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Abstract

Using the universe of housing transactions in England and Wales between 2008 and 2016, we measure the perceived value of fiber activation to the homebuyers. We exploit the discontinuity across the boundary of areas that got fiber enabled in different years. Although we find a price premium of 0.7%, the effect drastically differs across places. The strongest house price response is concentrated in London areas, mainly in neighbourhoods with a higher share of digital occupations. To further understand how different segments of the population capture the broadband dividends, we examine these results by the economic or racial composition of neighborhoods. Although our results show a strong willingness to pay a premium price for fiber broadband in deprived areas, this is only evident in white neighborhoods. These results suggest that the transition to new broadband technologies might deepen the digital divide due to the gap in the perceived returns and low take-up among some regions and neighbourhoods.

JEL Classifications: O18, O33, R21, R23

Keywords: Fiber Broadband, Spatial Discontinuity, House Price, Digital Divide, Neighborhood Ethnic Composition, Digital Occupations

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1 Introduction

Data-intensive digital services and platforms have become an important part of modern urban life. Access to high-speed internet is a prerequisite for using these digital services that can transform the way we work, learn, or use healthcare services. During the past decades, fiber-optic broadband emerged as a breakthrough technology expanding access to high-speed internet at an affordable cost. Between 2014 and 2019, monthly fixed internet spending (per GB of data) of UK households declined by 80%. At the same period, monthly data usage has gone up by 443%.[1] Despite its wide array of benefits and the government's commitment to universal service coverage, this new broadband technology did not diffuse evenly across different parts of the population. This disparate pattern can stem from the uneven returns to high-speed internet connectivity due to a lack of analog complements, such as skills and opportunities. According to World Bank Group (2016), this gap in returns to digital technologies, or the so-called digital dividends, is one of the major headwinds in universal access to digitization benefits.

This paper examines the perceived digital dividend of access to fiber broadband to households and how it varies across different segments of the urban population. We study the transition from standard broadband to superfast fiber broadband across the UK. The transition was triggered by the nationwide rollout of fiber-to-the-cabinet (FTTC) infrastructure across the UK. The rollout began in 2009, and by 2013 around 60% of all the urban postcodes was connected through FTTC. Still, the asymmetric digital subscriber line (ADSL) broadband was the dominant technology at the beginning of 2013 and was being used by 70% of users. Gradually, it was replaced by FTTC which expanded its share to around 50% of users by the end of 2019.

To assess the perceived digital dividend, we study how homebuyers respond to the arrival of FTTC broadband. We measure the premium prices they are willing to pay for properties located in FTTC-activated areas. To this end, we employ an empirical strategy that exploits the sharp discontinuity across neighboring postcodes that get connected to FTTC broadband in different years. In addition, we estimate the premiums if a property is located in close proximity of fiber network infrastructures, that increases the quality of FTTC broadband.

We first collect information on all the FTTC activation dates by postcodes and also the distribution points of FTTC broadband (commonly known as cabinets). This information

[1] Ofcom Communication Market Report, 2020.

provides us with the cabinet locations as well as the postcodes that they cover.[2] The detailed information about the fiber infrastructure helps us in two ways. First, we can calculate the distance between each postcode and a specific cabinet. This distance helps us infer whether a postcode is well-situated to access the FTTC infrastructure. Second, the activation dates at the postcode level allow us to group postcodes together and construct the areas with the same activation year. The last step enable us to exploit the geographic discontinuities in FTTC activation across the boundaries of these activation areas. We then study the variation in prices of comparable houses in these closely located postcodes which are connected to FTTC in different years. Specifically, we measure whether early FTTC activation or the proximity to FTTC infrastructure is capitalized in house prices and estimate the digital premium of access to FTTC broadband.

Using the aforementioned empirical design, we find a digital premium of 0.7% caused by FTTC activation. Moreover, we find that the digital premium for FTTC is the strongest when the property is located closer to the cabinet. This finding closely replicates the technical features of FTTC broadband that it gives a speed boost within a shorter distance from the cabinet. Our estimates of digital premium for FTTC activation can be interpreted as homebuyers' willingness to invest in upgrading the quality of high-speed internet. We find significant heterogeneity in this response across different regions and neighborhoods. The digital premium for the London region (1.7%) is more than twice the effect for the rest of the regions (0.7%). A similar pattern emerges when we look at price responses by the proximity to the city of London. We find a digital premium of 2% for properties located nearby London. Compared with that, the price premium for residential properties located away from London is only 0.6%. To understand what is driving the strong price response around London, we examine the occupational composition of these areas. One of the distinguishing features of London and its surrounding areas is the higher share of jobs with digital skill requirements.[3] After mapping the job postings' digital skill requirements to the occupations, we see that the effect closer to London is driven by the neighbourhoods in which a higher share of population is engaged in digitally-intensive jobs.

[2] The switching postcodes between cabinets is a rare incident and happens under very specific circumstances.

[3] For instance, in 2012, 46.4% of all job postings that required digital skills were in Travel To Work Areas (TTWAs) closer to London. The number of jobs with digital skill requirement in London was around half a million, which was almost ten times as high as in Manchester which ranked next with 59,000 digital jobs. Furthermore, the number of job postings with digital skill requirements in four TTWA near London – Slough and Heathrow, Reading, Guildford and Aldershot, and Luton – was higher than digital jobs in Manchester and Birmingham combined.

We also find significant variations across neighborhoods in willingness to invest for access to high-speed internet. We compare the well-off and deprived local areas as well as white and ethnic neighborhoods within these areas.[4] We identify deprived areas, both locally and nationally, by the presence of at least one neighborhood that falls into the bottom one-third of the deprivation rankings by the 2010 Index of Multiple Deprivation (IMD). We further divide the neighborhoods in the same local area according to their share of white or ethnic minority population. Our results show that the digital premium in house prices caused by FTTC activation is limited to deprived white neighborhoods. We find a strong digital premium of 1.4% in these neighborhoods, whereas the effect of FTTC activation is muted in other neighborhoods.

Our results provide two main contributions that are relevant to different strands of the literature. First, we design an empirical strategy that enables us to study the causal impact of access to the next generation of broadband on the residential property values. Our work is among the first papers that studies the effect of the fiber broadband. DeStefano et al. (2020) uses the postcode-level timing of fiber broadband availability and firm's distance from local exchange to instrument the adoption of cloud computing, and measures its impact on firm growth. Prior to the rollout of FTTC broadband, the geography of access to high-speed internet was defined by the distance from local telephone exchanges. The reason is that the standard broadband (ADSL) heavily relied on the telephone exchange network. However, the geography of access to high-speed internet drastically changed by the deployment of fiber. For FTTC broadband, it is the distance from the cabinet, not the distance from local exchanges, that determines the connection speed. The lack of information on the network of cabinets compelled previous papers to either limit themselves to the period before the rollout of FTTC or make strong assumptions that the deployment of cabinets and their locations do not bias their results. What distinguishes our paper is that we collect information on the granular cabinet network and thus measure the distance between properties and their cabinets.

In this regard, our paper also relates to the literature that exploits the geographical discontinuities in broadband access to study the effects on health outcome (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

[4]In this paper, we use the terms 'local area' and 'neighborhood' to refer to the middle-layer super output area (MSOA) and lower-layer super output area (LSOA), respectively.

Poulsen, 2019), trade (Malgouyres et al., 2021), and credit (D'Andrea and Limodio, 2019). The closest to our paper is Ahlfeldt et al. (2017) that studies the effect of ADSL broadband on house price between 1995 and 2010. What distinguishes our paper from others is that we are able to study the effect of the next generation of broadband technologies delivered via the fiber network that start to take-off after 2010.

Our second contribution relates to the literature that studies the digital divide. The notion first emerged as early as the mid-1990s in reference of the fact that digital technology was diffusing disproportionately to urban areas compared to rural areas. Empirical evidence reveals that the digital divide also exists along the socio-economic boundaries (Telecommunications and Administration, 1999; Mineta, 2000; Bucy, 2000; Rice and Haythornthwaite, 2006; Jones et al., 2009; Zickuhr and Smith, 2012; Vigdor et al., 2014). Disruptive effects of the COVID-19 pandemic shed a new light on this issue. During the pandemic, social distancing measures forced many individuals to stay at home and accelerated the shift towards digital services. However, the extent of individual adaptability varied substantially across socio-economic groups (Sostero et al., 2020; Bick et al., 2020; Stantcheva, 2022; Bonacini et al., 2021). More recent evidence suggests that a substantial part of these differences can be explained by the disparity in individual access to high-speed internet at home (Chiou and Tucker, 2020), which created the inequality of access to e-learning and telemedicine (Bacher-Hicks et al., 2021; McCullough et al., 2021). In relation to this literature, our results shed light on a potential source of disparities in access to high-speed internet. Our findings reveal that proximity to large cities or pre-existing difference in occupational and ethnic composition can generate uneven digital dividends across neighborhoods. The implication is that the transition to new broadband technologies can widen the digital divide leaving some regions or neighborhoods behind the frontier of high-speed internet.

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

2 Background

2.1 A Brief History of Fiber Broadband in the UK

The average download speed in the UK increased from 16 Mbps in 2013 to 85 Mbps in 2021.[5] The main technology behind this speed boost involves fiber optic cable. The previous generation of technologies, such as ADSL or ADSL2+, uses copper telephone cables that run from the local telephone exchanges to the residential properties. Since the strength of the signal over copper line decays with distance, actual speed depends on the distance of a property from its local exchange. For example, ADSL2+ connections could provide a maximum speed of 24 Mbps within a kilometer (km) from local exchanges. After that, the speed drops gradually, with only 8 Mbps speed (the same as the original ADSL) being available around 3 km away from the exchange.[6]

Fiber broadband replaces copper with fiber optic cable which provides faster connections. The initial rollout of fiber broadband in the UK was led by the commercial provider BT. In 2009, BT announced that it will invest £1.5 billion to connect ten million UK homes (Jackson, 2008). BT's rollout involved a part-fiber and a part-copper solution in which fiber cable runs from local exchanges to street-side cabinets while old copper telephone lines connect the street cabinets to the properties. This type of connection is known as fiber-to-the-cabinet (FTTC). Compared with that, a full fiber connection or fiber-to-the-premises (FTTP) deploys fiber all the way from a local exchange to the premise of a property. Figure 1 shows how the availability of ADSL, FTTC, or FTTP broadband changed over time in the UK. Most of the ADSL-type activation was complete by 2007. As the figure shows, fiber activation started in 2009 and the number of unit postcodes connected reached a peak at 2012. The bulk of the commercial rollout was complete by 2013-14.

A few points about the FTTC activation are worth noting. First, the rollout took place in multiple phases and the initial phases predominantly targeted urban areas. Table 1 shows the share of urban postcodes by FTTC activation year. Until 2013, above 80% of the postcodes activated were in urban areas. Activation in the rural areas, supported by the Building Digital UK (BDUK) programs, gained momentum in 2014.[7]

[5] Calculations using Ofcom data.

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

[7] 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 which are not considered as 'commercially viable' by the private sector.

Second, the distance from local exchanges does not determine the speed for FTTC connections. This is because the first leg of connections, the one between from local exchanges and street cabinets, uses fiber cable which has much higher transmission speed and bandwidth. Rather it is the distance from the street cabinet that governs the available FTTC speed. For example, the maximum download speed could be as high as 80 Mbps within 100 meters of the cabinet but the speed drops to 60 Mbps around 500 meters away and to 30 Mbps around 1 km away.[6]

Third, Virgin Media is another major commercial provider that played a part in faster broadband delivery. It launched its 50 Mbps broadband service in 2008, followed by an upgrade to 100 Mbps in 2010. Virgin Media uses the same coaxial cable that it uses for cable TV to provide broadband connections. Their infrastructure covers only half of the UK and mostly remained the same during the initial phases of FTTC rollout.

2.2 Broadband Coverage and Take-Up:

Availability alone does not lead to the adoption of faster internet. Figure 2 shows the percentages of premises that are covered and have taken up superfast broadband, which offers at least 30 Mbps download speed. By 2015, 80% of UK premises were covered by superfast broadband. However, only one-fourth of the premises actually signed up for superfast connections. Only in recent years has the gap between coverage and take-up narrowed to some extent.

Data on speed tests from ThinkBroadband shows a similar picture. Figure 3 shows the share of speed tests run for different types of broadband connections. Although the share of FTTC rapidly increased since early 2012, ADSL was the dominant technology until mid-2017. Also, note that the share of cable broadband (i.e., Virgin Media) held steady during this period.

To fully gauge how the expanded coverage affected speed, we plot the distributions of download speed using Ofcom data. Figure 4 shows that the average speed remains below 50 Mbps in 2013 – the earliest year for which data is available. The rightward shift of the distribution in later years means that more people are availing themselves of high-speed internet. However, we see an interesting pattern starting from 2017. The distribution of average download speed takes a bi-modal shape which shows a speed divide – part of the country has embraced high-speed broadband while the other part remains at the lower end of the distribution.[8]

The takeaways from the above discussion are: i) take-up lags far behind the availability of high-speed broadband, ii) low-speed connections, such as ADSL, still make a significant share of the commonly-used technologies, and iii) the availability and take-up of fiber and other technologies resulted in a two-peak speed distribution, which means part of the country has opted for high-speed broadband while the remainder keeps using low-speed connections.

The UK government's recent goal is to expand the gigabyte broadband coverage to 85% of the UK premises by 2025 (Hutton, 2021). But as the data shows, coverage alone does not guarantee that people would adopt high-speed broadband. Adoption depends on the economic values gained by households from having high-speed connections and could be influenced by a wide range of factors including location, jobs, or social ranks. Hence, in this paper, we set to measure how people valued fiber deployment using housing price appreciation. Our goal is to shed light on the factors that generate uneven value and adoption of high-speed broadband and result in the shape of speed distribution observed in the data. The next section outlines our empirical strategy in detail.

3 Empirical Strategy

3.1 Identification Using Spatial Discontinuity in FTTC Activation

We focus on housing market transactions to assess homebuyers' perceived value of fiber-enabled properties. The ideal experiment would involve comparing two otherwise similar properties, one with FTTC connection and another without, to see whether the FTTC activated property sells at a higher price. To measure any premium price paid for FTTC activation in a quasi-experimental setup, we examine the sale prices of properties across neighboring postcodes that have different years of FTTC activation.

As discussed in Section 2.1, the national scale of BT's FTTC rollout meant that engineers and other resources were high in demand. Hence, the Openreach, which maintains the infrastructure shared by BT and other providers, planned a rollout over multiple phases starting from 2009. FTTC connections deploy fiber cable between local exchanges and street cabinets while connecting the street cabinets to the properties using copper cable. Hence, the activation takes place at the cabinet level. As each cabinet goes live, a certain number

[8] This is not an urban-rural divide. Although Figure 4 plots the data from the entire UK, we can see a similar bi-modal shape within urban areas too.

of properties in the adjacent postcodes could get FTTC broadband. According to a report by the House of Commons Culture, Media and Sports Committee (2016), the Openreach or other broadband delivery programs often targeted areas that are easier to connect, creating a 'patchwork' of connections across premises. This could mean that the areas connected in different years may not be directly comparable. Hence, we focus on the boundary of such areas.

Specifically, we construct 'activation areas' by merging the polygons for unit postcodes with the same year of FTTC activation. The boundary of these areas give sharp discontinuity in the availability of FTTC broadband. We hereafter refer to these boundaries as 'activation boundaries'. Our identification comes from exploiting the spatial discontinuity in FTTC activation within a narrow distance from the activation boundaries (i.e., within 200 meters). This approach relies on the assumption that the location characteristics (e.g., access to supermarkets, parks, or stations) for neighboring postcodes on either side of the boundary do not change drastically while one side of the boundary (i.e., the early activation side) gets FTTC enabled before the other side.

Figure 5 shows an example of two activation areas neighboring each other. The red dots in the figure marks properties. The green area represents postcodes that are activated in 2011. The northwest part of the map (in yellow) was not activated until 2015. This type of randomness in FTTC activation across neighboring postcodes creates a sharp divide where one side can get FTTC broadband and the other side cannot. Our study design involves comparing properties located in such pairs of areas across the activation boundary.

3.2 Sample Construction and Empirical Model

We limit our sample to FTTC activation until 2013 to focus on FTTC activation in urban areas that was targeted by BT's commercial rollout. Table 1 shows that FTTC activation in early years was concentrated in urban areas. From 2014, a mix of urban and rural postcodes were activated. This is due to the rural rollout programs under BDUK gaining momentum around this time. To keep our sample homogeneous, we drop any rural postcodes even if they are activated by 2013.

We examine the properties within a narrow distance from the activation boundary. This restriction on the distance from boundary makes sure that the properties on both side of the boundary are comparable. In our preferred specification, we only consider properties that are within 200 meters from this boundary. We also check our main results with relaxing this restriction.

To identify the location of each boundary, we divide the entire geography into one square km grids (see Figure 6). If a cell is from a dense neigborhood and includes multiple boundaries, we further break it down to 100 square meters grids. We use these grids to control for time-variant location fixed effects across both sides of the boundary while we control time-invariant fixed effects by unit postcodes. In other words, the one grid cells help us capture trends in local housing markets (across activation boundaries) and postcode fixed effects help us control for any specific characteristics of the housing blocks.[9] Although our sample comes from the urban areas, where property sale data is less sparse, we take several steps to make sure we have enough observations to estimate the fixed effects in our empirical model. First, we check that we have 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 drop grids that have less 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% of the observations in the early activated (or late activated side) of the boundary.[10] In our robustness checks, we also relax this assumption to check any impact on our estimates. These steps bring down our effective sample to 206,579 property transactions across 49,094 postcodes.

Empirical Specification:

We estimate a hedonic pricing equation using the sample of property transaction prices from 2008-2016.

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

In this equation, i indexes property transaction, j indexes postcodes, k indexes grid-boundaries, and t indexes years.[11] Our dependent variable is the log of sales price of a property. FTTC activated is a binary indicator for the year after fiber activation is complete in a postcode. X includes property characteristics, such as total floor area, indicators for

[9]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).

[10]This restriction on grids is to ensure that we have sufficient observations on both side of the boundary so that our boundary specific year fixed effects could capture any year-to-year fluctuations in local housing markets.

[11]Note that a one square km grid can have multiple boundaries. Hence, we include time-varying fixed effects at the grid-boundary level.

property type (detached, semi-detached, terraced, or flat), lease type (freehold or leasehold), an indicator for newly-built properties, and categories for age. μ is postcode fixed effect and ρ measures year fixed effects by grid-boundary. ϵ is the error term. We cluster the error term 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.

Our identification relies on the staggered difference-in-difference design when the treatment, FTTC activation in this case, occurs at different years. The two-way fixed effects (TWFE) model has been a canonical specification of the ordinary least square (OLS) model to estimate the causal effect in such setups. However, recently, several papers have indicated that in the presence of treatment effect heterogeneity the TWFE estimates can be biased despite of satisfying the conventional (strict) exclusion condition of parallel trend (and no anticipation). This problem occurs when treatment effect varies over time or across treated groups (Borusyak and Jaravel, 2017; Goodman-Bacon, 2021; Sun and Abraham, 2021; De Chaisemartin and d'Haultfoeuille, 2020; Callaway and Sant'Anna, 2021).

In particular, the bias occurs when the TWFE estimation compares the late treated units against the early treated units as the control group. In this case, the estimate entails downward bias proportional to the increase in treatment effect overtime. This might be true in the current setup since the adoption of FTTC broadband takes time to mature and becomes widely adopted by the users as illustrated in Figures 2 and 3.

Following Goodman-Bacon (2021), Sun and Abraham (2021), and Callaway and Sant'Anna (2021), we limit our post-treatment 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 neighbouring postcodes across the activation boundary has an early and 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 late activation year acts as a control group that never gets treated during this period.

3.3 Variation in Distance from Cabinets

Our design also exploits the variation in the distance of a property from cabinets. As explained in the previous section, FTTC broadband gives a speed boost within a short distance from the cabinet. Hence, we examine whether housing prices respond diferentially when a property is located closer to the cabinet compared to the ones that are farther away. We test this hypothesis using interactions between FTTC activation and distance bands (<200 meters from cabinets, 200-400 meters from cabinets, and > 400 meters from cabinets). Specifically, we estimate the following regression:

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

4 Data and Summary Statistics

To test how housing prices respond to FTTC activation, we combine data from a number of sources. In this section, we describe our data sources and provide some descriptive statistics.

4.1 Property Transactions Data

We use property transaction records between January 2008 and December 2017. The data comes from 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 provides the near universe of all residential property transactions in England and Wales. In addition to the sales price, it also includes some of the property characteristics. The full address of the property is included. The type of building reported includes four main categories (detached houses, semi-detached houses, terraced houses, flat/maisonette) and a remaining category (others). We drop the few properties that do not fall in the four main categories and reported as others. Moreover, it indicates whether the property was built during the past ten years.

The open data for Environmental Protection Certificates (EPC) is another property-level data source that helps us to complement our information on property characteristics. In addition to the information on energy performance of a building, it also has 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 an address matching. We drop few observations when the reported number of habitable rooms is zero or more than twelve. We also drop 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 a good coverage that accounts for 85.3% of properties in registered transactions.

4.2 Neighbourhood Characteristics

We collect information on socio-economic, racial, and occupational composition of neighborhoods to study how the housing market reactions to the arrival of fiber broadband vary across neighborhood characteristics. This exercise helps us to understand which segment of the population absorbs the return to the provision of fiber broadband infrastructure. In this paper, we study the heterogeneity at two geographic levels. The first geographic unit that we refer to as a 'neighborhood' is a lower-layer super output area (LSOA) in England and Wales that is defined by the 2011 Census. LSOAs are small areas that their population does not exceed 3,000 people (or 1,200 households). The second geographic unit that we refer to as a 'local area' is the middle-layer super output area (MSOA). MSOAs often comprise several LSOAs but their population does not exceed 15,000 people (or 6,000 households).

Using the 2011 Census, we first build an index for ethnic composition of LSOAs according to their share of non-white population among all residents. The census also provides information on the occupations of employed residents, aged 16 to 74. The information is available at the three-digit occupation classes based on the Standard Occupational Classification 2010 (SOC 2010). That allows us to construct the index for the occupational composition of LSOAs. To identify the digital occupations we rely on a separate dataset. We use the universe of online job postings in 2012 across the United Kingdom that is collected by Burning Glass Technologies (BGT). Using the intensity of digital jobs at three-digit occupation level, we calculate the share of digital occupation across LSOAs.

Furthermore, we use the 2010 English Index of Multiple Deprivation (IMD) constructed by the Social Disadvantage Research Centre at the University of Oxford and the Department for Levelling Up, Housing and Communities.[12] The index captures different aspects of deprivation in disadvantaged neighborhoods such as income, employment, safety, school quality, living environment, and health. Using this information we identify the deprived local areas (MSOAs). According to our index, the MSOA is deprived if it includes at least one LSOA that falls in the bottom tertile of the most deprived LSOAs across the country.[13]

[12] Formerly known as the Ministry of Housing, Communities and Local Government (MHCLG).

[13] This follows the definition used by MHCLG (2019) to classify deprived local authorities.

4.3 Broadband Technologies

We web-scrape information from various sources about the local exchanges, cabinet locations, and FTTC activation dates at the postcode level. We calculate the straight-line distance between the postcode of a property and the postcode in which the connecting cabinet is located. Among other information, broadband speed comes from Ofcom. Ofcom publishes data on broadband speed and coverage starting from 2013 as part of its Connected Nations series. We use the average download speed by census output areas (OAs) to see how the speed distribution has changed over the years.

Table 2 reports the summary statistics for the key variables of our analysis. The average sale price is £202,000 during the sample period (2008-16). We truncate the sales price at £500,000. The average distance of the properties in our sample is 170 meters from the activation boundary and 280 meters from the cabinets. The broadband speed data from Ofcom is only available for 2013-16. During these years, the average download speed was 33 Mbps across the sample postcodes.

5 Results

In this section, we present our main results that show how housing prices respond to fiber activation. We also explore the heterogeneous responses across different geographic areas and social groups.

5.1 Housing Price Responses: Main Results

Table 3 shows the results from our baseline regression. Column 1, which is our preferred specification, shows that FTTC activation increases house prices by 0.7%. Columns 2-4 show that the response is robust to relaxing some of the constraints we impose on our sample. Specifically, Column 2 excludes the restriction that at least 10% of the observations in each grid should come from treated (or untreated) postcodes. Column 3 relaxes the 200 meters limit on the distance from the boundaries, whereas Column 4 reports the results without the property-level controls. In all three cases, we get statistically significant responses of similar magnitude. The last column presents the results for the regression including interaction terms between FTTC activation dummy and discrete categories of distance from the cabinet.[14] We find that the price effect is strong within 400 meters from the FTTC cabinet.

[14]Note that we measure the straight-line distance between postcode centroid of the property and the cabinet which connects it.

After that, the effect fades away. But the effect dissipates if the property is more than 400 meters away from the cabinet. These findings mimic the technical properties of FTTC broadband that speed boost is the strongest for the properties close to the cabinet.

Figure 7 shows the dynamic effects of FTTC activation. All three panels show that, prior to fiber activation, house prices appear to be the same for the places that are activated early (i.e., treated) and activated late (i.e., untreated throughout the study period). Following activation, we see an immediate jump in house prices and the effect remains at around 1% even after three years since activation. These figures confirm the validity of our design. After controlling for property characteristics, postcode fixed effects, and time trends by the grid-boundaries, we do not find any prior systematic price differences in our narrowly constructed areas across activation boundaries. The bottom panels of Figure 7 also plot the dynamic effects with relaxing some of the restrictions. Panel 7b and 7c produce the corresponding dynamic effects for the regressions in Column 2 and 3, respectively, of Table 3. Both figures show the robustness of the housing price estimates.

5.2 Regional Variation in Price Responses

We first examine our baseline estimates across different geographic regions. Table 4 reports the estimates for London and the rest of England and Wales. Although we have a smaller sample from London, it shows a strong digital premium of almost 1.7%. For the rest of the country, we find a 0.7% premium due to FTTC activation. We also check our results by the distance from London. We calculate the straight-line distance between each postcodes in our sample and the centroid of London. Column 3 and 4 of Table 4 show these results. We compare how the house price response varies within 30 km and beyond 30 km from the city of London.[15] We find a highly significant price response of about 2% within 30 km from London. Beyond 30 km, the price response is muted but is still significant. These findings suggest that the price premium for FTTC activation is not the same everywhere. While the activation in the early phases took place across a large subset of urban postcodes,[16] it is only the area surrounding London where consumers show a higher valuation as captured by the price appreciations.

London and its surrounding areas are ahead of the rest of the country in terms of many economic indicators (ONS, 2008). We try to understand to what extent these economic opportunities could play a role in driving the London-centric digital premium. To this

[15] We choose 30 km as a cutoff point because this is the distance traveled to work for 90% of the working population in England.

[16] Almost 60% of urban postcodes were activated by 2013.

end, we examine how the distribution of occupations changes across neighborhoods. Since workers in highly digital occupation will be more likely to value high-speed home broadband – both for work and non-work related activities, we calculate the share of digital occupations across neighborhoods. Specifically, we use skill requirements advertised in the job postings to calculate the share of jobs in each occupation that requires digital skills.[17] These shares measure the digital intensity of each occupation. Using them as weights, we take a weighted average of residents employed in different occupations at the neighborhood level.[18] This provides us with a measure of digital intensive occupations held in by the residents of a neighborhood. Finally, we calculate the share of digital intensive occupations out of the total number of people engaged in any occupation.[19]

Figure 9 plots the share of digital occupations across LSOAs in England and Wales. From this map, we could see that London and its surround areas have a higher concentration of digital jobs. Figure 10 plots the shares for London region. It shows that there is a considerable amount of variation in the shares of digitally intensive occupations across London LSOAs.

We consider all the neighborhoods that are at least partly located within 30 km from London and divide them by the median value of the share of digital intensive occupations. Those above the median value show a higher presence of digital jobs. Similarly, we also divide the neighborhoods that fall outside the 30 km radius into below- and above-median neighborhoods (low and high share of digital occupations, respectively). Figure 11 shows our estimates for digital premiums across these four types of neighborhoods. Panel 11a shows that outside the 30 km periphery the digital premium is only statistically significant for neighborhoods with low share of digital occupations. Although the coefficient for neighborhoods with higher share of digital occupation statistically zero, the point estimate is quite close to the previous one. Panel 11b shows the opposite picture. In this case, within 30 km from London, we see that the premium is 3% for the neighborhoods that are high in digital occupations, whereas the point estimate is less than 1% for the neighborhoods that have low

[17] We calculate these shares nationally using BGT job postings data in 2012. We use BGT's skill classifications and count job postings asking for skills belonging to the 'Information Technology' skill cluster family. Figure 8 shows the top-twenty skills of this family for the twenty most frequently occurring 3-digit occupation groups.

[18] The number of residents engaged in an occupation comes from the 2011 census. We use three-digit occupation (SOC 2010) data available at the LSOA level which is our definition of neighborhoods.

[19] We calculate the neighborhood share of digital occupation as,

$$\%\ digital\ occupation = \frac{\sum_{SOC}(\%\ requiring\ digital\ skills \times \#\ employed\ at\ 3digit\ SOC)}{Total\ \#\ employed\ residents}.$$

share of digital occupations. These estimates show that within London and its surroundings, the house price response is not uniform across all types of neighborhoods – the higher digital premium is driven by the neighbourhoods in which a higher share of population is engaged in digitally intensive jobs.

As a final exercise to understand the regional variation in the perceived value of FTTC broadband, we plot the broadband speed distributions for areas within and beyond 30 km from London (Figure 12). Earlier we noted the bi-modal shape of the national speed distributions, suggesting that some areas opt-in for higher speed while other areas remain at the low-speed end of the distribution. We now find that starting from 2015, the places that are closer to London show higher broadband speed compared to the places that are farther away from London. This is in line with the estimates from Table 4 that the places demonstrating a higher digital premium for FTTC connections are also the ones gaining higher speed.

Still, we can see from these figures that there are variation in speed within the areas closer to London (or farther away from London). For example, the areas farther away from major cities predominantly have lower speed but there are also areas that are part of the high-speed cluster. The opposite is also true. To understand this micro variation within regions, we next examine our results by the socio-economic characteristics of the neighborhoods.

5.3 Variation across Neighborhoods: Socio-economic Dimensions

In this section, we study how the price effects differ across different socio-economic groups. Using the 2010 Index of Multiple Deprivation (IMD), we first classify the local areas (i.e., MSOAs) into deprived and not-deprived areas (hereafter, well-off areas). We define a local area as deprived if at least one neighborhood (i.e., LSOA) of that area falls within the most deprived tertile across England. Column 1 and 2 in Table 5 shows these results. We find that the housing price response is around 1% in deprived areas. The price response is half of that in well-off areas and only marginally significant. In Column 3-6 of the same table, we examine these results for ethnic and white neighborhoods. To classify neighborhoods by their racial composition, we first calculate the average share of white people among all residents at each neighborhoods according to census 2011. We then divide neighborhoods within each local area by the median value. If the share of white people is higher than the median value for the local area, we define it as a white neighborhood. Otherwise, we consider it as an ethnic neighbourhood.

Column 3 and 4 of Table 5 show that within the well-off areas, both white and ethnic neighborhoods have insignificant price effects. The next two column shows the price effects for the deprived areas. We find a 1.4% digital premium for white neighborhoods of deprived areas, whereas the premium for ethnic neighborhoods is statistically zero.

We check the robustness of these results in Figure 13. Panel (a) plots the coefficient from Column 3-6 in Table 5 in which we use the ranking of neighborhoods based on multi-factor deprivation. Panel (b) produces similar results using the 2010 index of income deprivation (IID). We can see that the same patterns hold when we group areas based on income deprivation only. Instead of using a national scale, the bottom panels of the same figure defines deprivation on a local scale. If any neighborhood in a local area falls within the bottom tertile of the deprivation ranking for the respective local authority (LA), we consider it as a deprived area. Using this definition of deprivation relative to local standard also produces the same result, that is, the white neighborhoods within the deprived areas show a strong price premium. The coefficients for the other three neighborhoods are not significantly different from zero.

Finally, we check the dynamic effects by the racial composition of a neighborhood within deprived areas (Figure 14). Prior to FTTC activation, the parallel trend assumption holds across the treated and untreated side of the activation boundary. Following the activation, the house price premiums for white neighborhood rises rapidly to 2% but the premium prices for ethnic neighborhood remain at zero. This figure, along with Figure 13, supports the robustness and validity of our finding that the digital premium for FTTC activation, as captured by the house price responses, mainly comes from white neighborhoods in deprived areas.

6 Conclusion

The Covid-19 pandemic shed new light on the digital divide in individuals' access to the internet. High-speed broadband is the prerequisite for a smooth transition to remote work, e-learning, and digital health care. Thus, it is important to understand the economic and social factors that create the digital divide in society. We study the rollout of fiber-to-the-cabinet broadband that began around a decade ago in the UK. We first provide descriptive evidence that documents the substantial digital divide that emerged afterwards. We then examine the homebuyers' willingness to invest in broadband using the sharp discontinuity at the boundary of areas that are FTTC enabled in different years. We find that the digital premium in house prices, generated by FTTC activation, was limited to specific regions and neighbourhoods. Our results point out to muted responses outside of London and its surrounding areas. This is important to understand given the UK government's ongoing attempts for full-fiber rollout. Without additional interventions, expansion of broadband coverage alone might not occur uniformly across all regions. We also find that the price response is only evident in deprived white neighborhoods while ethnic neighborhoods lacks any response. This is of partcular concern that, without additional interventions, expansion of broadband coverage may not generate sufficient benefits for minority groups.

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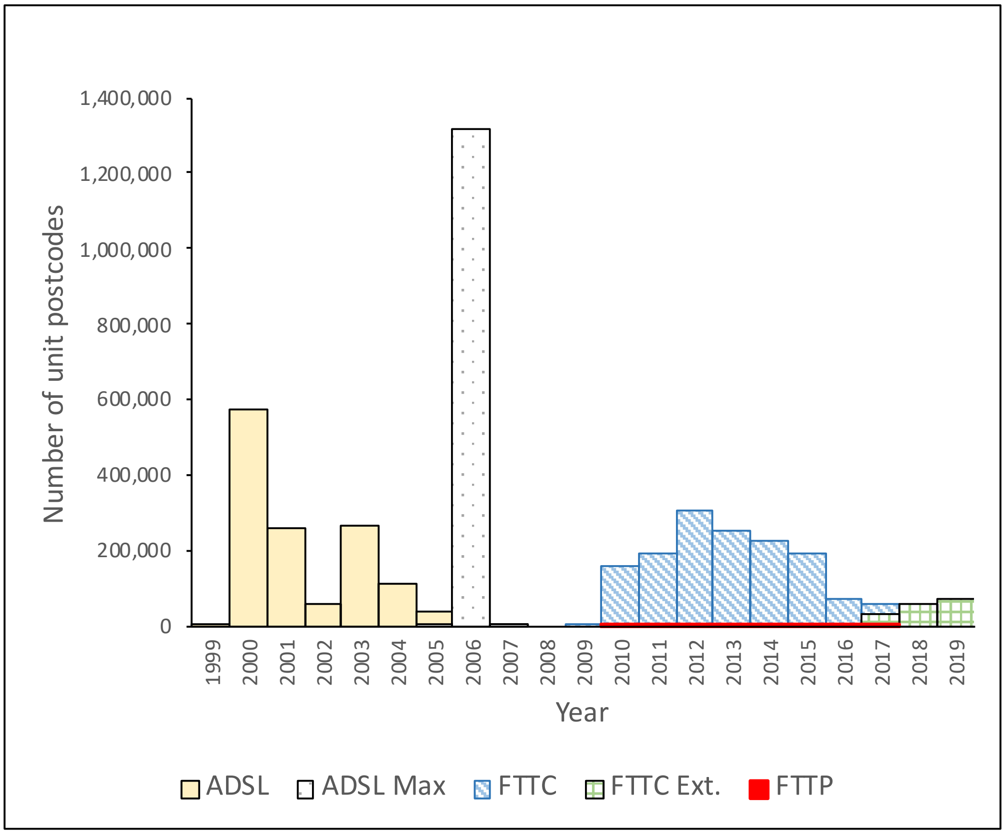
A Tables and Graphs

Figure 1

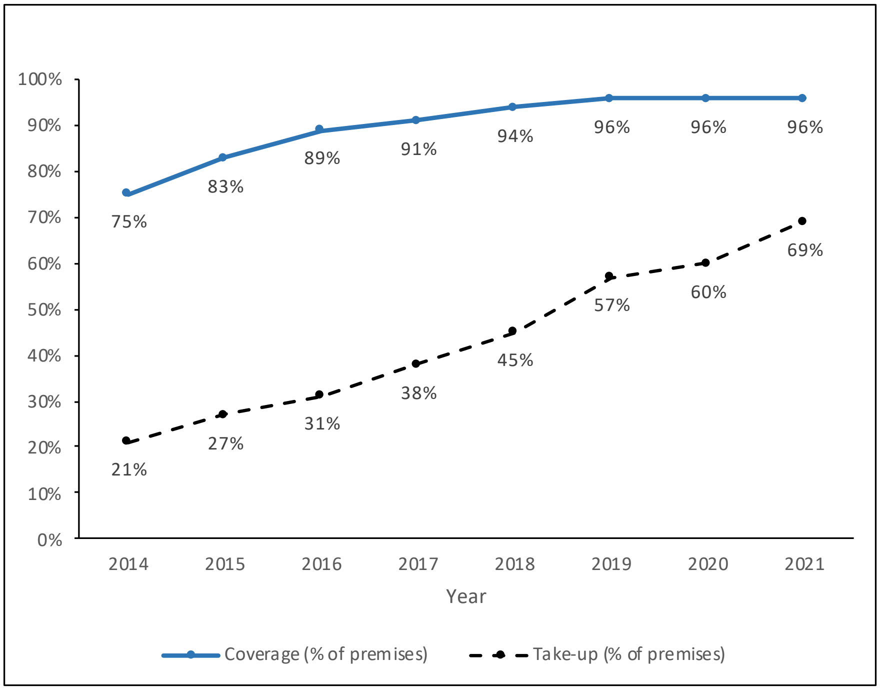
Type of broadband activation by year



Note: This figure shows number of postcodes with different types of broadband technologies activated by year. For example, 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 complete by 2013-14. Since then rural FTTC rollout, supported by the Building Digital UK (BDUK) programs, continued until the end of the period. From 2017, a wave of FTTC extension (FTTC Ext.) targeted upgrading the cabinets to connect more 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 unit postcodes.
(Source: Authors' own calculations.)

Figure 2

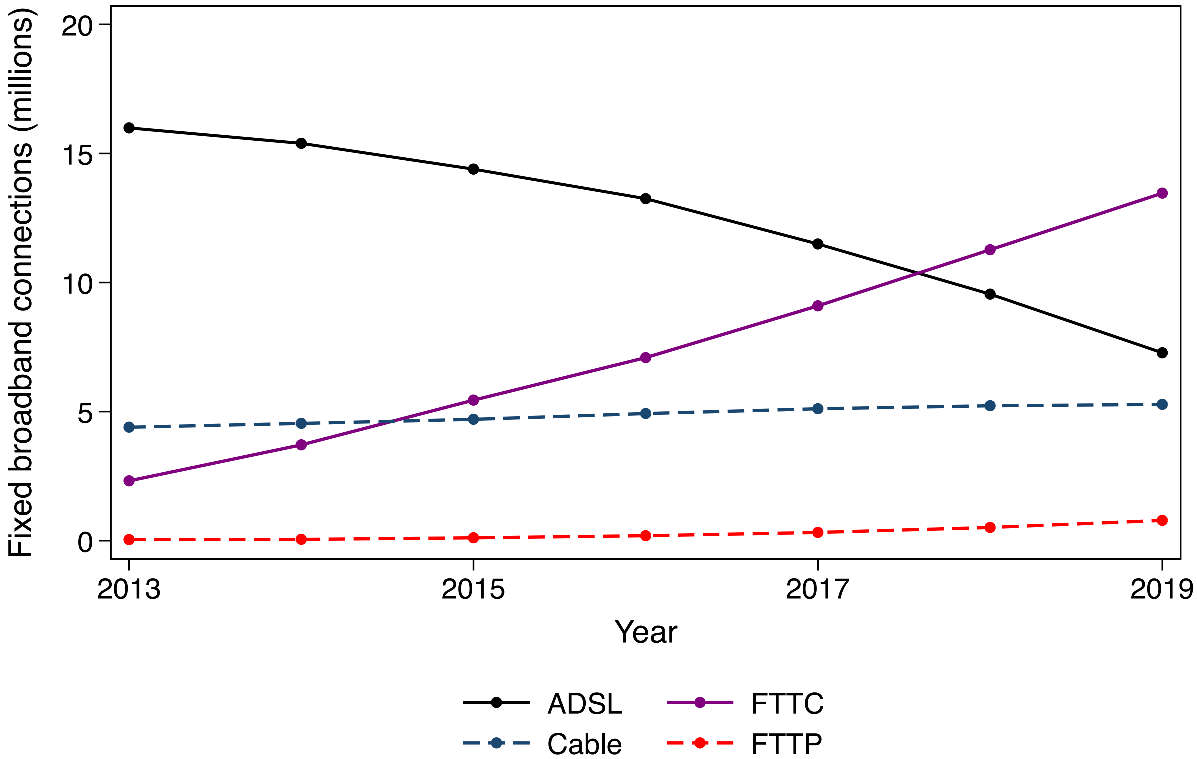
Superfast broadband (>30 Mbps) take-up vs. coverage



Note: This figure reports the percentages of premises in the UK that are covered by or have taken up superfast broadband, which is defined as connections with at least 30 Mbps speed. By 2017, 90% of premises was covered by superfast broadband but the take-up rate was less than 40%.
Source: Ofcom Connected Nations Reports.

Figure 3

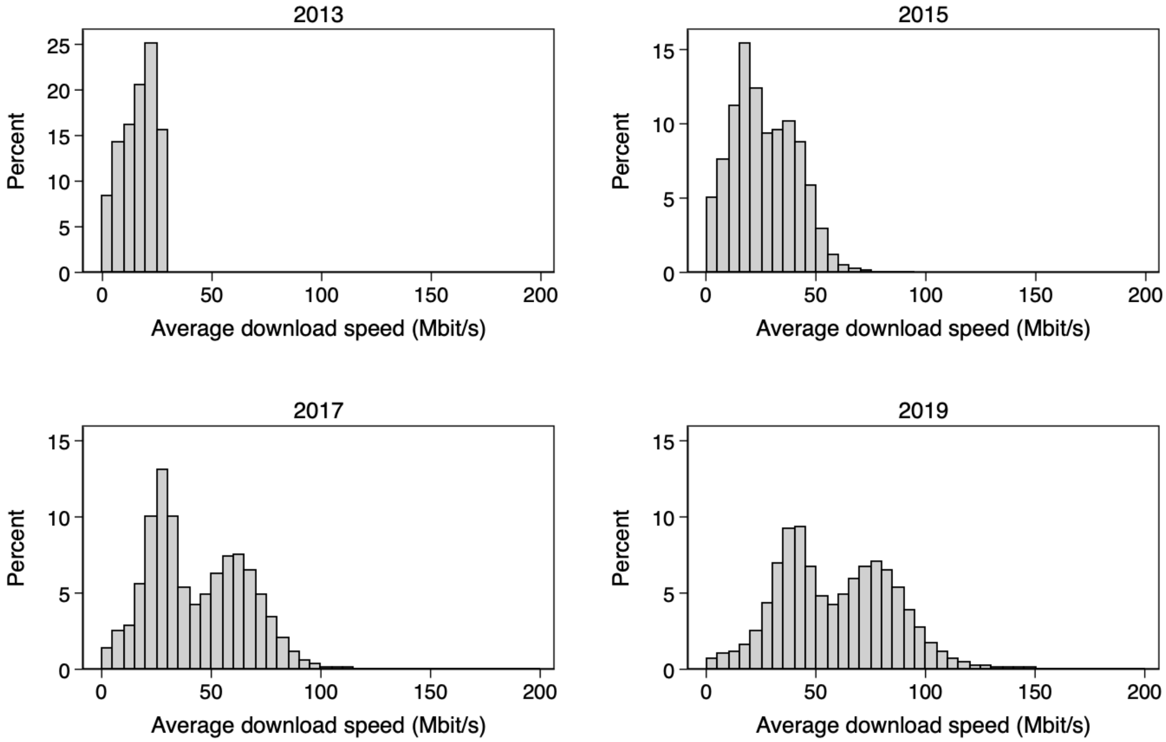
The dynamics of broadband technology adoption



Note: This figure shows the number of fixed broadband connections (in millions) for different types of technologies between 2013 and 2019. The numbers highlight the gradual transition between ADSL (including ADSL2+ and ADSL Max) and FTTC technologies.
(Source: Ofcom Communication Market Report, 2020).

Figure 4

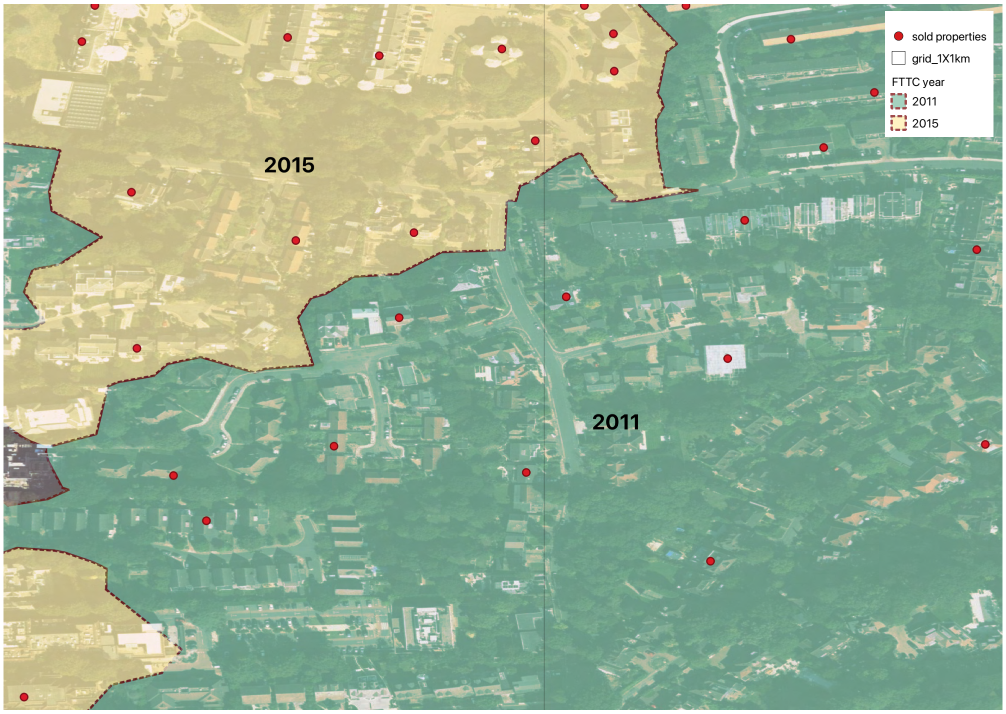
Distribution of average download speed (Mbit/s) by year



Note: The figure shows how the distribution of average download speed changed over time. Note that we use the postcode level speed data and calculate the average speed by the census output area (OA). The right tails of the distributions are truncated at 150 Mbps.
(Source: Ofcom Connected Nations Reports).

Figure 5

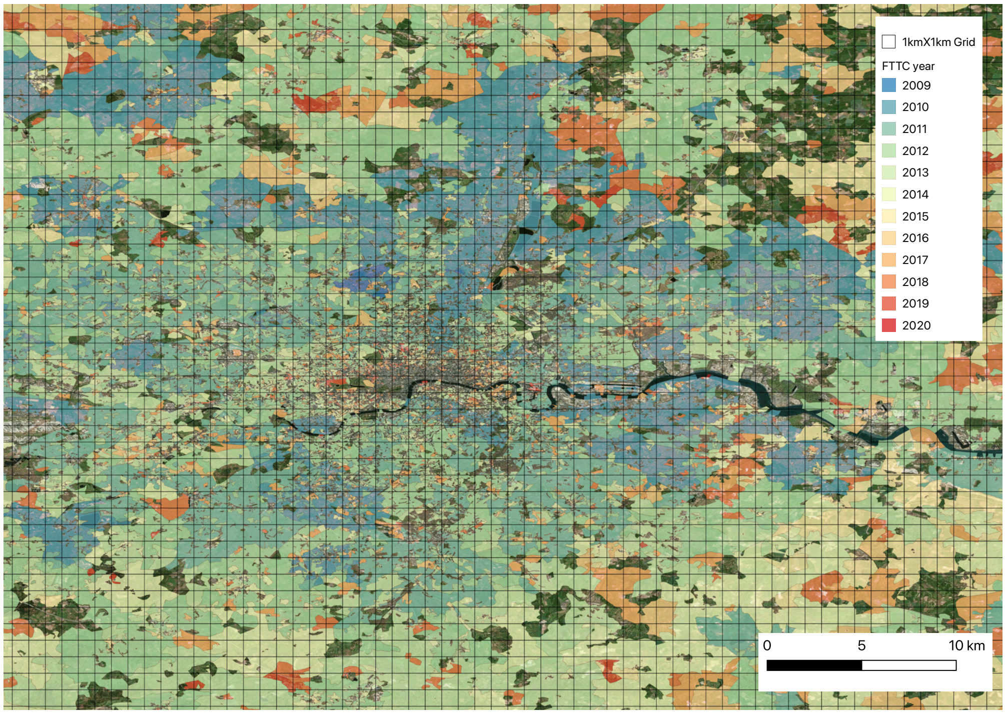
Variation in FTTC activation across neighboring postcodes



Note: This figure shows a typical example of activation boundary from our data. The southeast side (green) of the boundary has been FTTC enabled in 2011 and the northwest side (golden-yellow) is activated later in 2015. The red dots show sold properties.

Figure 6

Grid areas and FTTC activation years



Note: This map shows one square km grids that are constructed to identify the location of the activation boundaries. Note that we further break down the dense grids (i.e., with more than one activation boundaries) into 100 square meters grids. The activation areas (i.e., polygon of postcodes activated in the same year) are shown using different shades of color. The map shows that there is enough variation in the timings of FTTC activation. The map shows a part of the Greater London area.

Table 1: FTTC activation by postcode type

Year of activation	# of postcodes	% urban
2009	5,630	0.99
2010	151,077	0.86
2011	185,931	0.84
2012	294,164	0.88
2013	245,684	0.84
2014	224,852	0.54
2015	192,778	0.35
2016	79,885	0.46
2017	61,966	0.55
2018	32,069	0.45
2019	11,496	0.39

Notes: This table shows the percentage of urban postcodes that were FTTC activated in each year. From 2009-2013, above 80% of the activation took place in urban postcodes.
Source: Authors' own calculations.

Table 2: Summary statistics (Property transaction from 2008-2016)

	Mean	SD	Min	Max
Sale price	202225.26	99970.42	11000.00	500000.00
FTTC activated	0.90	0.30	0.00	1.00
Number of rooms	4.46	1.37	1.00	12.00
Total floor area (sq. m.)	85.01	29.36	24.00	293.00
% Semi-detached	0.32	0.47	0.00	1.00
% Terraced	0.34	0.47	0.00	1.00
% Flat/Maisonettes	0.14	0.35	0.00	1.00
% Leasehold	0.20	0.40	0.00	1.00
% Newly built	0.00	0.05	0.00	1.00
% Building age (1900-1949)	0.30	0.46	0.00	1.00
% Building age (1950-1975)	0.30	0.46	0.00	1.00
% Building age (1976-1990)	0.15	0.36	0.00	1.00
% Building age (1991-2006)	0.15	0.36	0.00	1.00
% Building age (2007 or later)	0.02	0.14	0.00	1.00
Distance from boundary (km.)	0.17	0.17	0.00	1.96
Distance from exchange (km.)	1.56	0.85	0.02	8.79
Distance from cabinet (km.)	0.28	0.30	0.00	21.43
Average download speed (Mbit/s)	33.37	19.21	0.00	646.90

Notes: This table shows the summary statistics of the key variable in our housing sample that was used in the regression analysis. Note that average download speed from Ofcom data is available for only 2013-2016.

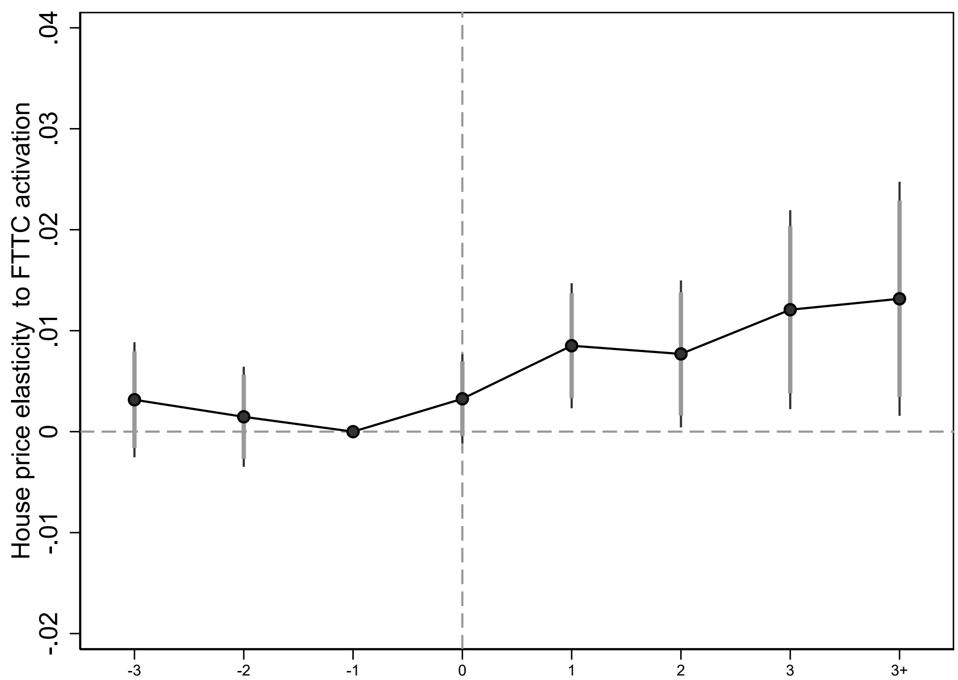
Table 3: Housing price response to FTTC activation (main results)

	Dependent Variable: *ln* (*price*)				
	Baseline	Robustness			Distance from cabinet
	Baseline (1)	No grid restriction (2)	No boundary restriction (3)	No control (4)	Distance (5)
FTTC activated	0.0074***	0.0083***	0.0077***	0.0069**	
	(0.0023)	(0.0022)	(0.0022)	(0.0032)	
FTTC activated for short distance from cabinet(<.2 km) 1					0.0097***
					(0.0034)
FTTC activated for medium distance (.2-.4 km)					0.0085***
					(0.0033)
FTTC activated for long distance (>.4 km)					0.0017
					(0.0044)
Postcode FE	Yes	Yes	Yes	Yes	Yes
Grid × Boundary × Year	Yes	Yes	Yes	Yes	Yes
House controls	Yes	Yes	Yes	No	Yes
Observations	197,168	228,697	267,320	197,168	197,168

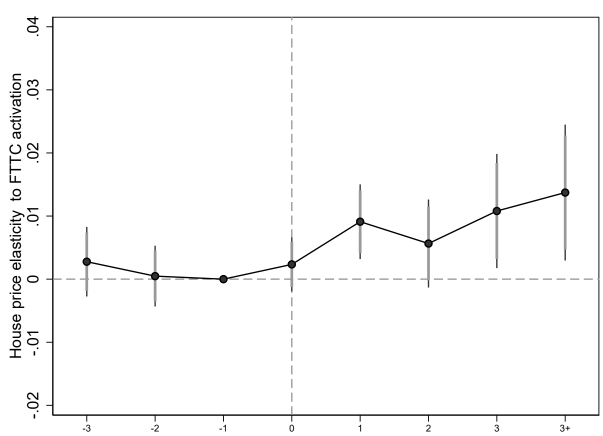
Note: The dependent variable in all columns is the logarithm of the house price. 'FTTC activated' is a dummy variable that takes 1 for all years following the activation year of FTTC. $Grid \times Boundary$ is a a set of fixed effect dummies for the neighboring pairs that located in the same grid on each side of the FTTC activation boundary. 'Grid' is defined as an area that varies from 1 to 0.1 square kilometers. We restrict our samples to the all postcodes that are within 200 meters from 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 total floor area. Standard errors are in parenthesis and clustered by the grid-boundary. *** and ** denote statistical significance at the 1 and 5 percent levels, respectively.

Figure 7

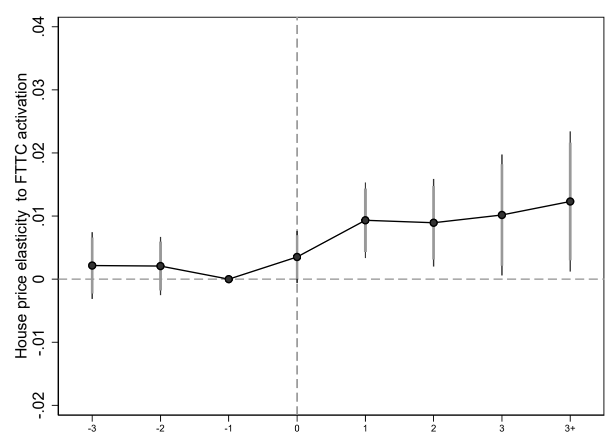
Housing price response to FTTC activation



(a) Baseline



(b) Without grid restriction



(c) Without boundary restriction

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 7a shows the baseline identification, Panel 7b shows the result without any restriction on grid cells, and Panel 7c shows the results without any restriction on the distance from boundaries.

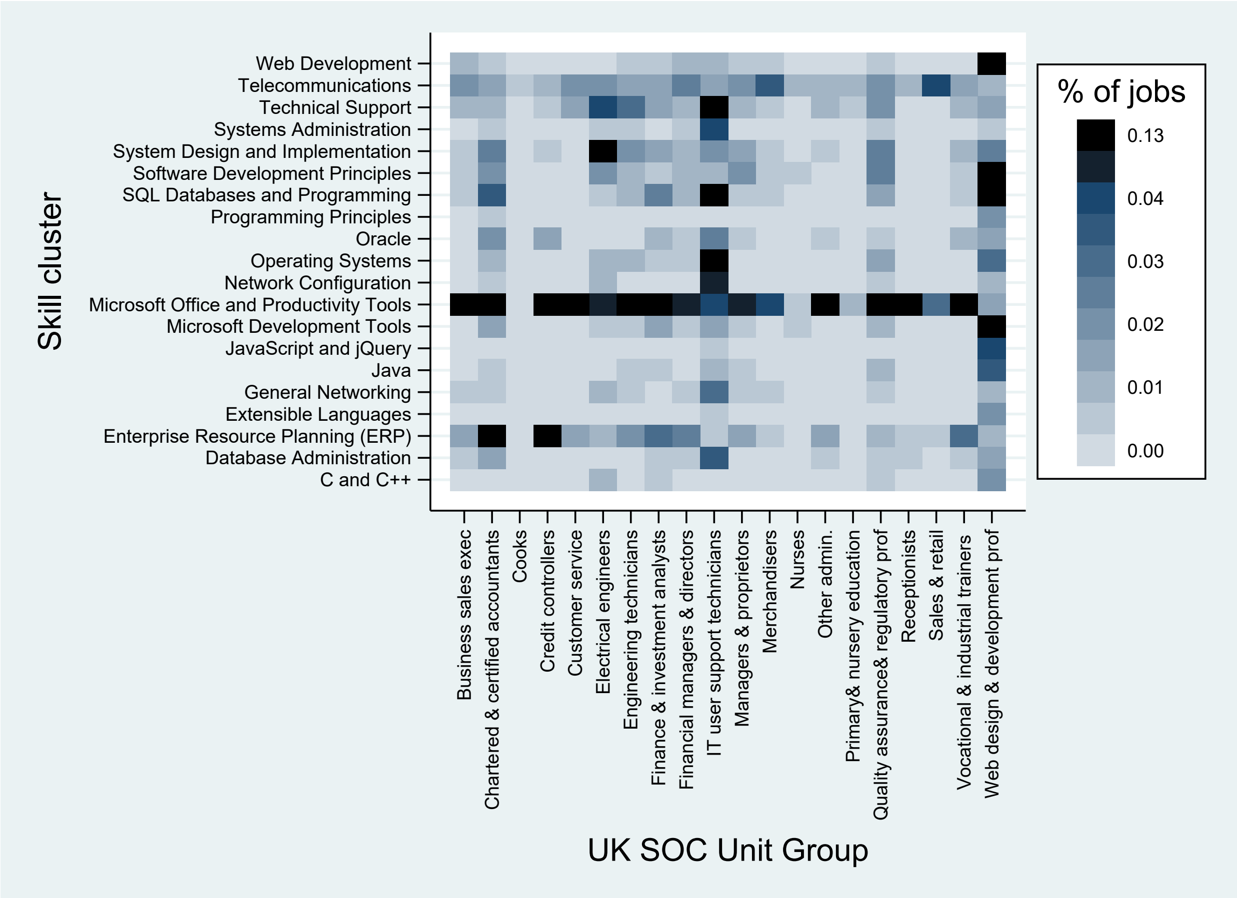
Table 4: House price responses across geographies

	Dependent Variable: ln ($price$)			
	(1)	(2)	(3)	(4)
	London	Rest	<30km (London)	≥30km (London)
FTTC activated	0.0169***	0.0065***	0.0198***	0.0057**
	(0.0064)	(0.0024)	(0.0065)	(0.0024)
Postcode FE	Yes	Yes	Yes	Yes
Grid × Boundary × Year	Yes	Yes	Yes	Yes
House controls	Yes	Yes	Yes	Yes
Observations	16,237	180,926	21,868	175,291

Note: The table reports housing price responses to FTTC activation across geographies. Column 1 and 2 show the results for the London region and the rest of the country, respectively. The next two columns divide the sample by the distance from London. Column 3 shows areas within 30 km from London and Column 4 shows areas more than 30 km away from London. 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 a set of fixed effect dummies for the neighboring pairs that 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 square kilometers. We restrict our samples to the all postcodes that are within 200 meters from 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 total floor area. Standard errors are in parenthesis and clustered by the grid-boundary. *** and ** denote statistical significance at the 1 and 5 percent levels, respectively.

Figure 8

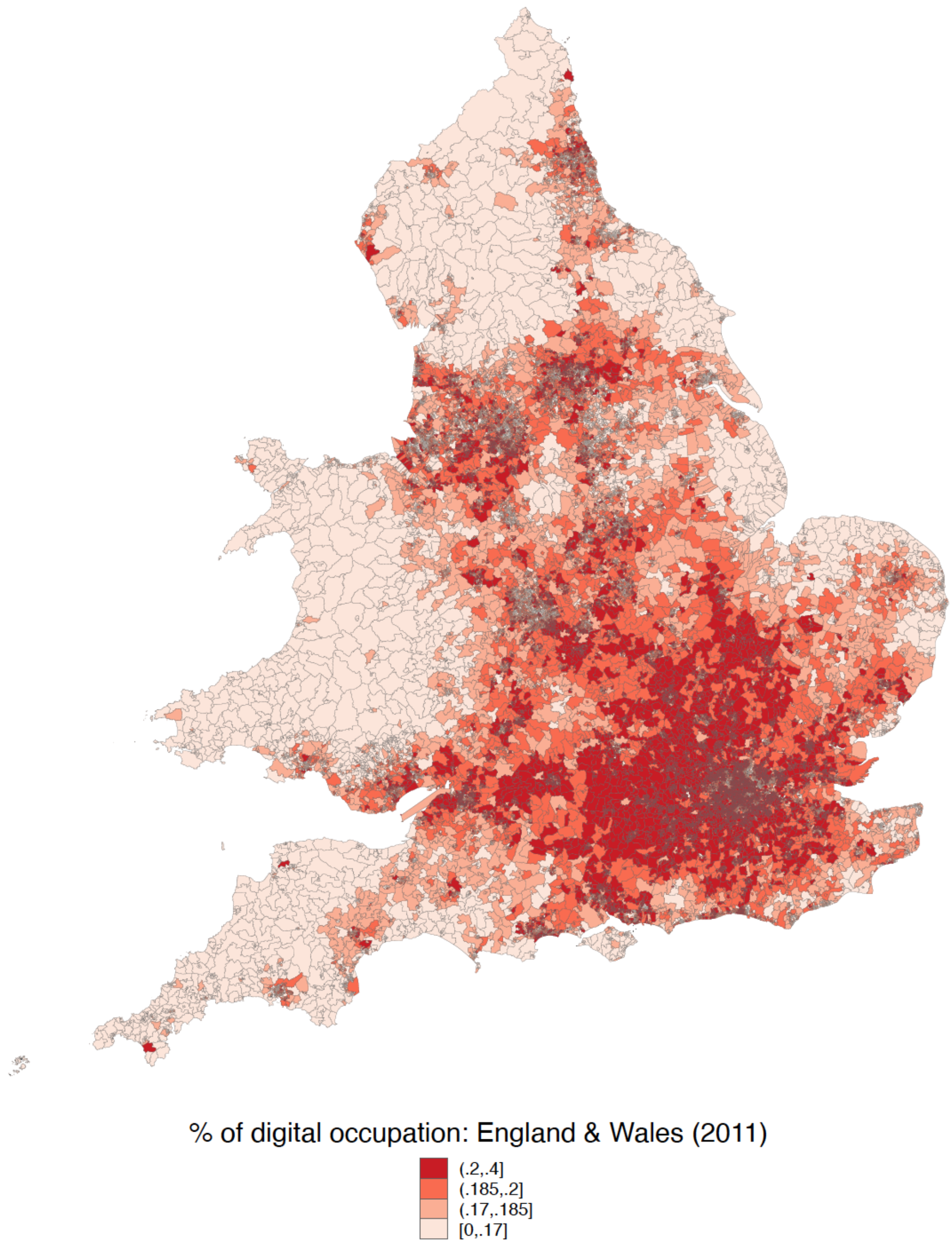
Mapping digital skills to occupations



Note: The figure shows the share of job postings across different skill clusters and 3-digit occupation codes. The vertical axis reports the top-twenty of the most frequently mentioned skill clusters in job postings. The horizontal category reports the top-twenty 3-digit occupation groups by the SOC 2010 occupation classifications. We use the universe of job postings from the 2012 Burning Glass Technologies (BGT). The skill clusters used come from BGT's skill classifications.

Figure 9

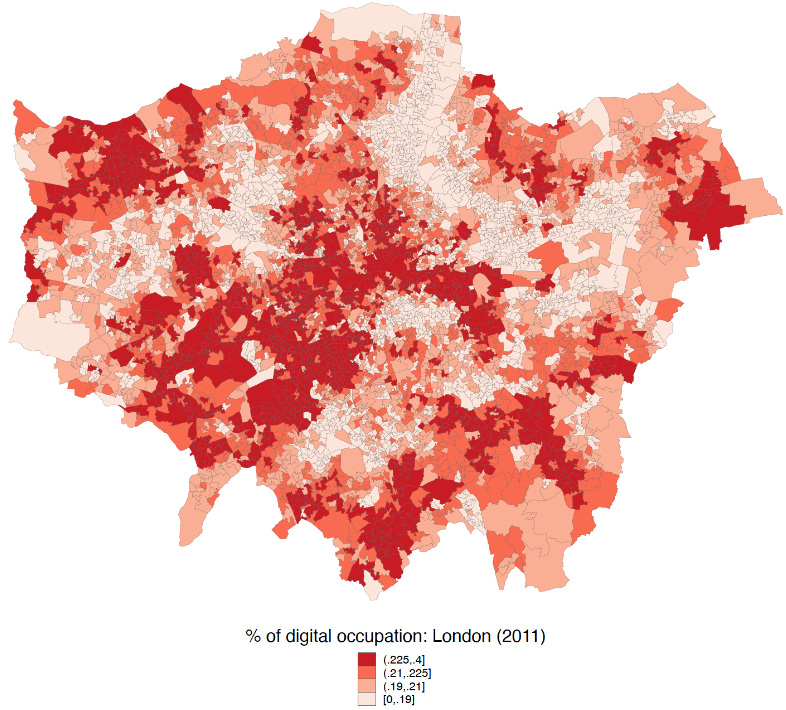
Distribution of digital jobs in England and Wales



Note: The figure shows the share of digital occupations calculated using the BGT job postings and the census 2011. The shares are reported at the LSOA level. The map shows the highest concentration of digital jobs is around London.

Figure 10

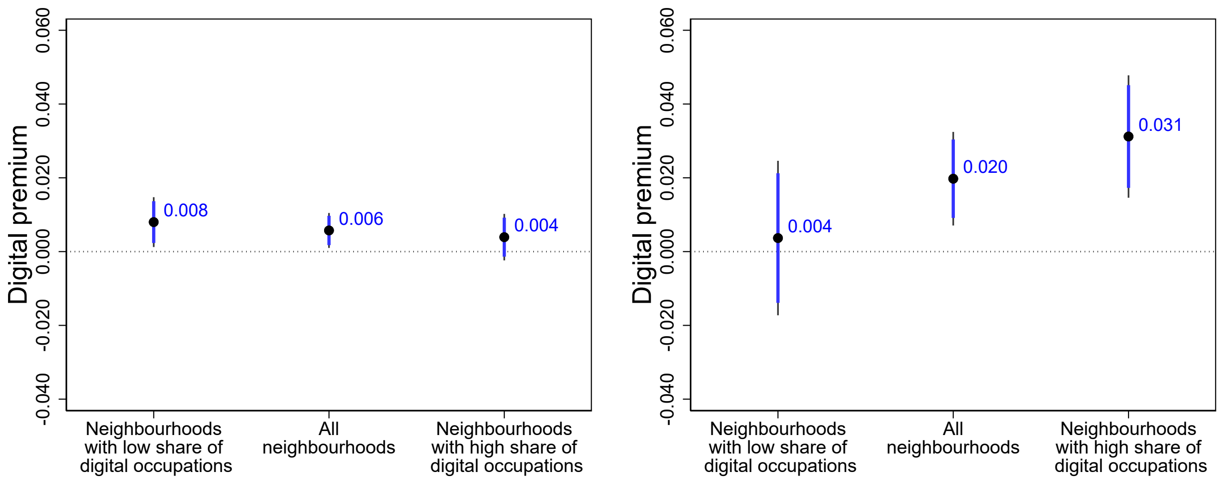
Distribution of digital jobs in London



Note: The figure shows the share of digital occupations calculated using the BGT job postings and the census 2011. The map shows the LSOAs in London region.

Figure 11

Digital premium across neighborhoods with low and high share of digital occupations



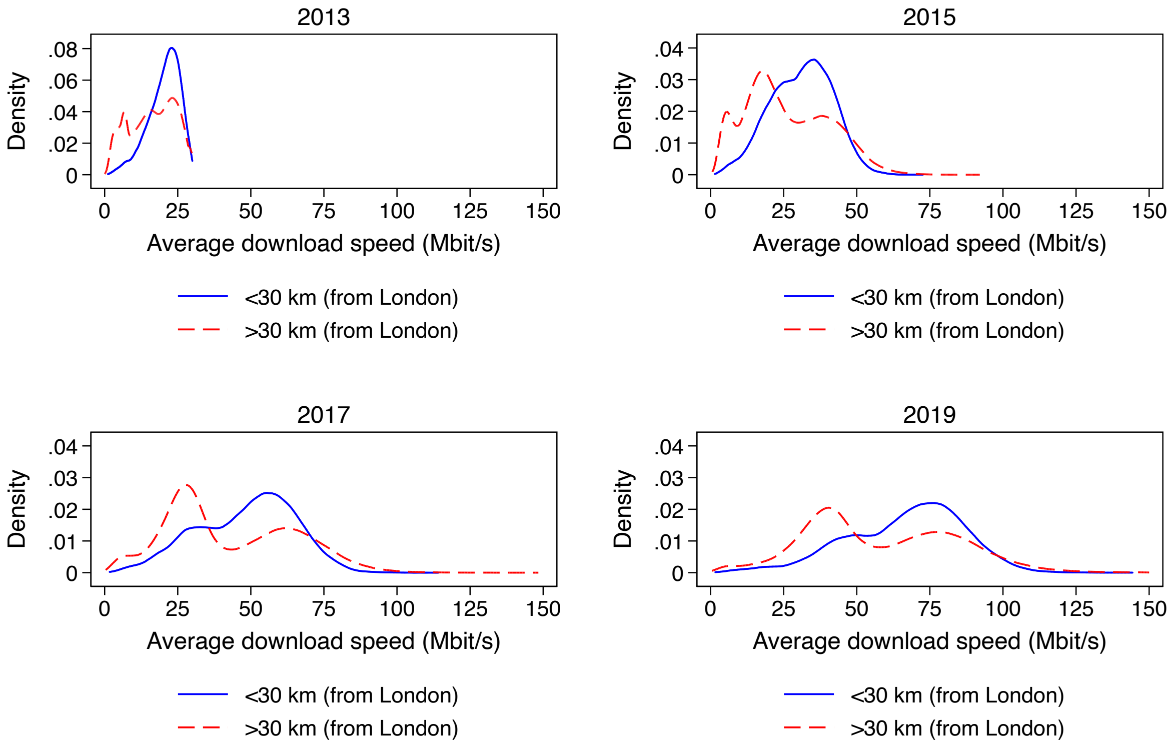
(a) ≥30 km from London

(b) within <30 km from London

This figure shows the effect of FTTC activation across neighborhoods with different occupational compositions. We divide neighborhoods according to the share of their population in digital intensive occupations. To calculate the digital intensity, we map digital skill requirements in job postings to the three-digit occupations. Panel 11a shows the estimated digital premium in house prices when we divide neighbourhoods (LSOAs) that are located more than 30 km away from London into two groups by the median value of the share of digital occupation. The above-median group is the neighborhoods with high share of digital occupations and the below-median group is the neighborhoods with low share of digital occupations. Panel 11b shows the similar results for LSOAs located within 30 km from London.

Figure 12

Distribution of average download speed (Mbit/s) (distance from London)



Note: The figure shows the distribution of average download speed for OAs that are closer to and farther away from London. The right tails of the distributions are truncated at 150 Mbps. Note that the bimodal shape of the distribution that we see nationally (Figure 4) is still visible. But most of the masses at the high-speed peak is coming from the areas closer to London.

Table 5: Digital premium in house prices caused by FTTC activation across deprived areas and ethnic neighborhoods

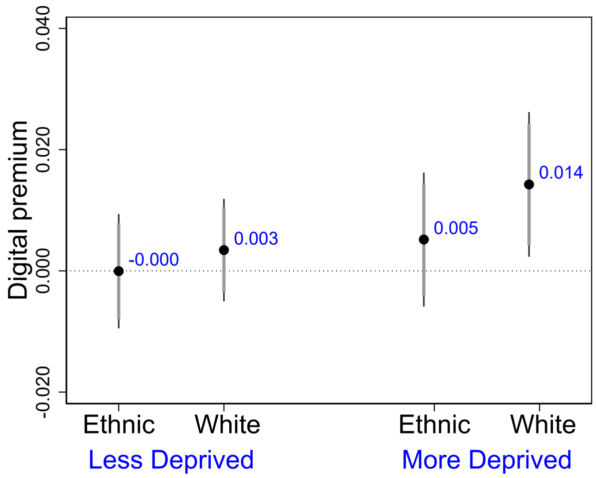
	Dependent Variable: *ln* (*price*)					
	Well-off areas (MSOAs)	Deprived areas (MSOAs)	Well-off areas (MSOAs)		Deprived areas (MSOAs)	
			Ethnic Neighbourhoods (LSOAs)	White Neighbourhoods (LSOAs)	Ethnic Neighbourhoods (LSOAs)	White Neighbourhoods (LSOAs)
	(1)	(2)	(3)	(4)	(5)	(6)
FTTC activated	0.0053*	0.0097***	-0.0000	0.0034	0.0052	0.0143**
	(0.0029)	(0.0038)	(0.0048)	(0.0043)	(0.0056)	(0.0061)
Postcode FE	Yes	Yes	Yes	Yes	Yes	Yes
Grid $\times Boundary \times Year$	Yes	Yes	Yes	Yes	Yes	Yes
House controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	103,810	92,490	50,672	51,704	39,830	51,153

Note: Columns 1 and 2 report the results when we divide local areas (MSOAs) in England according to their deprivation level. In 'Deprived MSOAs,' there is at least one neighbourhood (LSOA) that falls within the most deprived tertile of the country according to the 2010 Index of Multiple Deprivation. Columns 3 to 6 reports the results further dividing each of the deprived and well-off (non-deprived) MSOAs into two groups of ethnic and white LSOAs. To classify ethnic and white LSOAs, we calculate the average share of white people in all residents at each LSOA according to census 2011. For each MSOA, we then divide its LSOAs into two groups. We define an LSOA as white if the share of white people is higher than the MSOA median. Otherwise, the LSOA is considered an ethnic neighbourhood. 'FTTC activated' is a dummy variable that takes 1 for all years after the activation year of FTTC. $Grid \times Boundary$ is a a set of fixed effect dummies for the neighboring pairs that located in the same grid cell and on each side of the FTTC activation boundaries. 'Grid' is defined as an area that varies from 1 to 0.1 square kilometers. We restrict our samples to the postcodes that are within 200 meters from the boundary. House controls include a property type categorical variable (detached, semi-detached, terraced house, 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 total floor area. Standard errors are in parenthesis and clustered by the grid-boundary. *** and ** denote statistical significance at the 1 and 5 percent levels, respectively.

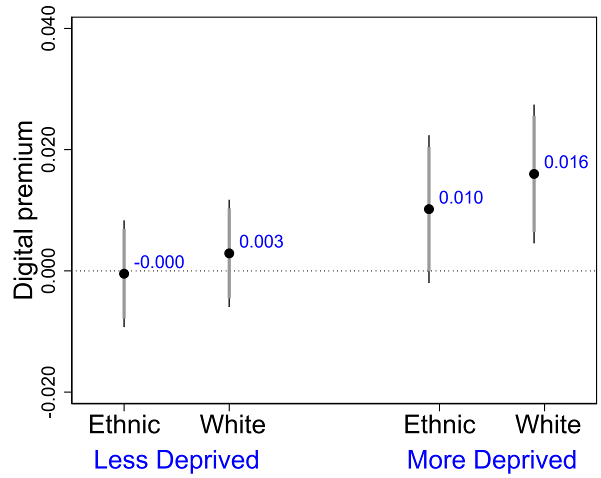
Figure 13

Digital premium in house prices by socio-economic composition of neighborhoods

Dividing MSOAs nationally across England

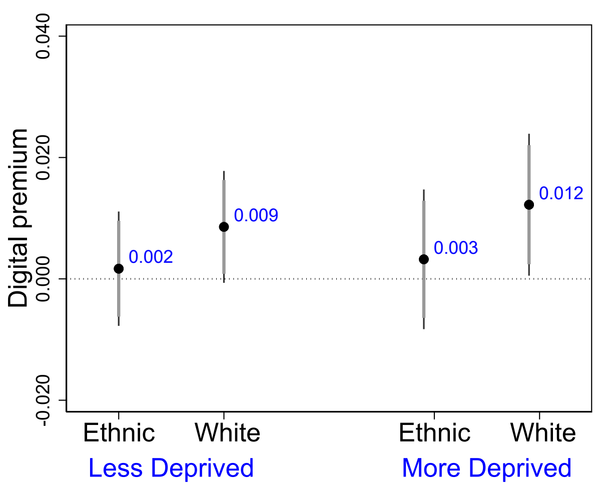


(a) Multi-factor deprivation

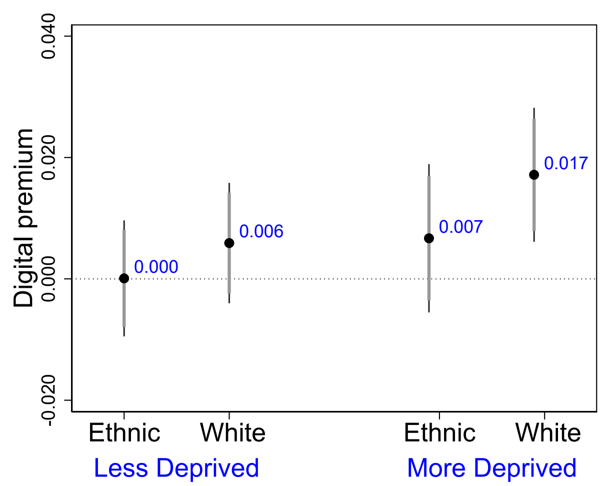


(b) Income deprivation

Dividing MSOAs locally within each local authority (LA)



(c) Multi-factor deprivation

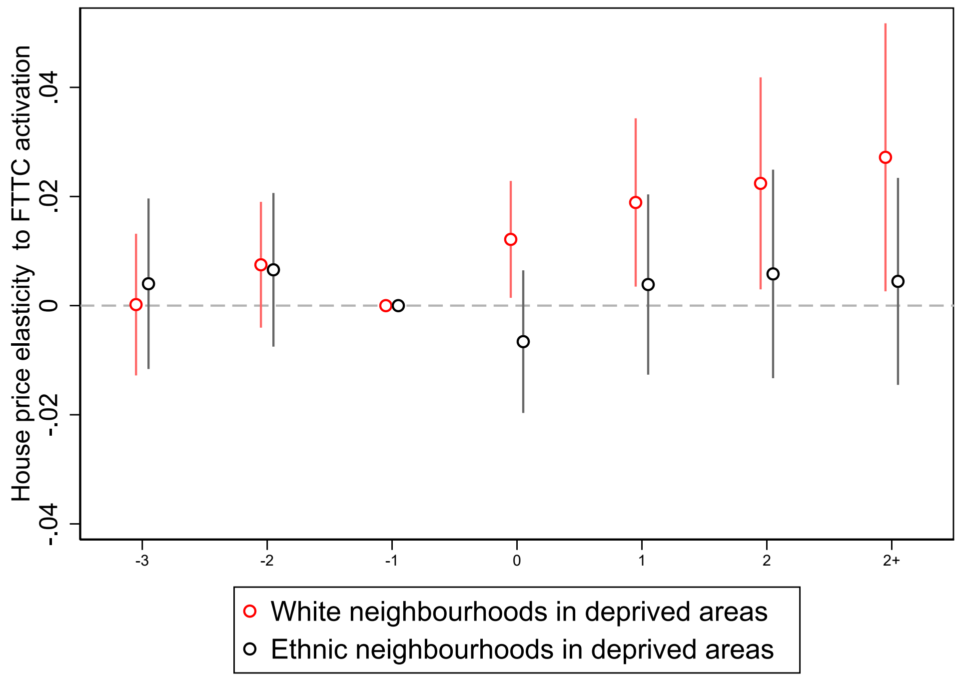


(d) Income deprivation

Note: The figure shows the estimates for digital premium across white and ethnic neighborhoods for deprived or less deprived (i.e., well-off) areas. The top panels classify the deprived areas compared to the bottom tertile of the most deprived LSOAs on a national scale, whereas the bottom panels compare to the bottom tertile of the most deprived LSOAs within the local authority.

Figure 14

Dynamic price responses in deprived areas: White vs. ethnic neighborhoods



Note: This figure shows the dynamic house price responses to FTTC activation across white and ethnic neighborhoods within the deprived areas (MSOAs). The white neighborhoods display a strong response which lasts even after several years following activation.