al. (2023) examine the postcode-level timing of fiber broadband availability and use a firm's distance from the local telephone exchange as an instrument to measure the adoption of cloud computing and its impact on firm growth. It is important to note that, before the rollout of FTTC broadband, access to high-speed internet was determined by the distance from local exchanges (LEs). This is because the previous broadband technology (ADSL) relied heavily on the telephone exchange network. With the deployment of fiber, the geography of high-speed broadband access has changed drastically. The connection speed for FTTC broadband is determined by the distance from a cabinet, rather than from the distance from LEs. However, the lack of information on cabinet networks forced previous papers either to limit their study periods before the FTTC rollout or rely on strong assumptions about cabinet deployment and their locations. We fill this gap by collecting granular information on cabinet networks and measuring distances between the properties and their respective cabinets. Moreover, unlike the UK's LE network that was designed in the 1930s—long before the introduction of broadband, the location of FTTC cabinets cannot be considered exogenous. We overcome this empirical challenge by constructing a quasi-experimental sample in the vicinity of FTTC activation boundaries. Other papers have looked into the effects of fiber broadband across different countries. Fackler et al. (2022) use a spatial regression discontinuity design exploiting variation at state borders from German states' broadband expansion policies and report that a 16 Mbit/s internet availability led to increases in sale prices by 8 per cent and rents by 3.8 per cent, with diminishing returns at higher speeds. They further provide support for economic surplus exceeding deployment costs for 90 per cent of households, while property owners benefit from subsidies through higher property prices. Guiffard (2024) uses a spatial discontinuity design on the border of fiber-to-the-home (FTTH) eligibility zones in France and finds that FTTH eligibility increased property prices by 0.9 per cent, much closer to the results reported in other papers, including ours and Ahlfeldt et al. (2017).

Our article also contributes to the literature on heterogeneous gains from high-speed broadband and the barriers that shape them. In a review of broadband impacts, Goldfarb and Tucker (2019) emphasize the role of large cities and agglomeration in amplifying digital benefits. Consistent with this, we show that the fiber broadband premium is largely concentrated in London and other major cities. Paul et al. (2023) construct a detailed dataset on broadband plans offered by US ISPs and find that the average income of a neighborhood strongly predicts fiber deployment. In contrast, racial composition and population density, when considered independently of income, do not explain differences in broadband availability. Ahlfeldt et al. (2017) examine housing market responses to broadband speed upgrades and find that the price premium is mostly concentrated in wealthy and dense areas. Our results align with these earlier findings, showing that the valuation of fiber broadband is highest in high-income localities. Moreover, a growing body of literature explores the relationship between broadband access and inequality, highlighting skill barriers as a key factor in determining who benefits from internet technologies (Akerman et al. 2015; Hjort and Poulsen 2019; Zuo 2021; Gürtzgen et al. 2021). Our article shows that the skill gap accounts for much of the disparity in the benefits of high-speed home broadband, even when examined independently of the income effect.

The rest of the article is organized as follows. Section 2 gives an overview of broadband rollout and take-up in the UK. Section 3 describes the data and summary statistics and Section 4 outlines our empirical strategy. We discuss our results in Section 5 and Section 6 concludes.

2. Background

2.1 A brief history of broadband in the UK

The commercial deployment of broadband infrastructure in the UK has gone through several major upgrades. Each upgrade is linked to the topology of the network built during the first half of the twentieth century by the incumbent—British Telecom (BT). The infrastructure consists of regional aggregation points, called LEs, which were initially connected to each subscriber's residence or business premise through copper lines. The LEs are, in turn, connected to a backbone national network, allowing users to make phone calls. Based on this fixed infrastructure, internet connections in the 1990s ran through the legacy public switched telephone network (PSTN) with a maximum speed of 56 kbps.[7]

The first wave of upgrades took place from 2000 to 2008 with the introduction of ADSL technologies (ADSL, ADSL Max, and ADSL2+). While the actual network remained intact during this process, active equipment (i.e., powered with electricity) was installed in every LE, thus enabling users to increase their connection speeds by one or two orders of magnitude compared to the PSTN service.[8] During this round of upgrades, the length of copper lines running from the LE to each property largely determined the actual speed experienced by users (Ahlfeldt et al. 2017). For example, while ADSL2+ connections could provide a maximum speed of 24 Mbps for properties up to 1 km away from the LE, subscribers residing more than 3 km away from the LE would only get one-third of that speed (around 8Mbps).[9]

2.1.1 FTTC broadband

Deployment of fiber brought the next major upgrade and provided a significant speed boost compared to the ADSL connections. In 2008 BT announced that it would invest £1.5 billion to connect 10 million UK homes using FTTC technologies within the next few years.[10] Under this plan, newer (and smaller) aggregation points called street cabinets were constructed within the LE catchment areas. The connection between the LE and the cabinets used fiber cables, which have a higher data transmission speed, whereas the cabinets were connected to the surrounding properties using copper lines (Fig. 1). This brought the distribution nodes closer to the properties and effectively reduced the length of the copper lines used (see Fig. A.1). Combined with the new active equipment in the cabinets, the reduced distance allowed for much "denser" data streams to travel over the same last-mile connections. As a result, FTTC connections could offer a maximum download speed of 80 Mbps.

A couple of points about the FTTC activation process are worth noting. First, BT's rollout took place in multiple phases and predominantly targeted urban areas. Between 2009 and 2013, at least 80 per cent of the postcodes activated each year were urban postcodes.[11] Most of the ADSL-type activations were completed by 2007. FTTC activation started in 2009 and the maximum number of unit postcodes were connected in 2012 (see Fig. A.2). The bulk of the commercial rollout was completed by 2013–14. After that, largely rural postcodes got FTTC activated through the Building Digital UK (BDUK) programs.[12]

Second, due to the use of fiber cable for the first leg of FTTC connections—the connection between the LE and cabinets—FTTC broadband speed does not vary with the distance between a property and the LE. Fiber cable lines have practically zero losses over these distances. For FTTC connections, it is the distance from the street cabinet that affects the actual speed. For example, although the maximum download

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[7] In some places where ISDN was available, the speed could rise up to 64 kbps.

[8] Each version of ADSL implements a different standard from the International Telecommunications Union (ITU) that improves the line's performance characteristics in terms of speed and reliability over the same copper medium.

[9] See https://www.broadbandspeedchecker.co.uk/guides/adsl-and-distance.html.

[10] ISPreview, 2008: BT reveals major £1.5bn next-gen fiber broadband plans, Source: https://www.ispreview.co.uk/news/EkEyEpAFykbCFYrArU.html

[11] Based on authors' own calculations.

[12] The BDUK program is an initiative of the Department for Digital, Culture, Media & Sport (DCMS) that aims to support broadband delivery through state aid or voucher programs in areas that are not considered as "commercially viable" by the private sector.

Figure 1. Topography of broadband technologies.

Note: This figure highlights how the rollout of FTTC infrastructure changed the geography of access to high-speed broadband. The figure shows a typical layout of fiber broadband infrastructure. The star shows the location of the local telephone exchange. It is important to note that broadband speed provided by the earlier generation technologies, such as ADSL, was closely related to the distance of a property from the LE. However, the installation of the street cabinets (shown by purple dots) brought the distribution points much closer to the properties. Thus, after the activation of the FTTC connections distance from the cabinet (and not the LE) is a determining factor of the actual speed that households can enjoy.

speed could be as high as 80 Mbps within 100 meters of the cabinet, the speed drops to 60 Mbps around 500 meters away, and to 30 Mbps around 1 km away from the cabinet.[13]

2.1.2 Other broadband technologies

During the same period, a much smaller-scale investment for fiber-to-the-premises (FTTP) technologies also took place. Compared to FTTC, a full-fiber connection (like FTTP) uses fiber all the way from a LE (and later from the cabinet) to each property. However, the number of postcodes with FTTP connections remained low, with less than 10,000 postcodes activated during this period (see Fig. A.2). Another major commercial provider playing a part in superfast broadband delivery is Virgin Media, a cable broadband provider, which launched its 50 Mbps broadband service in 2008, followed by an upgrade to 100 Mbps in 2010.[14] Virgin Media delivers broadband services using its own network infrastructure, which consists of the same coaxial cable used for its cable TV services. Its infrastructure covers only half of the UK and remained the same during the initial phases of the FTTC rollout.[15]

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[13] See https://www.increasebroadbandspeed.co.uk/chart-of-bt-fttc-vdsl2-speed-against-distance-from-the-cabinet

[14] See https://www.globenewswire.com/news-release/2008//15/389811/156365/en/Virgin-Media-Launches-the-UK-s-Fastest-Broadband.html, and also https://www.thinkbroadband.com/news/4441-virgin-media-announces-100-mbps-broadband-amp-q3-2010-results.

[15] See Ahlfeldt et al. (2017) for more details.

2.2 The importance of fiber connections

The importance of high-speed broadband connections that can be delivered with the FTTC architecture (and subsequently via FTTP or Cable DOCSIS 3.0) rests on the type of application, the amount of content that users demand, and the capabilities of each communication technology. In 2009, before the FTTC rollout started, the actual average download speed in the UK was 4.2 Mbps according to a report by the Office of Communications (Ofcom).[16] For ADSL connections, the average download speed that could be achieved with packages "up to" 20/24 Mbps was 6.5 Mbps while for ADSL services "up to" 8/10 Mbps it was 3.3 Mbps. With ADSL technologies, the room for improvement was minimal as the distance of each property to its LE was the main factor affecting these results. Compared to that, FTTC connections can provide at least 30 Mbps for properties located within 1 km of the cabinet, which represents the vast majority of properties covered in the UK (98.5 per cent). Moreover, the rollout of fiber cabinets significantly reshaped the geography of access to high-speed broadband. While the average distance to the LE is 1.56 km, the average distance to the cabinet is only 280 meters. This striking change in the network infrastructure is illustrated in Fig. 1.

In terms of applications, the Federal Communications Commission notes[17] that users need at least 3 Mbps of download speed for any type of streaming service, 5 Mbps for high-definition videos, 5-25 Mbps for telework, and 10 Mbps or more for large file downloads. If more than one resident uses the same connection, this will further reduce the available bandwidth for online activities. The upload speed also matters as it is crucial for a number of applications that facilitate teleworking, uploading of large files, content creation, web-services hosting, and improved performance. The transition from ADSL2+ to FTTC also brought notable improvement in upload speed. Ofcom reports that "on average, an ADSL2+ user who upgrades to a basic tier 36-38 Mbit/s FTTC service will benefit from an eleven-fold increase in upload speed from 0.8 Mbit/s to around 9 Mbit/s."[18]

The change in usage patterns and technological demand over time highlights the importance of fiber in recent years. The key message from Ahlfeldt et al. (2017) is that basic broadband (that is, ADSL) has a significant effect on property prices, and that further speed increases show diminishing returns. Particularly, the authors note that "It is interesting to see that the marginal effect (that is, the impact of a marginal increase in speed on net consumer surplus) is about zero close to the maximum actual speed that we observe in the data. There would be no particular reason for suppliers to provide speed above the maximum observed levels in our data, as no further surplus could be created." (Section 4.1, pp. 606–7). If we generalize this finding with our more recent data, the effect would be zero at the range of speed offered by FTTC connections (30 Mbps or higher). However, this could change in light of the need for improved access to digital services over time. Hence, it is important to examine how households perceive benefits from further speed increases. One explanation could be that we observe different effects from broadband access compared to other typical provisions like electricity, gas, or water supply to our homes. In these cases, the volume and standards have not changed for decades, whereas in the case of telecommunications, they appear to increase significantly every few years.

2.3 Broadband coverage and take-up

In the aftermath of the nationwide FTTC rollout its adoption did not follow at the same pace (Fig. A.3a). This is not uncommon in the literature as the coverage or availability of new technology alone does not guarantee its universal take-up (Greenstein and Prince 2006). Ofcom defines superfast broadband as

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[16] https://www.ofcom.org.uk/siteassets/resources/documents/research-and-data/broadband-research/broadband-speeds/bbspeeds2010/bbspeeds2010.pdf?v=333329

[17] https://www.fcc.gov/consumers/guides/broadband-speed-guide

[18] https://www.ofcom.org.uk/siteassets/resources/documents/research-and-data/broadband-research/broadband-speeds/home-broadband-performance-march-2021/uk-home-broadband-performance-technical-report-march-2021-data.pdf?v=326833

connections that deliver download speeds of at least 30 Mbps, which are typically obtained through fiber-based or cable broadband technologies. According to Ofcom's data, 91 per cent of the premises in the UK had access to superfast broadband by 2017. However, less than 40 per cent of the premises took up a superfast broadband subscription. More recently the gap between coverage and take-up has narrowed to some degree but still, as of 2021, approximately one-third of the premises still did not subscribe to superfast broadband.

The 2020 Communication Market Report published by Ofcom also shows how the broadband technology mix has changed over the years (Fig. A.3b). The report gives the share of connections for each type of technology out of the total number of fixed broadband connections during that year. From these shares, we can see a gradual transition toward FTTC technologies. In 2013, ADSL held 70 per cent of the broadband market and the market share for FTTC was only 10 per cent. Since then the share of FTTC connections gradually increased but ADSL remained the dominant technology until 2017. By 2018, FTTC surpassed ADSL for the first time, and in 2019, it captured half of the market, with ADSL's share dropping to 27 per cent. During this period, FTTP had a relatively low market share, reaching only 3 per cent in 2019. Note that cable broadband held a steady share of the market at 19–20 per cent throughout this period, which supports our previous assertion that cable coverage remained mostly unchanged during our study period.

This discussion shows that coverage alone does not guarantee that people will adopt high-speed broadband. Although superfast broadband mainly enabled by FTTC technologies quickly became available across most parts of the country, its take-up was slow. As a result, low-speed connections (that is, ADSL) still represent a significant share of the commonly used technologies. The factors behind this slow take-up are important to understand, especially in light of the UK government's recent goal to expand the gigabit broadband coverage to 85 per cent of the UK premises by 2025 (Hutton 2021). As take-up depends on the economic value gained by the households from the usage of high-speed broadband, we set out to measure it through housing price appreciation and examine how this valuation varies by area characteristics.

3. Data and summary statistics

We combine data from several sources to assess homebuyers' perceived value of fiber-enabled properties. This section describes the data sources and provides some descriptive statistics.

3.1 Housing price data

We collect property sale prices from 2008 to 2017 using the Price Paid Data (PPD) of the UK HM Land Registry. Under the Land Registration Act 2002 and the Land Registration Rules 2003, the UK HM Land Registry records all transactions and changes in property ownership rights, including mortgage, lease, or right of way (Coulomb and Zylberberg 2021). This granular data covers almost all residential property transactions in England and Wales. In addition to the sales price, it also provides other information about the property, such as the full address, types of buildings (detached, semi-detached, terraced, flat/maisonette, and others), and the construction period of the property. From this data, we exclude a small share of properties, reported as "others," that do not fall into the four main categories of property types. Additionally, we have information about the date that the properties were constructed, and more specifically, whether the property was built during the past ten years.

The second source of property-level data is the Energy Performance Certificates (EPCs) that help supplement the relatively limited property characteristics provided by the PPD. These certificates aim to provide information about the energy performance of a building, but they also include other property characteristics such as total floor area in square meters, the age of a building, and the number of rooms. We match this information with the property transaction data using precise address matching. We exclude a few observations when the reported number of habitable rooms is zero or more than twelve.

We also exclude the properties that fall outside the range defined by the 0.1 and 99.9 percentile values of total floor area or price per square meter. The EPC data has good coverage and accounts for 85.3 per cent of registered property sales available in the PPD.

3.1.1 Geography and local characteristics

We also examine the variation in housing market reactions across geographic areas. We augment our analysis with information from the classification of cities and towns published by the House of Commons Library (Baker 2018). Using the census-defined OAs,[19] the classification scheme groups population settlements of different size into different categories of cities and towns. The categories include core cities (London and outside of London), other cities, large towns, medium towns, small towns, and villages and small communities. An additional category identifies large, medium, and small towns (or villages) near urban conurbations. For our purpose, we regroup them into major cities (that is, core cities), other cities, and towns (large, medium, and small).[20]

We examine the role of income and skill in driving house price responses. Our data on income are at the MSOA-level and come from the income estimates for small areas in England and Wales published by the Office for National Statistics (ONS). We use the estimates for net weekly household income adjusted for housing costs in 2011–12. We also use the 2011 Census to measure the skill composition of an area. The census classifies all employed residents (aged sixteen and over) into occupational groups using the Standard Occupation Classification (SOC) 2010. We calculate the MSOA share of employed residents who are engaged in occupations requiring skill level 4, which is the highest level of skill in ONS classifications. These are professional occupations or high-level managerial positions that usually require a degree or relevant work experience. The following SOC sub-major groups fall into this category: eleven (corporate managers and directors), twenty-one (Science, research, engineering, and technology professionals), twenty-two (health professionals), twenty-three (Teaching and educational professionals), and twenty-four (business, media, and public service professionals). We use the share of residents working in these occupations as a measure of skilled workers to investigate whether high-skill areas exhibit higher returns to fiber broadband.

3.2 Broadband technologies

The key information required for this article is the precise spatial and temporal description of FTTC deployment. To collect this, we web-scrape different datasets from online resources that are built using data sourced from Openreach Limited, a subsidiary of BT. Openreach maintains the telephone cables, ducts, cabinets, and exchanges connecting nearly all homes in the country. We first extract information on the local distribution nodes (that is, street cabinets), which includes their exact locations and FTTC activation dates. In total, we find information on 104,425 cabinets. We link the cabinets to their respective LEs which are the regional distribution hub. A second dataset helps us to establish the link between each unit postcode in the country and the cabinet through which it is fiber enabled.[21] Armed with this granular information, we calculate the straight-line distance between the postcode of a property and the postcode in which the connecting cabinet is located. The activation dates help us determine when FTTC becomes available at each postcode, and the distance from the cabinet helps us gauge the range of FTTC speed available in the postcode.

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[19] OAs are the finest census-defined geographies that are used for statistical purposes. They have between 40 and 250 households (a resident population between 100 and 625 persons.

[20] We also report our results by the full breakdown in Appendix 1.

[21] This is a postcode-level dataset that includes information on both FTTC activation dates as well as which cabinet(s) serve the postcodes. The linking of the two datasets allowed us to retrieve cabinet locations. The process was not straightforward because of a lack of unique identifiers for the cabinets. We use string variables that describe the cabinet and locations to define a unique cabinet identifier. We also verify that the FTTC activation dates provided at the cabinet (i.e. local hub) level and postcode level match.

3.2.1 Broadband speed

Among other information, we also make use of the postcode-level information on broadband speed published by Ofcom as part of its Connected Nations series. Ofcom has published this data annually since 2013. We use it to check how speed varies across neighboring postcodes with and without FTTC connections.

3.2.2 Descriptive statistics

In Table 1, we report the summary statistics for the key variables of our analysis. The average sale price is £195,085 during the study period from 2008–17. In our sample, we truncate the sales price to £500,000. The average property in our sample has 4.5 rooms and 85 square meters of floor area. Of these, 20 per cent are detached homes, 33 per cent semi-detached, 33 per cent terraced houses, and the rest are flats (or maisonettes). Of the properties sold 20 per cent were leasehold. Only 1 per cent of the houses in our data are newly built, and only 17 per cent of the properties have been built since 1990. The average distance of the properties in our sample is 280 meters from the cabinets and 1.56 kilometers from the LEs. We report the average broadband speed for the last four years of our study period. During this period, the average download speed increased from 27 Mbps to 49 Mbps in our sample postcodes. Based on our geographic classification, 15 per cent of our data comes from major cities, 11 per cent from other cities, and the rest of the 75 per cent are from towns of different sizes. The MSOAs in our sample have an average weekly income of £466 and a population density of thirty-one persons per hectare. The average share of skilled workers in 23 per cent.

4. Empirical strategy

4.1 Spatial discontinuity in FTTC activation

In this section, we explain how we use spatial discontinuity in FTTC activation to estimate house price differentials. The ideal experiment would involve comparing two otherwise similar properties, one with an FTTC connection and another without, to see whether the FTTC-activated property sells at a higher price. To measure this FTTC premium in a quasi-experimental setup, we compare the sale prices of properties across neighboring postcodes that have been activated in different years.

When BT undertook the plan to connect millions of households with fiber broadband, the massive scale of the operation put engineers and other resources in high demand. Hence, Openreach (the infrastructure division of BT) carried out the task in multiple phases. The bulk of the commercial rollout was completed in eleven phases from 2009 to 2013–14. During each phase, BT announced an upgrade of a list of LEs. Usually, the entire area within an LE would not get fiber-enabled at the same time. As discussed in Section 2, FTTC activation involves deploying fiber from an LE to the street cabinets. With the line between the LE and street cabinet upgraded, a fixed number of adjacent properties could get FTTC broadband. According to a report by the House of Commons Culture, Media and Sports Committee (2016), Openreach or other broadband delivery programs often prioritized areas that are easier to connect, creating a “patchwork” of connections across the premises.[22] For the median LE in the UK, the first round of FTTC upgrade installed 57 per cent of the cabinets, serving 72 per cent of the premises in the area.[23] This gradual rollout over several phases—both within and across LE areas—resulted in a fragmented coverage of FTTC availability across the country. Figure 2a shows how the FTTC rollout years vary across a part of Central London.

The endogenous nature of the rollout means that we cannot readily compare areas activated in different years. We circumvent this problem by focusing on the postcodes lying across the boundary and by

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[22] See CMS Committee, establishing world-class connectivity throughout the UK, Second Report of Session 2016–17, HC 147, published on 19 July 2016.

[23] From authors’ own calculations.

Table 1. Summary statistics (2008–17).

	Mean	Standard deviation (SD)	Minimum	Maximum
Panel A: Housing sample (2008–17)				
Sale price (£)	195,084.58	95,783.25	11,000.00	500,000.00
Number of rooms	4.46	1.38	1.00	12.00
Total floor area (sq. m.)	85.24	29.58	24.00	293.00
Per cent detached	0.20	0.40	0.00	1.00
Per cent semi-detached	0.33	0.47	0.00	1.00
Per cent terraced	0.33	0.47	0.00	1.00
Per cent flat/Maisonettes	0.14	0.35	0.00	1.00
Per cent freehold	0.80	0.40	0.00	1.00
Per cent leasehold	0.20	0.40	0.00	1.00
Per cent newly built	0.01	0.10	0.00	1.00
Per cent building age (< 1900)	0.07	0.25	0.00	1.00
Per cent building age (1900–49)	0.30	0.46	0.00	1.00
Per cent building age (1950–75)	0.30	0.46	0.00	1.00
Per cent building age (1976–90)	0.15	0.36	0.00	1.00
Per cent building age (1991–2006)	0.15	0.36	0.00	1.00
Per cent building age (2007 or later)	0.02	0.15	0.00	1.00
Distance from boundary (km)	0.17	0.17	0.00	2.01
Distance from exchange (km)	1.56	0.85	0.02	8.79
Distance from cabinet (km)	0.28	0.31	0.00	21.43
Panel B: Broadband speed in Mbps (2014–17)				
Average download speed 2014	26.50	11.17	0.80	104.00
Average download speed 2015	33.05	14.74	0.80	131.60
Average download speed 2016	41.46	19.55	0.80	199.90
Average download speed 2017	49.20	24.55	0.80	646.90
Panel C: Geography and area characteristics				
Per cent major cities	0.15	0.35	0.00	1.00
Per cent other cities	0.11	0.31	0.00	1.00
Per cent towns	0.75	0.44	0.00	1.00
Net weekly household income (£)	465.78	91.44	210.00	960.00
Population density (per hectare)	31.10	23.33	0.20	210.40
Per cent skilled worker	0.23	0.08	0.07	0.62

Note: The table reports the summary statistics on the key variables from our housing and broadband data. Panel A shows the property-level information using the Price Paid Data (PPD) from 2008 to 2017. The average sale price was £194,030 during this period. Note that we report summary statistics for our entire housing sample in this table. The average price is slightly different for the sample of properties used in our preferred regression. See Tables A.7 and A.8 to see how the summary statistics in our regression sample compare to the out-of-sample postcodes. Panel B reports the average download speed from Ofcom's Connected Nation series. Ofcom data are available from 2013. We do not report the 2013 data here because the mean download speed is truncated at 30 Mbps. Panel C shows the shares of different types of geographic areas and average local characteristics in our data. We take the geographic classification of cities and towns published by the House of Commons Library (Baker 2018). For local characteristics, we use the 2011 census data and 2011–12 income estimates for small areas in England and Wales produced by the ONS.

comparing the segments that got FTTC activated with the segments that narrowly missed it. This strategy gives us a sample of properties located in adjacent postcodes that share similar local amenities (or disamenities). To locate the boundary of areas with different activation years, we first merge adjacent postcodes with the same year of FTTC activation and construct larger polygons.[24] The boundaries of these polygons provide sharp discontinuities in the availability of FTTC broadband. We hereafter refer to these

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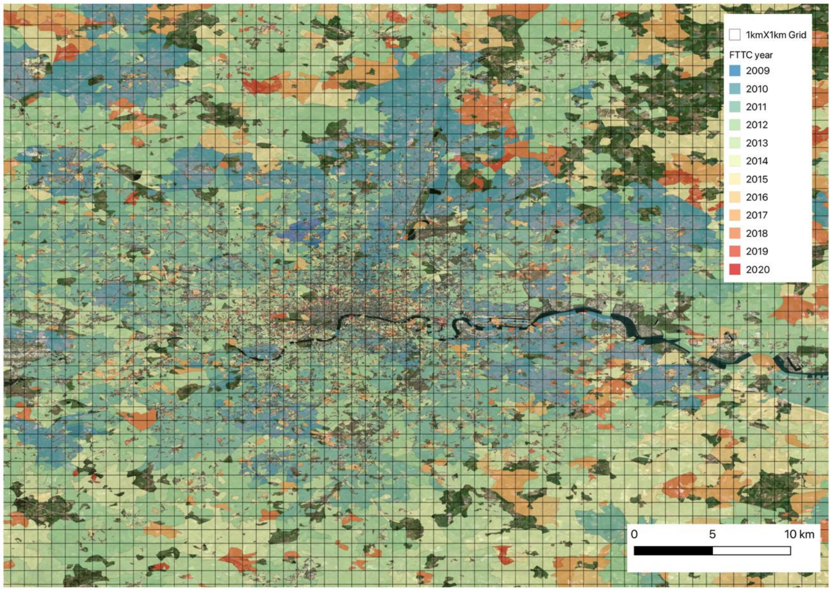
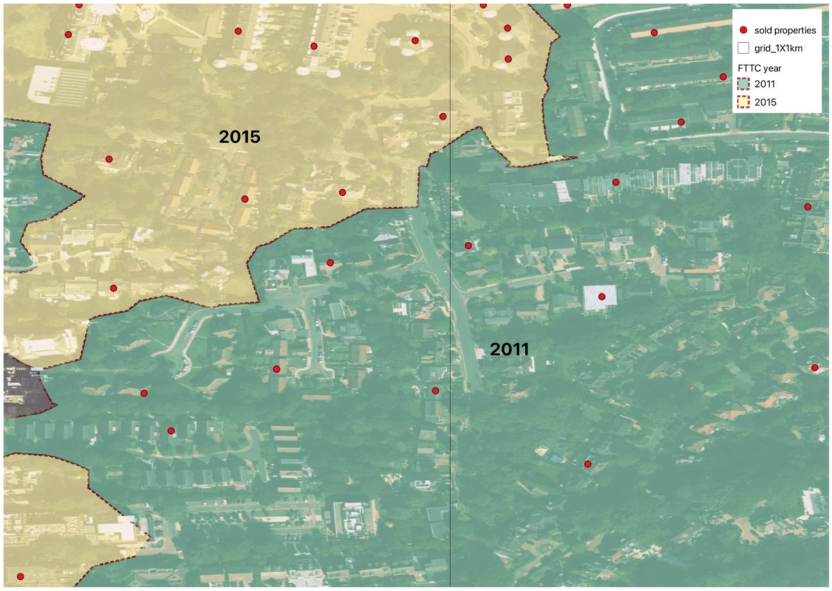
[24] Throughout the article, we refer to these polygons as fiber activation area or FTTC activation area. See Fig. 2b and Appendix Section 1.1 for more details.



(a) Fiber activation by year



(b) Differences across neighboring areas

Figure 2. Gradual rollout of fiber broadband. (a) Fiber activation by year. (b) Differences across neighboring areas.

Note: This figure shows the gradual rollout of FTTC technologies. In Panel (a), each color shows areas that are FTTC activated in the same year (i.e. fiber or FTTC activation areas). From the range of colors used in the map, we can see that there is enough variation in the timings of FTTC activation. Note that the map shows a part of Central London. We construct 1 × 1 km gridlines to identify the location of the boundary of areas activated in different years (i.e. activation boundaries). We further break down boundary lines as "activation boundaries." Our identification comes from exploiting the spatial discontinuity in FTTC activation within a narrow distance from these activation boundaries. This approach relies on the assumption that the local characteristics (e.g. access to supermarkets, parks, or stations) change gradually as we go farther away from the boundary, whereas FTTC availability sharply changes across the boundary.

Figure 2b illustrates our discontinuity design. The green polygon shows postcodes that have been FTTC-enabled since 2011. The adjacent postcodes in the yellow polygon were not activated until 2015. The red dashed line between the green and yellow polygons is the activation boundary that shows a sharp divide in FTTC availability with one side activated and the other side not activated between 2012 and 2015. The red dots in the figure mark the locations of properties sold in these postcodes. Our study design involves comparing neighboring properties located in such pairs of FTTC activation areas across the boundary.[25]

4.2 Validity of discontinuity design: evidence from speed data

In this section, we present evidence that broadband speed shows a discontinuous jump across the boundary lines following FTTC activation of the early-activated side. We use the distance of our sample postcodes from the activation boundary and plot the average download speed on both sides of the boundary. By the time Ofcom makes this data available, many areas in our sample are activated on both sides of the boundary. Hence, we check for this speed discontinuity using only a sub-sample of postcodes. Figure 3 shows how broadband speed responds after one, two, and three years of activation. The vertical line at zero represents the activation boundary. We measure the distance of postcodes from the boundary in meters along the horizontal axis. The right side of the vertical line (that is, positive distance values) shows postcodes that have already been activated, and the left side (that is, negative distance values) shows postcodes that are not activated by that year. We use data from 2013–17 to plot the average download speed for each fifty-meter bin. Panel 3a, 3b, and 3c show how download speed changes after one, two, and three years of activation, respectively. For example, for the year 2013, we compare treated postcodes in which one side of the boundary was activated in 2012 (that is, one year of activation) with neighboring (control) postcodes that are not going to be activated until a year later (in 2014). Stacking four years' observations from 2014–17 this way, Panel 3a shows a slight jump in download speed when one side remains activated for a year. The sharp discontinuity is more visible after two or three years of activation (Panel 3b or 3c).[26] These figures confirm that the sharp discontinuity in FTTC availability translates into a discontinuous jump in the actual broadband speed available to the customers. Also, the gradual widening of the speed gap aligns with what we know about take-up rates slowly catching up with the availability of FTTC broadband.

Figure 2. Continued
the dense grids (i.e. with more than one activation boundary) into 100 m^2 grids. In Panel (b), we zoom in on one of the boundaries of FTTC activation areas. This figure shows a typical example of the activation boundary we use for identification. The southeast part (shown in green) was FTTC enabled in 2011 and the northwest side (golden-yellow) was activated in 2015. The red dashed line shows the boundary between these two polygons. The red dots show properties sold in our sample. In our DID regression, we will compare properties sold across the activation boundaries. Between 2012 and 2015, the postcodes on the northwest side of the boundary were not treated and will work as a control group.

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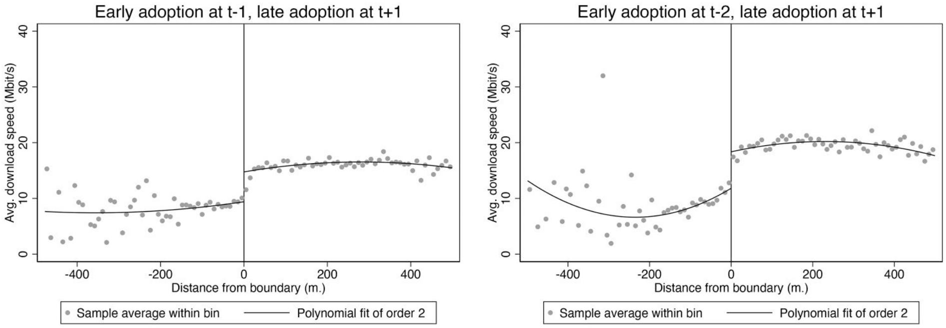
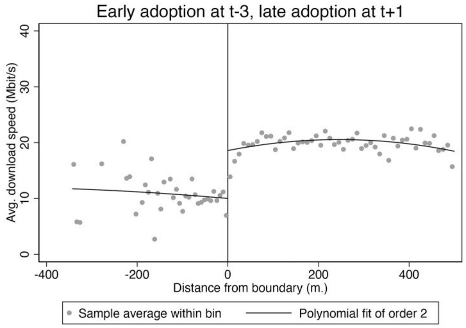
[25] The average distance of the properties in our housing dataset is 170 m from the activation boundary. In our preferred specification, we use properties that lie within 200 m of the boundary.

[26] Note that the average download speed reported here is calculated based on actual speed collected by telecoms operators and is influenced by customer subscriptions, distance from cabinets, and network disturbances, among other factors.



(a) 1 year of activation **(b)** 2 years of activation

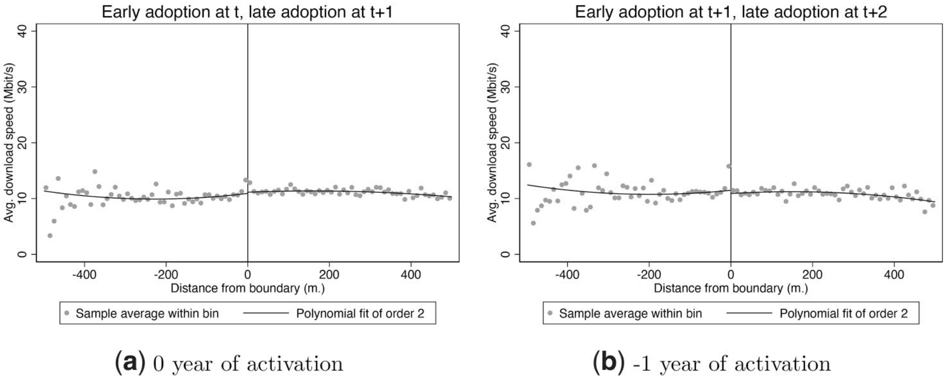


(c) 3 years of activation

Figure 3. Speed discontinuity across boundaries. (a) 1 year of activation. (b) 2 years of activation. (c) 3 years of activation.

Note: The figure checks discontinuity in broadband speed across activation boundaries. The horizontal axis measures the distance (in meters) of a postcode centroid from the boundary. The average download speed (in Mbit/s) is plotted on the vertical axis for each 50-m distance bin. In all three figures, the left side of the cutoff shows postcodes that are not activated until the next year. The right side of the cutoff shows postcodes that have been activated for 1, 2, or 3 years, respectively. These figures show a sharp discontinuity in broadband speed across the boundary, especially after 2 or 3 years of activation. The figure uses Ofcom's postcode-level data from the Connected Nations series from 2013–17. The plots are produced using the "rdplot" package in Stata. The line shows a quadratic fit of the raw data separately on each side of the cut.

The lack of data for earlier years does not allow us to check whether pre-FTTC broadband speed was the same across boundaries for the entire sample. For this reason, we perform a placebo check only for the postcodes that are not activated (or just activated) in 2013 or 2014 (Fig. 4). Panel 4a compares postcodes that are just activated (that is, zero year of activation) on one side of the boundary with postcodes on the other side not getting activated for another year. Panel 4b depicts pairs of areas where one side of the boundary is activated the next year (that is, −1 year of activation) and the other side is activated two years later. From these figures, we do not see any speed differences before FTTC activation or immediately in the year of activation. This exercise supports the idea that before FTTC activation, the neighboring postcodes from FTTC activation areas across these boundaries had access to similar broadband technologies, and the availability of FTTC broadband infrastructure created a marked difference in available speed across the boundaries.



(a) 0 year of activation **(b)** -1 year of activation

Figure 4. Speed discontinuity before activation. (a) 0 year of activation. (b) −1 year of activation

Note: The figure checks discontinuity in broadband speed across activation boundaries. The horizontal axis measures the distance (in meters) of a postcode centroid from the boundary. The average download speed (Mbit/s) is plotted on the vertical axis for each 50-m distance bin. Panel (a) compares postcodes that have been activated in the same year (right) with postcodes that are activated 2 years later (left). Panel (b) compares postcodes that are activated 1 year later (right) with postcodes that are activated 2 years later (left). Neither panel shows any visible difference in broadband speed before activation or immediately in the year of activation. The figure uses Ofcom's postcode-level data from the Connected Nations series from 2013–14. The plots are produced using the "rdplot" package in Stata. The line shows a quadratic fit of the raw data separately on each side of the boundary.

4.3 Estimation

We focus on BT's commercial FTTC rollout by considering only urban postcodes across boundaries for which at least one side was activated by 2013.[27] To keep the local characteristics similar on both sides of the boundary, we also restrict our sample to the properties located within 200 meters of the boundary.[28] Using the sample of properties sold between 2008 and 2017, we estimate the following hedonic pricing equation:

$$ln(price)_{ijkt} = \beta_1 FTTCactivated_{jkt} + \Gamma X_{ijkt} + \mu_j + \rho_{kt} + \varepsilon_{ijkt} \quad (1)$$

In the equation above, i indexes properties sold, j indexes postcodes, k indexes grids in which the boundary is located, and t indexes years. We use the log of the sale price of a property as the dependent variable. *FTTC activated* is a binary indicator for the year after the street cabinet of a postcode gets FTTC enabled. X includes property characteristics, such as total floor area, indicators for property type (detached, semi-detached, terraced, or flat), lease type (freehold or leasehold), an indicator for newly-built properties, and categories for age. μ denotes postcode fixed effects and ρ denotes grid fixed effects. We construct the grids by dividing the entire country into 1×1 kilometer cells (see Fig. 2a). This helps us to identify the location of each boundary. If a cell is from a dense neighborhood and therefore includes multiple boundaries, we break down the cells further into 100 square meter blocks. We use these grids to control for time-variant location fixed effects across both sides of the boundary while controlling for time-invariant fixed effects by unit postcodes. In other words, each grid-boundary pair helps us capture

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27. FTTC activation in early years was concentrated in urban areas. Since 2014, a mix of urban and rural postcodes has been activated. This is due to the government's support for rural rollout programs under BDUK. To keep our sample homogeneous, we drop any rural postcodes even if they were activated by 2013.
28. We check our results for different distance values from the boundaries and find similar estimates.

the trends in local housing markets (across activation boundaries) while the postcode fixed effects help us control for any specific characteristics of the housing blocks.[29]

We cluster the error term (ε) at the level of treatment variation in our design. In this case, these are the areas across each side of the boundary within a grid cell. This approach follows Bertrand et al. (2004) and helps to overcome the potential serial correlation and heteroskedasticity problems. A few points about our sample construction process are important to note here. Our sample comes from urban areas, where property sale data are less sparse. Still, we take several steps to make sure that we have enough observations to estimate the granular fixed effects in our hedonic regression. First, we check that we have sufficient observations from both sides of the activation boundary. Second, we restrict our sample to postcodes that have at least five transactions over the sample period. Finally, we exclude grids that have fewer than fifty observations, which is the bottom quintile of the grid size distribution. A final restriction on the grid cells is that we only consider those grids that have at least 10 per cent of the observations on the early-activated (or late-activated) side of the boundary.[30] These steps bring down our effective sample to 206,579 property transactions across 49,094 postcodes.

Our identification relies on the staggered difference-in-differences (DID) design in which the treatment (FTTC activation in this case) occurs over different years. The two-way fixed effects (TWFE) model has been a canonical specification of the ordinary least squares model to estimate the causal effect in such setups. However, several recent papers have shown that in the presence of treatment effect heterogeneity, the TWFE estimates can be biased despite satisfying the conventional (strict) exclusion condition of parallel trends (and no anticipation). This problem occurs when the treatment effect varies over time or across treated groups (Borusyak et al. 2024; De Chaisemartin and d'Haultfoeuille 2020; Goodman-Bacon 2021; Callaway and Sant'Anna 2021; Sun and Abraham 2021).

In particular, the bias occurs when the TWFE estimation compares the late-treated units and the early-treated units, while the latter serves as the control group. In this case, the estimate will suffer from a downward bias proportional to the increase of the treatment effect over time. This might apply to the current setup since the adoption of FTTC broadband takes time to mature and become widely adopted by the users as illustrated in Fig. A.3a and b.

Following Goodman-Bacon (2021), Sun and Abraham (2021), and Callaway and Sant'Anna (2021), we limit our posttreatment sample to the periods during which we can compare each treated group to the not-yet-treated groups. For example, in our sample, each pair of neighboring areas across the activation boundary has an early and a late FTTC activation side. We track each pair from 2008 up to the date when FTTC broadband becomes available for the late adopter. Hence, our sample design is such that the area with the early activation year acts as a treated group and the area with the late activation year acts as a control group that never gets treated during this period.[31]

4.3.1 Robustness checks

Our first set of robustness checks relaxes the restrictions on sample construction discussed earlier. Specifically, we check our main results without imposing any restrictions on the number of observations per grid cell and without restricting the sample within 200 meters of the boundary. We also check the sensitivity of the estimates to the inclusion of property characteristics.

We check the robustness of our results using the interaction-weighted (IW) estimator proposed by Sun and Abraham (2021). In Fig. A.5a, we show the event plot, which shows slightly larger estimates (around

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29. Unit postcodes in the UK have a size of fifteen households on average. It can identify houses up to specific blocks (or even a large building).
30. This restriction on grids is to ensure that we have sufficient observations on both sides of the boundary so that our boundary-specific year fixed effects could capture any year-to-year fluctuations in local housing markets.
31. We thank the anonymous referee who pointed out that, while our approach avoids "forbidden comparison" with the already activated units within the same grid-boundary, the earlier-enabled postcodes in other boundaries might still cause a problem. To check the magnitude of this problem, we use the IW estimator proposed by Sun and Abraham (2021) and report our main result in Appendix Figures, which we find to be largely similar to our TWFE results.

1 per cent) than what we find using TWFE estimators. In Fig. A.5b, we include the years after late activation. Since these results are similar, we keep using the TWFE estimator and limit our post-treatment periods to the years before late adoption.

Another potential source of bias for our boundary discontinuity design could be homebuyers sorting themselves across the boundaries in response to fiber activation. To examine this, we create density plots of property purchases across the boundary before and after activation. Figure A.4 shows the density of properties sold by the distance from the activation boundary (in five-meter bins). The distributions look quite similar across the boundary, both before activation (panel a) and after activation (panel b). From these graphs, we do not see that a large number of homebuyers flock across the boundary to buy houses on the fiber-enabled side.

Finally, we test our estimates by the distance of each property from its cabinet. As explained in the previous sections, FTTC broadband provides a strong speed uplift for properties located within a shorter distance from the cabinet. To test this hypothesis, we include interaction terms between the FTTC activation dummy and indicators for a range of distances, such as <200 meters from cabinets, 200–400 meters from cabinets, and >400 meters from cabinets. Specifically, we estimate the following regression:

$$\begin{aligned} ln(price)_{ijkt} = {} & \beta_1 FTTC\ activated_{jkt} + \beta_2 FTTC\ activated_{jkt} \times (0.2 - 0.4\,km\ from\ cabinet)_{jk} \\ & + \beta_3 FTTC\ activated_{jkt} \times (> 0.4\,km\ from\ cabinet)_{jk} \\ & + \Gamma X_{ijkt} + \mu_i + + \rho_{kt} + \varepsilon_{ijkt} \end{aligned}$$

According to the technical properties of FTTC, we expect to see higher house price premia for properties located closer to the cabinet compared with those that are farther away. In Appendix Section 1.3, we also check the sensitivity of our results to the exclusion of postcodes that might have cable coverage. Note that we do not observe the availability of cable broadband directly. We infer the presence of cable or full fiber from observing the maximum download speed reaching above the 80 Mbps threshold, which is the highest attainable speed for FTTC.

5. Results

This section presents the findings of our article. Section 5.1 shows our main estimation of housing price responses to FTTC activation using the spatial discontinuity at the boundary of areas activated in different years. In Sections 5.2 and 5.3, we estimate the heterogeneous responses across urban geographies and local area characteristics, highlighting the role of income and skills. Section 5.4 discusses our results.

5.1 Housing price responses to FTTC activation

5.1.1 Main results

Our estimation uses the variation in house prices across boundary lines to measure FTTC premia. We show these baseline results in Table 2. Column 1 shows our preferred specification in which we restrict our sample to the properties located within 200 meters from the activation boundaries. Our estimation shows that FTTC activation increases house prices by 0.7 per cent. This estimate is statistically significant with standard errors clustered at each side of the boundary within a grid. Our main specification includes postcode fixed effects, year fixed effects at the grid-boundary level, and a set of controls for property characteristics. In Columns 2 to 4, we show that the price response is robust to relaxing some of the restrictions we impose to construct our sample. Column 2 excludes the restriction that at least 10 per cent of the observations within each grid should come from treated (or untreated) postcodes. We impose this restriction to ensure that each grid has sufficient observations on both sides of the boundary. Column 3 relaxes the 200-meter limit on the distance from the boundaries and includes properties located farther

Table 2. Housing price response to FTTC activation (main results).

	Dependent variable: *ln (price)*				
	Baseline	Robustness			Distance from cabinet
		No grid restriction	No boundary restriction	No control	
	(1)	(2)	(3)	(4)	(5)
FTTC activated = 1	0.0071*** (0.0023)	0.0078*** (0.0022)	0.0076*** (0.0023)	0.0062* (0.0032)	
FTTC activated for short distance ($<$.2 km)					0.0099*** (0.0035)
FTTC activated for medium distance (.2–.4 km)					0.0077** (0.0034)
FTTC activated for long distance ($>$.4 km)					0.0012 (0.0045)
Postcode fixed effects (FE)	Yes	Yes	Yes	Yes	Yes
Grid × boundary × year FE	Yes	Yes	Yes	Yes	Yes
House controls	Yes	Yes	Yes	No	Yes
Observations	188,315	219,453	256,580	188,315	188,315

Note: The dependent variable in all columns is the logarithm of the house price. "FTTC activated" is a dummy variable that takes 1 for all years following the activation year of FTTC. Grid × Boundary is a set of year fixed effects for the neighboring pairs that are located in the same grid on each side of the FTTC activation boundary. "Grid" is defined as an area that varies from 1 to 0.1 km^2. We restrict our samples to all postcodes that are within 200 m of the boundary. House controls include a property type categorical variable (detached, semi-detached, terraced houses, and flat/maisonette), a dummy variable that shows whether the property is new, a dummy variable that shows whether it is sold on a freehold or leasehold basis, a categorical variable for age bands, a categorical variable for the number of rooms, and a continuous variable for the total floor area. Standard errors are in parenthesis and clustered on each side of the boundary.
***, ** and * denote statistical significance at the 1, 5 and 10 percent levels, respectively.

away from the boundary.[32] Column 4 reports the results without including the property-level controls. In all cases (except for column 4), we get statistically significant point estimates which vary from 0.7 to 0.8 per cent.[33]

5.1.1.1 Price responses by the distance from the cabinets

Column 5 in Table 2 presents the results for the regression, including interaction terms between the FTTC activation dummy and the discrete categories measuring the distance from the cabinet. We measure the straight-line distance between the postcode centroids of the property and the cabinet that connects the property to the FTTC infrastructure. We examine the price responses to FTTC activation of properties located within 200 meters, 200–400 meters, and beyond 400 meters from the cabinet. We find strong price effects for the first two distance bins, that is, within 400 meters of the FTTC cabinet. The effect diminishes after 400 meters. These findings are consistent with the technical properties of FTTC connections—the speed boost is the strongest for the properties located closer to the cabinet and dissipates as the distance from the cabinet increases.[34]

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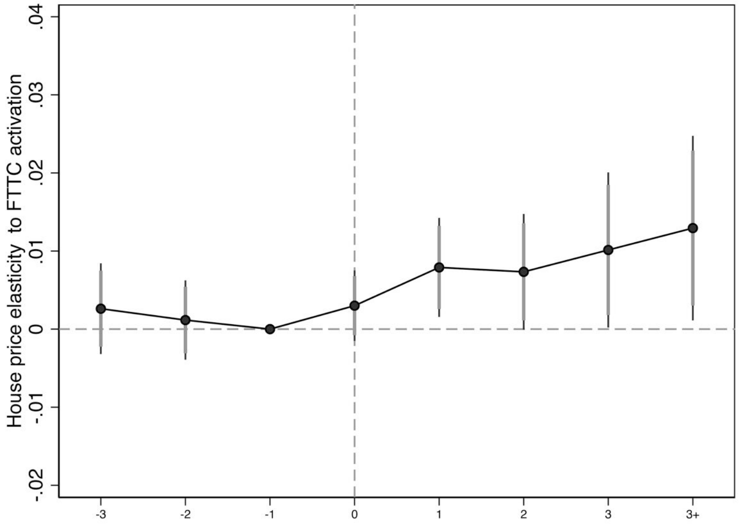
[32] In the unrestricted sample, 99 per cent of the properties sold lie within 766 m of the activation boundary.

[33] Table A.1 reports the results for postcodes with and without cable connections. We see the effect is strong in the postcodes without cable coverage.

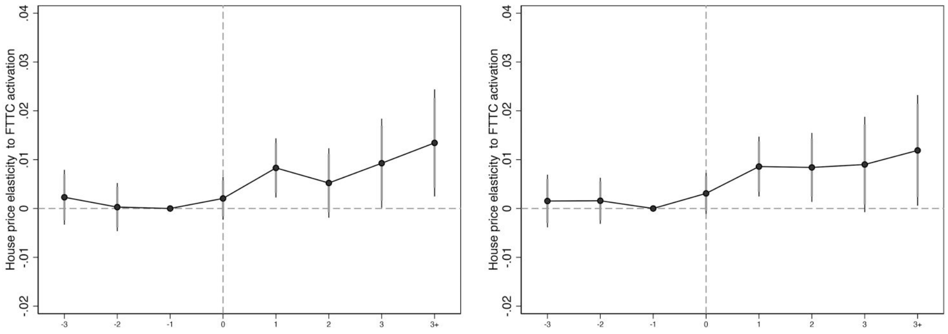
[34] We also test the sensitivity of the cabinet distance bins with a range of other technologically meaningful bins (less than 250 m and more than 250 m) and the results always show very similar behavior.

5.1.1.2 Parallel trend across boundaries before activation

In Fig. 5, we show the dynamic effects of FTTC activation. Before FTTC activation, house prices appear to be the same across the postcodes that are activated early (that is, treated) and activated late (that is, untreated throughout the study period). Following activation, we see a jump in house prices and the effect amounts to 1 per cent after three years of activation. This figure confirms the validity of our design that after controlling for property characteristics, postcode fixed effects, and grid-boundary-year fixed effects, there is no prior systematic price difference in the areas considered across the activation boundaries. The bottom panels of Fig. 5 plot the dynamic effects when we relax some of the restrictions imposed on the sample. Panel 5b and 5c, respectively, produce the corresponding dynamic-effect regressions of Columns 2 and 3 of Table 2. Both panels show similar price jumps following activation.



(a) Baseline



(b) Without grid restriction **(c)** Without boundary restriction

Figure 5. Housing price response to FTTC activation.

Note: The figure depicts the dynamic of house price response to FTTC activation. It indicates the parallel trends hold between the early and late adopters before the activation of FTTC broadband. Panel (a) shows the baseline identification, Panel (b) shows the result without any restriction on grid cells, and Panel (c) shows the results without any restriction on the distance from boundaries.

5.2 Geography of FTTC premia

In this section, we examine how FTTC premia vary across urban geographies. To characterize different types of areas, we rely on the classification of cities and towns published by the House of Commons Library (Baker 2018).[35] We group urban settlements based on the size of their population into three categories: major cities, other cities, and towns. Major cities include large population centers, such as London, Birmingham, Bristol, Cardiff, Leeds, Liverpool, Manchester, Newcastle upon Tyne, Nottingham, and Sheffield. Examples of "other cities" are Bournemouth, Brighton, and Hove, Coventry, Leicester, and Luton, which are cities with a population above 175,000. We group the rest of the settlements with a population of less than 175,000 as towns.[36]

Table 3 shows that the strongest price response comes from the major cities, with an FTTC premium of 2.4 per cent, whereas we do not find a sizable impact for other cities (column 2). In Table A.2, we show the response for London and the rest of the major cities separately. We find a 2–3 per cent response for both London and other major cities outside London.[37] We also find a smaller response of 0.4 per cent for the rest of the urban geographies, that is, towns, which turns out to be only marginally significant.

These results highlight the importance of geographic location in achieving benefits from high-speed broadband.[38] Early literature on broadband has focused on the urban–rural gap in broadband availability and usage (Goldfarb and Prince 2008). Compared to that, our results show that the house price premia to high-speed broadband are largely concentrated in major cities, which points toward a benefit divide between megacities and towns. We next delve deeper to understand why major cities disproportionately benefit from high-speed broadband.

Table 3. FTTC premia across cities and towns.

	(1) Major cities	**(2) Other cities**	**(3) Towns**
FTTC activated = 1	0.0239***	−0.0002	0.0048*
	(0.0061)	(0.0071)	(0.0027)
Postcode fixed effects (FE)	Yes	Yes	Yes
Grid × boundary × year FE	Yes	Yes	Yes
House controls	Yes	Yes	Yes
Observations	28,889	19,785	139,592

Note: The table reports housing price responses to FTTC activation across different geographies. Column 1 shows major cities, which include London, Birmingham, Bristol, Cardiff, Leeds, Liverpool, Manchester, Newcastle upon Tyne, Nottingham, and Sheffield. Other cities (column 2) include urban settlements with a population above 175,000, such as Bournemouth, Brighton and Hove, Coventry, Leicester, and Luton. Towns refer to settlements with a population below 175,000. In Table A.2, we show London separately from the rest of the major cities and break down the towns into large, medium, and small towns. The dependent variable across all columns is the logarithm of the house price. "FTTC activated" is a dummy variable that takes 1 for all years following the activation year of FTTC. Standard errors are in parentheses and clustered on each side of the boundary.
*** and * denote statistical significance at the 1 and 10 percent levels, respectively.

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35. City and town classification of constituencies and local authorities. Briefing Papers, 8322. See here for more details.
36. For our main results, we combine towns of different sizes in the same category since they do not show much response (except for small towns). In Table A.2, we report the results separately for large, medium, and small towns.
37. Since we have only a small number of observations for London and other major cities, we combine them in the same category. Tables A.2–A.4 show our results separately for London and the rest of the major cities.
38. We also check whether higher FTTC response to major cities arises due to a shorter distance from the cabinets. The average distance from the cabinets is 239 m for major cities, 243 m for other cities, and 282 m for towns. At 200 to 300 m away from the street cabinets, properties would get an expected download speed of 45–65 Mbps. Hence, the distance from the cabinet does not vary drastically to explain the differential premiums we observe across major cities and others. We also reproduce our results (not reported here) restricting our sample to those properties with a distance of 300 m from the cabinet. The coefficients are similar to those estimated with our entire sample, suggesting that the major cities show a differential premium even comparing properties that are relatively closer to the cabinet and thus get a relatively higher speed.

5.3 Heterogeneity by local characteristics

Major cities have a higher concentration of college graduates, which can lead to an increase in urban amenities (Diamond 2016). Potential complementarities between urban amenities and high-speed broadband may enhance residents' willingness to pay higher prices for broadband access. For example, Sinai and Waldfogel (2004) show that larger markets produce more locally targeted online content, which makes the internet a complement for urban agglomeration. We call this effect the consumption channel through which major cities could show a higher willingness to pay for fiber broadband. On the production side, the agglomeration benefits that large cities derive from broadband adoption is well-studied in the literature. Forman et al. (2012) find that the wage and employment growth attributed to the local investment in the internet is higher among the US counties with high income, large populations, and high skills. Akerman et al. (2015), Gürtzgen et al. (2021), and Hjort and Poulsen (2019) show that skilled workers gain more from high-speed internet. This skill-biased benefit could be another reason why major cities have larger premia.

Although this strand of literature focuses on the production channel mediated through workplace internet adoption, the benefit may as well apply to home internet connections. Zuo (2021) and Denzer et al. (2021) show that broadband availability at home improves labor market outcomes through facilitating job search activities. Although we do not know whether the skill bias translates beyond basic broadband speed (i.e., speed necessary for search, browsing, etc.), an early paper by Autor (2001) speculates how the internet could reshape labor service delivery as workers do some or all of their work from home or outside the office.[39]

In Appendix Section 1.2, we present a stylized model to formalize the idea that broadband speed could generate consumption and production amenities for households. Although distinguishing between these different channels is beyond the scope of this article, in the next part, we focus on area characteristics that are indicative of larger FTTC premia in major cities.

Table 4 (panels A and B) examines the relationship between area income and FTTC response. The consumption benefits of high-speed broadband make it more likely that people with higher incomes will have a higher demand for it. To test this, we divide the MSOAs in our sample by the median of net weekly household income adjusted for housing costs in 2011–12. The median value is £450 for our sample. In panel A, we classify an area as a high-income area if the MSOA has income that is above the national median value of income and a low-income area if the MSOA income falls below the national median value. We run interaction regressions by multiplying the indicator for FTTC activation with an indicator for high-income areas. The coefficient of the interaction term shows whether the FTTC premium differs for high-income areas. In Panel B, we calculate median values for each major city and divide the city-specific samples into high- and low-income areas.[40] From both panels, we can see that major cities have a 2.7–3.3 percentage points larger response in high-income areas. The difference in premium is statistically significant.

Since both the consumption and production value of high-speed broadband dictate that high-skilled populations are more amenable to accruing the benefits, we also examine the relationship between FTTC responses and the skill composition of an area. To capture the skill composition of an area, we use occupational information from the 2011 census. We calculate the MSOA share of employed residents who are engaged in occupations requiring skill level 4, which is the highest level of skill in ONS classifications. These are mainly professional or high-level managerial jobs.[41] Using this measure of skill, we divide the sample by the median share of the skilled population in the MSOA. In panel C of Table 4, we use the

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[39] Although our setup precedes the pandemic, work from home (WFH) was more prevalent among skilled workers. According to the American Time Use Survey (ATUS), around 15 per cent of working hours were performed at home in the USA from 2011 to 2018. Moreover, data processing services, specialized design services, and other professional services are the top three industries in terms of the share of work done at home, which was above 50 per cent even before the pandemic. In terms of occupations, computer scientists and artists appear in the top-five remote work occupations (Hensvik et al. 2020).

[40] We use local median values to make sure that London, with its higher proportion of above-median areas, does not have an outsized influence over our results.

[41] The following sub-major groups of SOC 2010 fall into this category: eleven (corporate managers and directors), twenty-one (science, research, engineering, and technology professionals), twenty-two (health professionals), twenty-three (teaching and educational professionals), and twenty-four (business, media, and public service professionals).

Table 4. FTTC premia across cities and towns—income and skill differences.

	(1) Major cities	**(2) Other cities**	**(3) Towns**
Panel A (by national median income)			
FTTC activated = 1	0.0069	−0.0078	0.0073*
	(0.0119)	(0.0086)	(0.0038)
FTTC activated = 1 × high income	0.0266**	0.0176	−0.0049
	(0.0133)	(0.0143)	(0.0053)
Postcode fixed effects (FE)	Yes	Yes	Yes
Grid × boundary × year FE	Yes	Yes	Yes
House controls	Yes	Yes	Yes
Observations	28,889	19,785	139,592
Panel B (by city-specific median income)			
FTTC activated = 1	0.0075	−0.0123	0.0073*
	(0.0096)	(0.0088)	(0.0038)
FTTC activated = 1 × high income	0.0326**	0.0237*	−0.0049
	(0.0134)	(0.0136)	(0.0053)
Postcode FE	Yes	Yes	Yes
Grid × boundary × year FE	Yes	Yes	Yes
House controls	Yes	Yes	Yes
Observations	28,889	19,785	139,592
Panel C (by national skill median)			
FTTC activated = 1	−0.0013	−0.0083	0.0073**
	(0.0101)	(0.0091)	(0.0037)
FTTC activated = 1 × high skill	0.0444***	0.0154	−0.0050
	(0.0129)	(0.0129)	(0.0056)
Postcode FE	Yes	Yes	Yes
Grid × boundary × year FE	Yes	Yes	Yes
House controls	Yes	Yes	Yes
Observations	28,889	19,785	139,592
Panel D (by city-specific skill medians)			
FTTC activated = 1	0.0062	−0.0103	0.0078**
	(0.0087)	(0.0093)	(0.0038)
FTTC activated = 1 × high skill	0.0362***	0.0183	−0.0060
	(0.0117)	(0.0134)	(0.0056)
Postcode FE	Yes	Yes	Yes
Grid × boundary × year FE	Yes	Yes	Yes
House controls	Yes	Yes	Yes
Observations	28,889	19,785	139,592

Note: The table reports differences in FTTC premia across income and skill groups. “High income” is an indicator for MSOAs with above-median income. “High skill” is an indicator variable for MSOAs with above-median shares of residents in skilled occupations. In Panels A and C, we use the national median values of the respective variables to define high-income (or high-skill) areas. In Panels B and D, we use city-specific median values to divide the sample for major cities. Major cities include London, Birmingham, Bristol, Cardiff, Leeds, Liverpool, Manchester, Newcastle upon Tyne, Nottingham, and Sheffield. “Other cities” include urban settlements with a population above 175,000 (e.g. Bournemouth, Brighton and Hove, Coventry, Leicester, and Luton). The rest of the settlements are grouped as towns. The dependent variable is the logarithm of the house price. “FTTC activated” is a dummy variable that takes 1 for all years following the activation year of FTTC. Standard errors are in parentheses and clustered on each side of the boundary.
*** ,** and * denote statistical significance at the 1, 5 and 10 percent levels, respectively.

median value of the entire sample (22.4 per cent). We refer to areas with above-median shares of skilled residents as high-skill areas and areas with below-median shares of skilled residents as low-skill areas. We find a 4.4 percentage point larger premium in high-skill areas, which is statistically significant. Since

London has a higher concentration of skilled workers, a larger share of observations from London gets classified as high-skill areas when we divide the sample by national median. To ensure that the skill premium gap is not driven by London alone, we use the medians of skilled workers for every major city to divide the city-specific sample into areas with high and low shares of skilled workers. Panel D shows that with city-specific medians, we still find a 3.6 percentage point higher premium for high-skill areas.

These results show that income and skill, along with geography, play an important role in determining price responses to FTTC broadband. It is important to note that the income or skill gap in premia does not occur uniformly across all urban geographies—only high-income or high-skill areas in major cities show a strong response. Since income and share of skilled population of an area are highly correlated, we examine whether the skill gap in premium still exists once we adjust for differences in income. In panel A

Table 5. Separating income and skill differences in FTTC premia.

	(1) Major cities	(2) Other cities	(3) Towns
Panel A (skill medians within income tertiles)			
FTTC activated = 1	0.0100	0.0117	0.0081**
	(0.0079)	(0.0094)	(0.0037)
FTTC activated=1 × High skill	0.0328**	−0.0240*	−0.0061
	(0.0128)	(0.0137)	(0.0052)
Postcode fixed effects (FE)	Yes	Yes	Yes
Grid × boundary × year FE	Yes	Yes	Yes
House controls	Yes	Yes	Yes
Observations	28,889	19,785	139,592
Panel B (income medians within skill tertiles)			
FTTC activated = 1	0.0226***	−0.0075	0.0080**
	(0.0083)	(0.0096)	(0.0038)
FTTC activated = 1 × high income	0.0030	0.0147	−0.0067
	(0.0118)	(0.0135)	(0.0052)
Postcode FE	Yes	Yes	Yes
Grid × boundary × year FE	Yes	Yes	Yes
House controls	Yes	Yes	Yes
Observations	28,889	19,785	139,592
Panel C (income medians within income tertiles)			
FTTC activated = 1	0.0189**	−0.0025	0.0067*
	(0.0092)	(0.0087)	(0.0037)
FTTC activated=1 × high income	0.0109	0.0048	−0.0040
	(0.0135)	(0.0131)	(0.0052)
Postcode FE	Yes	Yes	Yes
Grid × boundary × year FE	Yes	Yes	Yes
House controls	Yes	Yes	Yes
Observations	28,889	19,785	139,592

Note: The table reports differences in FTTC premia across income and skill groups. “High income” is an indicator for MSOAs with above-median income. “High skill” is an indicator variable for MSOAs with above-median shares of residents in skilled occupations. In Panel A, we calculate the median values within income tertiles calculated for the city. This helps us to compare high and low skill areas with similar income distributions. In Panel B, we check whether the income difference remains strong once we adjust for skill by comparing areas within the same skill tertile. In Panel C, we calculate median incomes after dividing the city-specific samples into income tertiles. This exercise helps us to see whether income differences remain significant one we account for income tertiles. Major cities include London, Birmingham, Bristol, Cardiff, Leeds, Liverpool, Manchester, Newcastle upon Tyne, Nottingham, and Sheffield. “Other cities” include urban settlements with a population above 175,000 (e.g. Bournemouth, Brighton and Hove, Coventry, Leicester, and Luton). The rest of the settlements are grouped as towns. In all columns, the dependent variable is the logarithm of the house price. “FTTC activated” is a dummy variable that takes 1 for all years following the activation year of FTTC. Standard errors are in parentheses and clustered on each side of the boundary. *** ,** and * denote statistical significance at the 1, 5 and 10 percent levels, respectively.

of Table 5, we first divide each major city by income tertiles and then calculate the median share of skilled residents within each tertile group. Based on the median skill share within the group, we divide each city-specific income tertile group into high-skill and low-skill areas.

In this way, we compare areas of relatively high and low skill that come from similar income groups.[42] We still find a difference of 3.3 percentage points between high and low-skill areas of major cities. The difference is statistically significant at 5 per cent level. We do not find any differences between skill groups in other cities or towns. In Panel B, we run the opposite exercise. Dividing the city-specific samples into skill tertiles, we compare areas with above median (high-skill) and below-median (low-skill) incomes within the skill groups. The difference in FTTC premia for high- and low-income areas is now much smaller in magnitude and turns insignificant when we compare within skill tertiles. These estimates show that the skill-biased premium remains large even when we try to break down the association between skill and income by comparing within the same income groups. But the opposite does not hold—comparing areas in similar skill tiers, we do not see the income difference materializes.

In the last panel of the table (panel C), we check whether the income differences could still play a role once we control for the income tertile. Like in other panels, we calculate the median values in two steps: first, we divide the sample into city-specific income tertiles, and then we again calculate median values of income within each tertile group. This helps us check whether income differences within the tertile group could still be driving the skill gap in premia observed in panel A. We find that there are no further income differentials once we examine within income tertiles. The point estimate is around 1 percentage point and is insignificant. Our findings suggest that the skill-biased premium is a primary reason why we see large responses to fiber broadband in major cities.[43]

Lastly, Table A.5 examines the importance of density within each type of geography. In the literature of urban economics, density plays an important role in determining agglomeration benefits (Glaeser et al. 2001; Glaeser and Gottlieb 2009). However, we do not find that FTTC premia differ significantly once we compare areas with high- and low-density both by national and city-specific median values. We conclude that micro variation in density does not seem to be important for determining the size of FTTC response once we account for the larger urban geographies.

5.4 Discussion

In this article, we assess the causal impact of fiber broadband on property prices and consider its relationship with geography, income, and skill. We show that fiber broadband matters for individuals residing in major cities, especially in areas with above-median income and skill. We further confirm that, taking into account income differences, skills have their distinct effect on mediating the fiber broadband premium. Our baseline estimate for FTTC premium (0.7 per cent) is not very different from the findings in Ahlfeldt et al. (2017) that show 1 per cent increase in house price for the previous-generation ADSL broadband. However, it is important to note that Ahlfeldt et al. (2017) find that speed upgrades show diminishing returns.[44] If we generalize their finding to the range of speed offered by fiber broadband,[45] the effect would be zero. Instead, we find a positive effect that is close to 1 per cent, which suggests constant returns even at a higher speed threshold. The paper also reports that urban areas in London and

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[42] We could think of the coefficient for the interaction term as a weighted average of skill-biased premia calculated across income tertiles.

[43] As a robustness check, we test whether the skill differential exists across different speed bands. Table A.6 shows that the difference between high-skill and low-skill areas is only salient for properties located within 200 m of the cabinets. At this distance, a property could potentially get the highest download speed offered by FTTC connections (65 Mbps or higher).

[44] The authors in Ahlfeldt et al. (2017) note that “It is interesting to see that the marginal effect (i.e., the impact of a marginal increase in speed on net consumer surplus) is about zero close to the maximum actual speed that we observe in the data. There would be no particular reason for suppliers to provide speed above the maximum observed levels in our data, as no further surplus could be created” (Section 4.1, pp. 606–07).

[45] FTTC connections offer at least 30 Mbps or higher download speeds. The maximum download speed that ADSL can offer is 24 Mbps although the average is more likely to be around 6.5 Mbps for these connections. See Section 2.2 for more details.

the East Midlands can achieve 3 per cent to 4 per cent high-speed broadband capitalization effects at the maximum speed available under ADSL2+, which is also close to the 2–4 per cent effects we find for major cities and in high-income or high-skill areas.

These results are important for a number of current policies in the UK and beyond. The UK Government introduced Project Gigabit in 2021 with the aim of covering 99 per cent of the country by 2032 with gigabit-capable broadband connectivity. In January 2025, Project Gigabit had already reached 86 per cent of its targets.[46] While the government provides demand stimulation incentives through a voucher scheme for eligible households, the adoption of full-fiber connections stood at only 9 million (33 per cent) households, whereas more than 27.2 million businesses and households are covered in the country. Ofcom also noted that rural areas are more likely to adopt high-speed connectivity, with over half (52 per cent) of homes signed up, compared with a third (32 per cent) in urban areas.[47]

Our findings show that income barriers could be lifted by the introduction of a voucher scheme, but it is unlikely that the skill dividend will materialize in the short term. To set realistic goals, policies like Project Gigabit need to acknowledge that in the absence of necessary skills, the demand will remain muted even if the coverage aspirations of the project are met. To address this issue and remove the cost of supplying two networks (copper based and full fiber) the UK Government has announced that it will "switch-off" copper connections in January 2027, moving all remaining customers to full-fiber or alternative services.

Lastly, our results on geographic variation of FTTC premia also align with Ofcom's estimates for full fiber take-up. Although we cannot provide direct estimates for rural areas, we also find a modest impact in a sparsely populated setting, that is, small towns in this case, while other (non-major) cities show no impact.

6. Conclusion

The UK government is committed to investing in the digital infrastructure that is necessary to unlock the benefits of a digital economy. One of these core digital infrastructures which have seen marked improvement over the last decade is fiber broadband. High-speed broadband, enabled by fiber-optic cables, could transform the way we work, learn, or use health care and other services. And yet recent experience during the COVID-19 pandemic has revealed large disparities in broadband access. To shed light on the gap in digital access, the early literature on computer and internet use focused on the urban–rural divide and income-related barriers.

In this article, we highlight the role of urban geographies, income, and skills in shaping unequal responses to more recent generations of high-speed broadband. We study the rollout of FTTC broadband that began around a decade ago in the UK. Given the large increase in speed upgrade offered by fiber broadband, it is not obvious that the estimated perceived benefits for previous-generation broadband (that is, ADSL) apply to fiber. We measure the homebuyers' willingness to pay for FTTC connections using the sharp discontinuity at the boundary of areas that are FTTC enabled in different years. Our estimates show that a premium gap exists between the large conurbations and smaller cities or towns. After accounting for the confounding effects of income, we find that skill remains a key driver of the response to fiber broadband.

Our article is the first to map the infrastructure of fiber broadband and devise a strategy to estimate the causal effect of access to fiber broadband on housing values. Given the ongoing attempts for a full-fiber rollout, it is important to understand how the existing economic and social factors interact with this new technology. Although network providers or regulators often claim success by pointing to near-complete coverage of services, our results highlight that adoption is often slow and unevenly distributed and depends on the perceived benefits of each new broadband technology. Without additional interventions, the expansion of full fiber alone might not suffice to achieve universal adoption across all regions.

[46] https://www.ofcom.org.uk/phones-and-broadband/coverage-and-speeds/connected-nations-update-spring-2025

[47] https://www.ofcom.org.uk/phones-and-broadband/coverage-and-speeds/full-fibre-broadband-reaches-nearly-7-in-10-homes

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Conflicts of interest

None.

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Appendix 1

Appendix 1.1: Spatial analysis of UK broadband data

The first step in this process is to obtain the shapefiles (polygons) for each UK postcode unit from the UK Ordnance Survey (OS hereafter), the national mapping agency for Great Britain. This dataset provides both the area that is covered by each postcode unit (six- or seven-digit codes depending on the area of the country) and the centroid of each unit. The postcode unit information used in this study is the most granular spatial information available from OS and there are approximately 1.7 million postcodes in the UK with an average of fifteen properties per postcode unit (while some can reach 100 properties).

The next step is to combine our UK FTTC broadband data with the spatial postcode information. Our goal is to construct a map of adjacent areas that have been activated at different years during the FTTC rollout. However, this information is not readily available. To achieve this, we use two separate sources of data:

1. The cabinet-level activation years for every cabinet in the UK scrapping information from resellers of Openreach data (a subsidiary of the incumbent operator in the UK—BT—that maintains the telephone cables, ducts, cabinets and exchanges that connect nearly all homes and businesses in the United Kingdom to the national broadband and telephone network).
2. The postcode unit coverage of each cabinet in the country (sources from resellers of Openreach data)

Combining these broadband data inputs we are able to add an activation year variable to our UK postcode unit shapefiles. Our spatial analysis is done in QGIS 3.22.3 and the steps followed are described below.

We first import all the UK postcode unit shapefiles (1.7 million shapefiles) and merge them into a UK shapefile. We then import the activation year data from Openreach and add the FTTC activation year data into the shapefile information. Next, we dissolve the UK file using activation year as our variable for merging adjacent postcode units together. This process leads to a spatial reconstruction of our data that allows us to study the changes across adjacent boundaries.

To construct our boundaries from the shapefile we use “Polygons to lines” from QGIS which creates a line boundary file for each year-activated “island.” As these “islands” may touch on various other regions with different activation years, we use the “Intersection” process from QGIS on the line file with itself. This results in a new lines dataset that differentiates across different activation year neighboring postcodes. For example, an “island” that is activated in 2012 will now have separate parts of its boundary that connect it to a 2011 area (2012–11 part of the island’s boundary), another for 2013 (2012–13 part), etc.

Last, we need to estimate the distance of each postcode unit to the right boundary. For this we use the postcode unit centroid coordinates from OS and we link this information with the intersected lines of the previous process. There are two separate ways that we achieve this. The first breaks the line boundaries into points that are 10 m apart each and then we use the “line to points” function to estimate the minimum distance from each postcode centroid to every point in the lines dataset. The second approach uses the "line to hub" approach that involves the lines dataset directly from the postcode unit centroids. With both methods, we end up with a dataset that contains the distance from the nearest boundary and the allocation of each postcode centroid to the respective boundary. The comparison across both processes shows that they are actually identical. The distances we get at the end of this process are in meters.

Further from the allocation of postcodes (and properties) to different activation-year boundaries, we also introduce a grid to improve the identification within local housing markets. Our baseline grid is 1 km by 1 km square, and we "intersect" the points layer with the grid layer to allocate boundaries to grid cells. In areas where many boundaries appear within grid cells, we narrow our grid to 100 m by 100 m to match the local housing markets in greater detail.

Appendix 1.2: A framework for household's willingness to pay for broadband

We consider a simple model of household consumption choice to guide our analysis of how households gain from high-speed broadband. As in Glaeser and Gottlieb (2009), we assume households optimally divide their income between the consumption of a non-housing good, C, and a housing good, denoted by H. The housing good is a combination of different amenities. We denote the amenity related to the quality of home broadband by h_b, whereas h_s denotes the continuum of all other amenities. Spending on broadband amenities not only allows the household to derive utility but it could also increase household income. In this setup, the household's problem can be written as follows:

$$\begin{aligned} max_{\{C,h_s,h_b\}} \quad & U(C,H(h_s,h_b)) \\ & s.t. \\ & C+P(h_s,h_b)\leq W(h_b) \end{aligned} \tag{A.1}$$

In the budget constraint, $P(h_s,h_b)$ shows the price of the housing good that is a hedonic function of broadband amenity h_b and other amenities h_s. The price of the non-housing good is normalized to 1 and $W(h_b)$ shows the income of the household that depends on the quality of broadband at home. For a utility-maximizing household, the optimal choice is obtained where the indifference curve is tangent to the offer curve. This allows us to infer the household's perceived value of the amenity from the local slope of the hedonic price function at the optimal level. This is the well-known insight in Rosen (1974) which suggests that the premia in housing prices (or rents) reflect the household's willingness to pay for their amenities. Solving for the shadow cost of the budget constraint, the first order condition with respect to the broadband amenity (h_b) gives us the following:

$$P_{h_b}(h_s,h_b)|_{h_s^*,h_b^*} = \underbrace{\frac{U_{h_b}(C,H(h_s,h_b))}{U_C(C,H(h_s,h_b))}|_{C^*,h_s^*,h_b^*}}_{Consumption \;\; amenity} + \underbrace{W_{h_b}(h_b)|_{h_b^*}}_{Production \;\; amenity} \tag{A.2}$$

The left-hand side of equation A.2 shows the premium price of the housing good for a higher broadband quality, while the right-hand side captures the household's willingness to pay. Unlike the traditional hedonic price model, the perceived value of home broadband has two distinct components, capturing the effects of both increased utility and a relaxed budget constraint. The consumption amenity facilitates households' consumption of online products and services. In this regard, it is akin to physical consumption amenities such as restaurants and gyms.[48] The production amenity captures the perceived benefit for households from enhancing their ability to work and earn more.

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[48] See the list of papers that study the effect of access to the consumption amenities on local residents' welfare: Glaeser et al. (2001), Couture (2016), Davis et al. (2019), Su (2022)

Appendix 1.3: Additional figures and tables

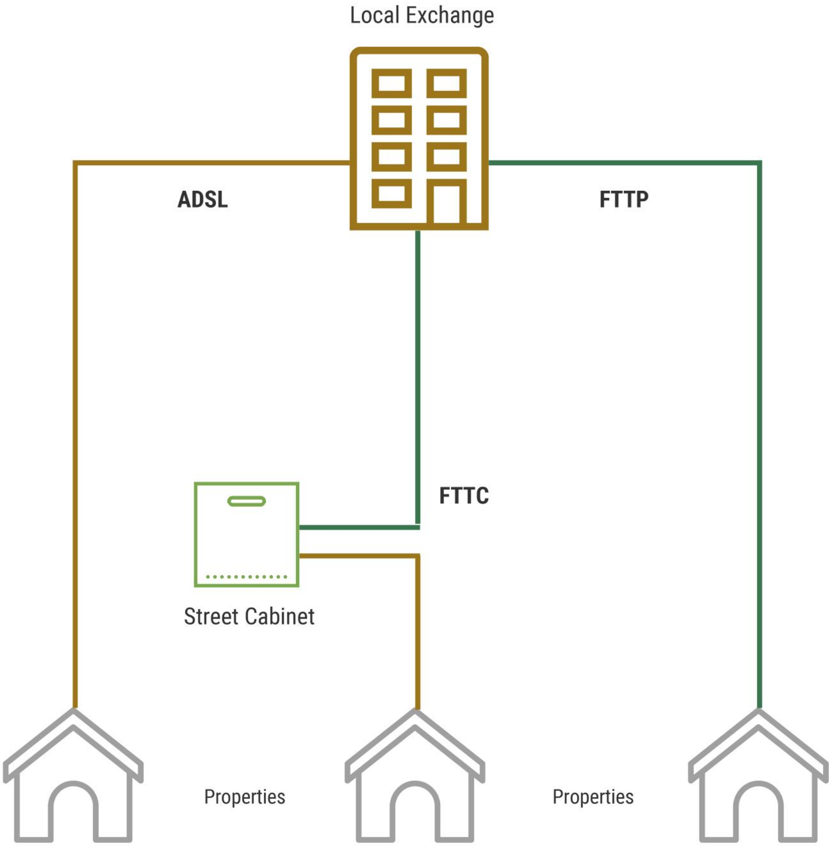


Figure A.1. Topography of different broadband technologies.

Note: This figure shows how different broadband technologies connect properties. ADSL technologies use copper cables for the connection between the LE and properties. FTTC technologies install fiber cable between the LE and street cabinets, whereas copper is used for the last leg from the street cabinets to the properties. Full fiber technologies such as FTTP deploy fiber all the way up to the premises.

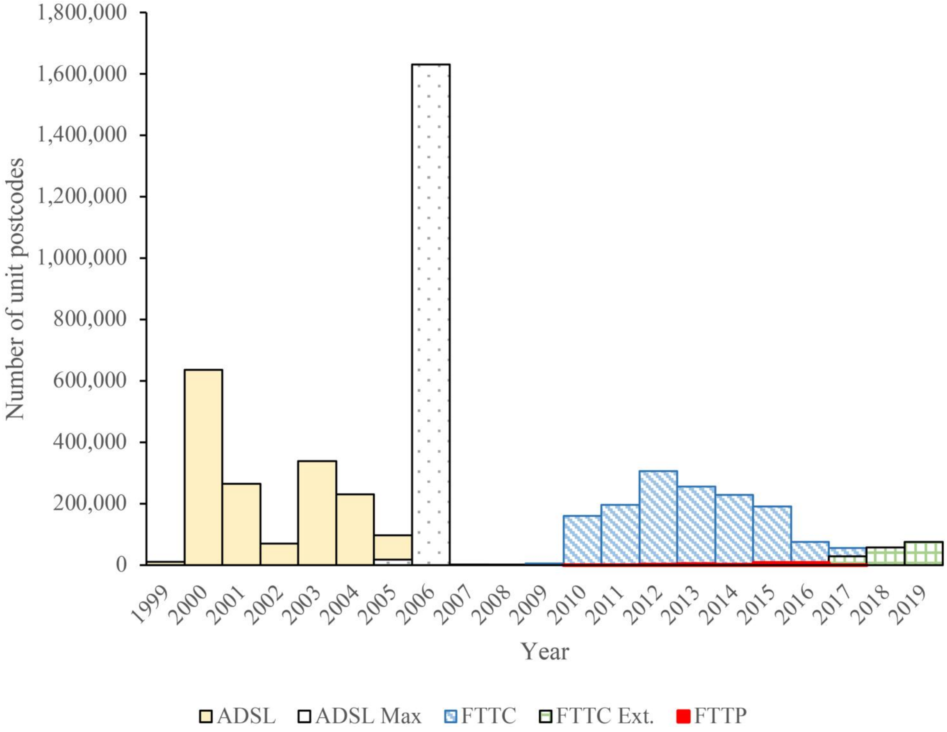
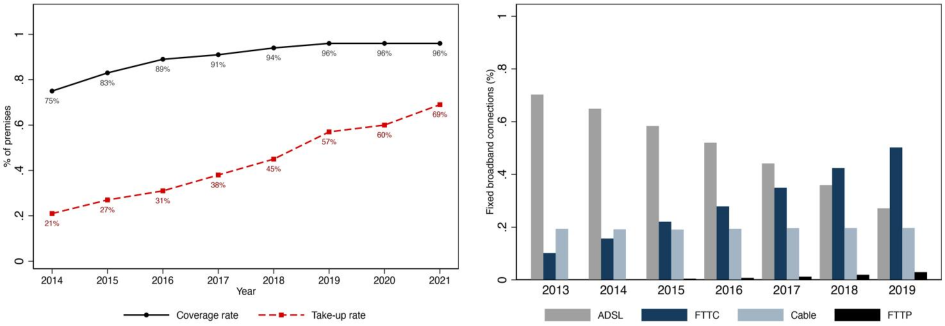


Figure A.2. Types of broadband activation by year. *Source*: Authors' own calculations.

Note: This figure shows the number of postcodes with different types of broadband technologies activated by year. ADSL activation was complete in most of the postcodes by 2005–06. FTTC activation started in 2009 and the bulk of commercial rollout by BT was completed by 2013–14. Since then FTTC rollout, supported by the BDUK programs, took place predominantly in rural postcodes. Starting in 2017, a wave of FTTC extensions (FTTC Ext.) upgraded the cabinets to connect additional properties. Although BT initially promised to connect 1.5 million homes with full fiber, FTTP rollout remained low during this period. Note that the UK has around 1.8 million active unit postcodes.

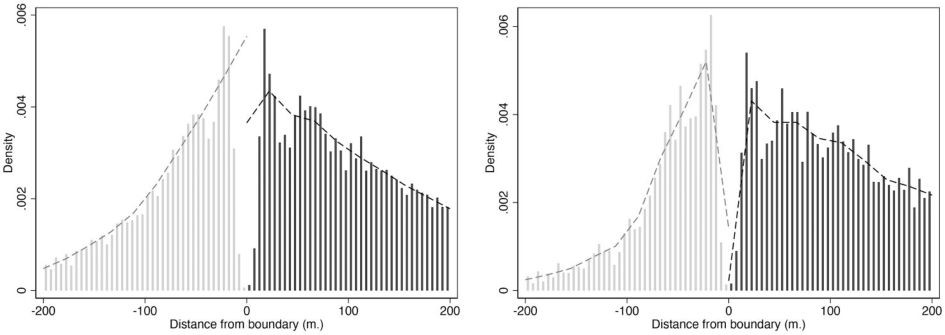


(a) Availability vs. takeup **(b)** Change in technology mix

Figure A.3. Change in superfast (≥ 30 Mbps) broadband take-up over time.

Note: This figure shows how the availability of FTTC broadband resulted in its gradual take-up. Panel (a) reports the coverage and take-up of superfast broadband, which refers to connections with at least 30 Mbps speed and is typically supported by fiber-based or cable broadband technologies. The solid line shows the percentages of premises in the UK that have superfast coverage, whereas the dashed line shows the percentage of premises that have taken up superfast broadband. By 2017, 90 per cent of the premises were covered by superfast broadband but the take-up rate was less than 40 per cent. Panel (b) shows how the technology mix delivering superfast broadband changed during this time. The figure reports the shares of different types of technology connections between 2013 and 2019. We can see a gradual transition from ADSL (including ADSL2+ and ADSL Max) to FTTC technologies. In 2013, ADSL held 70 per cent of the broadband market and the market share for FTTC was only 10 per cent. In 2018, FTTC surpassed ADSL in terms of market share for the first time. By 2019, FTTC captured half of the fixed broadband market and the share of ADSL dropped to 27 per cent. Cable held a steady share of the market at 19–20 per cent throughout this period. The market share of FTTP remained low, reaching 3 per cent by the end of the period. Note that we do not report a remaining technology category ("other") that is less than 1 per cent.

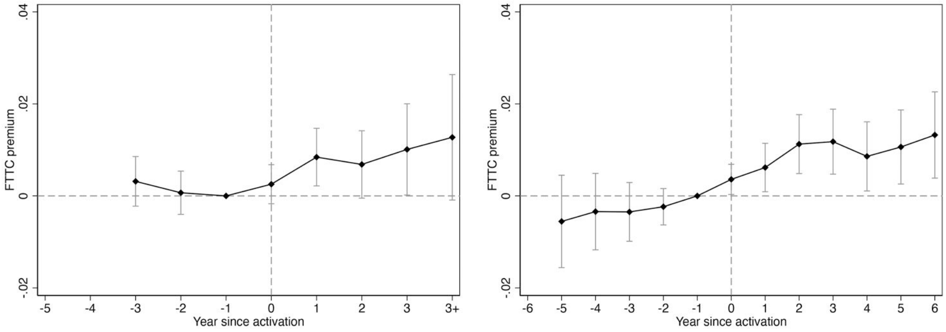
Source: Ofcom Connected Nations Reports and Communications Market Report, 2020.



(a) Before activation **(b)** After activation

Figure A.4. Distribution of property purchases across the boundary. (a) Before activation. (b) After activation.

Note: The figure shows the distribution of properties sold by the distance from the activation boundary. The distribution (shown in a darker color) on the right side of zero represents the early-activated side. The densities are shown in 5-m bins and up to 200 m, which is the farthest distance of the properties included in our regressions. This figure does not show any density spikes on the right side of the boundary after activation. We use the "rddensity" package proposed by Cattaneo et al. (2020) to create this figure. Based on the *t*-statistic for testing manipulation, we accept the null hypothesis that there is no discontinuity at the cutoff.



(a) Excluding years after late adoption **(b)** Including years after late adoption

Figure A.5. Event plot—Sun and Abraham (2021) estimator.

Note: The figure depicts the dynamics of house price responses to FTTC activation, estimated by the Sun and Abraham (2021) method. The dependent variable is log(price). In Panel (a), we exclude the years after late adoption in the grid, keeping it similar to our main estimation. We drop periods earlier than T-3 due to insufficient observations and pool the years T+4 and later in the last bin (denoted as period “3+” in the figure). For control cohorts, we use the late-activated side as we do not use the observations after the late side gets activated. The estimates show a 0.7–1 per cent jump in house prices after a year of activation. Aggregating the lagged effects, we find an average effect of 1 per cent, which is statistically significant. The pre-trends turn out to be small and insignificant. In Panel (b), we use the entire sample unlike our main estimation approach. Specifically, we include the years after late adoption in the grid as the interaction–weighted (IW) estimator directly accounts for treatment effects heterogeneity. We consider the period from T−5 to T+6 and drop earlier (or later) years due to insufficient observations. We treat adoption cohorts from 2017 onward as control cohorts. With our data ending in 2017, we do not observe these cohorts after activation. With more data points, we can examine more periods of leads and lags. We do not still observe any pre-trend. Posttreatment estimate as are roughly around 1 per cent.

Table A.1. Robustness check—presence of cable broadband.

	Cable **(1)**	**No cable** **(2)**
FTTC activated	0.0008	0.0101***
	(0.0029)	(0.0039)
Postcode fixed effects (FE)	Yes	Yes
Grid × boundary × year FE	Yes	Yes
House controls	Yes	Yes
Observations	104,879	81,724

Note: The table reports housing price responses to FTTC activation for postcodes with and without the coverage cable broadband. The coverage is inferred from speed data if a postcode reaches above 80 Mbps maximum speed, the highest that an FTTC connection can reach, in any year between 2014–17. The dependent variable in all columns is the logarithm of the house price. Standard errors are in parenthesis and clustered on each side of the boundary.

*** denotes statistical significance at the 1 and 5 per cent levels, respectively.

Table A.2. FTTC premia across cities and towns (all types).

	Major cities		Other cities	Towns		
	London (1)	Rest (2)	(3)	Large (4)	Medium (5)	Small (6)
FTTC activated = 1	0.0185*** (0.0064)	0.0289*** (0.0110)	−0.0002 (0.0071)	0.0014 (0.0043)	0.0064 (0.0050)	0.0085* (0.0045)
Postcode fixed effects (FE)	Yes	Yes	Yes	Yes	Yes	Yes
Grid × boundary × year FE	Yes	Yes	Yes	Yes	Yes	Yes
House controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	16,193	12,696	19,785	53,811	45,208	40,465

Note: The table reports housing price responses to FTTC activation across different types of cities and towns. In columns 1 and 2, we show the breakdown of major cities into London and the rest (Birmingham, Bristol, Cardiff, Leeds, Liverpool, Manchester, Newcastle upon Tyne, Nottingham, and Sheffield). Other cities (column 3) include urban settlements with a population above 175,000, such as Bournemouth, Brighton and Hove, Coventry, Leicester, and Luton. Columns 4–6 report the results for towns of different sizes. Following the city and town classifications published by the House of Commons Library in Baker (2018), we classify the settlements with a population of 60,000–175,000 as large towns, 25,000–60,000 as medium towns, and $<$25,000 as small towns. The dependent variable is the logarithm of the house price. "FTTC activated" is a dummy variable that takes 1 for all years following the activation year of FTTC. Standard errors are in parentheses and clustered on each side of the boundary.

*** and * denote statistical significance at the 1 and 10 per cent levels, respectively.

Table A.3. FTTC premia across cities and towns (all types)—income and skill differences.

	Major cities		**Other cities**	**Towns**		
	London (1)	**Rest (2)**	**(3)**	**Large (4)**	**Medium (5)**	**Small (6)**
Panel A (by national median income)						
FTTC activated = 1	−0.0175	0.0161	−0.0078	0.0087	0.0019	0.0117*
	(0.0179)	(0.0147)	(0.0086)	(0.0063)	(0.0069)	(0.0064)
FTTC activated=1 × high income	0.0432**	0.0325	0.0176	−0.0135	0.0093	−0.0068
	(0.0189)	(0.0201)	(0.0143)	(0.0087)	(0.0091)	(0.0096)
Postcode fixed effects (FE)	Yes	Yes	Yes	Yes	Yes	Yes
Grid × boundary × year FE	Yes	Yes	Yes	Yes	Yes	Yes
House controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	16,193	12,696	19,785	53,811	45,208	40,465
Panel B (by city-specific median income)						
FTTC activated = 1	0.0001	0.0176	−0.0123	0.0074	0.0019	0.0130**
	(0.0104)	(0.0169)	(0.0088)	(0.0062)	(0.0069)	(0.0063)
FTTC activated=1 × high income	0.0362**	0.0229	0.0237*	−0.0117	0.0093	−0.0111
	(0.0149)	(0.0226)	(0.0136)	(0.0090)	(0.0091)	(0.0106)
Postcode FE	Yes	Yes	Yes	Yes	Yes	Yes
Grid × boundary × year FE	Yes	Yes	Yes	Yes	Yes	Yes
House controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	16,193	12,696	19,785	53,811	45,208	40,465
Panel C (by national median skill)						
FTTC activated = 1	−0.0129	0.0070	−0.0083	0.0090	−0.0001	0.0151**
	(0.0124)	(0.0147)	(0.0091)	(0.0059)	(0.0067)	(0.0064)
FTTC activated=1 × high skill	0.0466***	0.0503**	0.0154	−0.0145	0.0137	−0.0138
	(0.0149)	(0.0217)	(0.0129)	(0.0092)	(0.0093)	(0.0091)
Postcode FE	Yes	Yes	Yes	Yes	Yes	Yes
Grid × boundary × year FE	Yes	Yes	Yes	Yes	Yes	Yes
House controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	16,193	12,696	19,785	53,811	45,208	40,465
Panel D (by city-specific median skill)						
FTTC activated = 1	0.0011	0.0118	−0.0103	0.0090	−0.0011	0.0151**
	(0.0105)	(0.0139)	(0.0093)	(0.0059)	(0.0069)	(0.0064)
FTTC activated = 1 × high skill	0.0339**	0.0369*	0.0183	−0.0145	0.0150*	−0.0138
	(0.0140)	(0.0189)	(0.0134)	(0.0092)	(0.0091)	(0.0091)
Postcode FE	Yes	Yes	Yes	Yes	Yes	Yes
Grid × boundary × year FE	Yes	Yes	Yes	Yes	Yes	Yes
House controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	16,193	12,696	19,785	53,811	45,208	40,465

Note: The table reports differences in FTTC premia across income and skill groups. “High income” is an indicator for MSOAs with above-median income. “High skill” is an indicator variable for MSOAs with above-median shares of residents in skilled occupations. In Panels A and C, we use the national median values of the respective variables to define high-income (or high-skill) areas. In Panels B and D, we use city-specific median values to divide the sample for major cities. Major cities include London, Birmingham, Bristol, Cardiff, Leeds, Liverpool, Manchester, Newcastle upon Tyne, Nottingham, and Sheffield. “Other cities” include urban settlements with a population above 175,000. The rest of the settlements are grouped as large towns (60,000–175,000 population), medium towns (25,000–60,000 population), and small towns (< 25,000 population). The dependent variable is the logarithm of the house price. “FTTC activated” is a dummy variable that takes 1 for all years following the activation year of FTTC. Standard errors are in parentheses and clustered on each side of the boundary.
*** ,** and * denote statistical significance at the 1, 5 and 10 percent levels, respectively.

Table A.4. Isolating income and skill differences in FTTC premia (all city and town types).

	Major cities		**Other cities**	**Towns**		
	London (1)	**Rest** (2)	(3)	**Large** (4)	**Medium** (5)	**Small** (6)
Panel A (skill medians within income tertiles)						
FTTC activated = 1	0.0076	0.0104	0.0117	0.0063	0.0091	0.0178**
	(0.0096)	(0.0124)	(0.0094)	(0.0054)	(0.0073)	(0.0076)
FTTC activated = 1 × high skill	0.0238	0.0476**	−0.0240*	−0.0090	−0.0051	−0.0163
	(0.0155)	(0.0204)	(0.0137)	(0.0083)	(0.0095)	(0.0106)
Postcode fixed effects (FE)	Yes	Yes	Yes	Yes	Yes	Yes
Grid × boundary × year FE	Yes	Yes	Yes	Yes	Yes	Yes
House controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	16,193	12,696	19,785	53,811	45,208	40,465
Panel B (income medians within skill tertiles)						
FTTC activated = 1	0.0199**	0.0253*	−0.0075	0.0076	0.0097	0.0119*
	(0.0097)	(0.0139)	(0.0096)	(0.0068)	(0.0068)	(0.0067)
FTTC activated=1 × high income	−0.0033	0.0080	0.0147	−0.0127	−0.0062	−0.0083
	(0.0126)	(0.0202)	(0.0135)	(0.0086)	(0.0094)	(0.0109)
Postcode FE	Yes	Yes	Yes	Yes	Yes	Yes
Grid × boundary × year FE	Yes	Yes	Yes	Yes	Yes	Yes
House controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	16,193	12,696	19,785	53,811	45,208	40,465
Panel C (income medians within income tertiles)						
FTTC activated = 1	0.0105	0.0256*	−0.0025	0.0018	0.0104	0.0083
	(0.0119)	(0.0139)	(0.0087)	(0.0062)	(0.0065)	(0.0067)
FTTC activated=1 × high income	0.0158	0.0078	0.0048	−0.0010	−0.0092	0.0005
	(0.0189)	(0.0187)	(0.0131)	(0.0085)	(0.0095)	(0.0111)
Postcode FE	Yes	Yes	Yes	Yes	Yes	Yes
Grid × boundary × year FE	Yes	Yes	Yes	Yes	Yes	Yes
House controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	16,193	12,696	19,785	53,811	45,208	40,465

Note: The table reports differences in FTTC premia across income and skill groups. "High income" is an indicator for MSOAs with above-median income. "High skill" is an indicator variable for MSOAs with above-median shares of residents in skilled occupations. In panel A, we calculate the median values within income tertiles for the city. This helps us to compare high- and low-skill areas with similar income distributions. In Panel B, we check whether the income difference remains strong once we adjust for skill by comparing areas within the same-skill tertile. In panel C, we calculate median incomes after dividing the city-specific samples into income tertiles. This exercise helps us to see whether income differences remain significant once we account for income tertiles. Major cities include London, Birmingham, Bristol, Cardiff, Leeds, Liverpool, Manchester, Newcastle upon Tyne, Nottingham, and Sheffield. "Other cities" include urban settlements with a population above 175,000. The rest of the settlements are grouped as large towns (60,000–175,000 population), medium towns (25,000–60,000 population), and small towns ($<$25,000 population). In all columns, the dependent variable is the logarithm of the house price. "FTTC activated" is a dummy variable that takes 1 for all years following the activation year of FTTC. Standard errors are in parentheses and clustered on each side of the boundary.

** and * denote statistical significance at the 5 and 10 percent levels, respectively.

Table A.5. FTTC premia across cities and towns—density.

	(1) Major cities	(2) Other cities	(3) Towns
Panel A (by national median density)			
FTTC activated = 1	0.0180	0.0050	0.0037
	(0.0146)	(0.0124)	(0.0032)
FTTC activated = 1 × high density	0.0071	−0.0076	0.0029
	(0.0168)	(0.0146)	(0.0057)
Postcode fixed effects (FE)	Yes	Yes	Yes
Grid × boundary × year FE	Yes	Yes	Yes
House controls	Yes	Yes	Yes
Observations	28,889	19,785	139,592
Panel B (by city-specific median density)			
FTTC activated = 1	0.0254**	0.0095	0.0038
	(0.0104)	(0.0088)	(0.0036)
FTTC activated = 1 × high density	−0.0028	−0.0247*	0.0022
	(0.0155)	(0.0145)	(0.0055)
Postcode FE	Yes	Yes	Yes
Grid × boundary × year FE	Yes	Yes	Yes
House controls	Yes	Yes	Yes
Observations	28,889	19,785	139,592

Note: The table reports differences in FTTC premia across density groups. “High density” is an indicator for MSOAs with above-median population density. In Panel A, we use the national median values of population density to define high-density areas. In Panel B, we separately calculate the median values for major cities. Major cities include London, Birmingham, Bristol, Cardiff, Leeds, Liverpool, Manchester, Newcastle upon Tyne, Nottingham, and Sheffield. “Other cities” include urban settlements with a population above 175,000. The rest of the settlements are grouped as large towns (60,000–175,000 population), medium towns (25,000–60,000 population), and small towns ($<$ 25,000 population). In all columns, the dependent variable is the logarithm of the house price. “FTTC activated” is a dummy variable that takes 1 for all years following the activation year of FTTC. Standard errors are in parentheses and clustered on each side of the boundary.

** and * denote statistical significance at the 5 and 10 per cent levels, respectively.

Table A.6. Skill differences by distance from the cabinet (major cities).

	(1) 0–200 m	(2) 200–400 m	(3) 400+ m
Panel A: By city-specific median skill			
FTTC activated = 1	−0.0051	−0.0052	0.0191
	(0.0144)	(0.0207)	(0.0396)
FTTC activated = 1 × high skill	0.0646***	0.0573**	−0.0349
	(0.0202)	(0.0267)	(0.0500)
Postcode fixed effects (FE)	Yes	Yes	Yes
Grid × boundary × year FE	Yes	Yes	Yes
House controls	Yes	Yes	Yes
Observations	13,759	9,636	4,422
Part B: Median skill within income tertiles			
FTTC activated = 1	0.0060	0.0146	0.0022
	(0.0142)	(0.0182)	(0.0268)
FTTC activated = 1 × high skill	0.0450**	0.0283	−0.0070
	(0.0223)	(0.0269)	(0.0396)
Postcode FE	Yes	Yes	Yes
Grid × boundary × year FE	Yes	Yes	Yes
House controls	Yes	Yes	Yes
Observations	13,759	9,636	4,422

Note: The table reports housing price responses to FTTC activation in major cities (London, Birmingham, Bristol, Cardiff, Leeds, Liverpool, Manchester, Newcastle upon Tyne, Nottingham, and Sheffield). We divide the sample into properties within 0–200, 200–400, and above 400 m from the cabinet. We interact indicators for "high-skill" (i.e. above median share of skilled workers) with the indicator for FTTC activation. In Panel B, we divide the high-skill and low-skill areas by median values calculated by income tertiles. This is to compare high-skill and low-skill areas within the same income tier. In all columns, the dependent variable is the logarithm of the house price. "FTTC activated" is a dummy variable that takes 1 for all years following the activation year of FTTC. Standard errors are in parentheses and clustered on each side of the boundary.

*** and ** denote statistical significance at the 1 and 5 per cent levels, respectively.

Table A.7. Comparison of in-sample and out-of-sample postcodes.

	Baseline sample (1)	Out-of-sample (2)	Rural (3)
Sale price (£)	190,178.52	192,581.16	220,361.69
Price per sq. M. (£)	2,357.40	2,372.12	2,318.29
Log of price	12.03	12.03	12.19
Number of rooms	4.40	4.40	4.89
Total floor area (sq. M.)	84.01	85.20	98.62
Per cent detached	0.18	0.17	0.40
Per cent semi-detached	0.31	0.30	0.30
Per cent terraced	0.36	0.34	0.25
Per cent flat/maisonettes	0.16	0.19	0.06
Per cent freehold	0.79	0.75	0.92
Per cent leasehold	0.21	0.25	0.08
Per cent newly built	0.01	0.02	0.01
Per cent building age ($<$1900)	0.08	0.09	0.17
Per cent building age (1900–49)	0.31	0.32	0.16
Per cent building age (1950–75)	0.26	0.28	0.30
Per cent building age (1976–90)	0.15	0.13	0.16
Per cent building age (1991–2006)	0.17	0.14	0.17
Per cent building age (2007 or later)	0.03	0.03	0.03
Geographic composition—type of urban area			
Urban major conurbation	27.31	37.07	
Urban minor conurbation	4.60	4.14	
Urban city and town	67.77	58.38	
Urban city and town (sparse)	0.32	0.41	

Note: The table reports summary statistics for different subsets of property data. We use the Price Paid Data (PPD) from 2008–17. Column 1 reports the summary statistics for our regression sample, which we refer to as the "baseline sample." Column 2 shows property characteristics for urban postcodes that are not used in our regression. Column 3 shows information for properties located in rural postcodes. Compared with our sample, column 2 shows slightly larger house prices and a larger share of flats and leasehold properties. However, the log of price, price per square meter, size of the properties, and other property characteristics are quite comparable. Column 3 provides a sharp contrast between urban and rural properties—rural properties are bigger in size, more likely to be detached properties, and less likely to be leaseholds. Also, a larger share is built in the nineteenth century. The bottom panel compares the geographic composition and shows that a larger share of out-of-sample postcodes are located in major urban areas.

Table A.8. Comparison of demographic characteristics (OA level).

	Baseline sample (1)	Out-of-sample (2)	Rural (3)
Population (count)	314.01	311.72	300.72
Population density (per hectare)	56.22	64.42	14.72
Per cent age: 0–15	18.69	18.69	17.10
Per cent age: 16–24	11.22	11.84	8.87
Per cent age: 25–44	27.90	28.58	21.59
Per cent age: 45–64	25.39	24.70	30.71
Per cent age: 65 and above	16.81	16.19	21.74
Median age (years)	40.11	39.25	46.28
Per cent ethnicity: white	88.25	84.85	97.76
Per cent ethnicity: black	2.32	3.71	0.29
Per cent ethnicity: Asian	6.69	7.92	0.95
Per cent ethnicity: mixed, others	2.74	3.51	1.00
Per cent employed: full-time	14.34	13.76	14.37
Per cent employed: part-time	40.58	39.10	35.85
Per cent self-employed	8.94	8.75	14.04
Per cent unemployed	4.17	4.76	2.86
Per cent managers, directors, and senior officials	9.86	9.75	13.60
Per cent professional occupations	16.65	16.59	17.20
Per cent assoc. professional, and technical occupations	12.16	12.18	11.87
Per cent administration and secretarial occupations	11.95	11.53	10.59
Per cent skilled trades	11.45	11.03	14.63
Per cent caring, leisure, and other service	9.86	9.82	9.19
Per cent sales and customer service	8.99	9.14	6.46
Per cent process, plant, and machine operatives	7.69	7.82	6.69
Per cent elementary occupations	11.39	12.14	9.77

Note: The table compares demographic or economic characteristics using the 2011 census. We use information at the output area (OA) level which is the finest geography available in the census. Column 1 reports the summary statistics for our regression sample, which we refer to as the "boundary sample." Column 2 shows property characteristics for urban OAs that are not used in our regression. Column 3 shows information for properties located in rural OAs. Compared with our sample, out-of-sample OAs have a higher population density. They also have a population that is slightly younger and more ethnic. The occupation and employment characteristics are largely comparable across columns 1 and 2. The last column shows stark differences between urban and rural OAs.

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