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Valuing the virtual: The impact of fiber to the home on property prices in France

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ABSTRACT

This paper examines the value that households place on very high-speed internet access, explicitly focusing on the impact of eligibility for Fiber to the Home (FTTH) technology on property prices. Using a Spatial Discontinuity Design based on the border of fiber eligibility zones which have significantly expanded under France's *Très Haut-Débit* plan, I find that FTTH eligibility is a significant determinant of property prices, with an average increase of 0.9 percent. I also consider heterogeneities in FTTH valuation, accounting for socioeconomic characteristics, local factors, and the performance of legacy copper networks. These findings highlight the growing importance of fast and reliable broadband access for households and have important implications for policymakers and Internet service providers.

1. Introduction

The *France Très-Haut Débit* (THD) Plan was unveiled by the French Government on February 20, 2013.[1] The French broadband policy aligns seamlessly with Europe's ambitious 'Digital Decade' vision for the 2020s, which centers on the goal of achieving a fully digital Europe by 2030, emphasizing connectivity and, notably, universal gigabit access.[2] The strategy to achieve the objective of covering the entire territory with very high-speed Internet[3] is largely based on the deployment of Fiber To The Home (FTTH) technology.[4] The deployment of broadband telecommunications infrastructure, similar to major public amenities such as high-speed train networks and highways, has been empirically linked to enhancements in economic wealth and activity (Czernich, Falck, Kretschmer, & Woessmann, 2011; Briglauer & Gugler, 2019), notably bolstering employment growth (Kolko, 2012; Whitacre, Gallardo, & Strover, 2014a), household income levels (Whitacre, Gallardo, & Strover, 2014b; Gallardo & Whitacre, 2018) and productivity (Mack & Faggian, 2013; Gallardo, Whitacre, Kumar, & Upendram, 2021). However, the relationship between these investments and economic inequalities remains ambiguous (Forman, Goldfarb, & Greenstein, 2012; Houngbonon & Liang, 2021; Zuo, 2021). These infrastructure investments can lead to local economic spillovers that benefit economic actors and the aggregate real economy, provided that the digital divide between urban and rural areas is reduced (Clercq, D'Haese, & Buysse, 2023). Given broadband's potential impact on economic wealth, this proactive European policy initiative necessitates rigorous scrutiny. This paper aims to explore the implications of FTTH rollout, directly addressing the pivotal question of its valuation by households.

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[1] The Very High-Speed Internet Plan is part of a European strategy -the Digital Agenda- which aims to provide all European citizens with access to a 30 Mb/s network.

[2] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age_en, accessed in September 2023

[3] ARCEP, the French telecom regulator, defines several levels of quality of bandwidth: High speed: from 512 Kb/s to 29.99 Mb/s; Very High Speed: 30 Mb/s and beyond.

[4] The FTTH implies a connection by an optical fiber line from end to end to the user's home. It is the fixed technology that brings the best performance in terms of downstream and upstream speeds.

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This study focuses on the case of France, which has made significant investments in FTTH network deployment with the objective to generalize FTTH access throughout the country by 2025. In an effort to bridge Europe's broadband penetration gap and accelerate the adoption of new-generation telecom technologies, the *France Très Haut-Débit* plan primarily relies on the deployment of optical fiber, which offers superior performance compared to xDSL technologies (with maximum speeds of up to 10Gbps and low latency). Beyond ensuring enhanced performance and high-quality data transmission, FTTH is presented as a technology aimed at meeting both current and future demands for high-quality internet connectivit (Prat, 2008). By providing ultra-high-speed access, FTTH technology contributes to the emergence of new content (streaming, online gaming, etc.), the intensification of certain practices (increased use of telecommuting, video conferencing, online commerce, cloud-based services, etc.), and the development of new tools (virtual and augmented reality, Internet of Things (IoT) connectivity, multi-device connectivity, etc.). While existing research emphasizes the importance of broadband for households (Ahlfeldt, Koutroumpis, & Valletti, 2017; Liu, Prince, & Wallsten, 2018), the specific advantages and value of FTTH technology for households, due to its enhanced capabilities, still require further exploration. This investigation is important for revealing consumer preferences and for assessing the wider societal and economic impacts of making very high-speed internet widely available.

One method to estimate the value households place on infrastructure is through analyzing the housing market. In this research, I utilize an hedonic pricing model to estimate household valuations for enhanced broadband Internet access. Hedonic pricing models provide a means to determine the willingness to pay (WTP) for non-market goods, such as connectivity. This approach has been effectively employed in various scenarios, including estimating the perceived negative externalities of wind turbines on housing prices (Gibbons, 2015; Dröes & Koster, 2016; Jensen et al., 2018), as well as evaluating the effects of the proximity to nuclear plants (Ando, Dahlberg, & Engström, 2017; Tanaka & Zabel, 2018). To deduce this households' willingness to pay for access to very high-speed Internet, I rely on an evaluation of the impact of the deployment of optical fiber networks in France within the context of the *France Très-Haut Débit* plan on the sale price of properties.

From a theoretical perspective, it is apparent that fiber optic technology exhibits a notable characteristic of real estate properties. Indeed, fiber optics is often considered as a sustainable improvement, this can lead to an increase in the value of the properties that benefit from it (Ahlfeldt et al., 2017). The French regulatory authority for electronic communications, posts, and press distribution (ARCEP) has made tools available on its website,[5] in order to monitor the deployment of the FTTH network in France and to inform consumers about the technologies and speeds available at their addresses. Based on this French open access data, I was able to build a new database combining information on property transactions and information on the internet network and in particular FTTH eligibility for the whole of France in 2019. Using data on fiber eligibility at the level of each building collected by ARCEP, it is possible to reconstruct eligibility zones with the finest precision possible using data made available in Q2-2020[6]. In addition, a French General Directorate of Public Finance database is available to collect all real estate transactions that have taken place, this information is associated with additional information on the property (selling price, characteristics on the type and size of the property ...).

To accurately estimate the valuation of FTTH by households, it is crucial to address several challenges in identifying the impact of fiber eligibility on property prices. One key challenge is disentangling the effect of FTTH eligibility from other positive locational characteristics, such as accessibility to transportation, proximity to schools, or nearby parks. Additionally, the availability of FTTH is endogenous, meaning it is influenced by factors that also determine the demand for FTTH and are likely to be correlated with property prices, such as income levels, education levels, local government policies or demographics.

To overcome these challenges, I leverage the progressive roll-out of FTTH and the construction of eligibility zones to determine the FTTH eligibility status of each property. The gradual deployment of FTTH infrastructure leads to variations in internet speed over time within a very small geographical area. Exploiting this discrete change in the eligibility boundary at a given point in time (the end of 2019), I employ a Spatial Discontinuity Design as an identification strategy. This approach allows me to compare the house prices of neighboring properties that are similar in terms of observable characteristics but differ in their FTTH eligibility status. By isolating the impact of FTTH eligibility in this manner, we can accurately evaluate its effect on property prices.

The findings of this paper underscore a notable and positive price effect of FTTH eligibility. Properties with FTTH eligibility witness an average price surge of 0.9%. A "donut" Regression Discontinuity approach is harnessed to allay apprehensions about non-random sorting around the eligibility threshold. The results also reveal a phenomenon of anticipation in the few months preceding actual FTTH eligibility. Sensitivity analyses and placebo tests further fortify our claims of FTTH eligibility's causal relationship with property prices. The sensitivity analysis demonstrates the consistent positive coefficient associated with fiber eligibility across varying analysis windows. Furthermore, the placebo test reveals no significant effect as the cut-off is shifted away from the actual eligibility boundary. These results further corroborate the causal relationship between FTTH eligibility and property prices.

The study goes beyond property price analysis to explore heterogeneity in FTTH valuation. Subgroup regressions unveil variations in the magnitude and significance of the effect based on the rural or urban context of the municipality where the property is located. The highest valuation of FTTH access (both in percentage and monetary terms) is observed in the most rural municipalities,

[5] In the form of interactive maps at the following web address: https://maconnexioninternet.arcep.fr/.

[6] The strategic choice of Q2-2020 as the reference period is pivotal, coinciding with the initiation of extensive updates in the database of fiber-eligible addresses through the "Ma connexion internet" tool. This timing ensures the derivation of reliable estimates for both already connected and pending connections. Furthermore, this data snapshot is selected for its relevance, being dated six months prior to this analysis, thereby encompassing the entirety of 2019 for comprehensive coverage. This temporal framing enhances the reliability and relevance of the analysis, aligning with the objective to provide a detailed and accurate assessment of FTTH eligibility. For a deeper insight into the specifics of the data update process, please consult the ARCEP website at https://www.arcep.fr/actualites/actualites-et-communiques/detail/n/marche-du-haut-et-du-tres-haut-debit-fixe-6.html, accessed in April 2023.

and then gradually decreases until it is no longer significant in medium-sized municipalities. On the other hand, a significant but smaller effect is found in the largest cities (>200,000 inhabitants). This finding can be attributed to the baseline quality of ADSL connections. Specifically, the poorer the quality of pre-existing ADSL speeds, the greater the perceived value of FTTH access, which offers consistent very high-speed internet without the variability seen in ADSL connections. It also appears that it is on the periphery of large towns that the value of fiber is the greatest, more than in the city centers, which may confirm the hypothesis that the value of access to FTTH stems from the greater use of teleworking. Additionally, the analysis reveals that the greatest increase in FTTH valuation occurs in the poorest quartile of municipalities, indicating the potential transformative power of fiber infrastructure in economically disadvantaged areas.

These findings highlight the positive impact of FTTH eligibility on property prices, underscoring the significant value households attribute to enhanced broadband connectivity. It also reveals the importance of considering heterogeneities in FTTH valuation based on socioeconomic characteristics, local factors, income levels… These insights are valuable for policymakers and stakeholders involved in expanding FTTH coverage, particularly in rural and economically disadvantaged regions.

The remainder of this paper is organized as follows. Section 2 describes the data used in this study. Section 3 introduces the identification strategy. Section 4 presents the results. Section 5 concludes.

2. The French broadband infrastructure

2.1. Context

Competitive landscape Since the 1990s, European electronic communications markets have gradually opened up to competition. A regulatory framework was established not only to facilitate this evolution, but also to protect these markets from potential abuses of dominant positions by both public and private monopolies that historically operated within them. Similar to most European markets, the French electronic communications market has also experienced this transformation.[7] In 2019, the timeframe of this study, the consumer electronic communications market in France was dominated by four major fixed and mobile operators,[8] engaged in intense competition that has led to some of the lowest prices in Europe. This market is also distinguished by significant investments (among the most dynamic in Europe) due to the rollout of fiber across fixed networks, where Orange, the incumbent operator, maintains a substantial presence.[9] The retail market for generalist offers has seen a rapid acceleration in the marketing of very-high-speed broadband offers,[10] while broadband accesses have fallen by around 10% over the same period.[11] This retail market, with four main players, is also dominated by Orange.[12]

The France très-haut débit plan and the decommissioning of the copper network There are two main fixed-line broadband technologies that coexist in France: xDSL, in particular ADSL (Asymmetric Digital Subscriber Line), and FTTH. Primarily, there is a physical difference between these two technologies: one relies on the copper network deployed for fixed-line telephony, while FTTH uses end-to-end optical fiber between the optical connection node and the subscriber. This physical difference implies significant differences in characteristics and quality. The most important is the potential bandwidth that each of these technologies can deliver: ADSL bandwidths can range from 1 to 15 megabits per second, while FTTH bandwidths can vary from a minimum of 100 Mbps to 8 Gbps. FTTH can be seen as an improved version of ADSL, offering very high-speed access (when ADSL offers high-speed) and low signal attenuation, for a more stable connection. Fiber optics is therefore the medium that offers the best performance and scalability.

Driven by major public policies, two opposing trends are underway in France. On the one hand, the massive rollout of FTTH through the *France Très Haut Débit* plan, and on the other, the decommissioning of copper and the dismantling of the copper network from 2023 by the incumbent operator, Orange.[13] Because of its physical characteristics, based on the fixed telephone network, the ADSL network covers 99% of the country (30 million copper lines), so in the 2000s, most French households benefited from ADSL. In February 2013, the Government defined the *France Très Haut Débit* plan, which succeeds an other national very high-speed broadband program launched in 2010. Among the 20 billion euros proposed by the State to develop access to very high-speed broadband for all, 3 billion euros in subsidies have been provided to support local authority projects led by Public Initiative Networks, with the aim of covering 100% of the population with broadband Internet (with a significant proportion of other broadband technologies) by 2022. The goal was to achieve fiber connectivity for 80% of premises by 2022, and then to generalize FTTH access throughout the country by 2025. As shown in Fig. 1, the number of premises eligible for fiber increased from 2.3 million in the fourth quarter of 2012 to 10.3 million in the fourth quarter of 2017. In 2020, a record year, 5.8 million premises became

[7] https://www.tresor.economie.gouv.fr/Articles/2023/01/17/la-concurrence-dans-le-marche-francais-des-communications-electroniques, accessed in February 2024.

[8] France counts four MNOs: Orange; SFR; Bouygues Telecom; Free Mobile.

[9] Orange was responsible for 56% of fiber optic fixed access deployments in France by the end of 2021, https://www.arcep.fr/uploads/tx_gspublication/consult-adm-fixes-bilan-et-perspectives-juillet2019.pdf, accessed in February 2024.

[10] With 9.4 million accesses in 2021, experiencing 61% growth between 2017 and 2019.

[11] Conventionally, when referring to these "new" fiber networks, very high-speed broadband is distinguished from high-speed broadband by a downstream speed greater than or equal to 30 Mbps. However, this distinction does not equate to a segmentation of technologies, as for some, the maximum speed available to the end customer depends on the technical characteristics of his or her line and active equipment. https://www.arcep.fr/uploads/tx_gspublication/consult-adm_3a-fev17.pdf, accessed in February 2024.

[12] https://www.arcep.fr/uploads/tx_gspublication/consult-adm-fixes-bilan-et-perspectives-juillet2019.pdf, accessed in February 2024.

[13] https://www.arcep.fr/actualites/actualites-et-communiques/detail/n/fermeture-du-cuivre-290722.html, accessed in June 2023

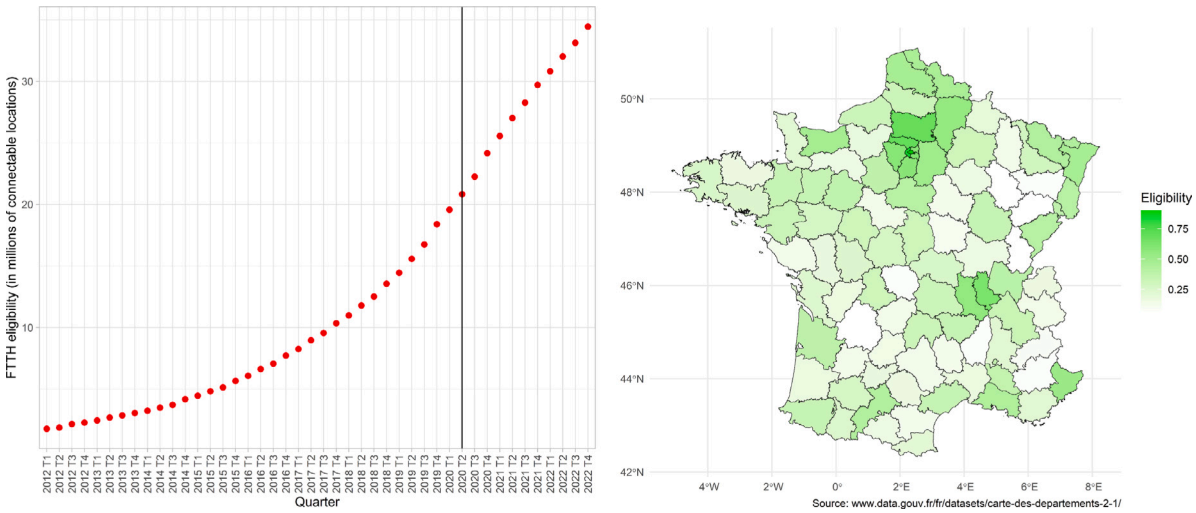

Fig. 1. The graph on the left shows the evolution of the number of premises (in millions) eligible for fiber in France since 2012, by quarter. The black bar represents the point in time chosen for this analysis: Q2-2020. The chart on the right shows all French départements and their fiber optic eligibility rates in Q2-2020.

eligible for fiber connectivity.[14] In total, by the end of the 1st quarter of 2020, 25.2 million premises were eligible for very-high-speed services, all technologies combined, including 18.6 million outside very dense areas.[15] Consequently, the deployment of fiber optic networks is setting the stage for what is emerging as the fundamental infrastructure for France's digital future.

The transition from copper to FTTH for high bandwidth and low latency has also been reflected in household preferences, with ultra-high-speed broadband enabling several additional uses,[16] highlighting a significant trend in household preferences regarding broadband services. Some studies (Grzybowski & Liang, 2015; Grzybowski, Hasbi, & Liang, 2018) have concluded that consumer valuation of FTTH broadband experienced a consistent increase over time, while the attractiveness of ADSL relative to FTTH decreased significantly, both in relative terms and absolute terms. These results indicate a clear shift in consumer priorities, with an increasing emphasis on the speed of connection provided by FTTH. Households are placing greater importance on the ability of their internet connection to deliver very high-speed performance, and FTTH is meeting these evolving expectations more effectively than ADSL.

Regulating fiber rollout in France Ahead of the deployment of the "new" fiber networks, the regulatory framework in France was completed in the early 2010s. ARCEP plays a major role in the roll-out of fiber in France, and has defined 3 types of zone to divide the role between private operators and local authorities,[17]: very dense zones, where private operators roll out their own network; relatively less dense zones, where operators show interest or join forces to roll out fiber; and lastly, less dense and less "profitable" zones, where the network is rolled out by local authorities, mobilizing public funding. Within this *Plan Très haut débit*, operators have committed to respecting FTTH network deployment objectives, and the Government has entrusted the ARCEP with the task of monitoring compliance with these commitments and sanctioning any failures to do so.[18] This has led to the creation of tools such as "Ma connexion internet" to regularly monitor premises that are not yet eligible for fiber. The ADSL broadband network remains a significant challenge, with the absence of FTTH alternatives in numerous instances. Consequently, regulatory authorities are committed to ensuring that the copper network's service quality meets the needs of its reliant users. Simultaneously, they are facilitating the transition towards fiber in regions where it has been extensively rolled out.

2.2 Data

To address the research question, a method was developed to integrate a comprehensive set of quarterly databases covering the period from Q2-2018 to Q4-2021 at the address level for the entire French metropolitan territory. This analysis encompasses 90

[14] https://www.amenagement-numerique.gouv.fr/fr/actualite/raccordements-ftth-etape-determinante-deploiements, accessed in February 2023

[15] The expedited deployment of FTTH, with the goal of universal eligibility for French residences in the medium term, highlights the importance of examining the FTTH eligibility frontier at a particular juncture within the deployment timeline. This methodological choice enables a more precise estimation of the impact of FTTH eligibility on property prices. Conducting this analysis amidst the peak phase of eligibility expansion strategically reduces the risk of endogeneity.

[16] Ultra-fast download and upload speeds, seamless streaming and online gaming, multiple device connectivity, cloud-based services and storage, video conferencing and telecommuting, virtual and augmented reality (VR/AR), Internet of Things (IoT) connectivity.

[17] https://www.arcep.fr/nos-sujets/la-couverture-internet-fixe-a-haut-et-tres-haut-debit.html, accessed in June 2023

[18] In accordance with Article L.33-13 of the French Post and Electronic Communications Code.

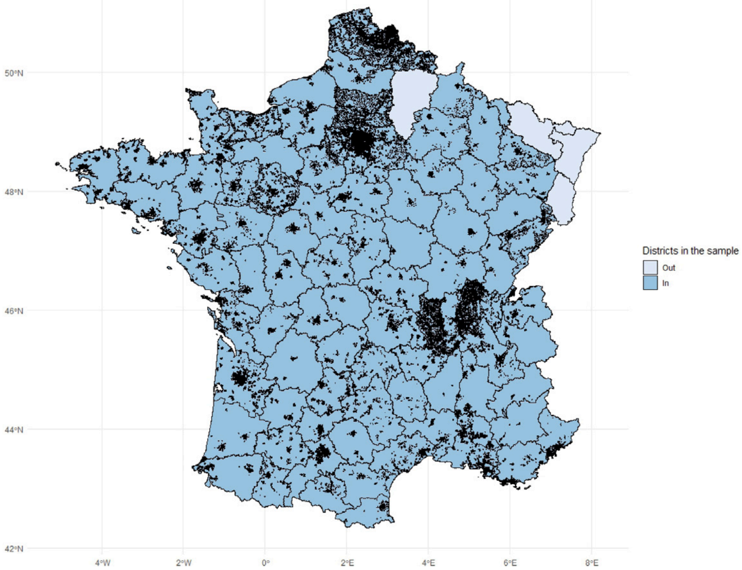

Fig. 2. Districts in the sample and FTTH eligibility areas at the end of 2019: 90 districts are included in the analysis. Some departments shown in light blue are not included in the sample. The Direction Générale des Finances Publiques, which produces the 'Demande de Valeurs Foncières' data, does not have the data for the French departments of Bas-Rhin (67), Haut-Rhin (68) and Moselle (57) for metropolitan France, due to the application of a local law. All transactions are recorded in the Livre Foncier, but the data is not currently open. The department of Aisne (02) is also not included in the analysis due to problems in processing FTTH eligibility data within the Ma connexion internet database. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

departments.[19] Fig. 2 illustrates the included departments and the corresponding FTTH eligibility areas at the end of 2019. The method involved merging two main datasets: one providing information on the broadband internet network at each address, and the other compiling all property transactions that occurred in France over the past 5 years. Since there was no common joining key available, the developed method played a crucial role in facilitating the merging process.

I specifically rely on the data files sourced from the French telecom authority allowing the construction of FTTH deployment maps with precision at the building level for every quarter since the second quarter of 2018 as shown in Fig. 3. These data were obtained from the "Ma connexion internet" tool,[20] which includes two sub-databases: one listing all addresses (the building database), and the other associating building identifiers with network characteristics such as internet speeds, fiber eligibility, and operators offering these technologies. To achieve the first research objective of merging fiber eligibility data with geospatial data sources, several steps were undertaken, as depicted in Fig. 4. I utilized fiber eligibility files to map out the history of FTTH deployment at the building level. This process involved using geospatial data, in particular based on the GPS coordinates of each dwelling, to generate Voronoi polygons, each encircling its respective point with a 30-meter radius.[21] These Voronoi diagrams facilitated spatial division into cells, each cell's proximity to a seed point indicating a specific quarter's FTTH eligibility. The polygons were subsequently aggregated to compile a comprehensive map of FTTH eligibility zones that align with the dataset for Q2-2020. It is important to note that due to the update cycle of the FTTH database, the data incorporated in Q2-2020 actually reflects the properties that were eligible for FTTH by the close of 2019.

The second dataset used was the "Demande de Valeurs Foncières" (Land Value Request) database, which is published and produced by the French General Directorate of Public Finance. This database provides information on property transactions that occurred in metropolitan France over the last five years, including transaction prices and property characteristics. The eligibility status of an address in a given quarter was determined based on whether the very high-speed internet connection capacities had been effectively deployed or if an agreement had been signed, meaning that the property will soon be eligible for FTTH,[22] by projecting coordinates of the transactions from the "Demande de Valeurs Foncières" database that occurred in 2019 onto the FTTH eligibility area in Q2-2020, which reflects the status at the end of 2019. This comprehensive merging method resulted in a unique dataset

[19] Excluding some departments due to their exclusion from the property transactions database (Bas-Rhin, Haut-Rhin, and Moselle) or flaws in the ARCEP database (Aisne).

[20] https://maconnexioninternet.arcep.fr/, accessed in January 2023.

[21] For all the map processing functions, I used the package sf and the package "qgisprocess" which allows the use of the commands of the software QGIS (Open Source geographic information system) with the interface R.

[22] The other properties including the buildings "connectable on demand", "in the process of being connected" or "targeted for future deployments" are considered as non-eligible.

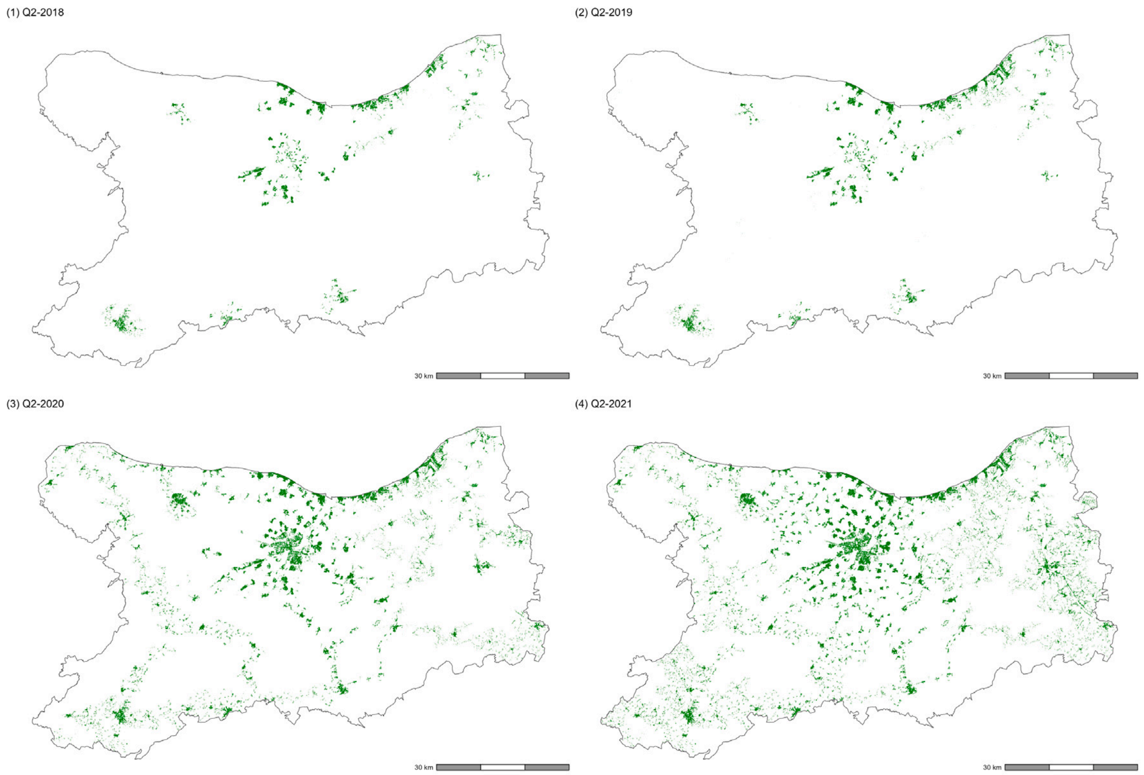

Fig. 3. Evolution of FTTH eligibility zones in the Calvados district (14) between Q2-2018 and Q2-2021.

that indicates the fiber eligibility status of each property at the time of the transaction and the distance to the nearest eligibility boundary.

To incorporate additional situational feature variables that could impact property prices, the "OpenStreetMap" databases at the department level were employed. These databases contain various geographical information, such as data on roads, footpaths, cafés, railway stations, and points of interest. Three map files were utilized: "points.shp" for calculating the distance to the nearest school, "buildings.shp" for deducing the proximity to the nearest railway station, and "natural.shp" for calculating the distance to the nearest park.[23] Also, in an attempt to take into account pre-existing ADSL quality, the distance to the nearest subscriber connection node was calculated using the OpenStreetMap map of subscriber connection nodes (NRA).[24] Furthermore, information at the commune level was added for heterogeneity analyses, based on indicators provided by INSEE for the year 2016.[25] Two variables were used: average income at the commune level and the degree of urbanity. Basic descriptive statistics of the variables used in the analysis by treatment group are provided in Table 7 in Appendix.

3 Methodology

3.1 Spatial discontinuity design

Measuring the effect of fiber eligibility on housing prices presents several challenges. The objective of this methodology is to isolate the impact of fiber eligibility from other factors that affect property prices and may be unobserved but correlated with FTTH eligibility. Additionally, endogeneity may arise due to the interplay between FTTH eligibility and factors influencing broadband demand, potentially leading to correlations with property prices.

[23] This data is sourced from the OpenStreetMap project, an open-source initiative for community-driven mapping. It is provided at the departmental level, with department boundaries based on the "Contours des départements français" from OpenStreetMap. The "buildings.shp" file details built-up areas as polygons, "points.shp" enumerates points of interest with GPS coordinates, and "natural.shp" outlines green spaces as polygons. For further details, visit https://www.data.gouv.fr/fr/datasets/carte-des-departements-2-1/, accessed in January 2024.

[24] https://www.data.gouv.fr/fr/datasets/localisations-des-noeuds-de-raccordement-abonnes-nra-et-optiques-nro-dans-openstreetmap/, accessed in January 2024.

[25] https://www.data.gouv.fr/fr/datasets/data-insee-sur-les-communes/, accessed in May 2023

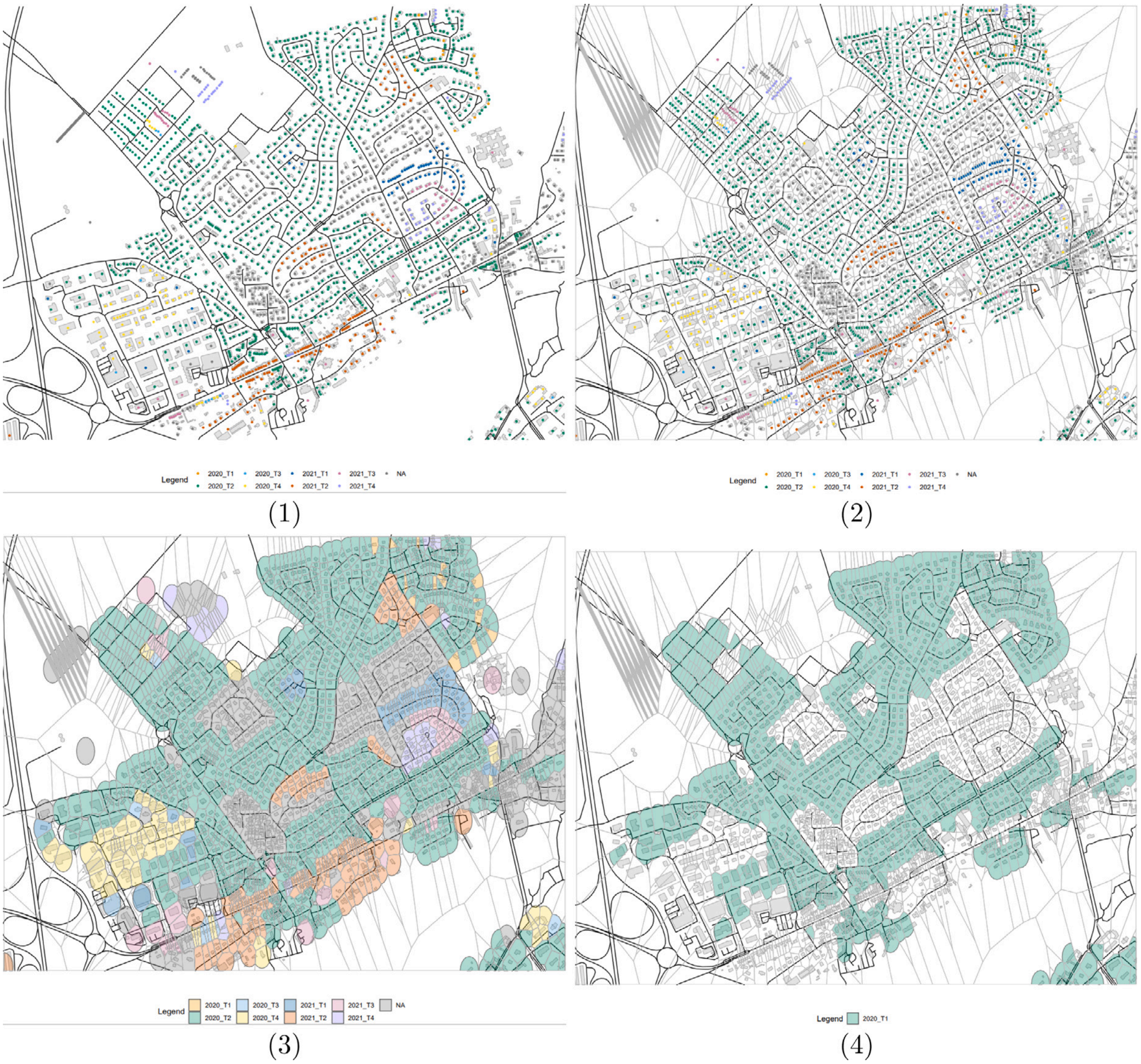

Fig. 4. Method for constructing FTTH eligibility boundaries: The series of four maps illustrates the methodology employed to merge an exhaustive set of quarterly databases, spanning Q2-2018 to Q4-2021, at the address level for the entire metropolitan French territory, encompassing 90 departments. Given the absence of a common joining key, the study meticulously progresses through the following stages to delineate the FTTH eligibility zones: Map (1) is displaying the projected points from ARCEP, each residence is tagged with a specific quarter indicating fiber eligibility; Map (2) is showcasing Voronoi polygons, these are constructed and circumscribed by a 30 m radius centered on each dwelling. Map (3) is illustrating the merging process, layers are conjoined based on fiber eligibility status and eligibility timeframe. Map (4) is depicting the comprehensive FTTH eligibility zone as of Q2-2020.

To address these challenges, the methodology employs a spatial discontinuity design based on fiber eligibility zones to evaluate the effect of FTTH eligibility on property prices. The FTTH connection represents a discrete change that allows properties to access higher-quality internet connectivity. Since the assignment rule is deterministic, this spatial discontinuity design adopts a sharp approach where the treatment probability (optic fiber eligibility of the property) changes from 0 to 1 at the eligibility cutoff.

The spatial discontinuity design combines elements of both quasi-experimental and randomized experimental methods. In the spatial discontinuity framework, treatment assignment is non-random but determined by a covariate's value on either side of a threshold—the eligibility boundary in this case. Additionally, this spatial discontinuity approach mimics the essence of a randomized experiment at a localized level (Chaplin et al., 2018; Bertanha & Imbens, 2020). The discontinuity regression aims to compare housing prices on opposite sides of the eligibility boundary, leveraging the naturally occurring variation near the boundary. The running variable is the distance from the FTTH deployment boundary at the time of the study. By focusing on observations in close proximity to the FTTH deployment boundary, a non-parametric estimation approach is employed, using a naive and arbitrary distance (e.g., 35 meters for the baseline estimates) to select relevant observations. Since the eligibility zone expands over time, the

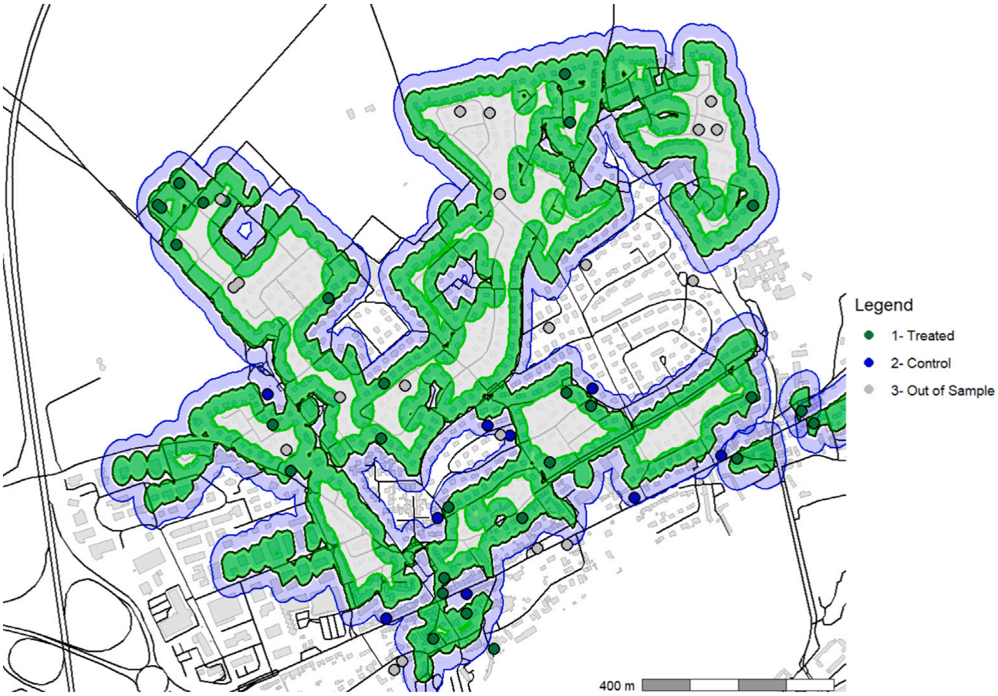

Fig. 5. Map depicting the spatial distribution of property transactions and FTTH eligibility zones in Bretteville-sur-Odon (14760). The green zone demarcates FTTH eligibility, with the intensified green bandwidth (ranging from 7.5 m to 35 m) signifying properties incorporated into the treatment group for non-parametric analysis. The designated blue zone is employed to construct the control group. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

variation in potential internet speeds generated by fiber eligibility on both sides of the eligibility boundary, during the deployment period, can be considered exogenous and treated as if it were randomly assigned.

The FTTH connection is established at the individual house level, introducing a characteristic that affects the property. Building on the assumption made by Ahlfeldt et al. (2017), the hypothesis is that the change in housing prices reflects the value associated with access to faster internet technology, specifically FTTH. An hedonic price model (Rosen, 1974) is employed, which assumes that the price of a property is determined by its specific characteristics (e.g., size, house or apartment) and its location-related attributes (e.g., distance to the nearest train station, school…). The hedonic price regression allows for the separation of various determinants of house prices, facilitating the measurement of the impact of FTTH eligibility on property prices.

The empirical specifications employed in this study aim to model the (log) price of properties sold at full postcode i and time t, associated with boundary j, using the following equation:

$$Y_{ijt} = \alpha + \beta FTTH_{ij} + \delta X_i + \gamma_t + \mu_i + \eta_j + \epsilon_{ijt} \tag{1}$$

Here, Y_{ijt} represents the log price of the property at postcode i and time t associated with boundary j. The variable $FTTH_{ij}$ is a binary indicator that signifies whether the property sold in postcode i associated with boundary j falls within the FTTH "eligible" zone (at the time of the study). The vector X_i consists of observed property and location characteristics (such as the number of rooms, building area, lot size, distance from the nearest school, distance from the nearest train station, distance from the nearest park, and the distance to the closest subscriber connection node). The term γ_t represents time fixed-effects (quarterly), while μ_i accounts for unobserved time-invariant effects at the postcode level. The variable η_j captures the effect of proximity to the nearest boundary j of FTTH deployment at the time of the study. Lastly, ϵ_{ijt} denotes the error term.

To summarize, this specification encompasses the logarithm of property price as a function of FTTH eligibility, along with a range of partially observed and unobserved internal property characteristics. Employing a non-parametric approach, the analysis focuses on properties located within a close proximity to the deployment boundary, explicitly leveraging the spatial discontinuities in FTTH eligibility and their impact on bandwidth speed. By employing this methodology, I aim to attribute differences in price changes across a common boundary to the fiber eligibility status of the properties. The sample is restricted to FTTH eligibility areas with at least one observation on each side of the boundary.

Because, the Regression Discontinuity Design (RDD) aims to compare means as the estimates approach the treatment threshold on either side, it is important that the estimates are not sensitive to observations precisely at the threshold (Almond, Doyle, Kowalski, & Williams, 2011). To address the potential concern of non-random sorting around the threshold, I employ a Donut Regression Discontinuity estimation (Barreca, Guldi, Lindo, & Waddell, 2011). This involves removing observations in the immediate proximity

Table 1
Table of comparison of prices and other characteristics of the properties in the eligible and non-eligible zones.

	Whole sample			Within 35 m of boundary		
	Non-Eligible (1)	Eligible (2)	SE (3)	Non-Eligible (4)	Eligible (5)	SE (6)
Log(price)	11.870	12.072	(0.029)***	11.921	12.112	(0.073)**
House	0.659	0.428	(0.017)***	0.341	0.327	(0.036)
Number of rooms	3.583	3.426	(0.041)***	3.133	3.233	(0.088)
Number of m2	83.932	76.094	(1.01)***	70.136	71.431	(1.971)
Distance train	10.479	4.317	(0.292)***	4.432	3.244	(0.314)***
Distance school	2.806	1.255	(0.062)***	1.103	0.893	(0.073)***
Distance park	2.825	0.909	(0.065)***	0.651	0.520	(0.041)***
Distance NRA	131.447	121.846	(2.414)***	121.878	123.624	(4.677)

Note: Columns 1, 2, 4, and 5 give the means of the variables that are used in the main regressions. Columns 3 and 6 give the clustered standard errors for the difference in means in parentheses. For the three first columns, all properties are considered. For the three last columns, only properties between 7.5 meters and 35 meters are selected. The treatment group are the sold properties located in the FTTH eligibility areas between 7.5 meters and 35 meters from the nearest eligibility area boundary. The control group is made up of the sold properties located outside of the FTTH eligibility areas between 7.5 meters and 35 meters from the nearest eligibility area boundary. The sample is restricted to FTTH eligibility areas with at least one observation on each side of the boundary.

of the FTTH boundary, acknowledging the possibility that properties at the frontier may differ systematically from surrounding observations. Hence, all observations ranging from 0 to 7.5 m, both above and below the threshold, were excluded from the analysis. Moreover, this RDD "donut" method tackles a second concern related to the method for determining treatment based on maps. It is likely that the eligibility of a dwelling at the border is not entirely accurate. In other words, there is a possibility that properties sold, whose geographical projection comes from the property transactions database, and are close to the fiber deployment boundary may not be assigned to the correct group (treatment or control). To mitigate this, I ensure that there are no treated properties in the control group and vice versa by deleting observations that are very close to the FTTH deployment boundary.

Fig. 5 provides a visual representation of the methodology employed and the sample selection process. The green zones indicate the areas eligible for optic fiber at the end of 2019 (corresponding to Q2-2020 data), while the black line represents the deployment frontier or cut-off point. To determine whether an observation is treated, we consider real estate sales of houses or apartments from Q1-2019 to Q4-2019 that fall within these green zones. The control group consists of sales outside these green zones. Therefore, the selection of observations for the non-parametric regression estimation is based on their distance to the deployment frontier (black line). On the treated side (highlighted green zone), only observations between 7.5 and 35 meters from the boundary are selected for the main regression. Similarly, on the control side, only observations between 7.5 and 35 meters are retained (represented by the blue area). Observations that are not selected appear in gray. The "boundary" fixed effect is determined by the closest zone boundary to each observation.

3.2 *Validity of the regression discontinuity identifying assumptions*

Before conducting a discontinuity regression, several assumptions need to be considered to ensure the validity of the analysis. First, it is assumed that observations can only transition from the control group to the treatment group and not vice versa. This means that once a house becomes eligible for optic fiber, it remains in the treatment group and cannot change its eligibility status. Secondly, all relevant variables, except the treatment variable, should exhibit smooth variation at the eligibility frontier. This implies that the potential outcomes of variables other than the treatment between the treatment and control groups must be continuous at the discontinuity threshold. This assumption is crucial to ensure that observations just outside the eligibility zone serve as appropriate counterfactuals for observations just inside the zone.

The validity of the design is assessed in Table 1, which examines dwelling properties and situational characteristics on each side of the FTTH eligibility boundary. The table also investigates how the log of the selling price varies across the boundary. Columns (1) and (4) present the mean values for properties sold in non-eligible areas, considering the whole sample and a bandwidth of 35 m, respectively. Columns (2) and (5) provide the average values for properties in FTTH-eligible areas with the same configuration.[26] Columns (3) and (6) display the clustered standard error of the difference in means between FTTH eligible and non-eligible properties. The results reveal that the differences in the log of the selling price remain statistically significant when a bandwidth is assigned. However, it is important to note that most differences in the own characteristics of properties become relatively small and statistically insignificant as the bandwidth decreases. The only variables that consistently maintain significant differences across the boundary are the locational variables (distance from the school, train station and park), probably due to the relative proximity to the city center of connected properties. All these variables are taken into account as controls in the estimated hedonic price model.

Furthermore, according to this RDD assumption, the variables describing the number of rooms, the building of the dwelling in square meters, and the proportion of houses show no significant jumps at the frontier, as depicted in Fig. 7. This suggests that these covariates exhibit a continuity at the threshold, further supporting the presence of a discontinuity only in the treatment variable

[26] To ensure accurate eligibility classification, properties sold within a distance of 7.5 meters from the boundary were excluded from the analysis.

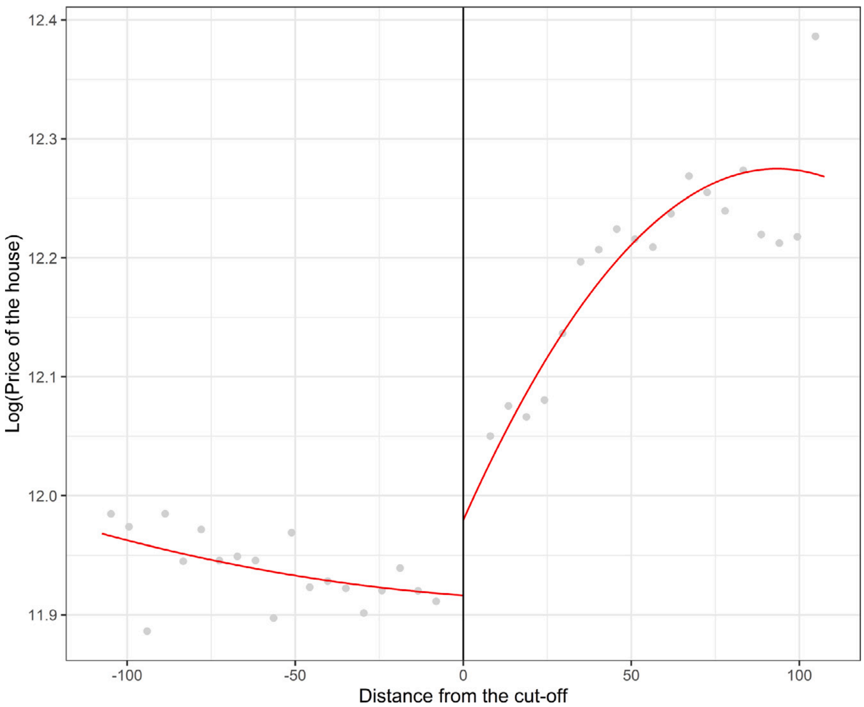

Fig. 6. This figure illustrates the spatial discontinuities in property prices based on FTTH eligibility. Negative distances indicate locations within the boundary segment that are not eligible for FTTH technology. The dots represent the mean transaction prices within 5-meter distance bins. The sample is restricted to FTTH eligibility areas with at least one observation on each side of the boundary.

(fiber eligibility) and the primary outcome (the log of the sale price). The RDD assumption assumes that variables other than the treatment and main outcome remain continuous at the threshold, and the observed continuity of these covariates reinforces this assumption. But, even though the jump is "small" (a few meters), we can see a small discontinuity in the situational variables, showing that the areas connected to fiber as a priority are those closest to city centers.

4 Results

4.1 Graphical analysis

To initiate the analysis, a graphical examination is conducted to explore the relationship between property prices and FTTH eligibility. Regression Discontinuity (RD) plots are utilized as a visual tool to assess the potential impact of FTTH eligibility on property prices. In Fig. 6, following some of the recommendations in Korting, Lieberman, Matsudaira, Pei, and Shen (2023), a discontinuity regression graph is presented, where the x-axis represents the distance from the boundary. Positive values indicate the treated side, while negative values indicate the control side. The boundary is depicted by the vertical bar at 0. On the y-axis, the logarithm of the property price is displayed. The red trend lines represent the predicted values derived from a regression of the outcome variable on a second-degree polynomial in distance to the boundary. The RD plot clearly demonstrates a distinct jump in the mean price of properties located within a narrow window around the eligibility threshold in the eligibility zone. This observation suggests a notable impact of FTTH eligibility on property prices.

4.2 The impact of FTTH eligibility on property prices

We can empirically address the hypothesis that households place a positive value on access to optic fiber, expecting an impact of optic fiber eligibility on property prices. Table 2 presents the results of estimating the model described by Eq. (1). The average effect of optic fiber eligibility is estimated for the entire sample in columns (1), while column (2) use a non-parametric estimation with a bandwidth considering all properties between 0 and 35 m from the nearest FTTH boundary. The column (3) use a "Donut" regression discontinuity estimation with a bandwidth considering all properties between 7.5 m and 35 m from the nearest FTTH boundary. Every model incorporates a set of control variables. These controls include property characteristics[27] (a dummy variable indicating

[27] The age of the dwelling variable, which is an intrinsic characteristic important in determining its value, is not included in the main analysis due to the incompleteness of this information for the entire sample. However, in an auxiliary analysis detailed in the Appendix in Table 11, the dataset comprising transactions

Table 2
Pricing results.

	Log(price)		
	(1)	(2)	(3)
FTTH	0.016***	0.015***	0.009***
	(0.003)	(0.003)	(0.003)
Quarter FE	Yes	Yes	Yes
PostalCode FE	Yes	Yes	Yes
Boundary FE	–	Yes	Yes
Boundary window (m)	–	0–35	7.5–35
R2	0.700	0.784	0.785
Num.Obs.	738 939	257 486	237 299
Valorization	€3,170	€3,342	€2,193

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.
Note: Column (1) displays the estimated coefficient reflecting the impact of optic fiber eligibility on property prices, using the entire sample without any selection. In columns (2) and (3), the effect of very high-speed Internet access is extracted from the discontinuity observed across FTTH eligibility boundaries. Additional controls are incorporated into each regression, complemented by quarter, postal code, and boundary fixed effects. Boundary estimates for a 0–35 m window are showcased in column (2), while those for a 7.5–35 m window are provided in column (3). Results for boundary windows spanning from 30 m to 200 m can be found in the Appendix. Standard errors (enclosed in parentheses) are clustered at the postal code level in column (1) and at the boundary level in columns (2) and (3).

whether the property is a house or not; the number of rooms; the building area in square meters), and location factors (proximity in kms to the closest train station, the nearest school, the nearest park, and the distance to the closest subscriber connection node).

Across all models, a consistently positive and significant impact of FTTH eligibility on property prices is observed. Focusing exclusively on the outcomes presented in column (3), which employs the Regression Discontinuity Design "Donut" approach for optimal accuracy, the initial findings indicate that FTTH-eligible properties experience an average price increase of 0.9%. This equates to an enhancement of €2,193 for a property with an average valuation of €231,900 within our dataset, which exclusively encompasses properties sold between Q1-2019 and Q4-2019.

These findings align with existing research on the influence of broadband internet availability on real estate values. For instance, Ahlfeldt et al. (2017) demonstrate the price differentiation between properties with ADSL and ADSL+ connections in England between 1995 and 2010. Similarly, our results resonate with studies specifically examining the impact of FTTH eligibility. Wolf and Irwin (2024) identified a 1.83% increase in home values attributable to fiber eligibility in Wisconsin, USA, while Whitacre (2023) estimated a fiber premium of approximately 1% across Iowa, Minnesota, and Texas. In England and Wales between 2008 and 2017, Koutroumpis, Ravasan, and Tarannum (2022) reported a housing price premium of 0.7% linked to FTTH access.

When analyzing transactions throughout 2019 against the backdrop of FTTH eligibility at year-end, the coefficients likely reflect an anticipatory response among buyers. I tried to distinguish the two effects on property prices: the immediate impact of FTTH eligibility and the anticipatory effect due to announcements by service providers or municipalities. In Table 8 in the Appendix, I explore this dynamic by examining the data in several distinct periods while maintaining the FTTH eligibility boundaries of the main analysis: directly during the eligibility phase in column (1), throughout the latter half of 2019 (Q3 and Q4), during the three quarters leading up to this period (Q4 2018, Q1 and Q2 2019), and in the three quarters prior to those (Q1, Q2, and Q3 of 2018). We can notice that property prices increase not only when FTTH becomes available but also in anticipation of this availability. Our findings clearly demonstrate that property valuations are at their highest during the quarters of actual FTTH availability. However, a significant, though lesser, premium on property prices is also detectable in the quarters leading up to FTTH eligibility, highlighting a distinct anticipatory valuation effect among buyers.

4.3 Robusteness

I conduct some further checks to validate the positive and significant effect of FTTH eligibility on housing prices. Specifically, a sensitivity analysis was performed to ascertain that our findings remain consistent across different analytical windows, defined by varying distances from the eligibility boundary (the cut-off). Fig. 8 illustrates the variation of the coefficient associated with fiber eligibility on real estate transaction prices, by adjusting the analysis window from 30 m to 200 m in one-meter increments. This involves selecting only observations within a buffer zone on both sides of the eligibility boundary. Remarkably, the coefficient remains consistently positive and significant, stabilizing at a range of 110 m.

has been augmented with "building permit" information, which specifies the authorization date for some dwelling's construction. Given the availability of this data commencing only from 2013, I introduced a binary variable set to 1 for homes constructed post-2013, and 0 for those built earlier. Within this sample, properties developed after 2013 represent a mere 1.5% of all transactions. Incorporating this variable into our econometric models yields results that are in alignment with the main findings, thereby reinforcing the consistency and robustness of our analysis.

Table 3
Pricing results by urban–rural subsamples.

	Log(price)				
	(1)	(2)	(3)	(4)	(5)
FTTH	0.038**	0.027**	0.025***	−0.001	0.014***
	(0.019)	(0.013)	(0.008)	(0.007)	(0.004)
Quarter FE	Yes	Yes	Yes	Yes	Yes
PostalCode FE	Yes	Yes	Yes	Yes	Yes
Boundary FE	Yes	Yes	Yes	Yes	Yes
Boundary window (m)	7.5–35	7.5–35	7.5–35	7.5–35	7.5–35
R2	0.713	0.706	0.741	0.751	0.774
Num.Obs.	4653	9980	24 130	45 424	153 112
Valorization	€7,201	€4,845	€3,951		€3,734

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

Note: Across all columns, the impact of ultra-high-speed Internet access is estimated through the discontinuity across FTTH eligibility boundaries. The Spatial Regression Discontinuity estimates presented are provided for a 7.5–35 m boundary window. Additional controls are incorporated into each regression, complemented by quarter, postal code, and boundary fixed effects. Standard errors (enclosed in parentheses) are clustered at the Boundary level. The column (1) includes all municipalities defined as rural; column (2), towns with fewer than 10,000 inhabitants; column (3), towns with fewer than 50,000 inhabitants; column (4), towns with fewer than 200,000 inhabitants and column (5), towns with more than 200,000 inhabitants.

To further examine the causal impact of fiber eligibility and demonstrate that the observed effect is likely due to the progressive deployment of fiber, a placebo test was conducted. Fig. 9 demonstrates the results obtained by shifting the cut-off on both sides of the border and performing the same estimation procedure, but this time assigning either a false treatment group or a false control group (with a 35 m boundary window on both side of the false cut-off). It can be observed that as we move away from the actual cut-off, no significant effect is observed. While our results are robust to various tests and suggest a causal relationship between fiber eligibility and property prices, it is important to avoid generalizing these findings beyond the determined window of analysis.

4.4 Heterogeneity analysis

The valuation of Fiber-to-the-Home is not uniform across households and exhibits sensitivity to the socioeconomic environment of municipalities. Local determinants play a pivotal role in shaping this valuation. To disentangle these effects, we resort to subgroup regressions, revealing variations in both effect size and significance level depending on the context.

4.4.1 Spatial disparities in FTTH valuation: A rural-urban perspective

Exploring the differential valuation of FTTH between rural and urban settings, this analysis categorizes the sample into five distinct sub-groups reflecting the urbanization gradient of the municipalities where properties are transacted. Table 3 details regression analyses conducted on these sub-groups, defined by the urbanization level of the municipalities where transactions occurred: (1) rural communes, (2) communes with fewer than 10,000 residents, (3) communes with 10,000 to 50,000 residents, (4) communes with fewer than 200,000 residents, and (5) communes with over 200,000 residents. The analysis reveals a pronounced and diminishing gradient of FTTH eligibility's impact from rural areas towards urban centers, with the most substantial effects observed in less populated areas. This indicates a potential premium associated with FTTH in regions where deployment challenges and lower operator profitability may enhance the value of properties with fiber access in rural communes. Such a premium accentuates the role of public intervention in FTTH deployment, especially in sparsely populated areas (Clercq et al., 2023).

Additionally, when expressed in monetary terms, a consistent trend emerges: the FTTH premium is notably higher in rural and sparsely populated areas. These are consistent with the literature that identifies a stronger fiber premium in contexts of previously weak connectivity (Deller & Whitacre, 2019; Molnar, Savage, & Sicker, 2019). This suggests an higher valuation placed on transitioning from limited to high-quality broadband in these areas, attributable in part to the baseline quality of the copper (ADSL) infrastructure.

To assess the impact of pre-existing ADSL quality which can play an important role on FTTH valuation, two variables have been constructed. The first is a binary indicator at the address level for sub-optimal initial ADSL speeds (below 10 Mbit/s)[28] and the distance to the nearest subscriber connection node, reflecting ADSL quality. I interacted the FTTH eligibility variable with these "pre-existing ADSL" variables. Using non-parametric donut estimation, we see that the interaction is significant and positive for rural areas or the smallest towns, both for the dummy variable "bad ADSL" in the Table 9 and for the variable distance to the connection node in the Table 10 available in Appendix. This means that the poorer the pre-existing quality of ADSL speeds, the higher the value of FTTH eligibility, providing a better understanding of this stronger result for rural areas.

[28] This is a dummy variable =1 when the pre-existing ADSL downstream speed at the address was less than 10 mbit/s maximum, addresses classified as "INEL", "HD05" and "HD3". The dummy is =0 when the maximum potential speeds were higher, this corresponds to categories "BHD8" and "THD30" according to the ARCEP classification available at https://static.data.gouv.fr/resources/ma-connexion-internet/20230310-164324/doc-maconnexioninternet-v2022t4.pdf, accessed in January 2024

Table 4
Pricing results by distance groups.

	Log(price)			
	(1)	(2)	(3)	(4)
FTTH	0.015	0.010	0.020***	0.026***
	(0.010)	(0.012)	(0.006)	(0.007)
Quarter FE	Yes	Yes	Yes	Yes
PostalCode FE	Yes	Yes	Yes	Yes
Boundary FE	Yes	Yes	Yes	Yes
Boundary window (m)	7.5–35	7.5–35	7.5–35	7.5–35
R2	0.760	0.782	0.752	0.749
Num.Obs.	26 270	18 302	47 609	36 094
Valorization	€3,886	€3,197	€5,809	€5,133

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.
Note: Across all columns, the impact of ultra-high-speed Internet access is estimated through the discontinuity across FTTH eligibility boundaries. The Spatial Regression Discontinuity estimates presented are provided for a 7.5–35 m boundary window. Additional controls are incorporated into each regression, complemented by quarter, postal code, and boundary fixed effects. Standard errors (enclosed in parentheses) are clustered at the Boundary level. Property sales are grouped according to distance from the centroids of France's major cities (namely, Bordeaux, Brest, Clermont, Dijon, Lille, Lyon, Marseille, Metz, Montpellier, Nantes, Nancy, Nice, Orléans, Paris, Rennes, Rouen, Saint-Etienne, Strasbourg, Tours, and Toulouse). All properties in district 75 (Paris) are deleted. Column (1) includes all properties that are less than 3 km s from the centroids of one of the major French cities; column (2), properties between 3 and 6 km s; column (3), properties between 6 and 20 km s and column (4), properties between 20 and 50 km s.

4.4.2 From city centers to peripheries: The gradient of FTTH property premiums

Centrality to urban hubs can be a significant determinant of FTTH valuation. By pinpointing the centroids of France's major cities (namely, Bordeaux, Brest, Clermont, Dijon, Lille, Lyon, Marseille, Metz, Montpellier, Nantes, Nancy, Nice, Orléans, Paris, Rennes, Rouen, Saint-Etienne, Strasbourg, Tours, and Toulouse), I categorized properties into concentric zones based on their distance from these urban cores. This allows for the delineation of varying proximity levels to these central nodes, effectively characterizing urban peripheries. Four distinct categories were thus established: The first encompasses properties sold within a 3 km radius of the centroids of these principal cities ; The second comprises properties transacted between 3 km and 6 km from the centroids; The third category includes properties sold between 6 km and 20 km from the centroids; The fourth category consolidates properties traded between 20 km and 100 km from the centroids. The results in Table 4 indicate a nuanced relationship. Properties located 20 km to 50 km from city centers, likely on the urban fringe, exhibit a pronounced FTTH premium (the average price of FTTH-eligible properties registers a 2.5% premium). This suggests that as one moves away from the immediate urban core, where broadband options might be plentiful, into the peripheries, the presence of FTTH significantly elevates property value. This elevation is likely driven by residents' desire to telecommute and to maintain strong digital connectivity despite being distanced from urban amenities.

4.4.3 Economic disparities and FTTH valuation

Table 5 offers an exploration into FTTH valuation based on the municipality's average income. Regression models were constructed for specific income brackets: municipalities with an average income below €9,500 are covered in (1), those ranging between €9,500 and €10,250 in (2), municipalities within the €10,250 to €10,750 bracket are in (3), and municipalities boasting an average income exceeding €10,750 are analyzed in (4). An intriguing pattern is observed: the highest valuation for FTTH is reported in the lowest income quartile. This could reflect a scarcity of reliable high-speed internet in these municipalities, magnifying the perceived value of FTTH. Furthermore, in economically disadvantaged areas, FTTH might be viewed not just as an amenity but as a transformative tool. It can catalyze economic development by attracting businesses, enhancing online education, and facilitating remote work, thereby playing a pivotal role in bridging the digital divide.

4.4.4 Fiber saturation: How deployment rates shape FTTH valuation

Lastly, to confirm this intuition about the potential impact of FTTH eligibility rates on value creation in a municipality, I explore how the extent of FTTH deployment within a municipality can influence how residents value this high-speed internet infrastructure. Subgroups of properties have been constructed according to the FTTH deployment rate in the municipality as of Q2-2020. Regression models were estimated for sub-samples with different FTTH deployment rates: less than 60% of eligible dwellings in the municipality (1), less than 80% (2), less than 90% (3), and more than 90% (4). As Table 6 elucidates, areas characterized by lower FTTH eligibility rates witness a heightened property valuation, indicating a premium associated with fiber connectivity. In regions where FTTH infrastructure is sparse, its mere availability is viewed as a rare and valuable asset. The demand–supply dynamics in such regions can influence property values, as homeowners and potential buyers recognize the comparative advantage provided by FTTH in an otherwise digitally underserved area.

This analysis underscores that household FTTH valuations exhibit heterogeneity based on several determinants, including socioeconomic attributes, local characteristics, and income levels. These insights are paramount for policymakers and stakeholders, emphasizing the importance of understanding regional nuances when devising strategies for FTTH deployment.

Table 5
Pricing results by revenue quartiles.

	Log(price)			
	(1)	(2)	(3)	(4)
FTTH	0.022***	0.022**	−0.001	0.001
	(0.007)	(0.009)	(0.009)	(0.005)
Quarter FE	Yes	Yes	Yes	Yes
PostalCode FE	Yes	Yes	Yes	Yes
Boundary FE	Yes	Yes	Yes	Yes
Boundary window (m)	7.5–35	7.5–35	7.5–35	7.5–35
R2	0.726	0.764	0.747	0.796
Num.Obs.	54 595	33 173	20 992	100 588
Valorization	€4,327	€3,745		

*p < 0.1, **p < 0.05, ***p < 0.01.
Note: Across all columns, the impact of ultra-high-speed Internet access is estimated through the discontinuity across FTTH eligibility boundaries. The Spatial Regression Discontinuity estimates presented are provided for a 7.5–35 m boundary window. Additional controls are incorporated into each regression, complemented by quarter, postal code, and boundary fixed effects. Standard errors (enclosed in parentheses) are clustered at the Boundary level. Column (1) includes all municipalities with an average income below €9,500; column (2), municipalities with an average income between €9,500 and €10,250; column (3), municipalities with an average income between €10,250 and €10,750; column (4), municipalities with an average income above €10,750.

Table 6
Pricing results by eligibility quartiles.

	Log(price)			
	(1)	(2)	(3)	(4)
FTTH	0.019**	0.008	0.004	0.016**
	(0.007)	(0.005)	(0.007)	(0.008)
Quarter FE	Yes	Yes	Yes	Yes
PostalCode FE	Yes	Yes	Yes	Yes
Boundary FE	Yes	Yes	Yes	Yes
Boundary window (m)	7.5–35	7.5–35	7.5–35	7.5–35
R2	0.758	0.760	0.753	0.761
Num.Obs.	36 155	71 012	59 296	70 836
Valorization	€3,204			€5,396

*p < 0.1, **p < 0.05, ***p < 0.01.
Note: Across all columns, the impact of ultra-high-speed Internet access is estimated through the discontinuity across FTTH eligibility boundaries. The Spatial Regression Discontinuity estimates presented are provided for a 7.5–35 m boundary window. Additional controls are incorporated into each regression, complemented by quarter, postal code, and boundary fixed effects. Standard errors (enclosed in parentheses) are clustered at the Boundary level. Column (1) includes all properties sold in municipalities with an FTTH eligibility rate of less than 60%; column (2), those with an FTTH eligibility rate of between 60% and 80%; column (3), those with an FTTH eligibility rate of between 80% and 90%; column (4), those with an FTTH eligibility rate of over 90%.

5 Conclusion and policy implications

This study elucidates the nuanced impact of Fiber to the Home (FTTH) eligibility on property valuations, highlighting variability across different locational contexts. The findings reveal a clear and positive valuation of very high-speed Internet access by households, with FTTH eligibility emerging as a pivotal factor influencing property prices. Specifically, properties eligible for FTTH exhibited an average price increase of 0.9%, translating to an additional €2,193 for a property priced at the sample's average of €231,900. This underscores the significant premium households assign to fiber optic access. Moreover, the exploration into the heterogeneity of this effect unveils its pronounced strength in predominantly rural areas, where properties gain more value upon becoming FTTH-eligible. Such an increase is notably influenced by the existing quality of ADSL services, suggesting that areas with inferior ADSL quality experience more substantial gains from transitioning to fiber optic. Additionally, this premium extends to properties on the outskirts of major urban centers, further emphasizing the broad spectrum of FTTH's value across different settings.

These findings have policy implications. Policymakers should focus on expanding FTTH coverage in rural and poor regions, where the demand for and benefits of high-speed internet are most pronounced. Ensuring universal access to FTTH infrastructure necessitates public intervention and investment to eliminate disparities in digital access and close the digital divide. Policymakers should also consider the local context and tailor their strategies accordingly. The impact of FTTH may vary depending on the degree of rurality or urbanity and income levels. Understanding these heterogeneities is essential for effective decision-making

Table 7
Descriptive statistics.

	0	1	Overall
	(N=360 944)	(N=378 020)	(N=738 964)
Log(Price)			
Mean (SD)	11.9 (0.696)	12.1 (0.708)	12.0 (0.709)
Median [Min, Max]	11.9 [9.90, 14.2]	12.1 [9.90, 14.2]	12.0 [9.90, 14.2]
House			
Mean (SD)	0.649 (0.477)	0.420 (0.494)	0.532 (0.499)
Median [Min, Max]	1.00 [0, 1.00]	0 [0, 1.00]	1.00 [0, 1.00]
Number of rooms			
Mean (SD)	3.56 (1.51)	3.40 (1.47)	3.48 (1.49)
Median [Min, Max]	4.00 [1.00, 67.0]	3.00 [1.00, 56.0]	3.00 [1.00, 67.0]
Building area			
Mean (SD)	83.4 (41.8)	75.5 (36.6)	79.4 (39.4)
Median [Min, Max]	80.0 [9.00, 800]	71.0 [10.0, 735]	75.0 [9.00, 800]
Distance from train station			
Mean (SD)	10.3 (10.9)	4.28 (6.51)	7.24 (9.41)
Median [Min, Max]	6.84 [0, 90.7]	1.85 [0.00713, 76.4]	2.97 [0, 90.7]
Distance from school			
Mean (SD)	2.77 (3.31)	1.24 (1.88)	1.98 (2.78)
Median [Min, Max]	1.32 [0.00152, 33.7]	0.565 [0.00112, 32.0]	0.766 [0.00112, 33.7]
Distance from park			
Mean (SD)	2.78 (3.70)	0.890 (1.74)	1.81 (3.02)
Median [Min, Max]	0.940 [0, 37.8]	0.323 [0, 26.0]	0.475 [0, 37.8]
Distance from NRA			
Mean (SD)	131 (62.4)	122 (56.3)	127 (59.5)
Median [Min, Max]	133 [0.152, 302]	138 [1.11, 301]	135 [0.152, 302]
Quarter			
2019/01	78 064 (21.6%)	82 685 (21.9%)	160 749 (21.8%)
2019/02	85 724 (23.8%)	91 900 (24.3%)	177 624 (24.0%)
2019/03	101 093 (28.0%)	107 761 (28.5%)	208 854 (28.3%)
2019/04	96 063 (26.6%)	95 674 (25.3%)	191 737 (25.9%)

Note: This table presents descriptive statistics for various variables across the entire sample of transactions, prior to any selection based on proximity to the FTTH deployment frontier. The first column details transactions involving homes that were not eligible for fiber as of the end of 2019. The second column pertains to transactions for homes within FTTH-eligible zones at the end of 2019. The third column aggregates descriptive statistics for the full sample, providing a comprehensive overview.

Table 8
Pricing results.

	Log(price)		
	(1)	(2)	(3)
FTTH	0.012***	0.006*	−0.006
	(0.004)	(0.004)	(0.004)
Quarter FE	Yes	Yes	Yes
PostalCode FE	Yes	Yes	Yes
Boundary FE	Yes	Yes	Yes
Boundary window (m)	7.5–35	7.5–35	7.5–35
R2	0.796	0.785	0.770
Num.Obs.	126 754	149 303	113 741

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.
Note: Column (1) presents the coefficient estimate capturing the direct impact of FTTH eligibility on property prices for the quarters when eligibility was confirmed (Q3 and Q4 of 2019). Column (2) reveals the coefficient estimate illustrating the FTTH eligibility anticipatory effect on property prices during the three quarters preceding the eligibility confirmation (Q4 2018, Q1 and Q2 2019). Column (3) offers the coefficient estimate for an earlier period, comprising the three quarters before the anticipatory phase (Q1, Q2, and Q3 of 2018), while still applying the FTTH eligibility boundaries as of the end of 2019. Estimates across a 7.5–35 m distance window are provided. Standard errors (enclosed in parentheses) are clustered at the boundary level.

and resource allocation for future investment and growth potential (Clercq et al., 2023). By understanding these dynamics and considering the policy implications, policymakers can make informed decisions to promote the deployment of FTTH infrastructure and foster economic growth.

CRediT authorship contribution statement

Jean-Baptiste Guiffard: Conceptualization, Data curation, Formal analysis, Methodology, Project administration, Resources, Software, Supervision, Visualization, Writing – original draft, Writing – review & editing.

Table 9
Pricing results by urban–rural subsamples (interaction with the pre-existing ADSL quality at the address level)

	Log(price)				
	(1)	(2)	(3)	(4)	(5)
FTTH	0.009	0.030**	0.023**	−0.002	0.019***
	(0.021)	(0.013)	(0.010)	(0.008)	(0.005)
bad_ADSL	−0.042	0.075*	−0.007	0.008	−0.003
	(0.046)	(0.041)	(0.017)	(0.014)	(0.010)
FTTH ×bad_ADSL	0.077**	−0.023	0.015	−0.002	−0.011
	(0.037)	(0.038)	(0.017)	(0.014)	(0.010)
Quarter FE	Yes	Yes	Yes	Yes	Yes
PostalCode FE	Yes	Yes	Yes	Yes	Yes
Boundary FE	Yes	Yes	Yes	Yes	Yes
Boundary window (m)	7.5–35	7.5–35	7.5–35	7.5–35	7.5–35
R2	0.715	0.707	0.740	0.753	0.775
Num.Obs.	4646	9969	24 099	45 063	151 619

$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.
Note: In every column, the analysis quantifies the interaction between ultra-high-speed Internet (FTTH) access and the quality of pre-existing ADSL by leveraging the discontinuities at FTTH eligibility boundaries. Here, the pre-existing quality of copper network is measured through a dummy indicating if the downstream speed at the address was less than 10 mbit/s maximum. The Spatial Regression Discontinuity estimates presented are provided for a 7.5–35 m boundary window. Additional controls are incorporated into each regression, complemented by quarter, postal code, and boundary fixed effects. Standard errors (enclosed in parentheses) are clustered at the Boundary level. The column (1) includes all municipalities defined as rural; column (2), towns with fewer than 10,000 inhabitants; column (3), towns with fewer than 50,000 inhabitants; column (4), towns with fewer than 200,000 inhabitants and column (5), towns with more than 200,000 inhabitants.

Table 10
Pricing results by urban–rural subsamples (Interaction with the distance from the closest subscriber connection nodes)

	Log(price)				
	(1)	(2)	(3)	(4)	(5)
FTTH	−0.028	−0.014	0.022	0.008	0.023**
	(0.041)	(0.027)	(0.022)	(0.017)	(0.011)
distance_NRA	−0.024	0.017	0.020*	0.010	−0.008
	(0.035)	(0.017)	(0.011)	(0.010)	(0.010)
FTTH ×distance_NRA	0.001*	0.000*	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Quarter FE	Yes	Yes	Yes	Yes	Yes
PostalCode FE	Yes	Yes	Yes	Yes	Yes
Boundary FE	Yes	Yes	Yes	Yes	Yes
Boundary window (m)	7.5–35	7.5–35	7.5–35	7.5–35	7.5–35
R2	0.714	0.706	0.740	0.751	0.773
Num.Obs.	4653	9980	24 130	45 424	153 112

$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.
Note: In every column, the analysis quantifies the interaction between ultra-high-speed Internet (FTTH) access and the quality of pre-existing ADSL by leveraging the discontinuities at FTTH eligibility boundaries. The quality of the incumbent copper network is assessed based on the proximity to the nearest subscriber connection node. The Spatial Regression Discontinuity estimates presented are provided for a 7.5–35 m boundary window. Additional controls are incorporated into each regression, complemented by quarter, postal code, and boundary fixed effects. Standard errors (enclosed in parentheses) are clustered at the Boundary level. The column (1) includes all municipalities defined as rural; column (2), towns with fewer than 10,000 inhabitants; column (3), towns with fewer than 50,000 inhabitants; column (4), towns with fewer than 200,000 inhabitants and column (5), towns with more than 200,000 inhabitants.

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Appendix

See Tables 7–11 and Figs. 7–9.

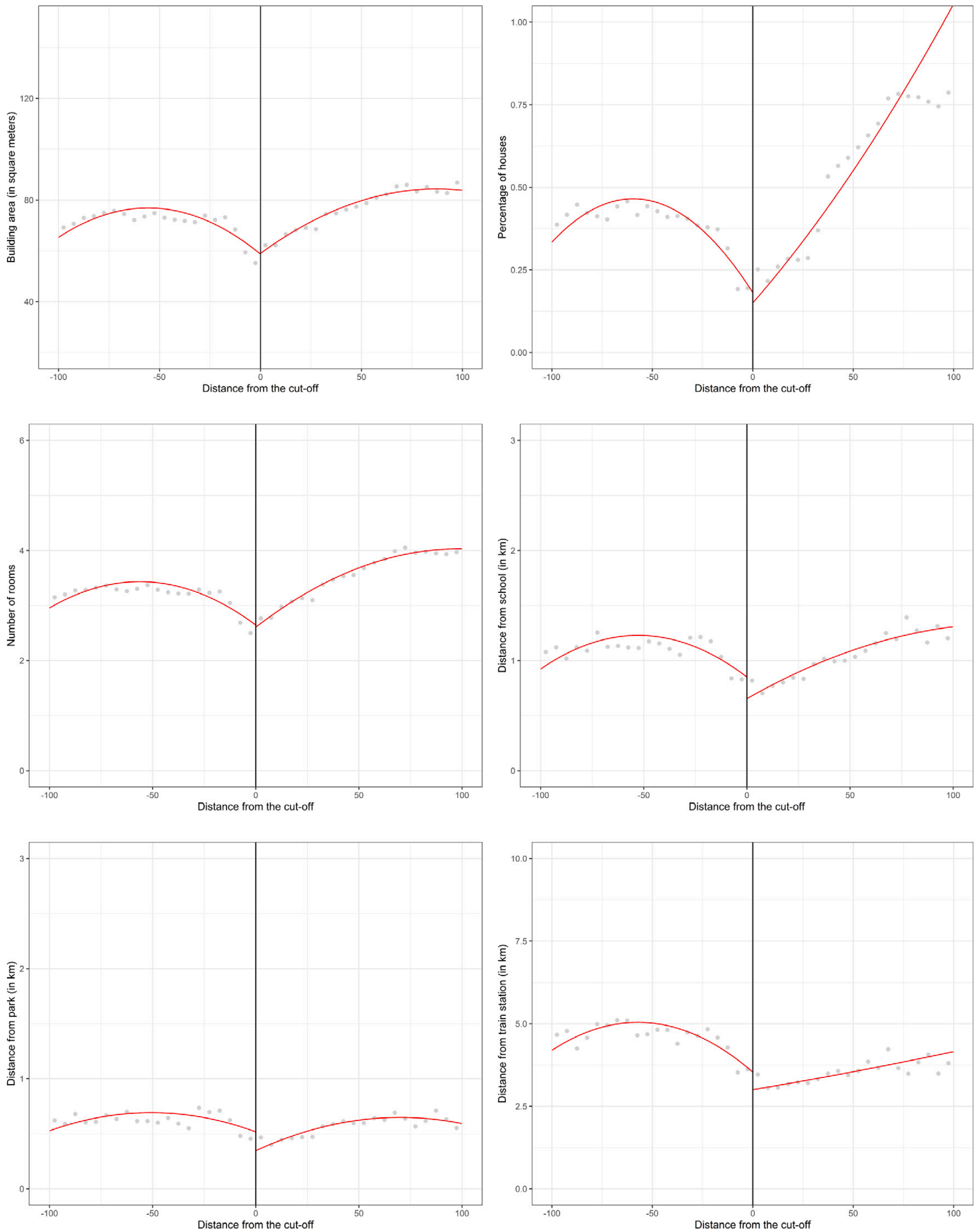

Fig. 7. This figure illustrates the spatial discontinuities in property covariates (building and land area, number of rooms and distance from the nearest school) based on FTTH eligibility. Negative distances indicate locations within the boundary segment that are not eligible for FTTH technology. The dots represent the mean transaction prices within 5-meter distance bins. The red lines depict the predicted values obtained by regressing the outcome variables against a second-degree polynomial function of the distance to the boundary. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

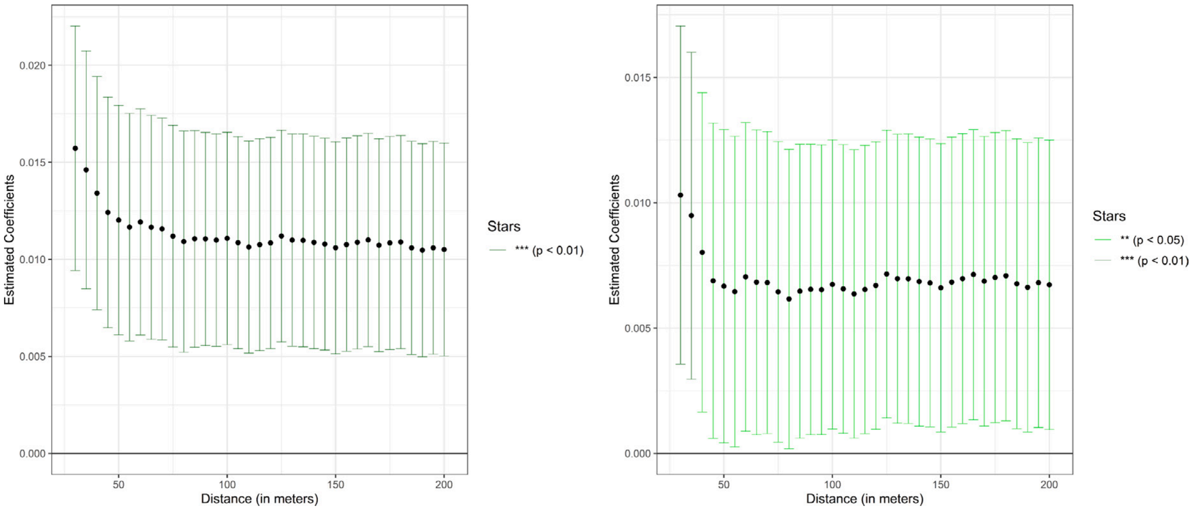

Fig. 8. Sensitivity Analysis of FTTH Impact on Property Prices: This figure demonstrates the variability of the coefficient associated with FTTH eligibility and its effect on property transaction values. The analysis window is systematically adjusted in five-meter increments, ranging from 30 m to 200 m. The left-hand panel adopts a non-parametric approach, in line with the main results methodology, selecting all properties adjacent to the FTTH boundary. In contrast, the right-hand panel applies a 'donut' regression discontinuity model, excluding properties within 7.5 m of the boundary. Error bars are color-coded to reflect different levels of statistical significance.

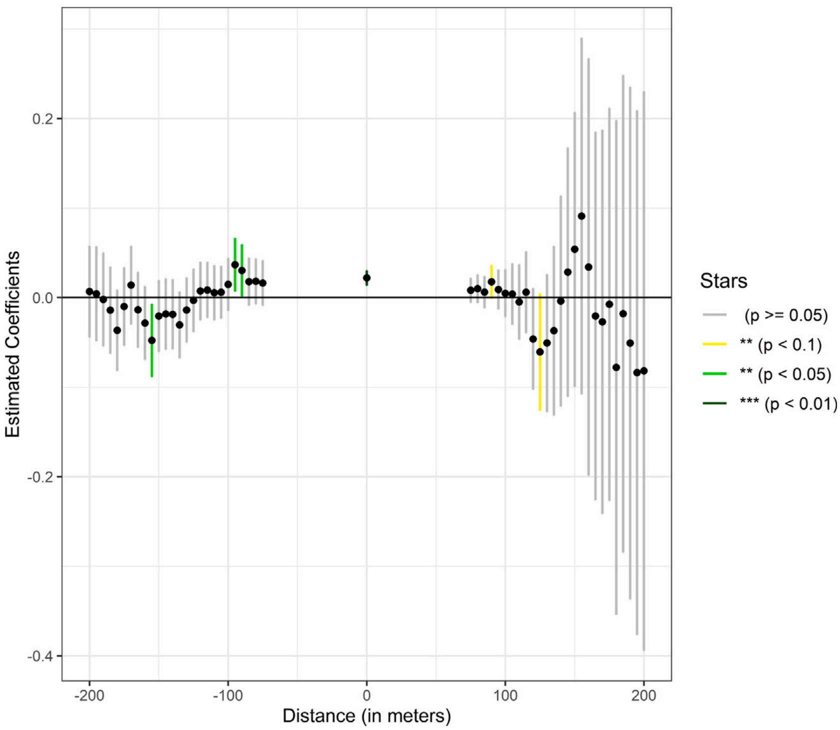

Fig. 9. Placebo test: each estimation is estimated by shifting the cut-off on both sides of the border and performing the same estimation procedure as in Table (2), but this time assigning either a false treatment or a false control group (with a 35 m boundary window on both side of the false cut-off). The coloration of the error bars denotes the levels of statistical significance.

Table 11
Pricing results (with control of the date of construction of the dwelling)

	Log(price)		
	(1)	(2)	(3)
FTTH	0.016***	0.015***	0.010***
	(0.003)	(0.003)	(0.003)
Recent	0.091***	0.098***	0.097***
	(0.008)	(0.014)	(0.014)
Quarter FE	Yes	Yes	Yes
PostalCode FE	Yes	Yes	Yes
Boundary FE	–	Yes	Yes
Boundary window (m)	–	0–35	7.5–35
R2	0.700	0.784	0.785
Num.Obs.	738 939	257 486	237 299
Valorization	€3,244	€3,493	€2,356

*p < 0.1, **p < 0.05, ***p < 0.01.
Note: Column (1) displays the estimated coefficient reflecting the impact of optic fiber eligibility on property prices, using the entire sample without any selection. In columns (2) and (3), the effect of very high-speed Internet access is extracted from the discontinuity observed across FTTH eligibility boundaries. Additional controls are incorporated into each regression, complemented by quarter, postal code, and boundary fixed effects. Boundary estimates for a 0–35 m window are showcased in column (2), while those for a 7.5–35 m window are provided in column (3). Results for boundary windows spanning from 30 m to 200 m can be found in the Appendix. Standard errors (enclosed in parentheses) are clustered at the postal code level in column (1) and at the boundary level in columns (2) and (3).

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