

UNIVERSITÉ PARIS 1 PANTHÉON-SORBONNE

Institut d'études du développement de la Sorbonne (IEDES)
UMR Développement et Sociétés
École doctorale d'économie

Thèse pour l'obtention du titre de Docteur en Sciences Économiques

présentée et soutenue publiquement le 24 septembre 2024 par

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**Essais en économie du numérique : Trois évaluations d'impact de
l'Internet à haut débit**

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PhD Thesis for the Degree of Doctor of Philosophy in Economics

Prepared and publicly defended on September 24, 2024 by

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Essays in Digital Economics: Three Impact Evaluations of Broadband Internet

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Essays in Digital Economics: Three Impact Evaluations of Broadband Internet

Jean-Baptiste Guiffard

Abstract

This thesis explores the subjective value of high-speed Internet from the perspectives of three key economic agents: citizens, households, and businesses. Through three distinct chapters, the study employs rigorous impact evaluation methodologies, including difference-in-differences, spatial regression discontinuity, and Poisson estimates, to assess broadband Internet's economic and social impacts. The first chapter examines how broadband access influences political participation in Sub-Saharan Africa, finding that high-speed internet increases both the likelihood and frequency of protests, particularly in countries with active political rights. The second chapter analyzes the impact of Fiber to the Home (FTTH) on property values in France, revealing that FTTH eligibility significantly raises property prices, especially in rural areas with weaker pre-existing infrastructure quality. The third chapter investigates the relationship between mobile broadband quality and firm creation in Tunisia, demonstrating a positive correlation between 4G network density and new business establishments, with pronounced effects in rural regions. The findings underscore the pivotal role of broadband internet in shaping modern economies, demonstrating its significant impact on political participation, economic welfare, and business development. This thesis emphasizes the critical need for targeted investments in digital infrastructure, highlighting their importance in fostering equitable growth and reducing disparities across different regions and socio-economic environments.

Keywords: Broadband Internet, Impact Evaluation, Infrastructure, Telecommunications, Development.

Acknowledgments

*I was just guessing at numbers and figures
Pulling the puzzles apart
Questions of science, science and progress
Do not speak as loud as my heart*
– The Scientist, Coldplay

Cette thèse est l'aboutissement d'un long parcours, marqué par des défis, des découvertes, et de magnifiques rencontres. Je n'aurais pu accomplir ce chemin sans le soutien et la bienveillance de mes proches et collègues. Je souhaite remercier tous ceux qui m'ont soutenu et encouragé tout au long de cette aventure.

Je tiens tout d'abord à exprimer ma profonde gratitude à mes parents, Gérard et Irène, pour leur amour inconditionnel, leur soutien indéfectible, et leur foi en moi depuis le début de ma scolarité. A travers leur regard et leur intérêt, ils ont été l'un des principaux moteurs de ma réussite. Un grand merci également à mes frères et soeurs, Anne-Sophie, Emilie, Thibaud, Océane, Benjamin, et Iris, ainsi qu'à mes beaux-frères Pascal, Ulrich, et Vianney. Je pense aussi avec affection à mes neveux et nièces : Simon, Célia, Ismaël, Léo, Gabrielle, Salomé, Trystan, Elisa, Solal, Elia et Judith. Vous formez tous une famille qui a toujours été une fierté et un pilier. Je tiens également à dédier cette thèse à mes grands-parents, qui ne sont plus parmi nous. Je souhaite les remercier pour la bienveillance et la gentillesse qu'ils ont eu tout au long de ma scolarité et de mes études supérieures. Ils occupent toujours une place précieuse dans mes pensées.

Ensuite, je souhaite exprimer toute ma gratitude et mon affection envers mes amis de Normandie et d'ailleurs (pour beaucoup de Bretagne...) : Valentin, Solenn, Léo, Annabelle, Nicolas, François, Camille, Robin, Patrick, Goluck, Joanna et Zaccharia. Que vous ayez été proches ou plus éloignés, votre soutien a toujours été une source de réconfort et de motivation. Les discussions que nous avons eues autour de mes sujets de thèse ont été pour moi un puits d'inspiration et un moteur essentiel pour avancer. Sans vous, cette thèse n'aurait jamais pu voir le jour. Je souhaite aussi remercier Anne-Lise pour le soutien que tu as été au quotidien pendant toutes ces années.

Je suis également reconnaissant d'avoir suivi le master EPOLPRO à l'Institut d'études du développement de la Sorbonne (IEDES), une formation passionnante, inspirante et qui

rayonne par sa singularité dans le paysage du développement en France, ce master a profondément marqué ma trajectoire professionnelle et personnelle. J'essaie toujours aujourd'hui de faire vivre l'esprit de l'IEDES dans mes actions et chacun de mes choix. Je souhaite remercier les camarades de la promotion 2019, dont certains sont devenus des amis chers, et qui ont été d'un soutien inébranlable tout au long de cette thèse. Parmi eux, Pauline Kergall, Rayan Chebbi-Giovanetti, et Margaux Jutant, je suis particulièrement reconnaissant pour votre amitié et votre présence à mes côtés.

À mes directeurs de thèse, François Roubaud et Mohamed Ali Marouani, je vous suis profondément reconnaissant pour votre encadrement, votre patience et vos conseils avisés qui ont été essentiels pour la réalisation de cette thèse. Je tiens également à remercier ma directrice de mémoire, Mireille Razafindrakoto, pour son soutien constant et ses encouragements pendant ce parcours. Je souhaite également exprimer ma reconnaissance à mon comité de thèse : Virginie Comblon, et Joël Cariolle, pour leur expertise et leurs précieux conseils qui ont guidé ce travail.

Je souhaite remercier chaleureusement les membres de mon jury de thèse : Jenny Aker, Marc Bourreau, Joël Cariolle, François Combarnous, et Georges Houngbonon, d'avoir accepté de faire parti de ce jury et pour l'intérêt qu'ils ont porté à mon travail, ainsi que pour leurs remarques constructives et leurs suggestions pertinentes.

Je tiens à exprimer ma reconnaissance envers mes co-auteurs, Julianne Liang, Pauline Kergall, Mohamed Ali Marouani, Louise Aïmène et Marc Ivaldi. Travailler avec vous a été une expérience enrichissante et je vous remercie pour votre collaboration et votre amitié.

Au cours de ce parcours doctoral, j'ai eu la chance de rencontrer des personnes formidables qui sont devenues des amis chers. Je tiens à remercier particulièrement Antoine Castet, qui a été un compagnon indispensable tout au long de ce périple. Il brille par son intelligence et sa sagacité, sa passion pour les données et les sciences économiques et sociales, ainsi que par sa profonde bienveillance. Avec Amandine Degert et Célina Colella, nous formions un groupe soudé et attentif, qui m'a permis de traverser cette aventure avec sérénité. Ils sont aujourd'hui des amis très proches, et je leur suis reconnaissant pour tout ce qu'ils m'ont apporté : le réconfort, les rires, et un soutien indéfectible. Je tiens à exprimer ma profonde reconnaissance à tous mes amis rencontrés durant ce parcours : Chaima Ben Abderrahmen, Michael Chaves, Annélia Delescluse, Clément Dumont, Etienne Dagorn, Aykiz Dogan, Jala Emad Youssef, Laken Ganemtore, Louise Aïmène, Julianne Liang, Karine Marazyan (avec

qui nous avons fondé le séminaire AuToMat), Katia Korneeva, Phuong Le, Raquel Oliveira, et Pablo Rotelli. Votre soutien indéfectible et votre amitié m'ont été d'une grande valeur tout au long de cette aventure, et je vous en suis profondément reconnaissant. Je tiens à exprimer ma profonde gratitude à mes collègues doctorants de l'UMR Développement et Sociétés : Gala Aguero, Francesco Mirra, Mélody Mourlhion-Ostrowski, et Phasy Res. Merci pour votre camaraderie, votre soutien, et les moments précieux partagés tout au long de ce parcours.

Je suis également reconnaissant envers les enseignants-chercheurs et chercheurs de l'UMR Développement et Sociétés : Tania Angeloff, Julien Brachet, Jordie Blanc-Ansari, Sylvie Capitant, Alain Desdoigts, Esther Delesalle, Gaëlle Gillot, Charlotte Guénard, Pierre Janin, Anne Le Naëlou, et Gilles Spielvogel. Merci pour vos précieux retours, nos échanges bienveillants, et votre soutien tout au long de ma thèse. Un remerciement tout particulier à Charlotte Guénard et Sylvie Capitant, directrices de l'IEDES, ainsi qu'à l'université Paris 1 Panthéon-Sorbonne, pour m'avoir donné l'opportunité d'être ATER dans le master d'études du développement. Ces deux années ont été extrêmement enrichissantes. Je souhaite également exprimer ma gratitude à Gilles Spielvogel pour sa direction de l'UMR, qui a insufflé une nouvelle dynamique au laboratoire, apportant des bénéfices considérables à l'ensemble de notre équipe. Je tiens à adresser un grand merci à l'administration de l'UMR et de l'IEDES : Adel Boulkaboul, Anne Courtois, Karine Demandre, Béatrice Garcia, Jérôme Chassain, Jordane Raisin-Dadre, et Franck Viroleau, pour le plaisir de travailler avec vous et les moments partagés. Merci également aux personnes sur le campus : Auriane, Cécile, et Hiba, pour leur gentillesse, et leur soutien. Enfin, je souhaite exprimer ma reconnaissance à mes étudiants, qui ont été un moteur déterminant et une source constante d'inspiration.

Je souhaite aussi remercier l'entreprise Orange de m'avoir donné l'opportunité d'effectuer cette thèse à travers le dispositif CIFRE. Je souhaite remercier mes collègues de la Direction des Affaires Réglementaires et amis d'Orange : François Jeanjean, Lionel de Rivières, Pauline Derez, Anne-Marie Allouet. Je souhaite une expression particulière à Enrick Arnaud-Jouffray et Adrien Raizonville, doctorants eux aussi à Orange, qui m'ont accueilli et accompagné au début de ce parcours. Je souhaite remercier aussi mes supérieurs et ceux que j'ai pu croiser durant ces trois années : Philippe Béguin, Fadhel Lakhoud, Matthieu Agogue. Je pense aussi à Volcy, Thierry, Luisa et Hicham.

En Tunisie, je remercie sincèrement Ramzi Channouf, Rim, Ahmed, et Feyrouz pour leur accueil chaleureux et leur amitié.

Enfin, je tiens à remercier Louis Pape et Marc Bourreau, pour leur confiance pour ce contrat de post-doc à Telecom-Paris.

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General Introduction

Let us work to link the people of the world.

– Al Gore, ITU

Advances in digital technologies have revolutionized our society and economy. Their roles in driving economic growth and enhancing various social goods are widely acknowledged (Draca, Sadun, and Van Reenen 2006, Goldfarb and Tucker 2019, Hjort and Tian 2021). Beyond economic advantages, information and communications technology (ICT) is uniquely positioned to foster a more socially sustainable future (OECD, 2004). Consequently, massive infrastructure investments are being made in developed and developing countries to harness these transformative technologies.

The concepts, methods, and tools digital technologies encompass continually evolve. Information and communication technologies¹ includes all services enabling users to access, extract, store, transport, and manipulate information digitally through telecommunications. According to Goldfarb and Tucker 2019, the defining feature of digital technologies, which represent information in bits, lies in their ability to process information efficiently. This digital processing dramatically reduces storage, computation, and information transfer costs. Since costs can limit the choices and actions of economic and social agents, digital economics, to which this thesis belongs, examines the economic, social, and political impacts that result from these reduced costs, which can sometimes approach zero.

The narrative surrounding digital technologies often emphasizes their potential to deliver extensive economic and social benefits. This thesis particularly highlights the role of high-speed Internet². High-speed Internet, often defined as broadband, provides download speeds of at least 25 Mbps and upload speeds of at least 3 Mbps, enabling quick data transfer and seamless streaming of digital content³. The Internet, particularly broadband, offers signifi-

¹ICTs refers to all communication technologies, including the Internet, mobile phones, computers, software, social networks, and applications. <https://aims.fao.org/fr/information-and-communication-technologies-ict>, accessed in August 2024

²Internet can be defined as a vast and interconnected system of software applications and computing devices. See <https://www.broadbandsearch.net/definitions/internet> accessed in August 2024.

³FCC, 2015. <https://www.fcc.gov/reports-research/reports/broadband-progress-reports/2015-broadband-progress-report> accessed in August 2024.

cant advantages for economies, societies, and political systems worldwide by facilitating the exchange of information and services and supporting business, shopping, leisure activities, and political action. However, it also presents substantial risks that must be addressed to fully realize its potential.

0.1 A brief history of the Internet

When discussing the history of the Internet, often hailed as the “greatest invention of our time” (The Economist, 2012⁴), and more broadly, the history of digital technologies, we must look back to the technologies developed during World War II (Abbate 2000). The Second World War sparked interest in computers for tasks such as code breaking, atomic weapon development, and calculating artillery ballistic tables (Ceruzzi 2003). Following these military applications, computers became commercially available in the early 1950s, with early examples including the UNIVAC I and the IBM 701 (Yates et al. 1997). As the 1970s progressed, the cost of large mainframe computers steadily decreased. Mainframes were utilized for applications like processing large databases, maintaining records, and executing complex statistical and mathematical programs. Experiments in the 1970s and 1980s led to the independent development of several networks with their protocols tailored to their specific environments, such as ARPANET, ALOHAnet, and SATNET (Conley 2023).

When DARPA combined the TCP (Transfer Control Protocol) standard developed in 1974 with the IP (Internet Protocol) developed in 1978, a common and official standard, TCP/IP, began to be used in 1981 (Postel 1981). This protocol allowed distinct networks to communicate regardless of their internal workings, creating a "network of networks" – the Internet (Peterson and Davie 2007). The modern commercial Internet began to gain wider use with the proliferation of dial-up access in the 1990s and the emergence of the hypertext transfer protocol (HTTP), the foundation of data communication for the World Wide Web, the information system enabling content sharing over the Internet.

With the advent of the World Wide Web, individuals could now access vast amounts of text, music, images, video, and data from a computer. It also allowed them to produce and make content available to others. Thus, information dissemination and person-to-person communication became instantaneous and free. But above all, it relies on a network of infrastructures that play a central role in the functioning of the Internet.

⁴<https://www.economist.com/1843/2012/08/17/whats-the-greatest-invention-of-all-time> accessed in August 2024.

0.2 The critical role of infrastructure in broadband Internet

Access to the Internet is not just a matter of protocols or devices (like mobile phones, tablets and computers); it fundamentally relies on physical infrastructure. As Greenstein, 2020 points out, “*The external face of the internet has become part of everyday life. However, the internal structure and operation of the internet have remained largely invisible, both to the public and to most economists.*” Internet networks depend on physical infrastructure to function, and this thesis focuses on studying high-speed internet infrastructure to understand the economic, social and political effects of the Internet.

We can describe high-speed internet telecom infrastructure using Figure 1. This diagram is showing that the first component of the physical high-speed internet network consists of international and regional infrastructures that provide “international connectivity” globally. The majority of internet traffic passes through submarine cables. These submarine cables connect to the second component of the network, known as the domestic backbone network. The backbone, or core network, comprises terrestrial cables that transport internet traffic from the landing points of submarine cables to different regions within a country.

The third element of the high-speed internet physical network consists of access network infrastructures that connect the backbone network to users, often referred to as the last mile. These access network broadband infrastructures come in two main types. On one side, we have mobile broadband technologies, particularly cellular networks that rely on antennas to transmit data. These technologies allow the end user to access broadband services on the move and from any physical location covered by their mobile broadband service provider. These antennas come in different generations⁵. The first broadband antenna technology is 3G or UMTS (Universal Mobile Telecommunications System), which offers download speeds of up to 2 Mbps. The commercial deployment of 3G began in 2001, with the first commercial 3G network launched by NTT DoCoMo in Japan on October 1, 2001.⁶ The second broadband antenna technology is 4G or LTE (Long-Term Evolution), which provides significantly higher speeds, with downloads up to 1 Gbps. The commercial rollout of 4G began in 2009, with the first commercial 4G network launched by TeliaSonera in Sweden and Norway in December 2009. Finally, the latest mobile broadband technology to develop is 5G, which offers much higher speeds than previous generations, with theoretical maximum download speeds of up

⁵<https://www.verizon.com/about/our-company/5g/difference-between-3g-4g-5g?msocid=3a954aac44b367893be25ec145fb6666> accessed in August 2024

⁶<https://www.nttdocomo.ne.jp/english/corporate/about/outline/history/index.html> accessed in August 2024.

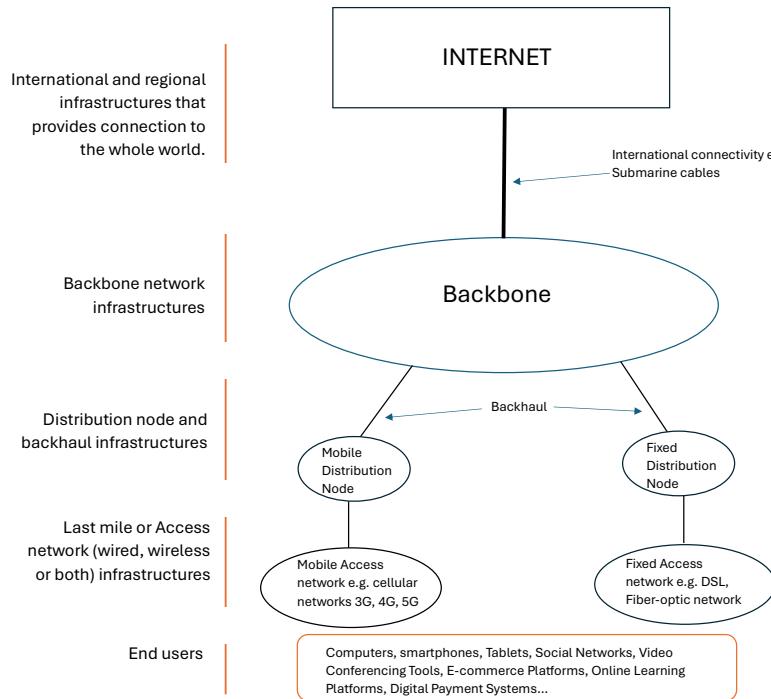


Figure 1: Network Components of Broadband Infrastructure

to 10 Gbps and upload speeds of up to 1-2 Gbps. The commercial deployment of 5G began in 2019, with the first commercial 5G networks launched in South Korea in April 2019 by major telecom operators such as SK Telecom, KT, and LG Uplus.

Fixed broadband technologies refer to those technologies where the end user must remain at the exact location to use the broadband service because access is associated with a specific physical location. While wireless and satellite connections exist, we primarily consider wireline connections: first, xDSL technologies, which rely on the copper telephone network and provide limited speeds (ADSL and VDSL speed values). More recently, fiber networks have been deployed, offering significantly superior performance. Technical and financial constraints largely drive the choice between fixed and mobile broadband technologies. Fixed broadband is more common in densely populated areas, often alongside mobile broadband, while mobile broadband is more prevalent in less densely populated regions. This presents a significant investment challenge (Gelvanovska, Rogy, and Rossotto, 2014).

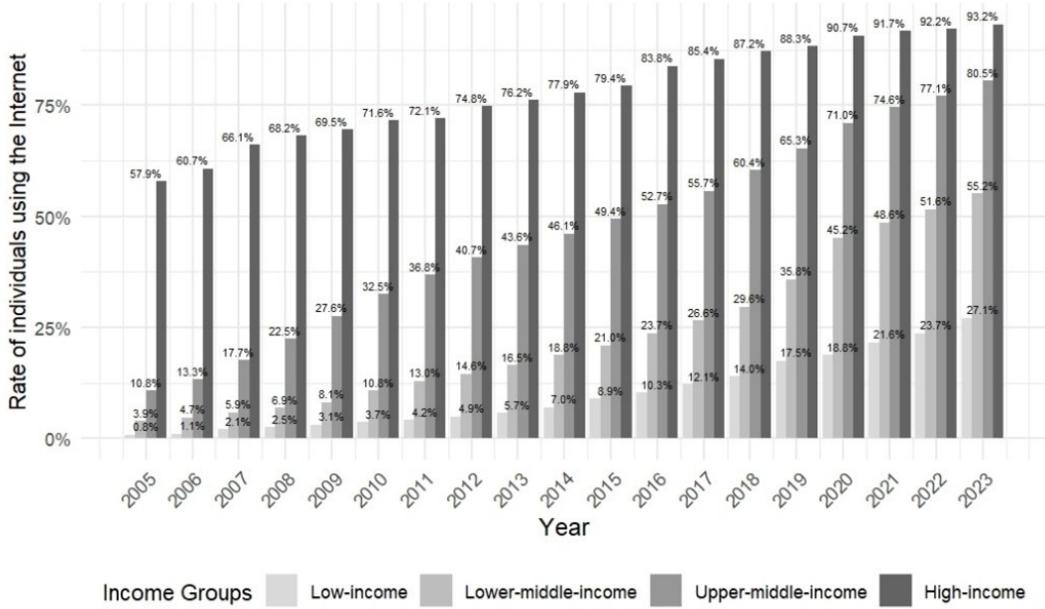


Figure 2: Trends in Internet Usage by Income Level Across Country Groups.

0.3 Global Internet expansion and digital divide

The commercial Internet spread rapidly in the United States, with universities playing a pivotal role in the diffusion process (Goldfarb 2006). By 2000, near-universal availability and widespread adoption in the United States had occurred (Greenstein 2000). This was also the case in most developed countries, as evidenced by the high rates of Internet usage among individuals in high-income countries, reaching 93.2% in 2023, as shown in Figure 2. Internet usage remained low in developing countries in the 1990s but exploded from the 2000s onwards.

The graph 2 shows that in upper-middle-income countries, the rate of individuals using the Internet increased from 10.8% in 2005 to 80.5% in 2023, while in lower-middle-income countries, this rate rose from 3.9% to 55.2% over the same period. Although this rate has significantly increased in lower-income countries, it remains much lower, going from 0.8% in 2005 to 27.1% in 2023. These access inequalities are between developed and developing countries and within these countries. According to ITU figures in 2023, in high-income countries, the rate of internet usage stands at 94.9% in urban areas and 88.4% in rural areas. In contrast, in low-income countries, a significant digital divide is evident: while 47% of individuals use the internet in urban areas, only 16.6% do so in rural areas. These statistics highlight one of the previously mentioned risks: unequal access to the internet and the inability of some actors to benefit from the potential positive effects of the internet.

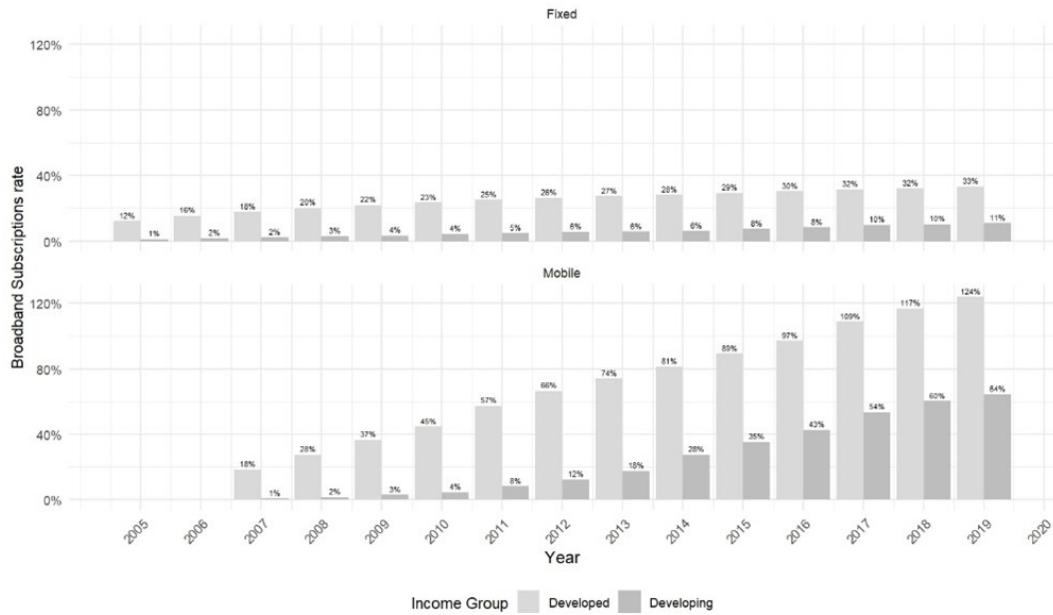


Figure 3: Trends in Broadband Subscriptions Across Developed and Developing Country Groups.

The surge in internet usage is closely linked to the increase in fixed broadband subscriptions in developed countries, which rose from 12% in 2005 to 33% in 2019. However, the dramatic rise in mobile broadband penetration stands out, increasing from 18% in 2007 to 124% in 2019 (a rate above 100% due to individuals often having multiple mobile broadband subscriptions). This disparity between fixed and mobile broadband penetration is especially pronounced in developing countries. While fixed broadband subscription rates reached only 11% in 2019, mobile broadband penetration soared from 1% in 2007 to 64% in 2019. By 2023, fixed broadband subscription rates stood at 38.7% in high-income countries but only 0.5% in low-income countries. In contrast, mobile broadband penetration rates were 129% in high-income countries and 65.2% in low-income countries, highlighting the crucial role of mobile broadband in providing high-speed internet access in developing regions. This trend is accompanied by an explosion in mobile broadband coverage in low-income and lower-middle-income countries, as illustrated in Figure 4. For example, 4G coverage in low-income countries has surged from just 4% of the population in 2015 to 39% in 2023.

0.4 High-speed Internet in the economic literature

The economic literature has extensively explored the impact of broadband Internet on economic growth, drawing parallels with the broader effects of ICTs in various markets. Just

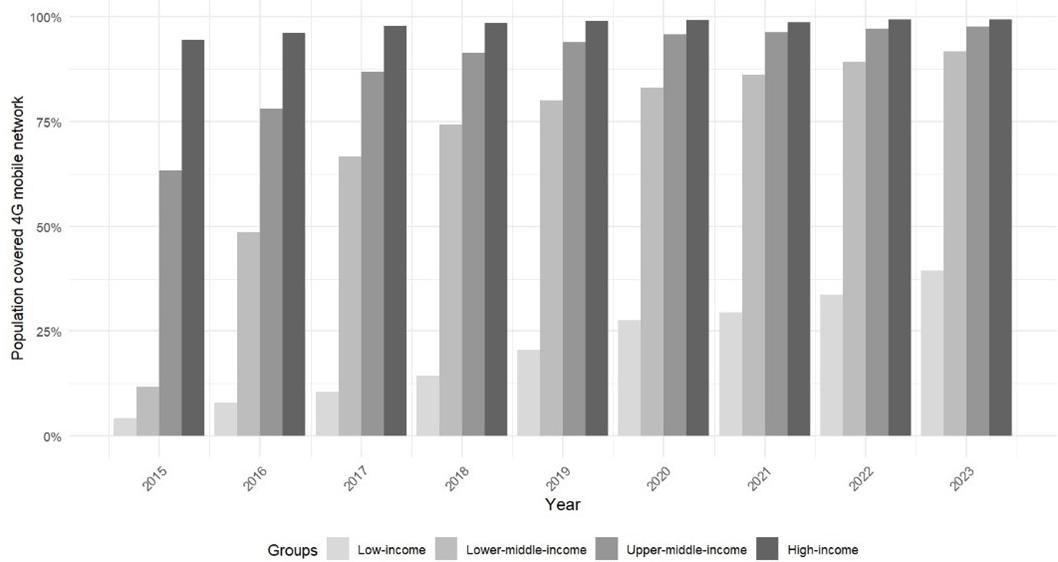


Figure 4: Trends in 4G Population Coverage Across Different Country Groups

as ICTs have been shown to reduce search costs in financial markets (Barber and Odean 2001), labor markets (Autor 2001), and retail markets (Borenstein and Saloner 2001; Bakos 2001), high-speed Internet has significant economic consequences that have been widely studied. Broadband Internet is recognized as a General Purpose Technology (GPT) (Bresnahan and Trajtenberg 1995; Carlaw and Lipsey 2006; Liao et al. 2016), a category of technology that drives wide-ranging economic growth by enhancing business productivity, facilitating innovation, and creating new market opportunities.

The positive impact of broadband on economic growth is well-documented in both macroeconomic and local contexts. For instance, Koutroumpis, 2009, Czernich et al., 2011, Kolko, 2012, and Briglauer and Gugler, 2019 have all demonstrated that broadband Internet significantly contributes to economic growth, often exceeding the influence of other ICTs, as noted by Vu, 2011. At the microeconomic level, the positive impact on productivity has also been highlighted in studies by Chen, Liu, and Song, 2020 and Haller and Lyons, 2015, further underscoring the transformative role of broadband in driving economic performance. The Internet profoundly transforms the economy by enabling new activities and business models.⁷

The impact of broadband Internet on development has been particularly significant in

⁷In recent years, the proliferation of smartphones and the widespread availability of mobile and fixed high-speed Internet have fueled the growth of an extensive range of new businesses within the “sharing economy,” such as Uber, Lyft, and Airbnb. These technologies have also supported the expansion of mobile information services, including social media, ticketing, messaging platforms, and countless other applications (Greenstein 2020).

poorer countries, where its economic effects often surpass those observed in wealthier nations (Appiah-Otoo and Song 2021). The positive effects of reduced information costs, driven by digital technologies, have been widely studied in developing countries. For instance, research by Jensen, 2007, Aker and Mbiti, 2010, Aker, 2010 has demonstrated how digital technologies can enhance market efficiency, reduce price dispersion, and improve welfare in these regions. A systematic review by Oloyede et al., 2023 further consolidates these findings, highlighting the broad range of benefits digital connectivity brings to developing economies.

Moreover, the impact of Internet access on economic growth in developing countries has been a key focus of research. Studies such as those by Goldbeck and Lindlacher, 2021 and the influential work by Hjort and Poulsen, 2019 underscore how the introduction and expansion of broadband Internet can drive substantial growth by improving access to information, increasing productivity, and fostering innovation. These effects are particularly crucial in contexts where traditional infrastructures are weak, and the potential for digital leapfrogging offers a unique opportunity for accelerated development.

Households benefit from better employment and educational opportunities through access to online information and services, improving their well-being and standard of living (Greenstein and McDevitt 2011) and also in developing countries (Bahia et al. 2024). The Internet can also promote equality of opportunity by providing equitable access to essential information and services and strengthening social ties, especially in rural areas, through social networks. Furthermore, the Internet is often seen as a catalyst for democracy and civic participation. It enables citizens to inform themselves, organize, and express themselves more freely, thus facilitating social mobilization and government transparency (Diamond 2010).

However, the digital divide can exacerbate existing economic inequalities, leaving rural populations (Forman, Goldfarb, and Greenstein 2012) and developing countries behind compared to urban areas and developed nations. The impact of ICTs on development is debated. Rodrik, 2018 argues that ICTs may slow economic development in certain contexts by reducing long-term job growth through automation or shifting jobs away from manufacturing. Additionally, the dangers of social isolation, which diminish face-to-face interactions, can have adverse effects on mental health (Braghieri, Levy, and Makarin 2022) and undermine social capital (Geraci et al., 2022). The spread of misinformation and fake news via social networks can polarize societies and jeopardize social cohesion (Allcott and Gentzkow 2017). Politically, authoritarian regimes can use the Internet to monitor and repress dissidents (Morozov 2012), and the manipulation of elections through disinformation campaigns poses a significant challenge to democracy (Diamond and Plattner 2012).

0.5 The Value of Broadband Internet

Three major economic agents are studied in this thesis: households, businesses, and citizens. The measurement of the subjective value of high-speed internet is therefore approached from different perspectives depending on the agent considered. Based on the marginalist school framework,⁸ we can define subjective value as the value attributed to a good or service by an individual based on their preferences, needs, desires, and specific circumstances. This subjective value can be applied to high-speed connectivity.

Households may attribute a high subjective value to high-speed internet for several reasons. High-speed internet can provide access to information or entertainment (such as fast access to a vast amount of information, content, and streaming services). It can also improve their quality of life by enabling teleworking, teleconsultations, and easier access to various opportunities. Additionally, high-speed internet can be a factor in social integration, as it facilitates access to social networks, strengthens social ties, and enables participation in online communities. The second chapter of this thesis aims to quantify this subjective value through willingness-to-pay for very high-speed internet.

Beyond measuring the subjective value of high-speed internet for households, it is also crucial to consider changes in overall welfare that may arise from shifts in internet consumption not captured by these traditional subjective value measures. Specifically, the subjective value of high-speed connectivity for individuals as citizens is of great importance, particularly in the context of exercising political freedom. High-speed internet can enhance the ability to exercise one's rights, express opinions, and mobilize for democratic causes. Therefore, assessing its value through the lens of its potential benefits for democracy (such as increasing the chances of participating in protests and making one's voice heard) is the objective of the first chapter of this thesis.

Finally, the subjective value of high-speed internet is critical for businesses, as it directly impacts their performance and competitiveness. High-speed internet enhances operational efficiency, fosters innovation, and enables businesses to expand into new markets. Additionally, reliable high-speed connectivity is vital for effective communication, coordination, and agility in a rapidly evolving competitive landscape. The third chapter of this thesis aims to

⁸The founders of the marginalist school, Carl Menger (Menger, Klein, and Hayek 2011), William Stanley Jevons (Jevons 1871), and Léon Walras (Walras 1874), developed the theory of subjective value in the late 19th century. These economists marked a turning point in economic thought by introducing the concept of marginal utility, which posits that the value of a good is determined by the additional satisfaction a person gains from consuming one more unit of that good. The marginalist school relied on key concepts, particularly utility and preferences. In economics, utility measures a person's satisfaction from consuming a good or service, which depends on individual preferences. These preferences reflect the choices and priorities of economic agents.

measure this subjective value for firms seeking to maximize profits by analyzing the impact of high-speed internet on business creation and examining how it modifies agglomeration effects and firm allocation.

Thus, studying the subjective value of high-speed Internet for households, businesses, and citizens through high-speed Internet infrastructures is essential because it allows us to understand the needs and priorities of different economic agents. This understanding helps guide public policies and investments in digital infrastructure to maximize social and economic well-being. By quantifying subjective value, we can better assess the overall economic impact of high-speed internet deployment and justify necessary investments. Recognizing the perceived value by economic agents enables the design of strategies to reduce the digital divide and ensure equitable access to the benefits of high-speed internet. Ultimately, understanding and maximizing the positive impacts of digitization on society and the economy is crucial.

0.6 Chapter summaries

This thesis is structured into three chapters, each measuring the subjective value of high-speed internet for different agents: citizens, households, and businesses.

The first chapter, "*From Connection to Coordination: High-Speed Internet and Protests in Africa*," tests the hypothesis that access to broadband internet, which allows access to new content and platforms such as social networks, unconditionally increases the likelihood of participating in protests and the frequency of protests in Sub-Saharan Africa. Using a difference-in-differences design, the study leverages the gradual arrival of fiber optic submarine cables from 2009 to 2014 and the distance to terrestrial cables as a proxy for exposure to high-speed internet. The findings indicate that exposure to mobile and fixed high-speed internet increases the probability of individuals participating in protests and the likelihood of protests occurring in exposed areas. This significant relationship exists only in countries that actively exercise political rights and civil liberties, with coordination mechanisms playing a more substantial role than informational mechanisms.

The second chapter, "*Valuing the Virtual: The Impact of Fiber to the Home on Property Prices in France*," published in *Telecommunications Policy*,⁹ examines the hypothesis that households positively value access to very high-speed internet. However, this valuation varies according to socio-economic contexts in France. The research uses a hedonic pricing model and a spatial donut regression discontinuity design to estimate this value, comparing property

⁹Guiffard J.-B. (2024). Valuing the Virtual: The Impact of Fiber to the Home on Property Prices in France. *Telecommunications Policy*, 48(4), 102732. doi: 10.1016/j.telpol.2024.102732

transactions on either side of the FTTH deployment boundary in 2019. The results show that FTTH eligibility significantly increases property prices, with an average increase of 0.9 percent, particularly in rural areas. These variations in valuation can be attributed to the poorer performance of pre-existing fixed networks.

The third chapter, "*From Bytes to Business: Mobile Broadband, Firm Creations, and Digital Divide in Tunisia*," explores how new firms increasingly seek locations with better connectivity to leverage potential competitive advantages in Tunisia. The study uses a count model and panel data regressions with fixed effects using data on Tunisian firms and 4G antenna density to measure the impact of mobile broadband internet on business creation. The findings reveal a robust positive relationship between the density of 4G antennas per 10,000 inhabitants and the number of new business creations, with more substantial and delayed effects in rural areas, especially on the outskirts of major urban centers. This effect also varies according to company size (less than 6 workers or 6 workers or more). This challenges the "death of distance" hypothesis and highlights the significant role of mobile broadband in stimulating local economic growth while shedding light on the economic implications of the digital divide.

0.7 Main contributions

This thesis makes significant contributions, mainly through the use of diverse datasets—especially telecom infrastructure data—and advanced impact evaluation methodologies supported by substantial technical expertise in telecom operations.

The collection, processing, and utilization of these telecom infrastructure data are central to the methods and arguments used throughout the thesis. The variety of high-speed internet telecom infrastructure data is evident in the chapters. Chapter 1 utilizes data on core networks, addressing the challenge of precise data availability in Africa. This includes data on submarine fiber optic cables from Europe to Africa, landing points, and service dates, helping to determine when high-speed international connectivity became available in each Sub-Saharan African country. Additionally, data on terrestrial backbone cables are used to construct a proxy for high-speed internet exposure. The further an individual is from these terrestrial cables, the lower the likelihood of accessing sufficient broadband speeds.

Chapter 2 employs fixed high-speed internet infrastructure data, primarily a compilation of addresses eligible for fiber, indicating the quarter of eligibility. This database, provided by the French telecom regulator (ARCEP), allows for determining FTTH eligibility at the address level across metropolitan France. These data are used to construct eligibility zones to determine property treatment status (fiber-eligible or not) at the time of sale. The distance

to the eligibility boundary supports the spatial regression discontinuity methodology for causal identification. Additional data on maximum ADSL speeds, also compiled by ARCEP, help understand why fiber's impact on property prices might be more substantial in less dense areas with weaker pre-existing ADSL speeds.

Chapter 3 focuses on mobile high-speed internet infrastructure, utilizing OpenCellID data to locate mobile phone antennas, their generation (2G, 3G, 4G), ownership, and service dates. In the Tunisian context, these data are used to create indicators such as the density of 4G antennas per 10,000 inhabitants in each Tunisian delegation and mobile coverage. These indicators measure mobile high-speed internet quality at the administrative unit level and are used to analyze how the quality of mobile broadband infrastructure affects firm creation in Tunisia.

The diversity of data utilized in this thesis is matched by applying a range of rigorous impact evaluation methodologies. Each chapter is dedicated to conducting a thorough impact assessment using distinct methodological approaches adapted to the specific research questions. The first chapter employs a difference-in-differences (DiD) approach, which is particularly effective in capturing causal effects over time by comparing changes across different groups and using the arrival of optic-fiber submarine cable as the date of treatment and as an exogenous shock. The second chapter adopts a spatial regression discontinuity design (RDD), a powerful tool for estimating causal impacts by exploiting geographic boundaries as natural experiments. Additionally, this thesis leverages various other econometric techniques in Chapter 3, including panel data methods with two-way fixed effects (TWFE) Poisson models and spatial econometrics combined with economic geography. These methodologies provide robust estimates of the impacts under study and contribute to the methodological literature by demonstrating their application in diverse contexts.

The use of telecom infrastructure data in this thesis is deeply informed by nuanced expertise in the functioning of both fixed and mobile Internet networks, which guides and justifies several key methodological choices. For example, this expertise led to a critical reassessment of the methodology used by Hjort and Poulsen, 2019 in Chapter 1. The preference for crowd-sourced data over traditional sources, specifically the choice to use OpenCellID data instead of GSMA data, was informed by a detailed understanding of mobile network operations and the superior granularity that OpenCellID offers. Similarly, the analysis of fiber networks is enriched by a thorough understanding of their technical workings and the regulation of telecommunications networks, which allows for more accurate and relevant application of the data. This technical expertise ensures that the methodologies employed are theoretically robust and practically aligned with the real-world dynamics of high-speed Internet telecom infrastructure.

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Chapter 1

From Connection to Coordination: High-Speed Internet and Protests in Africa

1.0.1 Abstract

What is the role of broadband Internet in shaping political participation in Africa? This study leverages the staggered arrival of submarine Internet cables and the terrestrial backbone network in Africa to examine the influence of high-speed Internet on protests. Combining large-scale cross-country surveys on political behaviors and disaggregated data on conflict events, robust difference-in-differences estimates indicate a significant increase in both the likelihood of protest participation and the frequency of protests. This effect is particularly observed in countries that actively exercise political rights and civil liberties. The analysis explores two key mechanisms—information dissemination and coordination facilitation—with the latter being the predominant factor influencing the observed effects.

JEL Classifications: L96 ; O18 ; D72

Keywords: *Governance ; Political Mobilization ; Protest ; High-speed Internet ; Sub-Saharan Africa*

1.1 Introduction

As Al Gore declared in the 1994 Telecommunication Development Conference (ITU)¹, the rise of the Internet in the 1990s promised a new era where Information and Communication Technologies (ICTs) would be a catalyst for fundamental liberties, democratic processes, and public discourse (Howard 1993). Theoretical frameworks such as Diamond's (2010) concept of 'Liberation technology' articulates the impact of ICTs in empowering communities, reshaping interactions, and invigorating civic engagement (Katz 1997 ; Oates 2003). The role of ICTs, and particularly the Internet and related services, in events like the Arab Spring (Tufekci and Wilson 2012 ; Khamis, Gold, and Vaughn 2012) and Sub-Saharan Africa's 'Third Wave of Protests' (Branch and Mampilly 2015 ; Mateos and Erro 2021) underscores their potential as democratizing forces in developing countries, aligning with Diamond's view (Weare 2002; Mudhai 2003; Ben Ali 2020). However, the Internet might also limit democratic freedoms and foster misinformation. Morozov (2011) coined the term 'Freedom Recession' to highlight the risks associated with ICT proliferation, such as increased censorship and the curtailment of democratic freedoms (e.g., expression, protest, voting rights, and organizational affiliations)². Additionally, the spread of misinformation (Vosoughi, Roy, and Aral 2018) poses significant threats to the formation of political beliefs and attitudes.

In light of these contrasting perspectives, the aim of this paper is to investigate the relationship between broadband Internet access and political behaviors. To do so, I employ a difference-in-difference methodology to evaluate how the exposition to broadband Internet³ impacts political mobilization, with a particular focus on protests in Sub-Saharan Africa. Additionally, I disentangle the mechanisms through which information dissemination and coordination enhancement operate and examine how these effects vary within different institutional contexts.

Assessing the impact of broadband Internet in developing regions presents methodological challenges, primarily due to endogeneity and data constraints. This study refines the approach pioneered by Hjort and Poulsen (2019), exploring how temporal changes associated with the introduction of submarine cables intersect with spatial variations in broadband access. Unlike in developed countries where existing fixed telecom networks often serve as

¹"To promote; to protect; to preserve freedom and democracy, we must make telecommunications development an integral part of every nation's development. Each link we create strengthens the bonds of liberty and democracy around the world." (Gore 1994)

²Dictators can perceive ICTs as a mean of strengthening their hold on the power. The Internet can strengthen their control over the population and facilitate the identification of political opponents.

³Broadband Internet is defined by the Federal Communications Commission as access to high-speed Internet at minimum speeds of 25 Mbps downstream and 3 Mbps upstream, utilizing various technologies including fiber, wireless, cable, DSL, and satellite.

instrumental variables ([Czernich 2012](#); [Falck, Gold, and Heblisch 2014](#); [Campante, Durante, and Sobrino 2018](#)), this study leverages the phased deployment of submarine fiber-optic cables between 2009 and 2014 as a natural experiment. By utilizing the proximity to backbone networks as an instrument, as suggested by Miner's research ([Miner 2015](#)), this approach introduces exogenous variation in Internet access, thereby mitigating potential biases⁴.

Data from geolocated Afrobarometer surveys across ten coastal Sub-Saharan countries, encompassing two survey waves before and two survey waves after the broadband enhancements, forms the empirical basis of this study. The treatment year is identified as the year a country first connects to a submarine fiber-optic cable, with treatment groups defined by proximity to existing backbone infrastructure. Individuals closer to the cables, within a specified radius (1200 meters), are expected to experience greater Internet speeds and access quality, influencing their ability to engage with online content (and potentially participate in collective actions). The identification strategy aims to compare groups of individuals who live near the terrestrial network to those who live further away, whereas the progressive arrival of submarine cables from Europe enabled the connected countries to access high-speed Internet. The analysis is augmented by ACLED data, aggregated at the 0.1×0.1 degrees cell level. The spatial analysis also considers the distance from terrestrial cables as a crucial factor in defining treatment and control cells, aiming to assess the comparative effects in cells near the terrestrial network against those positioned further away, as the phased arrival of submarine cables ushered in enhanced Internet access in these areas.

Cell phones have revolutionized the information environment by decentralizing and amplifying the dissemination of information ([Bailard 2009](#)). Extensive empirical literature in developing countries explores the deployment of communication technologies and their multi-faceted impacts ([Jensen 2007](#); [Jenny C. Aker 2010](#); [Jenny C. Aker, Ksoll, and Lybbert 2012](#); [Jack and Suri 2014](#); [Jenny C. Aker and Cariolle 2023](#)). A significant focus has been placed on the political and governance implications of ICTs, particularly in the context of broadband Internet. For example, studies such as Guriev, Melnikov, and Zhuravskaya ([2021](#)) have demonstrated that in countries without Internet censorship, the expansion of 3G networks correlates with decreased government approval and increased support for populist parties. Similarly, Cariolle, Elkhateeb, and Maurel ([2024](#))'s research using Afrobarometer data across 25 African countries indicates that Internet usage for information access adversely affects the demand and perception of democracy. Moreover, Donati ([2023](#)) revealed that in South Africa, mobile Internet availability in 2016 significantly affected voter turnout and shifted vote shares, with information access and enhanced coordination playing pivotal roles. Ad-

⁴Only terrestrial cables established before the introduction of submarine cables are included, ensuring that the analysis captures the causal effects of broadband connectivity.

ditionally, Hatte, Loper, and Taylor (2023) highlighted that the Facebook “Free Basics” initiative has promoted the electoral success of female candidates in Africa by enhancing their online visibility.

While existing research has addressed the impact of ICTs on democratic institutions, such as political accountability (Jenny C. Aker, Collier, and Vicente 2017) and electoral fraud (Gonzalez 2021), this study broadens the quantitative analysis of ICTs’ role in political mobilization within developing countries—a relatively underexplored area. It examines the likelihood of individuals participating in protests over the past year, focusing on how mobile and fixed broadband Internet access affects this probability, particularly through specific online content and social networks. Unlike previous research, which primarily addressed the effects of 2G networks in conflict scenarios (Pierskalla and Hollenbach 2013; Bailard 2015), this research explores explicitly the more advanced capabilities of broadband technology and its distinct influence on political mobilization. Manacorda and Tesei (2020) have explored the dynamics of economic downturns and expanded 2G coverage in Africa from 1998 to 2012 and their impact on political protests, emphasizing the crucial role of information flow and peer influence in fostering protest participation. Building on this foundation, this study aims to ascertain whether the influence of broadband Internet on protest participation is consistent across different political and economic environments, effectively testing the unconditional nature of this effect. Some recent studies also delve into the effects of social networks on political mobilizations, referencing the influence of Facebook’s language availability on protests (Fergusson and Molina 2019) and analyzing how social media platforms facilitate the spread of protests and strikes in China (Qin, Strömberg, and Wu 2021).

The findings of this paper suggest that the arrival of submarine cables in Africa significantly increases the likelihood of participation in protests and the frequency of such events. This paper states that this effect is due to exposure to broadband internet and unconditional to economic trends and conditions. This effect is particularly noted in “free” countries, where political rights and civil liberties are actively exercised. The analysis investigates two primary mechanisms—information dissemination and coordination facilitation—with enhanced coordination emerging as the principal driver behind the observed impact. This relationship has undergone numerous robustness tests, suggesting a causal effect.

The rest of the paper is structured as follows: Section 1.2 attempts to comprehend what the arrival of optical fiber underwater cables implies for access to broadband connectivity as well as for political behavior and attitudes in Sub-Saharan Africa in order to add additional depth to the study topic and some contextual elements. Section 1.3 describes the data. Section 1.4 describes the methodology, including the difference-in-difference approach and the data sources used. Section 1.5 presents the empirical findings, analyzing the impact

of broadband Internet on political protests. Section 1.6 discusses the implications of these findings, exploring the mechanisms of information dissemination and coordination and to what extent the institutional context plays a role in this relationship. Finally, Section 1.7 concludes.

1.2 Context

This section provides a detailed background to enhance understanding of the arrival of optic-fiber submarine cables, the subsequent expansion of broadband Internet, and its potential implications in Africa. It supports the methodological framework of this study and explores potential mechanisms that might link broadband Internet exposure to political mobilization.

1.2.1 Submarine optic-fiber cables, backbone network and International broadband connectivity in Sub-Saharan Africa

Since the late 1990s, Sub-Saharan African countries have witnessed exponential mobile cellular and mobile broadband network growth. Mobile technology can be considered a “leapfrog” technology, which has been able to circumvent the need for extensive fixed network infrastructures to reach the majority of the African population (Jenny C. Aker and Cariolle 2023). This has resulted in Internet users accessing the Internet via mobile devices rather than the traditional method of using a computer (Napoli and Obar 2013). The prevalence of mobile Internet access, especially in middle and low-income African countries, underscores this trend (GSMA 2019).

Remarkably, by 2020, the coverage of at least a 2G network extended to 88.4% of the African population, a stark increase from the 10% coverage in 1999. Moreover, mobile broadband accessibility experienced significant growth, with coverage rising from 51.3% in 2015 to 77.4% in 2020. This growth signifies a robust expansion in telecommunications penetration, which escalated from 1.7% in 2010 to 33.1% by 2019 (ITU 2020). As illustrated in Figure 1.1, the progressive deployment of submarine fiber-optic cables plays a crucial role in this narrative, enhancing international broadband connectivity and shaping the digital landscape of Sub-Saharan Africa.

Satellites and submarine cables (associated with backbone cable network) are the two ways to get broadband international connectivity⁵. Submarine cables are the preferred choice

⁵The international connectivity is the international telecommunications capacity “that binds together the networks of countries and major cities” (<https://www.itu.int/en/ITU-T/studygroups/2013-2016/03/Pages/iic.aspx>, accessed January 2024)

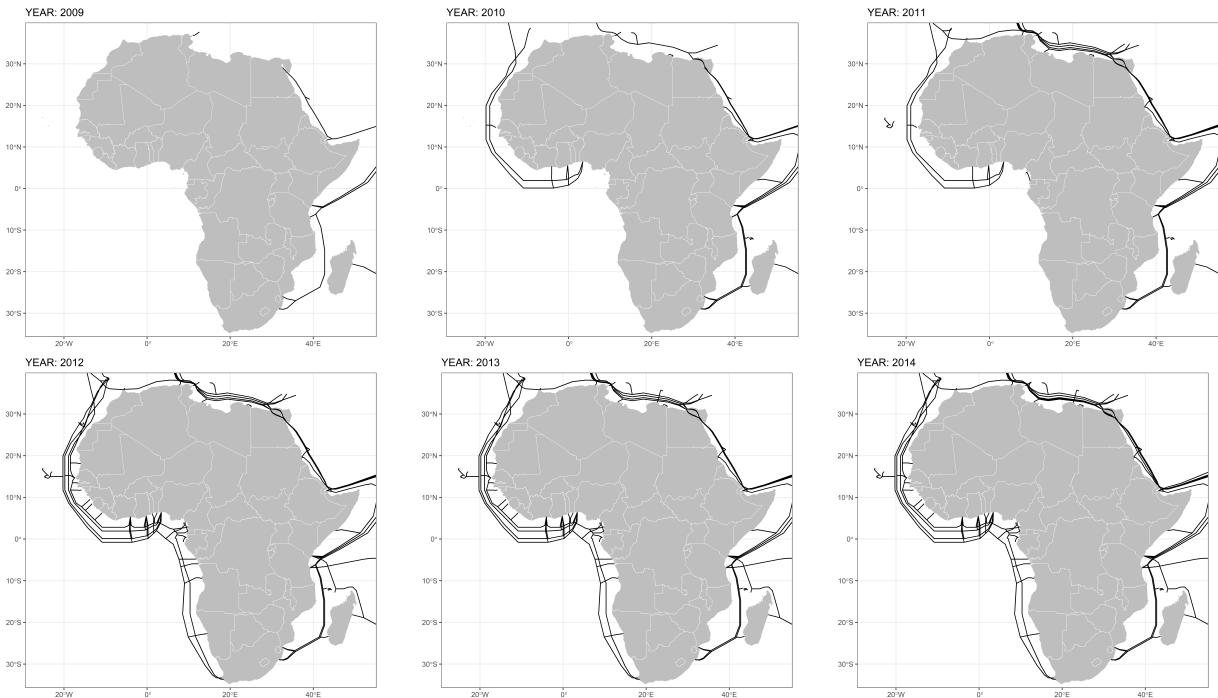


Figure 1.1: The gradual arrival of optic-fibre submarine cables in Sub-Saharan Africa

for their cost-efficiency, offering lower expenses for operators per subscriber and reduced international connectivity costs ([Mason 2011](#)). In contrast, satellite communications, despite suffering from higher latency and jitter issues ([Analysys Mason 2013](#)), provide essential access to remote and hard-to-reach areas where laying cables is not feasible or too costly. This strategic preference has led operators to extensively use submarine cables to broaden network infrastructures, particularly emphasizing cables linking Sub-Saharan African countries directly with Europe.

As illustrated in Figure 1.2, each submarine cable is connected to a terrestrial network known as a backbone network that connects the entire country ([Gelvanovska, Rogy, and Rossotto 2014](#)). This backbone or the core network, typically operated by national telecom providers, is engineered to facilitate the transfer of substantial data volumes across vast distances using lines with high bandwidth capacity⁶. The backbone network plays a crucial role in distributing Internet traffic nationwide, leveraging expansive fiber cables for the bulk of data transmission.⁷ The final phase of connectivity, known as the ‘last mile’,

⁶During the period of this study, the terrestrial Internet infrastructure in nearly all African countries was developed and maintained by a national telecom operator. Each country is covered by only one backbone network before the arrival of optic-fibre submarine cables.

⁷The route of backbone networks adheres to stringent economic and logistical criteria to optimize operational efficiencies and reduce costs. In coastal countries for example, a critical objective is to ensure connectivity to international networks by integrating backbone networks with submarine cable landing points.

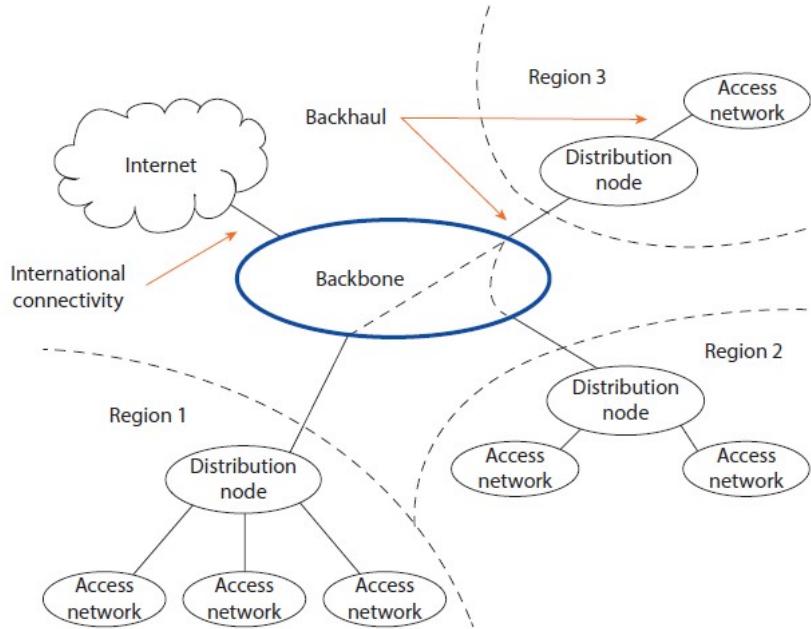


Figure 1.2: Network Components of Broadband Infrastructure (Source: World Bank, 2014)

bridges the gap to the end-users through a combination of fiber or copper cables and mobile antennas supporting various generations of mobile data technologies (3G, 4G, 5G), ensuring comprehensive digital access.

The last mile (both antenna and fixed networks, e.g. xDSL) reaches the end user directly, although the quality of the Internet speed reduces rapidly as the distance to the core network increases, depending on the technology used⁸. As shown in Figure 1.9 in the Appendix, the number of antennas decreases with the distance from the backbone. Thus, between 2012 and 2016, 43.7% of new 3G antennas located between 0 and 10 km from the backbone cables were less than 1200 meters and 44.2% of new 4G antennas⁹. Figure 1.13 in the Appendix

The network design also considers the country's topographical constraints, with planners strategically minimizing expenditures and terrain-related technical difficulties. Additionally, backbone networks are designed to efficiently connect major urban centers and densely populated areas with the highest demand for connectivity. Also the synergy with other infrastructural developments is important; during the construction of roadways or electrical grids, backbone networks are frequently installed or enhanced to leverage shared costs and infrastructure pathways. https://cio-wiki.org/wiki/Backbone_Network, accessed in June 2024

⁸For fixed network (copper network) the attenuation decreases very quickly 1.5 km after the splitter, depending on the technology (ADSL, VDSL, ADSL2...). For mobile networks (cell phone antennas), the signal quality decreases rapidly after a 1km distance as shown in Figure 1.10 from Karray and Jovanovic (2013).

⁹The location of antennas and the creation of new antennas is obtained via OpenCell-ID (<https://opencellid.org/>) which is an open cellular dataset. This database, in addition to giving the date of entry

shows the evolution of the location of antennas in Senegal between 2012 and 2019; we can see a location that is first and foremost along the existing submarine cables before the arrival of submarine cables in 2010. Thus, some relatively more remote antennas can be connected, especially via microwave technology¹⁰.

The SEACOM cable, initiating its service in 2009, represents the first major submarine optic-fiber cable connecting Marseille to Mumbai via key African ports like Djibouti, Mombasa, Sar Es Salaam, Maputo, and Mtunzini. From 2009 to 2012, this pioneering project was followed by multiple deployments, significantly expanding international broadband access along the majority of Sub-Saharan Africa's coastal regions (Table 1.11). Considering the substantial proportion of African Internet content hosted overseas (Kende and Rose 2015), submarine cables from Europe have been instrumental in significantly enhancing both the bandwidth and the Internet penetration rates across Sub-Saharan Africa (BBC, 2009¹¹; State of the Internet Report, 2012¹²). Notable increases in bandwidth and Internet penetration by approximately 3 to 5 percentage points in regions connected by these cables underscore the transformative impact of this infrastructure (Cariolle 2021). This development marks a significant milestone for African countries engaged with the global broadband revolution¹³. Additionally, broadband Internet significantly improves content accessibility and usage pat-

of the antenna in the database, which can be used as a proxy for the date of commissioning, allows one to know the technology of the antenna (GSM, UMTS, LTE), the owner operator ... From the location of the antennas, it is possible to find the mobile coverage of each technology (2G, 3G, 4G).

¹⁰Mostly via radio-relay system which is a signal transmission system (GSMA 2018).

¹¹BBC. (2009, July 23). Kenya cable ushers in broadband era. BBC News. Retrieved May 23, 2022, from <http://news.bbc.co.uk/2/hi/africa/8163900.stm>

¹²Communications, Ascendant. “Akamai Releases Fourth Quarter 2012 ‘State of the Internet’ Report.” Response Source Press Release Wire. Response Source, April 23, 2013. <https://pressreleases.responsesource.com/news/77353/akamai-releases-fourth-quarter-2012-state-of-the-internet-report/>.

¹³Makeni, J. (2009, April 8). Will Africa join Broadband Revolution? BBC News. Retrieved May 24, 2022, from <http://news.bbc.co.uk/1/hi/world/africa/7987812.stm>

Table 1.1: Download capacity requirement (in Kbps or Mbps) for different services and uses

Capacity Requirement	Services and uses
80 kbps	VoIP calling
Broadband Internet (> 512 Kbps)	
2 Mbps	Video conferencing
3–10 Mbps	Browsing
10 Mbps	Social Networks
10 Mbps	Streaming videos
Very high-speed Internet (> 30 Mbps)	
10–100 Mbps	File sharing/download (documents, images, videos)

terns. For example, Skouby et al. (2014) analyzed broadband capacity requirements for households and small businesses. The findings, detailed in Table 1.1, highlight that optimal web browsing and seamless social network access demand a baseline level of broadband speed, measured in Mbps. Such levels of performance are contingent upon the availability of robust broadband Internet infrastructure.

There is a significant increase in internet penetration across subsaharan Africa, rising from a mere 2% in 2005 to 37% by 2023 (ITU, 2024). However, this growth in connectivity does not uniformly extend across all demographic sectors. When looking at our sample, statistical analysis shows a correlation between internet usage and urban residency (correlation coefficient = 0.144), education (correlation coefficient = 0.136 for primary education), and age (negative correlation with age, coefficient = -0.137), which suggests that younger, better-educated individuals in urban areas are more likely to use the internet daily. Conversely, a slight negative correlation exists with being female (correlation coefficient = -0.090), indicating lower usage rates among women. These disparities underscore a demographic skew towards a more urban, educated, and predominantly young male population having better access to digital resources. This demographic bias is significant as it influences the nature of political mobilization and the representativeness of online activism, potentially excluding rural, older, and less educated populations with differing views and participation levels in political processes.

1.2.2 Democracy, Mass Mobilizations and Telecom Infrastructures

The widespread expansion of broadband Internet around the world depends crucially on key telecommunications infrastructures, such as fiber-optic submarine cables, which play a central role. These cables are strategically valuable but are not only technologically significant; they can trigger various socio-economic effects in connected areas. A kind of techno-optimism about their deployment is tangible among the players in the sector, reflected in the discourse of the operators who, organized in conglomerates, are in charge of deploying fiber optic submarine cables. For instance, Funke Opeke's commentary on the Main One cable—which connects Europe to Africa—underscores its significant impact in lowering Internet costs and increasing bandwidth speeds, ushering Africa into the digital era¹⁴. This enhanced connectivity is instrumental in unlocking economic potential and bolstering social dimensions such as improved communication, heightened awareness, and increased governmental

¹⁴Kermeliotis, B. C. C. P. A. T. (2012, January 10). Underwater cables bring faster Internet to West Africa. CNN. Retrieved November 30, 2021, from <https://edition.cnn.com/2012/01/10/business/funke-opeke-cable-internet/index.html>

transparency¹⁵.

This connectivity fosters economic opportunities and improves aspects of social life, including communication, awareness, and governmental transparency¹⁶. Miner's (2015) analysis underscores the influence of high-speed Internet expansion on political landscapes, particularly in dismantling long-standing political monopolies in Malaysia. These developments underscore the imperative for detailed investigation into the extensive political and socio-economic ramifications of broadband Internet's proliferation in Sub-Saharan Africa, pointing to its potential as a powerful tool for democratic engagement and political mobilization.

The 'Third Wave of Protests' across Sub-Saharan Africa underscores the pivotal role of the Internet in fueling modern social movements (Mateos and Erro 2021). These movements, characterized by demands for greater institutional accountability and democratic reforms (Cheeseman 2019), showcase a profound dissatisfaction with existing political structures (Branch and Mampilly 2015). In Senegal and Burkina Faso, movements like *YEM* (*Y'en a Marre*) and *Balai Citoyen* have leveraged social media, especially Facebook, to drive their activism. These platforms have been instrumental in event coordination, engaging the diaspora, and circulating key information and visuals—ranging from protest scenes to confrontations with the police. The capacity to share photos and videos and forge online activist communities has significantly amplified awareness and facilitated coordinated actions. This new dimension of activism highlights the Internet's transformative influence on political mobilization, challenging established political norms and fostering innovative avenues for protest and discourse.

A member of the *Balai Citoyen* national coordination in Ouagadougou recounted in September 2018, “*Social media was extensively used to broadcast our real-time activities. We shared visuals of people camping at the Revolution Square, the chases with the riot police, and the clashes. We believed that exposing these brutalities and repression would spark outrage and attract more supporters*” (Translated from French). Similarly, a leader from *Y'en a Marre* in Dakar, August 2018, shared, “*The Internet has significantly boosted our visibility both in Senegal and internationally. We utilize the power of social networks to spread our messages and reach as many ‘minds’ as possible with Y'en a Marre [...] You've seen the impact of our university of commitment. People could follow us everywhere, thanks to the*

¹⁵Funke Opeke, discussing the Main One fiber-optic submarine cable's connection from Europe to Africa through various points, highlighted its role in advancing the information age in Africa, touching upon the benefits for educational institutions, business opportunities, social awareness, better communication, and government transparency.

¹⁶Funke Opeke speaking about the Main One fiber-optic submarine cable connecting Europe to Africa via Morocco, the Canary Islands, Senegal and Côte d'Ivoire said “When you think of Africa coming into the information age, you think of educational institutions, you think of business opportunities, you think of social awareness, better communication, transparency in government.”

live broadcasts we did on Facebook" (Translated from French)¹⁷.

While the democratizing potential of the Internet is well-recognized, it's important to note that authoritarian regimes have adeptly utilized New Information and Communication Technologies to consolidate their power. Insights from Morozov (2011) highlight how such regimes manipulate digital platforms to extend their influence over citizens, thereby reinforcing their authoritarian rule. The complex relationship between Internet access and political dynamics suggests that increased online engagement might paradoxically facilitate government efforts to galvanize support in authoritarian contexts. This nuanced impact of the Internet on political landscapes underlines the critical need for careful analysis of its influence within varying governance frameworks, recognizing that its effects might not uniformly align with democratic ideals but could inadvertently empower regimes that strategically harness digital tools for their ends.

1.3 Data

To address the research question effectively, I require geolocalized survey data on political attitudes and behaviors, detailed records of event locations and their frequencies, and precise mappings of key telecommunications infrastructure. Additionally, I integrate supplemental information at cell and country levels to construct robust control variables and facilitate a heterogeneity analysis.

Backbone's location and submarine cables' activation date The *African Terrestrial Fibre* (AfTerFibre) database¹⁸ is an open data project that provides a mapping of most of Africa's terrestrial fiber optic infrastructure. This database lists crucial information on the backbone network across African countries, detailing the paths of terrestrial Internet cables, their deployment locations, the operators managing them, and their phases of installation. The network configuration as of 2009¹⁹ is illustrated in Figure 1.3 with black lines indicating the routes of these cables, offering a precise geographical depiction of the connectivity landscape prior to the arrival of submarine cables.

¹⁷Dimé, Mamadou, et al. "« Afrikki Mwinda »: Y'en a Marre, Balai Citoyen, Filimbi et Lucha – Catalyseurs d'une Dynamique Transafricaine de l'engagement Citoyen." *Africa Development / Afrique et Développement*, vol. 46, no. 1, 2021.

¹⁸<https://afterfibre.nsrc.org/>

¹⁹For this econometric methodology, particular attention is directed toward infrastructure established before 2009, the year that marks the initiation of optic-fiber submarine cable implementation in the region. This specific focus allows for the isolation of effects attributable to these new introductions from those of existing infrastructure.

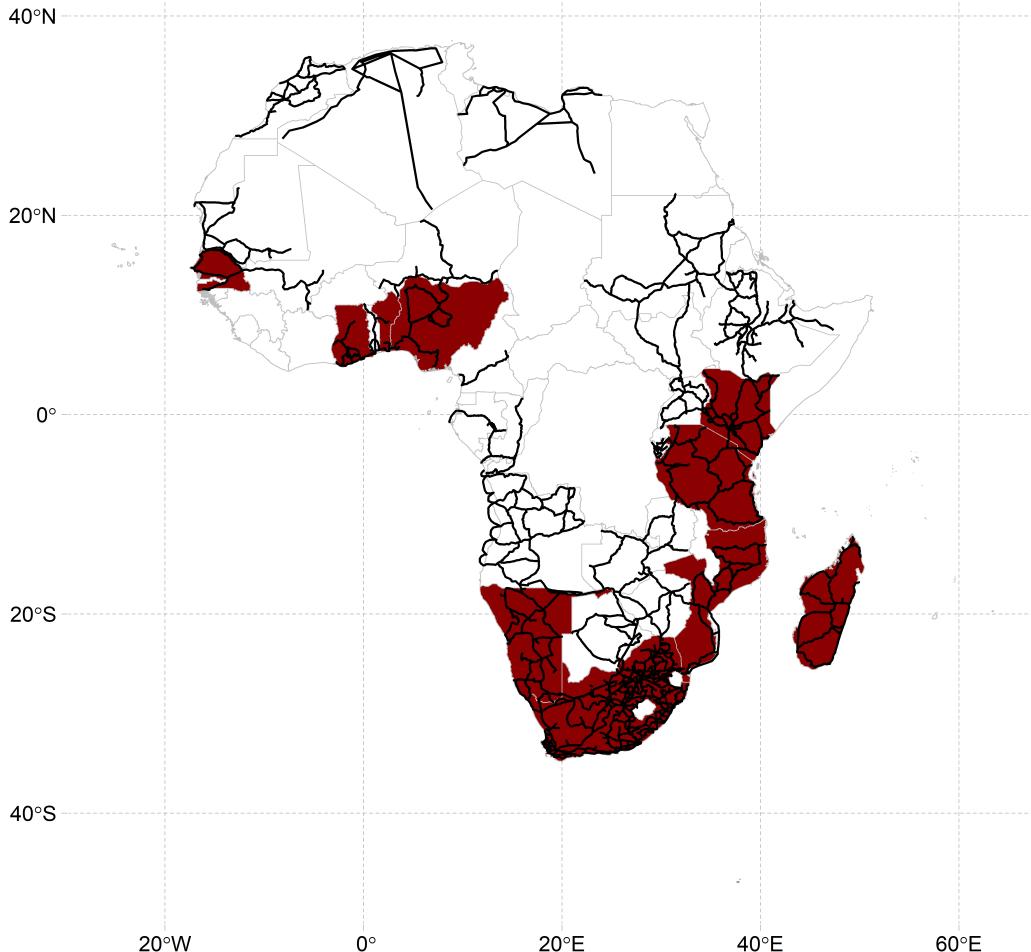


Figure 1.3: This map illustrates the ten Sub-Saharan African countries included in our study—Benin, Ghana, Kenya, Madagascar, Mozambique, Namibia, Nigeria, Senegal, South Africa, and Tanzania—highlighting the routes of existing backbone cables operational prior to the introduction of submarine cables. These countries were specifically selected based on several criteria: each had at least two waves of Afrobarometer surveys conducted both before and after the arrival of submarine cables in 2009, detailed data on terrestrial cable routes existing before 2009 were available, and their coastal locations ensured a clear delineation of the treatment related to submarine cable access.

Additionally, the arrival dates of these submarine cables in each country, as depicted in Figure 1.1, are sourced from Infrapedia²⁰. This source provides data concerning each submarine cable's construction and activation years. These dates are referenced in Table 1.2, underpinning the temporal framework for the econometric analysis.

Political Attitude and Behavior: Individual Level Data from Afrobarometer

This study utilizes geolocated data from the Afrobarometer²¹, which has been systematically collecting opinion polls in multiple African countries since 1999, with the first survey wave encompassing 37 countries by 2021²². The Afrobarometer surveys, which capture public attitudes towards democracy, governance, and a range of social and economic issues, have progressively included more countries across the seven subsequent waves, thus facilitating a robust longitudinal analysis. This study focuses on ten coastal countries with survey data available both before and after the introduction of submarine cables²³: Benin, Ghana, Kenya, Madagascar, Mozambique, Namibia, Nigeria, Senegal, South Africa, and Tanzania.

I focus on key variables derived from face-to-face interviews conducted in the Afrobarometer surveys. These variables encompass three main dimensions: political mobilization, political attitudes, and digital practices. The main set of variables of interest enters the field of political mobilization, capturing a spectrum of civic engagement activities as reported by respondents. Among a list of actions that citizens can take, respondents were asked if they had personally taken any of these actions in the past 12 months. Each survey asks about participation in a protest in the past 12 months and whether the respondent has recently participated in a community meeting, discussed politics, is an active member of an association, or joined with others to address an issue. I focus on the likelihood that the individual

²⁰www.infrapedia.com.

²¹The geolocated data of the observations employs an advanced geographic coding system by AidData recommended by Roodman (2024). A trained team performed the geocoding of the Afrobarometer data using a rigorous double-blind process. This involved two independent coders assigning geographic coordinates to each location. Additional quality control measures were implemented to ensure accuracy (BenYishay et al. 2017).

²²Afrobarometer. (2021). Afrobarometer. Retrieved December 1, 2021, from <https://afrobarometer.org/countries>. The geocoding process utilized in this study aims to maximize the precision of location data. However, any residual inaccuracies in geolocation could lead to misclassifications of individuals relative to infrastructure, such as proximity to backbone networks. Such misplacements might result in either overestimating or underestimating the treatment effect, depending on whether individuals are incorrectly classified as being closer to or further from key infrastructure than they are. Despite efforts to ensure accuracy, if any misclassification remains, it is hoped to be random.

²³The timing of these survey waves provides a valuable opportunity for pre-trend analysis. The first four rounds of the Afrobarometer survey were conducted prior to the introduction of optic-fiber submarine cables in Africa, beginning in 2009. This pre-trend analysis is crucial for evaluating the impact of the widespread deployment of broadband Internet on the political, social, and economic dimensions captured by the Afrobarometer.

Table 1.2: Year of the different waves of the Afrobarometer surveys and date of arrival of the first submarine fiber-optic cables by country

Country	Survey	Treatment
Benin	(2005, 2008, 2011, 2014)	2010-Q3
Ghana	(2005, 2008, 2012, 2014)	2010-Q3
Kenya	(2005, 2008, 2011, 2014)	2009-Q3
Madagascar	(2005, 2008, 2013, 2015)	2010-Q3
Mozambique	(2005, 2008, 2012, 2015)	2009-Q3
Namibia	(2006, 2008, 2012, 2014)	2012-Q2
Nigeria	(2005, 2008, 2013, 2015)	2010-Q3
Senegal	(2005, 2008, 2013, 2014)	2010-Q3
South Africa	(2006, 2008, 2011, 2015)	2009-Q3
Tanzania	(2005, 2008, 2012, 2014)	2009-Q3

Note: This table outlines the study's data structure across three columns. The first column enumerates the ten countries included in the sample. The second column details the dates of the Afrobarometer surveys conducted in each country, starting with wave 3 and continuing through to wave 6. The third column specifies the treatment date when each country first received fiber optic submarine cable connectivity, marking the onset of enhanced broadband access.

has or has not participated in a protest. This question was coded into an indicator variable by separating those who participated in a protest at least once in the last 12 months from those who did not participate at all. I have added variables related to political attitudes, the frequency of use of information sources (monthly, weekly, or several times a day), and the demand for democracy. The Afrobarometer also includes Internet usage variables from round 4. Respondents are asked if they use the Internet and, if so, how often: monthly, weekly, or several times a day. I create various dummy variables based on the intensity of Internet usage.

Cell-Level Characteristics I build cells of $0,1 \times 0,1$ degrees²⁴. These cells allow to add location fixed effects in the specification and integrate different controls at the cell level. I use satellite data measuring light intensity, which is traditionally used as a proxy for an area's development level. This development indicator is available for 4 periods: 2002, 2005, 2008, and 2013. Following the recommendations of Gibson et al. (2021), I use VIIRS²⁵ night lights data, which are considered to be more accurate to predict economic activity in rural areas and spatial inequality in urban areas than DMSP²⁶ night lights data.

Tracking Protests with Objective Data : ACLED The Armed Conflict Location & Event Data Project (ACLED) is an extensive, geolocated database documenting political violence and protests globally, including regions like Africa, the Middle East, Latin America, the Caribbean, and various parts of Asia, Europe, and the United States. ACLED records event details such as dates, involved parties, casualties, and event types. Based on a cell level of 0.1×0.1 degrees for all 10 countries, I was able to use the geolocation of "protest" or "riot" type events to determine for each year whether there had been a mass mobilization event within each cell. In this way, I constructed a binary variable at the cell level that was equal to 1 when an event for the year under consideration had taken place and 0 otherwise. The database aggregates data annually for each cell, summing up all protests and riots to provide an objective view of political mobilization in all the countries covered.²⁷

²⁴0,1 degrees correspond roughly 10 kms

²⁵Visible Infrared Imaging Radiometer Suite

²⁶Defense Meteorological Satellite Program

²⁷There is a potential source of measurement error that can bias event reporting, which may disproportionately favor certain areas. For instance, larger cities often benefit from more comprehensive international media coverage, potentially leading to an overestimation in the results, especially since firms are more commonly situated in urban settings. In our analysis, geographical differences in reporting that are constant over time are accounted for through the inclusion of cell-level fixed effects, which help mitigate these potential distortions.

Assessing Freedom and Democracy in Selected Countries: Freedom House Proxy

Freedom House annually evaluates global freedom since 1972 ([House 2020](#)). Their 2021 assessment covered 210 countries and territories. Their data, encompassing political rights, civil liberties, and freedom status, are widely used as proxies for democracy measures ([Högström 2013](#)). The Freedom House Index categorizes countries based on the average of political rights and civil liberties into three statuses: free, partly free, or not free. In 2013, this classification placed five countries of our sample as “free” (Benin, Ghana, Namibia, Senegal, South Africa) and five as “partly free” (Kenya, Madagascar, Mozambique, Nigeria, Tanzania).

1.4 Methodology

This section outlines the methodological framework designed to assess the influence of enhanced broadband Internet accessibility on political mobilization, analyzed through two distinct approaches. First, I investigate the impact of broadband Internet availability on individuals’ propensity to participate in protests. Second, using a cell-level analysis, I objectively assess how broadband Internet availability affects the likelihood of protest events.

1.4.1 Individual-Level Analysis: Assessing Propensity to Participate in a Protest

Figure 1.4 is a map that illustrates the data that lay the foundation for the impact evaluation method used to answer our research question. It delineates two distinct buffer zones surrounding the backbone cables. The first buffer, extending up to 1200 meters from the backbone, defines the “connected” area, while the second buffer, spanning from 1200 meters to 10 kilometers, defines the control area. Individuals within these buffers are marked on the map using colored dots, and their inclusion in the study depends on their location in these designated zones. This distinction facilitates the classification of individuals into either the treatment or control group based on their proximity to the backbone infrastructure²⁸. I leverage two primary sources of variation to assess the propensity to participate in protests: temporal variation, as depicted in Figure 1.1, based on the gradual arrival of optic-fiber submarine cables in the coastal countries of Sub-Saharan Africa²⁹; and spatial variation, which is based on the proximity of respondents to the nearest backbone network, illustrated

²⁸Notably, the distribution of these points mirrors the underlying population densities, necessitating the application of weights in regression analyses to maintain representativeness.

²⁹Following the methodology of Hjort and Poulsen ([2019](#)), landlocked countries are excluded from this study due to the ambiguous nature of their treatment through coastal neighbors.

Table 1.3: Summary Statistics Before and After the Submarine Cable Arrival (1)

Variable	Before			After		
	Control (1.2-10km)	Treated (0-1.2km)	Difference	Control (1.2-10km)	Treated (0-1.2km)	Difference
Dependent variables						
	N=9920	N=4765		N=12095	N=6464	
Individual Characteristics and Education						
Age	36.348 (0.145)	35.484 (0.247)	-0.864***	36.821 (0.131)	35.911 (0.22)	-0.91***
Female	0.503 (0.005)	0.505 (0.009)	0.002	0.506 (0.005)	0.504 (0.008)	-0.002
Urban	0.536 (0.005)	0.629 (0.009)	0.093***	0.58 (0.004)	0.681 (0.007)	0.101***
Primary educ	0.687 (0.005)	0.685 (0.008)	-0.002	0.715 (0.004)	0.723 (0.007)	0.007
Secondary educ	0.286 (0.005)	0.275 (0.008)	-0.01	0.316 (0.004)	0.328 (0.007)	0.012
University educ	0.031 (0.002)	0.023 (0.003)	-0.008**	0.085 (0.003)	0.092 (0.004)	0.008*
Economic Characteristics						
Unemployment	0.311 (0.005)	0.314 (0.008)	0.002	0.275 (0.004)	0.277 (0.007)	0.002
Bad living conditions	0.705 (0.005)	0.697 (0.008)	-0.008	0.667 (0.004)	0.661 (0.007)	-0.006
Nightlight intensity	17.04 (0.215)	16.208 (0.367)	-0.831*	21.395 (0.201)	19.088 (0.339)	-2.307***
Participate in a protest	0.164 (0.004)	0.147 (0.006)	-0.016*	0.101 (0.003)	0.11 (0.005)	0.009*

Note: The sample consists of Benin, Ghana, Kenya, Madagascar, Mozambique, Namibia, Nigeria, Senegal, and Tanzania. The treatment group includes individuals within 0 to 1200 meters from the nearest terrestrial cable, while the control group comprises individuals located beyond 1200 meters and up to 10 kilometers away. This distance cap ensures comparability among individuals. In the Table, 'Before' refers to data from Afrobarometer survey rounds 3 and 4, while 'After' pertains to rounds 5 and 6, aligning with the timing of broadband Internet access improvements.

Table 1.4: Summary Statistics Before and After the Submarine Cable Arrival (2)

Variable	Before			After		
	Control (1.2-10km)	Treated (0-1.2km)	Difference	Control (1.2-10km)	Treated (0-1.2km)	Difference
Political Behaviors and Attitudes						
Vote in the last elections	0.78 (0.004)	0.805 (0.007)	0.025***	0.793 (0.004)	0.782 (0.007)	-0.011*
Trust in Presidency	0.65 (0.005)	0.671 (0.008)	0.021*	0.585 (0.005)	0.603 (0.008)	0.018**
Preference for Democracy	0.74 (0.005)	0.762 (0.008)	0.022**	0.742 (0.004)	0.749 (0.007)	0.007
Satisfied with democracy	0.54 (0.005)	0.614 (0.009)	0.074***	0.534 (0.005)	0.537 (0.008)	0.003
Freedom of Thought	0.86 (0.004)	0.894 (0.006)	0.034***	0.869 (0.003)	0.883 (0.005)	0.014***
Freedom to join organisations	0.919 (0.004)	0.92 (0.007)	0.001	0.914 (0.003)	0.924 (0.004)	0.01**
Free vote	0.95 (0.003)	0.956 (0.005)	0.007	0.953 (0.002)	0.956 (0.003)	0.004

Note: The sample consists of Benin, Ghana, Kenya, Madagascar, Mozambique, Namibia, Nigeria, Senegal, and Tanzania. The treatment group includes individuals within 0 to 1200 meters from the nearest terrestrial cable, while the control group comprises individuals located beyond 1200 meters and up to 10 kilometers away. This distance cap ensures comparability among individuals. In the Table, 'Before' refers to data from Afrobarometer survey rounds 3 and 4, while 'After' pertains to rounds 5 and 6, aligning with the timing of broadband Internet access improvements.

in Figure 1.5. As the distance from the backbone network increases—considering the sparse backhaul infrastructure in the region—the likelihood of accessing broadband Internet (both mobile and fixed) significantly diminishes.

I refine the robustness and precision of my analysis by building on the approach of Hjort and Poulsen (2019) and by adding additional waves to expand the sample size. The inclusion of two additional waves from the Afrobarometer surveys—waves 3 and 6—also enriches the analysis by enabling a thorough examination of pre-treatment trends. This expansion is critical for affirming the parallel trends assumption, a key component of difference-in-differences analyses.

The analysis benefits from more precise geolocation data and refined definitions of the treatment group following Roodman (2024). Recent advancements in the geocoding of survey locations by AidData (BenYishay et al. 2017) provide more reliable geographic coordinates, facilitating a more detailed spatial analysis. A critical adjustment in this study is the revision of the criteria for defining the treatment group. Unlike the 500-meter baseline used in the study by Hjort and Poulsen (2019), this analysis employs a 1200-meter radius from any backbone infrastructure as the threshold for considering an area “treated”. This adjustment is informed by technical considerations regarding signal attenuation in both fixed networks (e.g., copper) and mobile antenna coverage.

Table 1.5: Summary Statistics Before and After the Submarine Cable Arrival (3)

Variable	Before			After		
	Control (1.2-10km)	Treated (0-1.2km)	Difference	Control (1.2-10km)	Treated (0-1.2km)	Difference
Information Access and Internet Use						
News on radio (weeks)	0.854 (0.004)	0.847 (0.006)	-0.007	0.799 (0.004)	0.805 (0.006)	0.007
News on TV (weeks)	0.587 (0.005)	0.613 (0.009)	0.026**	0.632 (0.004)	0.653 (0.007)	0.021***
News on Newspaper (weeks)	0.587 (0.005)	0.613 (0.009)	0.026**	0.632 (0.004)	0.653 (0.007)	0.021***
Internet Use (weeks)	0.118 (0.005)	0.106 (0.008)	-0.012	0.231 (0.004)	0.235 (0.007)	0.004
Internet Use (days)	0.049 (0.003)	0.03 (0.005)	-0.019***	0.138 (0.003)	0.136 (0.005)	-0.002
N=99522	N=53826			N=99522	N=53826	
Number of protests	0.005 (0.002)	0.044 (0.002)	0.039***	0.033 (0.006)	0.223 (0.009)	0.19***
ACLED data (Cell Level) - Adjacent Cells						
Pr(Protest > 0)	0.003 (0)	0.014 (0)	0.011***	0.014 (0.001)	0.051 (0.001)	0.037***
N=437121	N=53826			N=437121	N=53826	
Number of protests	0.005 (0.001)	0.044 (0.001)	0.039***	0.032 (0.002)	0.223 (0.005)	0.191***
ACLED data (Cell Level) - All Cells						
Pr(Protest > 0)	0.003 (0)	0.014 (0)	0.012***	0.012 (0)	0.051 (0.001)	0.039***

Note: The sample consists of Benin, Ghana, Kenya, Madagascar, Mozambique, Namibia, Nigeria, Senegal, and Tanzania. The treatment group includes individuals within 0 to 1200 meters from the nearest terrestrial cable, while the control group comprises individuals located beyond 1200 meters and up to 10 kilometers away. This distance cap ensures comparability among individuals. In the Table, 'Before' refers to data from Afrobarometer survey rounds 3 and 4, while 'After' pertains to rounds 5 and 6, aligning with the timing of broadband Internet access improvements. The statistics describing ACLED data are analyzed at cell level. Cells through which a terrestrial cable passes are considered as treated.

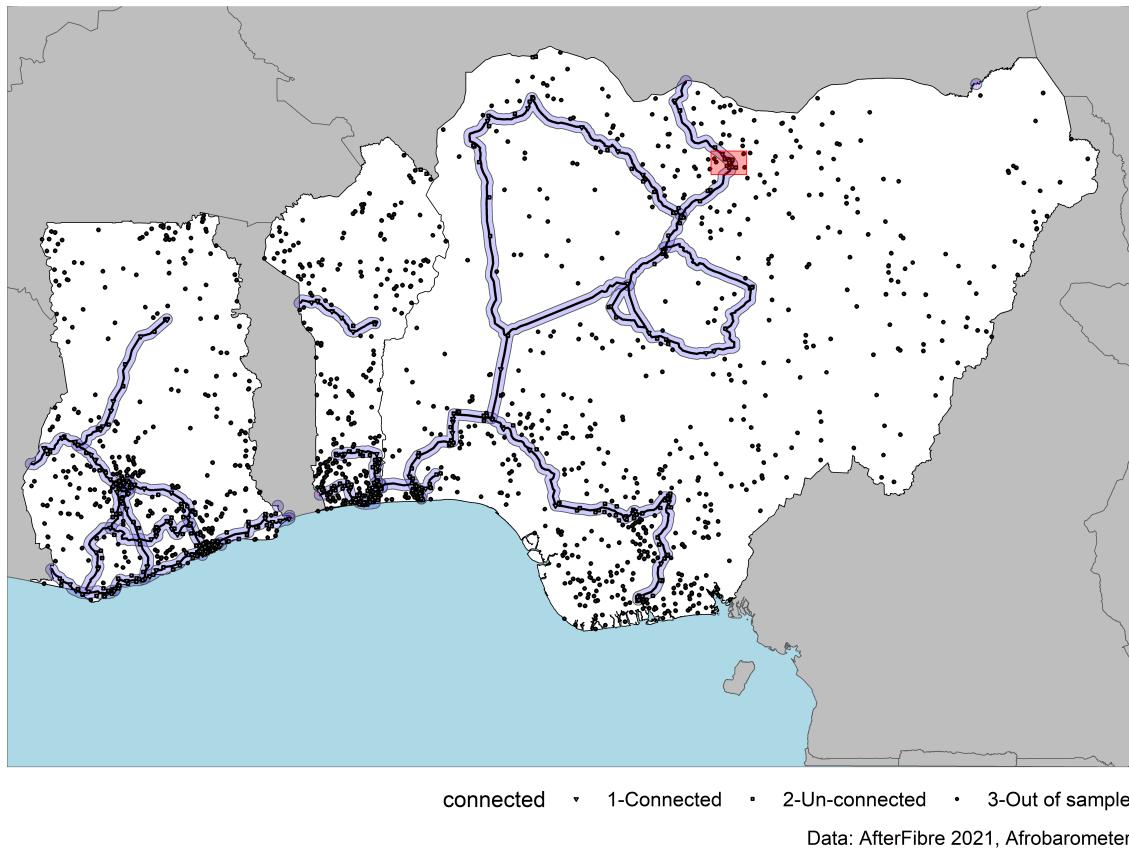


Figure 1.4: This map highlights three countries from the sample, showcasing all geolocated observations from the Afrobarometer database. Utilizing the Afterfibre database, it displays the routes of backbone cables that were in place before the introduction of submarine cables. Along these routes, two buffer zones are delineated: one extending from 0 to 1200 meters from the backbone and another from 1200 meters to 10 kilometers. These buffers categorize the connectivity status of individuals within these zones. The red rectangle over Nigeria provides a zoomed-in view to demonstrate the study's methodological approach more clearly.

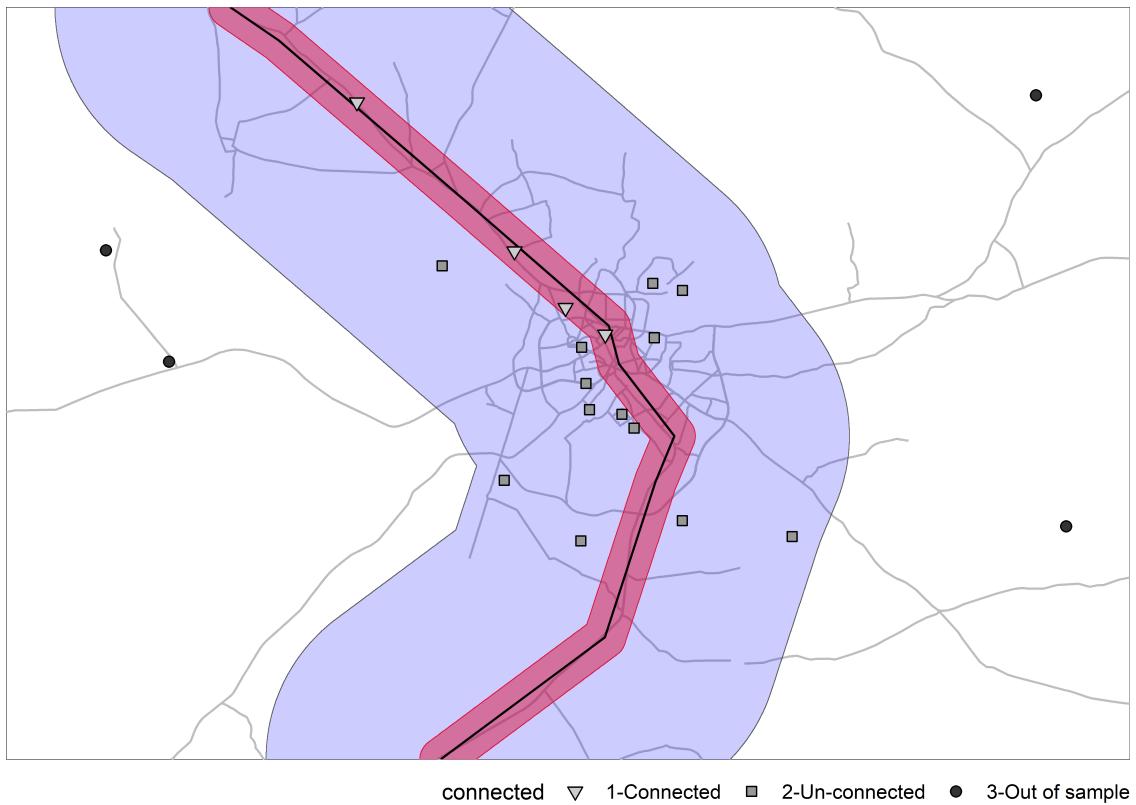


Figure 1.5: This map centered on Kano, Nigeria, details the methodology approach for this study. The black line marks the actual location of the existing backbone cable. The distance to the backbone defines the respondent's status (connected or control), and buffers have been drawn to show how individuals are integrated into the treatment or control group. All individuals outside the two buffers are excluded from the sample. The color of the individuals shows the treatment status.

In the baseline specification, I use a connection radius of 1200 meters to distinguish the treated individuals from the “control” individuals. Eq (1) quantifies the relationship between the chances of having participated in a protest for a given location and period on the one hand and on the other hand if a location is connected to a submarine Internet cable arriving from Europe via a terrestrial backbone cable:

$$Y_{ijct} = \alpha + \beta \times SubCables_{ict} \times Connected_i + \delta_j \times Connected_i + \zeta \times X_{ij} + \gamma_{ct} + \epsilon_{ijct} \quad (1.1)$$

where Y_{ijt} is a governance outcome for individual i in cell j in country c , and time period t . Then, $SubCables_{ict}$ is a dummy variable indicating whether the submarine cable was in service in the country c and thus whether fast Internet was available in the country at time t . $Connected_i$ corresponds to the treatment and control group variable based on the distance with backbone cables. X_{ij} is a vector of individual and cell level controls, including nighttime light intensity, whether the individual is urban or not, the age, the gender, and whether the individual has a primary education. The δ_j coefficient captures time-invariant differences in governance outcomes between treatment and control groups. γ_{ct} gives country-specific time period fixed effect.

1.4.2 Cell-Level Analysis: Evaluating Broadband’s Influence on Protests and Riots Incidences

To objectively measure the impact of broadband on protests and riots, I supplemented the declarative survey data with information from the Armed Conflict Location Event Data Project (ACLED). This approach integrates the geographic locations of submarine cables with data on the occurrence and timing of protests and riots, employing a spatial resolution of 0.1×0.1 degrees³⁰. This analysis covers all sampled countries from 2000 to 2017. The treatment status of cells is determined by the passage within the cell of a backbone cable already in service before the arrival of fiber optic submarine cables in 2009. Following the methodology of Berman et al. (2017), this study conducts two primary analyses: the first includes all cells without a backbone as the control group, while the second considers only those cells directly adjacent to treated cells, applying a neighboring-pair fixed effects approach (Acemoglu, García-Jimeno, and Robinson 2012; Buonanno et al. 2015; Lambais 2020).

To address the local determinants of protests and enhance the exogeneity of our ap-

³⁰Equivalent to approximately 10×10 km at the equator.

proach, I also exploit variations in high-speed Internet availability due to the deployment of submarine fiber-optic cables. Eq (2) assesses the relationship between the occurrence of protests and riots at the cell-year level and the presence of a terrestrial backbone cable linked to an optic-fiber submarine Internet cable. This analytical framework aims to isolate the influence of enhanced connectivity on the frequency and distribution of protests within the studied regions.

$$Y_{jt} = \alpha + \beta \times SubCables_{jct} \times Connected_j + \zeta_j + \gamma_{ct} + \epsilon_{jt} \quad (1.2)$$

In this model, (j, t, c) represent cell, year, and country, respectively, where ζ_j captures cell fixed effects and γ_{ct} denotes country and year fixed effects. The dependent variable, Y_{jt} , captures the incidence of mobilization events at the intersection of cell and year. Mobilization, encompassing protests and riots, is quantified in two distinct manners: firstly, through a binary variable indicating the occurrence of at least one protest or riot within a cell in a given year; secondly, via an alternative metric that accounts for the total number of protests and riots. Our coefficient of interest, β , pertains to the interaction term between $SubCables_{jct}$ and $Connected_j$. This coefficient is instrumental in quantifying the effect on the likelihood of event occurrences triggered by a significant improvement in Internet speeds, deemed to be exogenous, consequent to the deployment of submarine fiber-optic cables.

In addition, the estimation of Eq (2) includes cell-fixed effects in order to control for time-invariant co-determinants of political mobilization and economic activity at the local level. The country \times year fixed effects are also included to filter out any time-varying country-level characteristics that affect the occurrence of protests or riots.

1.4.3 Validity of the identifying assumptions

Following Kahn-Lang and Lang (2020) recommendations on Diff-in-diff and pre-trend analysis, it is essential to examine whether the control and treatment groups are not only identical in “trends” but also in “levels” and if not, include some variables as controls in the model. Through a detailed examination presented in Tables 1.3, 1.4, and 1.5, this study scrutinizes the disparities in observable attributes between the treatment and control groups before (specifically, during the two rounds preceding the intervention: rounds 3 and 4) and after the introduction of broadband Internet (round 5 and 6). These attributes encompass both individual and economic factors and the key outcomes of interest relevant to this investigation. It is important to remember that the treatment group is characterized by its proximity to the backbone network, thereby possessing a greater technical potential for broadband connectivity.

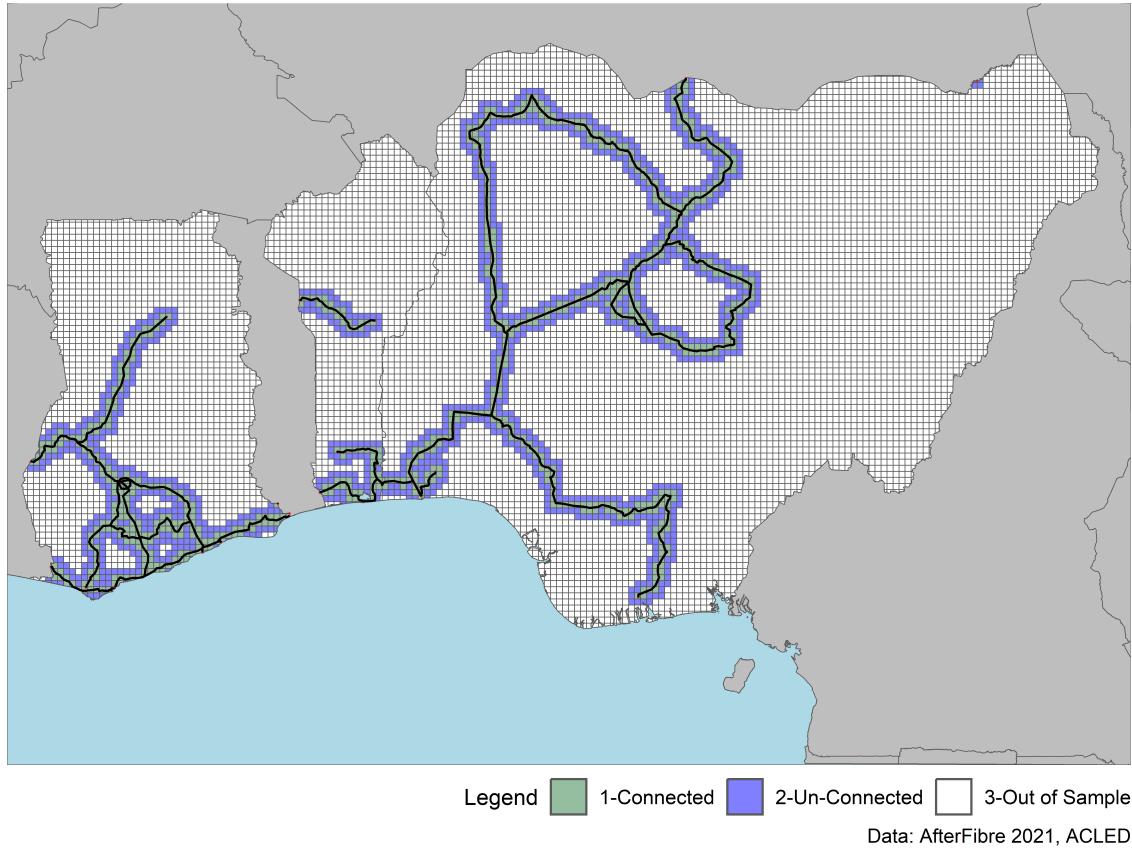


Figure 1.6: This map displays a grid of 0.1 by 0.1-degree cells covering three sample countries. Utilizing the Afterfibre database, it illustrates the routes of backbone cables existing prior to the introduction of submarine cables. Cells intersected by these terrestrial cable routes are labeled as connected. Adjacent cells not intersected by the cables are labeled as unconnected.

The two groups are substantially different in terms of individual and cell characteristics, according to descriptive research comparing treatment and control units for governance outcomes and a few control factors. In terms of individual attributes, there was no significant difference in gender distribution between the groups. However, the treatment group was significantly younger than the control group, a trend that persisted following the deployment of optic-fiber submarine cables. While the educational levels between the two groups showed no significant difference initially, a gap emerged at the “university” level following the introduction of broadband access. From an economic development point of view, differences are observed by the light intensity throughout the night; control group cells exhibited higher levels of light intensity, indicating greater economic activity compared to those in the treatment areas post-intervention. Prior to and following the deployment of submarine cables, no statistically significant disparity in unemployment rates was observed between the two groups, and the same is true for the declared level of bad living conditions. The proportion of urban inhabitants in the treatment group, standing at 62.9%, is notably higher than the 53.6% observed in the control group, a difference that persists post-treatment. The inclusion of similar and enough urban and rural people in the two groups allows us to rule out a solely urban effect and more readily detect an effect related to the arrival of optic-fiber submarine cables. Despite these precautions, a significant disparity in urbanization levels between the treated and control areas remains evident, with a larger fraction of individuals in the treatment group identifying as “urban” compared to their counterparts in the control group.

There are major differences in usage across the groups when it comes to potential sources of information for individuals: observations in the treated group are more inclined towards television and newspapers for gathering information, a trend that continued beyond the treatment date. Post-treatment, this group also showed a higher propensity for radio usage as an information source. Notably, a divergence in daily Internet use between the treatment and control groups disappeared after the introduction of broadband. Additionally, prior to the treatment, the treatment group displayed greater satisfaction with existing institutions and a more pronounced preference for democracy. Their likelihood of having voted in recent elections did not significantly change following the treatment. However, post-treatment, the probability of engaging in protest activities in the past year increased in the treatment group (11%) compared to the control group (10.1%). The treated group initially exhibited a higher level of satisfaction and preference for democracy and a greater sense of freedom in expressing their thoughts. Yet, after the broadband intervention, these differences in democratic satisfaction and preference ceased to be statistically significant between the two groups.

Before the arrival of submarine cables, the difference between the chances of a protest or riot in a cell considered treated was significantly higher. This difference increased in subsequent periods. Before the arrival of the submarine cables, the chances of there being a protest or riot in a given year in a treated cell was 1.4%, while in the control cells, this rate was 0.3%. After the arrival of the submarine cables, this rate increased in both zones but was greater in absolute terms in the treated zones, reaching 5.1% compared with 1.4% for the control zones.

Prior to the deployment of submarine cables, the likelihood of witnessing a protest or riot within cells designated as treated was significantly higher than in control cells. This disparity became more pronounced in periods following the introduction of submarine cables. Specifically, before the cables' introduction, the probability of experiencing a protest or riot within a year stood at 1.4% in treated cells, as opposed to a mere 0.3% in control cells. Subsequent to the cables' arrival, the incidence rate escalated in both regions but did so more markedly within the treated areas, peaking at 5.1%, in stark contrast to a 1.4% increase observed within the control areas. This data highlights a clear augmentation in political activism, especially in regions directly impacted by the advent of enhanced broadband infrastructure.

The validity of the empirical methodology rests on the assumption that the evolution of the shares of “protesters” in the areas near and far from the backbone would have been similar in the absence of the arrival of the submarine fiber optic cables. We should observe identical trends between 2005 and 2008, given that the period during which the submarine cables from Europe were gradually connected to Africa extends from 2009 to 2014. The ensuing survey wave in 2012 encapsulates the expanded influence of broadband connectivity. To ascertain the feasibility of our identification strategy, I examine the parallel trends assumption by graphically comparing the annual participation rates in at least one event between individuals within 1.2 kilometers of a backbone and those between 1.2 and 10 kilometers away. Illustrated in Figure 1.7, this comparison reveals that, while trends align between 2005 and 2008, they start to deviate from 2008 to 2012, corroborating our hypothesis for causal identification. Specifically, the proportion of “protesters” in the treated regions begins to exceed that in the control regions during this period.

A similar pattern is discerned when analyzing ACLED data, where Figure 1.7 charts the annual occurrence of protests or riots across cells linked to the backbone versus those unconnected. Trends maintain parallelism from 2005 to 2008 but diverge notably from 2008 to 2012, affirming our causal identification hypothesis. Post-introduction of submarine cables, the frequency of protests or riots in treated areas not only surpasses that in control areas but does so by a widening margin, underscoring the transformative impact of broadband

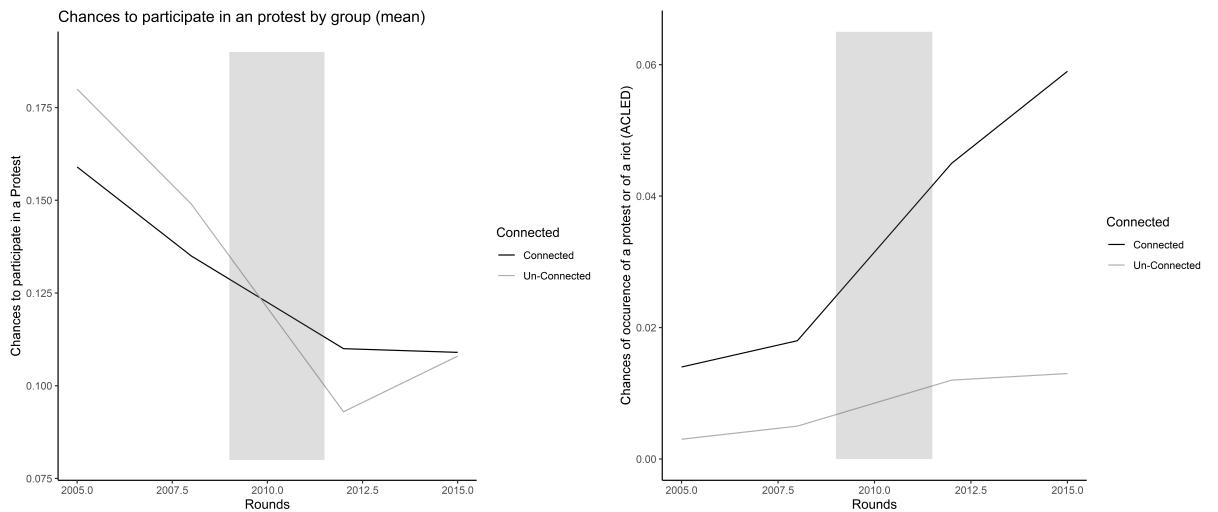


Figure 1.7: Left-hand panel displays the proportion of individuals within specified groups who participated in at least one protest over the past 12 months, across each available survey wave. The treatment group includes individuals within 1200 meters of the nearest backbone cable, while the control group comprises those located between 1200 meters and 10 kilometers away. On the right, each point represents the proportion of cells in which at least one protest or riot occurred during the specified year. Here, ‘treated cells’ are those intersected by a terrestrial cable, whereas ‘adjacent cells’ serve as the control group.

expansion on political mobilization.

1.5 Results

1.5.1 Submarine cable arrival and Internet use

I use the distance from the backbone network as a proxy for Internet usage as a methodologically robust approach with precedents in governance and political economy studies, such as those conducted by Miner (2015). This section aims to statistically validate the use of geographic proximity to backbone infrastructure as an effective proxy for broadband Internet access and use. The inclusion of an Internet usage question in the fourth round of Afrobarometer surveys allows us to see how the arrival of broadband Internet in Sub-Saharan African countries has affected Internet use as a function of distance from the backbone network.

I classified individuals into groups based on their proximity to the nearest backbone: (0-1.2kms; 1.2-3kms; 3-5kms; 5-7kms; >7kms). The analysis then utilized the following econometric model to evaluate the interaction between the timing of broadband introduction and the geographic distance group:

$$Y_{ijt} = \alpha + \beta \times SubCables_{ict} \times DistGroup_i + \delta_j \times Cell_j + \gamma_{ct} + \epsilon_{ijct} \quad (1.3)$$

Here, $Y_{ij(i)t}$ is a binary variable indicating whether individual i in cell j at time t uses the Internet on a weekly or daily basis. The interaction term $SubCables_{ict} \times DistGroup_i$ quantifies the differential impact of proximity to the backbone on Internet usage rates.

Figure 1.8 displays the estimation results from this model, revealing a significant increase in daily Internet usage for individuals located within 1.2 kms of a backbone following the deployment of submarine cables. This finding corroborates the hypothesis that proximity to backbone infrastructure significantly enhances Internet accessibility.

Further empirical analyses assess the broader implications of increased broadband on political mobilization. Table 1.6 details the regression results, showing a 2.9 percentage point increase in the probability of daily Internet use in areas connected to the submarine cables. This increase can be attributed to two principal effects: a price effect, where the entry of submarine cables significantly lowers the cost of international connectivity as documented by (Kende and Rose 2015), potentially influencing retail prices and boosting demand for mobile and fixed-line services; and a quality effect, where enhanced data transmission speeds improve user experience and access to a wide array of digital content, thereby increasing the utility and perceived value of Internet subscriptions.

1.5.2 Main results

Table 1.7 shows that the introduction of submarine cables, which significantly enhances broadband access, increases the probability that an individual within the treated group will participate in a protest by approximately 3.8 percentage points, as evidenced in column (5) incorporating cell fixed effects and control variables.

Columns (3) and (6) explore the influence of the distance from terrestrial cables—a continuous measure of treatment—on protest participation likelihood. The findings reveal a negative relationship: as the distance to the backbone cable increases by one kilometer, diminishing potential access to high-speed Internet, the probability of an individual engaging in protest activity subsequent to the arrival of submarine cables decreases by 0.5 percentage points. I changed the outcome of eq (3) to focus specifically on whether an individual i in cell j during time period t had participated in a protest in the previous year. This adjustment revealed that the significant effect (at the 10% significance level) was predominantly observed within the group located 0 to 1.2 kilometers from the nearest backbone cable, as illustrated in Figure 1.8.

These results may not mean that connected individuals are more inclined to attend

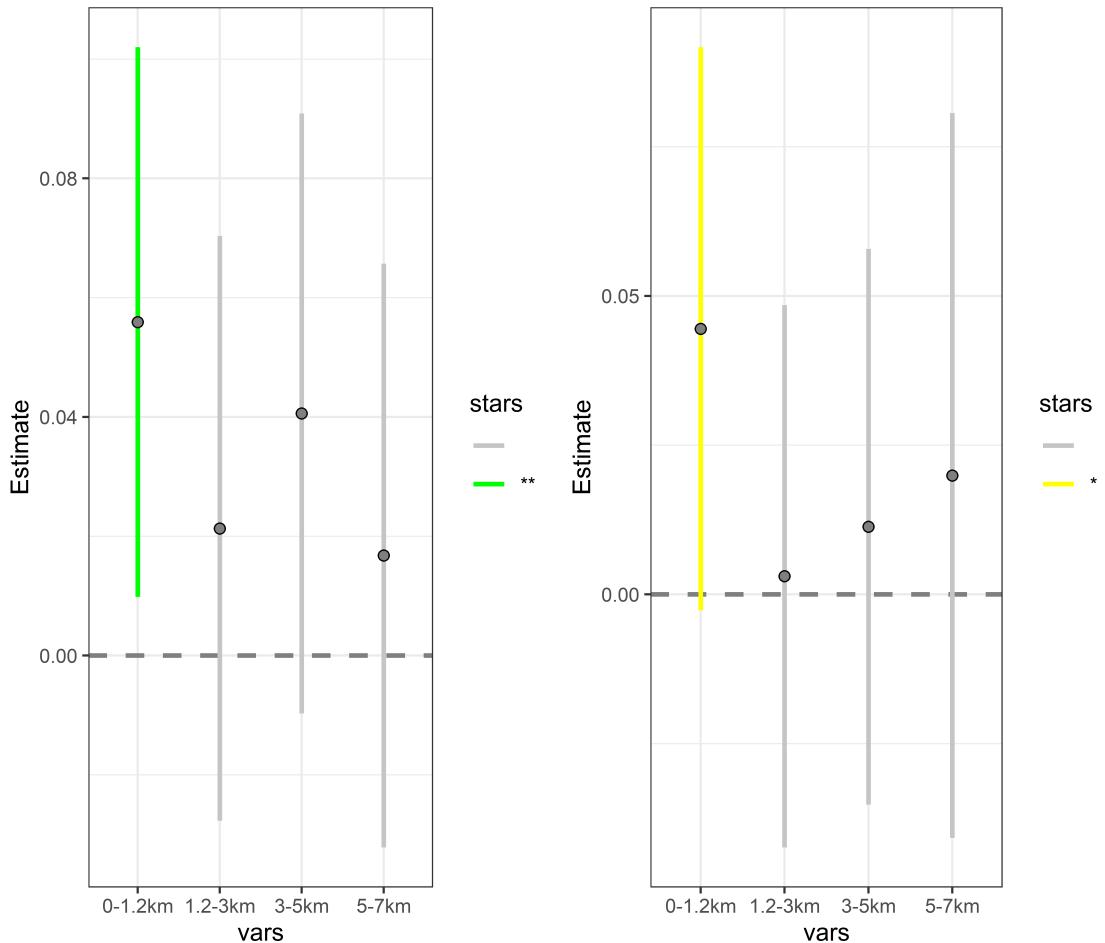


Figure 1.8: These graphs depict the evolution of interaction coefficients between various distance groups (0-1.2 km; 1.2-3 km; 3-5 km; 5-7 km; >7 km) and the introduction of fiber optic submarine cables. On the left, the plotted coefficients relate to a dummy variable indicating individuals' daily Internet use. On the right, the coefficients correspond to a dummy variable reflecting whether an individual has participated in a protest in the past 12 months. Each graph illustrates the differential impact of proximity to fiber optic cables on Internet usage and protest participation.

Table 1.6: Submarine Cable Arrival and Internet Use

	Internet Use			
	Daily (0/1)		Weekly (0/1)	
	(1)	(2)	(3)	(4)
SubCableXConnected	0.029** (0.015)	0.029** (0.015)	0.032* (0.017)	0.036 (0.022)
CountryxYear	Yes	Yes	Yes	Yes
GADM2xConnected	Yes	No	Yes	No
CellxConnected	No	Yes	No	Yes
Num.Obs.	25 402	25 402	25 402	25 402
R2	0.166	0.196	0.206	0.236

* p < 0.1, ** p < 0.05, *** p < 0.01

Note: The sample includes Benin, Ghana, Kenya, Madagascar, Mozambique, Namibia, Nigeria, Senegal, South Africa, and Tanzania. Individuals are considered connected if they are closer than 1.2 km to the backbone network. Internet use (0/1) data come from Afrobarometer. Time FEs are years. The outcome of the model (1) and model (2) is a dummy variable indicating if the individual is using the Internet every day. Location FEs for the model (1) are the reported location at the level GADM (Database of Global Administrative Areas) level 2. Location FEs for model (2) are the reported location at the 10*10 Cell level. The outcome of model (3) and model (4) is a dummy variable indicating if the individual is using Internet every week. Location FEs for the model (3) are the reported location at the level GADM (Database of Global Administrative Areas) level 2. Location FEs for the model (4) are the reported location at the 10*10 Cell level. Robust standard errors clustered at the level of location FEs.

protests. It may be an effect of the Internet and social networks on the tendency of individuals to assume their protest activities. If more individuals in connected areas have access to social networks, they may be more informed about the protest activities of other citizens and have more confidence in reporting their own protest activities, knowing that other citizens are reporting them on social networks. Therefore, they are more likely to report to interviewers that they participated in a protest in the past 12 months.

Table 1.7: Submarine Cable Arrival and Chances to Participate in a Protest

	Chances to Participate in a Protest					
	(1)	(2)	(3)	(4)	(5)	(6)
SubCableXConnected	0.039*** (0.013)	0.037*** (0.013)	-0.005* (0.003)	0.037*** (0.014)	0.038*** (0.014)	-0.005* (0.003)
CountryxYear	Yes	Yes	Yes	Yes	Yes	Yes
GADM2xConnected	Yes	Yes	Yes	No	No	No
CellxConnected	No	No	No	Yes	Yes	Yes
Num.Obs.	32 478	32 226	32 226	32 478	32 226	32 226
R2	0.074	0.080	0.080	0.107	0.113	0.113

* p < 0.1, ** p < 0.05, *** p < 0.01

Note: The sample includes Benin, Ghana, Kenya, Madagascar, Mozambique, Namibia, Nigeria, Senegal, South Africa, and Tanzania. Individuals are considered connected if they are closer than 1.2 km to the backbone network. The outcome of models (1), (2), (4) and (5) is a dummy variable indicating if the individual have participated in a protest in the last 12 months. Models (3) and (6) are based on a continuous treatment. Time FE are years. Location FE for the model (1), (2) and (3) are the reported location at the level GADM (Database of Global Administrative Areas) level 2. Location FE for the model (4), (5) and (6) are the reported location at the 10*10 Cell level. Models (2), (3), (5) and (6) include control variables: nighttime lights intensity, urban, age, female, primary education. Robust standard errors clustered at the level of location FE.

1.5.3 Robustness

I confirm that the estimation of the effect of broadband Internet on protest likelihood is robust to variations in the defined “treatment” radius around the backbone cables. Figure 1.12 demonstrates this through a series of estimates for various connection radii, revealing that the estimated effect diminishes and loses significance as the radius extends beyond 2.5 kilometers, although it remains significant well past the initial 1200-meter radius used in our baseline analysis.

To further test the robustness of these findings, I systematically removed each country from the sample and re-estimated Eq (1). The results, detailed in Tables 14 and 15, consistently show that the positive and significant effect of broadband on protest participation is not driven by any single country.

As an additional check, I excluded individuals residing near landing points—where submarine cables connect to the terrestrial network—limiting the sample to observations more than 20 kilometers away. This adjustment aims to mitigate any urban bias, as those living near large cities might have had differential access to high-speed Internet or distinct pre-

existing propensities to protest. The results, as shown in Table 1.12, hold under this scrutiny and exhibit even stronger coefficients. I also removed the biggest cities of the sample in Table 1.13, the results remain robust.

Donut regression analyses were also conducted to address potential edge effects around the treatment boundary. By systematically excluding observations within certain proximity ranges to the backbone—specifically between 800 and 1600 meters, and adjusting the intervals in subsequent models—the results, presented in Table 1.17, affirm the robustness of our findings across various configurations.

Considering the precision of geographic data as categorized by BenYishay et al. (2017), I analyzed a subset of the data with the highest location accuracy (precision levels 1 to 3). Table 1.19 shows that the results maintain their significance and direction, although they become nonsignificant when only the most precise data (precision level 1) is used, likely due to the reduced sample size.

Additionally, beyond employing fixed effects at the GADM2 and cell levels, the same regressions were conducted with fixed effects at the GADM1 level (regions). The results remain robust, as detailed in Table 1.14.

Furthermore, I experimented with varying the control group’s size, excluding areas beyond 5 kilometers and incrementally adjusting the radius up to 15 kilometers to ensure comparability with connected areas. The robustness checks, detailed in Table 1.18, confirm that our findings are not sensitive to the inclusion of more distant and potentially less comparable control areas.

Lastly, as a placebo test, I simulated the displacement of the backbone cables by 12.5 degrees in four directions and recalculated the treatment and control groups accordingly, as illustrated in Figure 1.14. The regressions based on these “false” backbone locations, as shown in Table 1.20, yielded no significant results, reinforcing the causal inference of our original setup.

These extensive robustness checks validate that the observed impact of broadband availability on protest likelihood in Sub-Saharan Africa is consistent and causally attributable to enhanced Internet access.

1.5.4 Impact on the probability of occurrence of a demonstration or riot

Table 1.8 reports the baseline results for various sample compositions and definitions of the variables. The dependent variable is conflict incidence. We see that in all columns, the interaction term between the treatment date (the arrival of submarine cables) and the

variable of being in a connected cell (determined by the fact that a backbone cable was crossing the cell before 2009), is positive and significant at the 1 percent level. This means that the arrival of submarine cables, which allowed a significant increase in the availability of high-speed Internet, increased the probability of protests and riots in cells crossed by a backbone cable. Column (1) shows the results of estimating model (2) over the entire sample of cells, with the coefficient showing that the arrival of undersea fiber optic cables increased by 2.2 percentage points the chances that a protest or a riot occurred in connected cells. This result is consistent with the neighbor-pair fixed effects approach in column (2). Column (3) by using the number of protests and riots that occur each year in each cell as an outcome, with the whole sample. Thus, the arrival of fiber optic submarine cables increased the average number of protests and riots in connected cells by 0.114. Column (4), which relies on an estimate based only on connected cells and neighboring cells, shows similar results.

Table 1.8: Submarine Cable Arrival and Chances of occurrence of a protest in a Cell

	Protest Incidence		Number of Protests	
	(1)	(2)	(3)	(4)
SubCableXConnected	0.022*** (0.001)	0.020*** (0.001)	0.114*** (0.014)	0.110*** (0.014)
CountryxYear	Yes	Yes	Yes	Yes
CellxConnected	Yes	Yes	Yes	Yes
Num.Obs.	1 035 720	360 522	1 035 720	360 522
R2	0.315	0.360	0.484	0.498

* p < 0.1, ** p < 0.05, *** p < 0.01

Note: The analysis includes data from Benin, Ghana, Kenya, Madagascar, Mozambique, Namibia, Nigeria, Senegal, South Africa, and Tanzania. Cells intersected by a backbone network are classified as 'connected'. The dependent variable across all models is a dummy indicating whether at least one protest occurred within a cell in a given year, as used in models (1) and (2). In models (3) and (4), the outcome measures the total number of protests occurring within a cell in a given year. Temporal fixed effects are controlled by year, and spatial fixed effects are applied at the 10x10 km cell level. The control group for models (1) and (3) comprises all cells not designated as treated. For models (2) and (4), the control group includes only cells adjacent to treated cells. Standard errors are robust and clustered at the cell level.

1.6 Understanding how Fast Internet Affects Political Attitudes and Behaviors in Sub-Saharan Africa

This section delves into how the arrival of optical-fiber submarine cables, and the consequent expansion of broadband Internet availability in Sub-Saharan Africa, influences protests. The role of broadband Internet in facilitating participation in protests and bolstering collective action is examined through two primary channels.

1.6.1 Information vs Coordination

The proliferation of broadband Internet, with its vast array of content and accelerated information dissemination, potentially affects protest activities by enriching public awareness on political and social issues, thereby changing citizens' perceptions and beliefs. Such an increase in protest participation likelihood may stem from "enhanced information" dissemination capabilities and "enhanced coordination" mechanisms ([Manacorda and Tesei 2020](#)). Enhanced information provides insights into socio-political issues, while enhanced coordination, facilitated by broadband-enabled social media platforms, improves the efficiency of collective mobilization efforts. Specifically, by providing information on whether one's peers will participate in a protest, broadband Internet through social medias can increase the responsiveness of citizens in their peer's propensity to participate in a protest through a better horizontal communication.

To figure out which channel wins out over the others, I firstly estimate the effect of submarine cables arrival on the perception about institutions and the government. If we perceive a deterioration in the perception of these institutions, this would corroborate the effect of information as a vector for participation in a protest, which would then explain the motivations of protesters. I estimated Eq (1) and replace the outcome with the satisfaction with democracy and trust in institutions as shown in Table 1.9. The analysis revealed no massive and negative impact on democratic and institutional perceptions. Indeed, we do not perceive any negative effects on trust in institutions (President, Parliament, ruling party, police). Furthermore, an examination aimed at detecting any erosion in institutional reputation, focusing on perceived corruption, was conducted by assessing the effect of submarine cable introduction on corruption perceptions across the same institutions. I find no significant effect other than an increase in the perception of police corruption.

I estimated Eq (1) and replaced the outcome with the use of various information sources (radio, television, and newspaper). The arrival of submarine cables, which significantly increased the availability of high-speed Internet, positively impacted the use of radio as a

Table 1.9: Estimates of the effect on the arrival of submarine cables on political attitudes

Outcomes	Estimates	Estimates (with controls)
Trust Presidency	0.000 (0.021)	-0.001 (0.021)
Trust Parliament	0.017 (0.018)	-0.001 (0.021)
Trust Rulling Party	0.028 (0.022)	0.021 (0.018)
Trust Police	0.000 (0.018)	0.001 (0.015)
Perception corruption Presidency	0.010 (0.019)	0.010 (0.019)
Perception corruption Parlement	0.017 (0.016)	0.017 (0.016)
Perception corruption Government	0.020 (0.015)	0.019 (0.015)
Perception corruption Police	0.031*** (0.011)	0.030*** (0.011)
Satisfied with Democracy	0.004 (0.018)	0.004 (0.018)
Radio	0.025* (0.013)	0.025* (0.013)
TV	0.003 (0.021)	0.004 (0.021)
Newspaper	0.003 (0.021)	0.004 (0.021)
Chances to Join Others to Raise an Issue	0.029* (0.016)	0.029* (0.016)
Discuss Politics	0.008 (0.018)	0.008 (0.018)
Vote	-0.002 (0.015)	-0.003 (0.015)
Interest in Public Affairs	-0.016 (0.018)	-0.017 (0.018)
Freedom of Thought	-0.004 (0.016)	-0.006 (0.016)
Freedom to Vote	-0.008 (0.011)	-0.007 (0.011)
Freedom to Join orgas	-0.002 (0.012)	-0.002 (0.012)
Active Member of religious group	-0.036 (0.025)	-0.036 (0.025)
Active Member of community group	0.027* (0.015)	0.026* (0.015)

Note: The sample includes Benin, Ghana, Kenya, Madagascar, Mozambique, Namibia, Nigeria, Senegal, South Africa and Tanzania. Time FEs are years. Location FE_s are the reported location at the level of Grid-cells of 0.1*0.1 decimal degrees, which is roughly 10*10 km. Individuals are considered connected if they are closer than 1.2 km to the backbone network. Robust standard errors clustered at the level of location FE_s.

source of news, but did not affect television or newspaper usage. It means that despite the broadened access to online platforms, radio remains the dominant news source for most Africans, likely due to its affordability and accessibility. This absence of a negative impact on traditional media suggests that conventional sources and online content are not substitutes. Consequently, informational dynamics seems non-critical in explaining the relationship between high-speed Internet access and the propensity to engage in protest activities.

To investigate the potential for improved coordination among citizens facilitated by broadband Internet, I utilized the variable that describes the likelihood that an individual reported that he or she had ever joined with others to raise an issue or would do so if given the opportunity as a proxy for individuals' aptitude to coordinate. In the same way as before, I estimated Eq (1) by replacing outcome with a dummy variable that separates those individuals who responded that they do not want to join with others to raise an issue from those who have already done so or would do so if they had the opportunity. Thus, I find that the arrival of submarine cables has a positive impact on the chances that individuals will be inclined to stand together with others to raise an issue. The analysis revealed that the deployment of submarine cables could enhance individuals' propensity to unite with others for communal advocacy. Additionally, an examination of survey responses related to an individual's engagement in community groups or associations allowed for further differentiation. By creating a binary classification of active versus inactive or non-associated members, it was observed that the introduction of fiber optic submarine cables arrival markedly increases the likelihood of active participation in community groups.

These insights highlight the pivotal role that coordination plays in mediating the effects of high-speed Internet access on political mobilization. This suggests that enhanced connectivity goes beyond merely promoting individual participation; it significantly bolsters the dynamics of collective action within communities. Similar to how mobile phones revolutionized the information landscape ([Bailard 2009](#)), broadband Internet access has the potential to vastly improve the coordination among individuals, especially through social networks. This enhanced connectivity could facilitate the surmounting of collective action problems ([Olson Jr 1971](#)), thereby fostering greater in-group cooperation and coordination.

1.6.2 Analyzing Broadband's Impact on Democratic Aspirations: A Test of the Liberation Technology Hypothesis

Beyond the explanatory channels, it is worth assessing how the arrival of fiber optic submarine cables influences perceptions related to the exercise of fundamental freedoms, thereby evaluating Diamond's theory of "liberation technology" ([2010](#)). Initial findings indicate that

the increased availability of broadband Internet does not significantly alter the likelihood of individuals exercising their freedoms, such as voicing opinions, voting, or expressing political views as seen in Table 1.9.

Table 1.10: Submarine Cable Arrival and Chances to Participate in a Protest

	Free		Partially Free	
	(1)	(2)	(3)	(4)
SubCableXConnected	0.049*** (0.016)	0.048*** (0.016)	0.016 (0.025)	0.018 (0.025)
CountryxYear	Yes	Yes	Yes	Yes
GADM2xConnected	No	No	No	No
CellxConnected	Yes	Yes	Yes	Yes
Num.Obs.	18 816	18 706	13 662	13 520
R2	0.105	0.110	0.109	0.115

* p < 0.1, ** p < 0.05, *** p < 0.01

Models (1) and (2) analyze data from five countries classified as 'free' by Freedom House: Benin, Ghana, Namibia, Senegal, and South Africa. Models (3) and (4) focus on five countries rated as 'partially free': Kenya, Madagascar, Mozambique, Nigeria, and Tanzania. Individuals are considered 'connected' if they reside within 1.2 km of the backbone network. The dependent variable in all models is a dummy indicating whether an individual participated in a protest in the last 12 months. Temporal fixed effects are applied by year, while spatial fixed effects correspond to the 10x10 km cell level reported location. Models (2) and (4) include control variables: nighttime lights intensity, urban, age, female, primary education. Robust standard errors clustered at the level of location FEs.

Furthermore, this analysis delves into how the relationship between the introduction of submarine cables and protest participation varies according to the freedom level of traditional media, based on data from Freedom House. It posits that in countries with more restricted traditional media, the potential for Internet censorship increases, despite the technical challenges of censoring a decentralized network like the Internet. Countries were categorized into two groups: those with "free" traditional media and those with "partially free" media. The findings, outlined in Table 1.10, reveal that the positive impact of increased Internet availability on protest participation is significantly positive only in countries classified with "free" traditional media.

These observations align with Guriev, Melnikov, and Zhuravskaya (2021), who found

that 3G network deployment diminishes government approval exclusively in contexts where the Internet remains uncensored. This suggests that in environments with tighter information controls, particularly concerning the Internet, the capacity for public mobilization is diminished. Such evidence challenges Diamond (2010)'s assertion regarding the liberating influence of new technologies, indicating that the broader context of media freedom plays a crucial role in realizing the democratic potential of broadband Internet expansion.

1.7 Conclusion

In this paper, I evaluate the impact of broadband Internet on collective action within Sub-Saharan Africa, leveraging the exogenous variation provided by the staggered introduction of fiber-optic submarine cables from Europe between 2009 and 2014. The analysis employs an identification strategy that combines the timing of submarine cable connectivity at specific landing points with a proxy for individual Internet access, based on proximity to terrestrial backbone networks.

Empirical results indicate an increase in daily Internet usage corresponding with the arrival of submarine cables. Using data from the Afrobarometer and the Armed Conflict Location & Event Data Project (ACLED) across ten countries, I applied a difference-in-difference approach to identify a significant positive effect of high-speed Internet on the probability of participating in protests and the occurrence of protest events. This relationship was validated through a series of robustness checks, reinforcing the causal impact of broadband accessibility on political mobilization. It thus appears that the effect of broadband Internet on the likelihood of participating in a protest is unconditional on economic conditions, unlike the effects identified with older telecom technologies (such as 2G).

The analysis also explores the mechanisms driving this relationship, focusing particularly on the role of enhanced coordination as a facilitator of protest participation. Despite exploring the “liberating” effect of ICTs as theorized by Diamond, the findings do not support a positive impact on perceived democratic freedoms, such as freedom of expression, organizational participation, or voting rights. However, the analysis does reveal a significant positive effect of broadband Internet on the likelihood of individuals joining with others to raise an issue, as well as on active participation in community groups. These results underscore the importance of coordination mechanisms in mediating the relationship between high-speed Internet access and political mobilization. This positive relationship between Internet broadband and the likelihood of taking part in a demonstration is only found in democracies.

These findings suggest that while broadband Internet enhances collective action capabil-

ities, its effects on broader democratic freedoms are complex and require further exploration to fully understand their scope and limitations within the context of economic development and political change.

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1.9 Appendix

Table 1.11: Europe/Africa Fibre-Optic Submarine Cables since 2009

Year	Name	Technology (Design capacity)	Landing Points
2009	SEACOM/Tata Fibre-optic TGN-Eurasia	(1.28 Tbps)	Dar Es Salaam, Tanzania; Djibouti City, Djibouti; Jeddah, Saudi Arabia; Maputo, Mozambique; Mombasa, Kenya; Mtunzini, South Africa; Mumbai, India; Zafarana, Egypt
2010	Glo-1	Fibre-optic (2.5 Tbps)	Accra, Ghana; Lagos, Nigeria
2010	MainOne	Fibre-optic (1.28 Tbps)	Abidjan, Ivory Coast; Accra, Ghana; Lagos, Nigeria; Dakar, Senegal
2012	Africa Coast to Europe (ACE)	Fibre-optic (12.8 Tbps)	Cotonou, Benin; Kribi, Cameroon; Abidjan, Ivory Coast; Bata, Equatorial Guinea; Libreville, Gabon; Banjul, Gambia; Accra, Ghana; Suro, Guinea-Bissau; Conakry, Guinea; Monrovia, Liberia; Nouakchott, Mauritania; Lagos, Nigeria; Dakar, Senegal; Freetown, Sierra-Leone; Durban, South-Africa; Sao-Tome, Sao-Tome and Principe
2012	West Africa Cable System (WACS)	Fibre-optic DWDM (14.5 Tbps)	Sangano, Angola; Limbe, Cameroon; Praia, Cape Verde; Pointe-Noire, Congo; Abidjan, Ivory Coast; Muanda, Congo Dem Rep; Accra, Ghana; Swakopmund, Namibia; Lagos, Nigeria; Yzerfontein, South-Africa; Lome, Togo

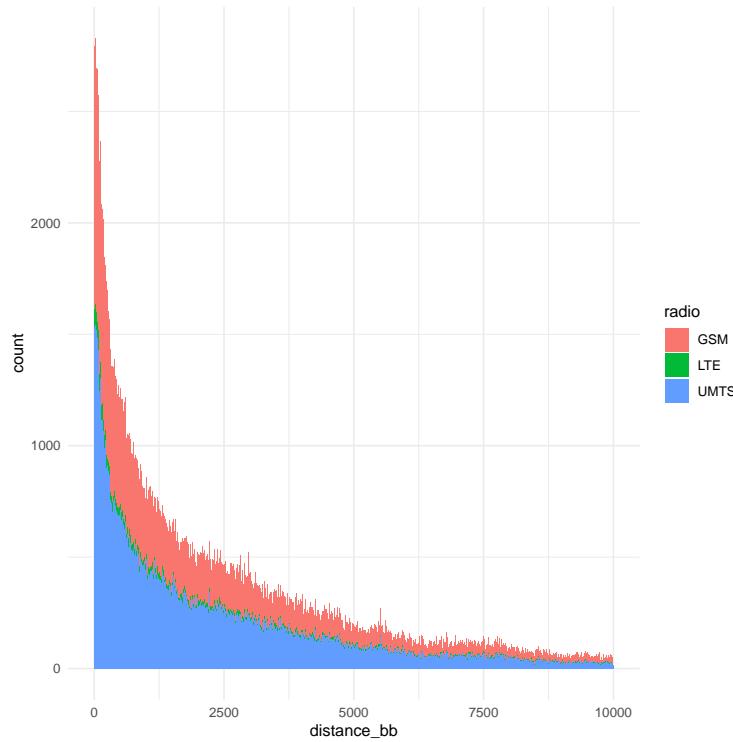


Figure 1.9: Density of the number of new antennas (2G, 3G, 4G) between 2012 and 2016 in relation to the distance to the backbone for the 10 countries in the sample.

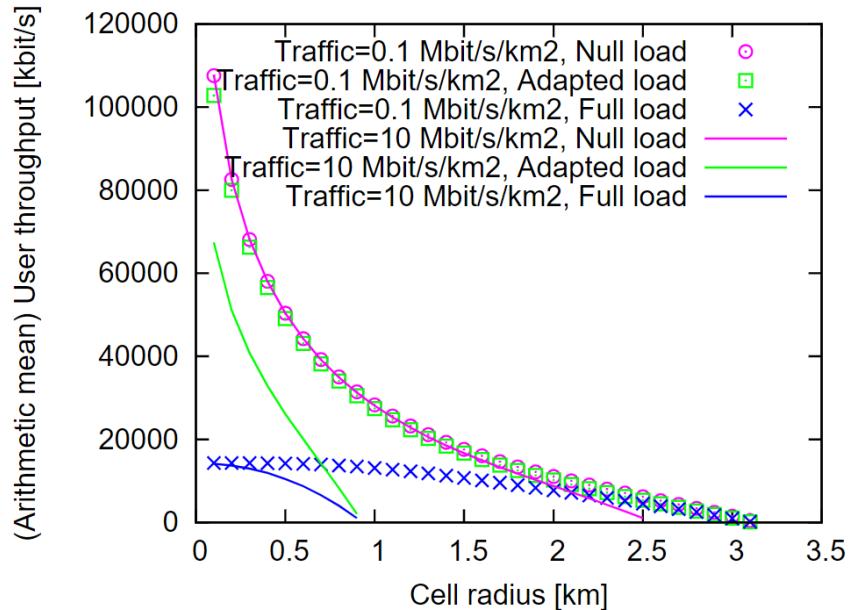


Figure 1.10: Mean user throughput as function of the cell radius for different load situations (Source: Karray and Jovanovic 2013).

Table 1.12: Submarine Cable Arrival and Chances to Participate in a Protest (excluding landing points areas)

	Chances to Participate in a Protest			
	(1)	(2)	(3)	(4)
SubCableXConnected	0.047*** (0.014)	0.045*** (0.014)	0.044*** (0.015)	0.044*** (0.016)
CountryxYear	Yes	Yes	Yes	Yes
GADM2xConnected	Yes	Yes	No	No
CellxConnected	No	No	Yes	Yes
Num.Obs.	27 266	27 046	27 266	27 046
R2	0.081	0.086	0.119	0.124

* p < 0.1, ** p < 0.05, *** p < 0.01

Note: The sample includes Benin, Ghana, Kenya, Madagascar, Mozambique, Namibia, Nigeria, Senegal, South Africa, and Tanzania. Individuals are considered connected if they are closer than 1.2 km to the backbone network. The outcome of all models is a dummy variable indicating if the individual have participated in a protest in the last 12 months. Time FEs are years. Location FEs for the model (1) and (2) are the reported location at the level GADM (Database of Global Administrative Areas) level 2. Location FEs for the model (3) and (4) are the reported location at the 10*10 Cell level. Models (2) and (4) include control variables: nighttime lights intensity, urban, age, female, primary education. Robust standard errors clustered at the level of location FEs.

Table 1.13: Submarine Cable Arrival and Chances to Participate in a Protest (excluding the biggest cities)

	Chances to Participate in a Protest			
	(1)	(2)	(3)	(4)
SubCableXConnected	0.028** (0.014)	0.027* (0.014)	0.025* (0.015)	0.025* (0.015)
CountryxYear	Yes	Yes	Yes	Yes
GADM2xConnected	Yes	Yes	No	No
CellxConnected	No	No	Yes	Yes
Num.Obs.	26 941	26 735	26 941	26 735
R2	0.081	0.087	0.116	0.123

* p < 0.1, ** p < 0.05, *** p < 0.01

Note: The sample includes Benin, Ghana, Kenya, Madagascar, Mozambique, Namibia, Nigeria, Senegal, South Africa, and Tanzania. Individuals are considered connected if they are closer than 1.2 km to the backbone network. The outcome of all models is a dummy variable indicating if the individual have participated in a protest in the last 12 months. Time FEs are years. Location FEs for the model (1) and (2) are the reported location at the level GADM (Database of Global Administrative Areas) level 2. Location FEs for the model (3) and (4) are the reported location at the 10*10 Cell level. Models (2) and (4) include control variables: nighttime lights intensity, urban, age, female, primary education. Robust standard errors clustered at the level of location FEs.

Table 1.14: Submarine Cable Arrival and Chances to Participate in a Protest (GADM1 Fixed Effects)

	Chances to Participate in a Protest		
	(1)	(2)	(3)
SubCableXConnected	0.033*** (0.012)	0.033*** (0.012)	-0.004* (0.002)
CountryxYear	Yes	Yes	Yes
GADM2xConnected	No	No	No
CellxConnected	No	No	No
Num.Obs.	32,478	32,226	32,226
R2	0.047	0.052	0.053

Note: The sample includes Benin, Ghana, Kenya, Madagascar, Mozambique, Namibia, Nigeria, Senegal, South Africa, and Tanzania. Individuals are considered connected if they are closer than 1.2 km to the backbone network. The outcome of all models is a dummy variable indicating if the individual have participated in a protest in the last 12 months. Time FEs are years. Location FEs for the model (1), (2) and (3) are the reported location at the level GADM (Database of Global Administrative Areas) level 1. Models (2) and (3) include control variables: nighttime lights intensity, urban, age, female, primary education. Robust standard errors clustered at the level of location FEs.

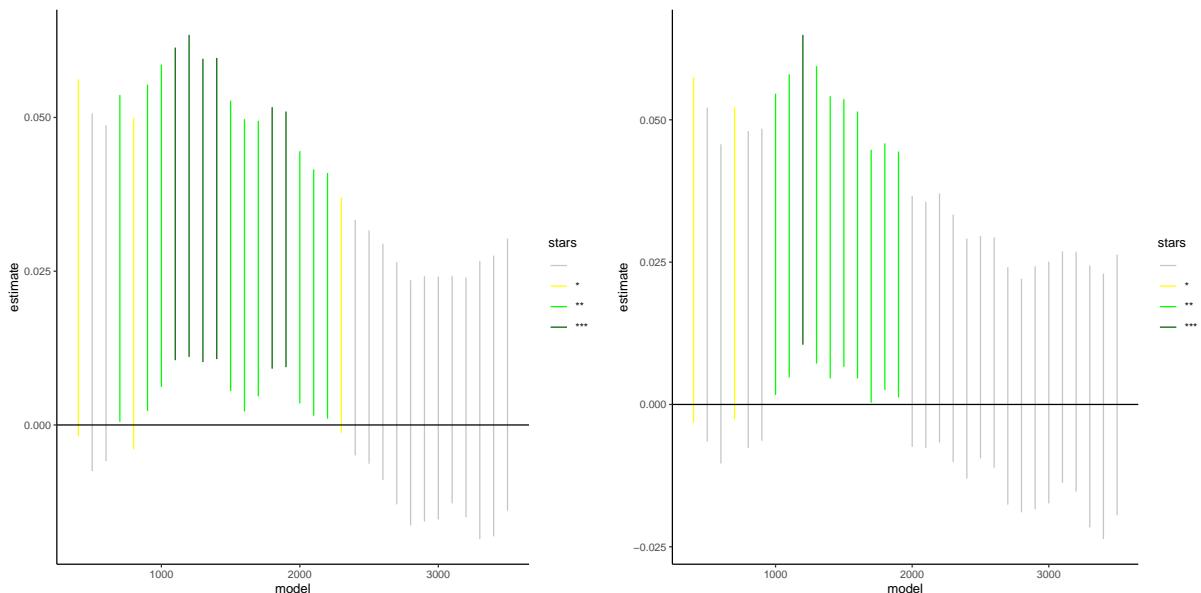


Figure 1.11: Variation of Connection Radius - Effect of the arrival of submarine cables on the chances to part.

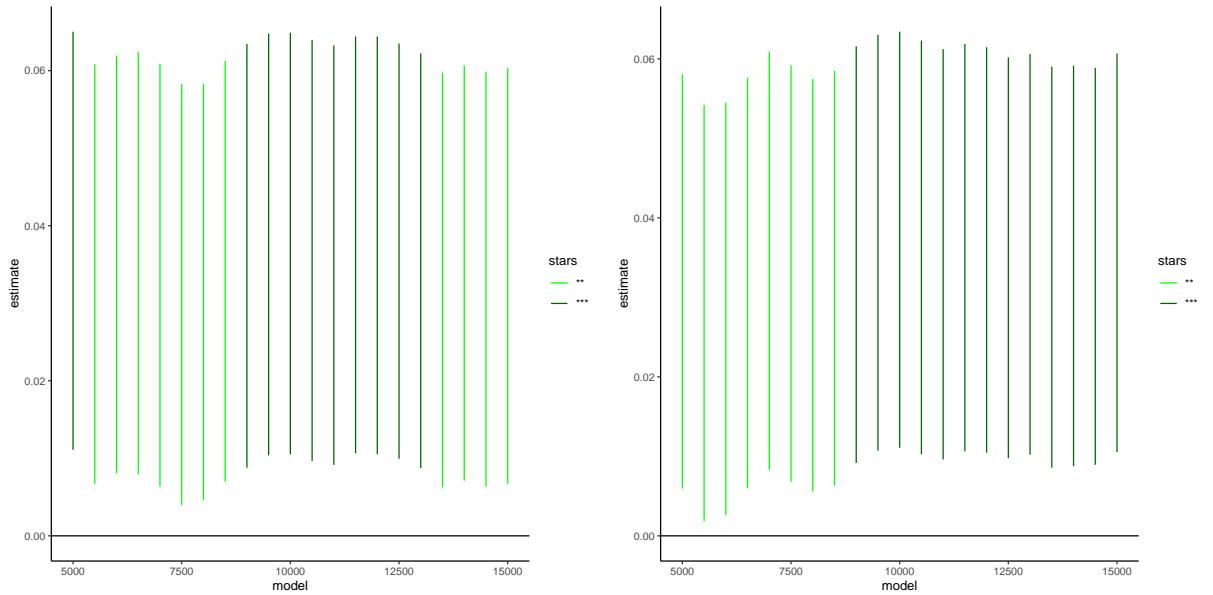


Figure 1.12: Variation of Size of the control group - Effect of the arrival of submarine cables on the chances to part.

Table 1.15: Submarine Cable Arrival and Chances to Participate in a Protest (remove countries one by one)

	BEN	GHA	KEN	MDG	MOZ	NAM	NGA	SEN	ZAF	TZA
SubCableXConnected	0.030** (0.015)	0.037** (0.016)	0.036** (0.015)	0.040*** (0.014)	0.047*** (0.014)	0.027* (0.015)	0.038*** (0.014)	0.039*** (0.015)	0.044*** (0.015)	0.035** (0.014)
CountryxYear	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
GADM2xConnected	No	No	No	No	No	No	No	No	No	No
CellxConnected	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Num.Obs.	30 452	28 831	28 789	30 346	29 432	29 132	29 736	29 827	25 332	30 425
R2	0.114	0.106	0.112	0.104	0.108	0.117	0.107	0.110	0.087	0.103

* p < 0.1, ** p < 0.05, *** p < 0.01

Note: The sample includes Benin, Ghana, Kenya, Madagascar, Mozambique, Namibia, Nigeria, Senegal, South Africa and Tanzania. Countries are removed from the sample one by one, and the Eq (1) is estimated. Time FEes are years. Location FEes are Grid-cells of 0.1*0.1 decimal degrees, which is roughly 10*10 km. Individuals are considered connected if they are closer than 1.2 km to the backbone network. Robust standard errors clustered at the level of location FEes.

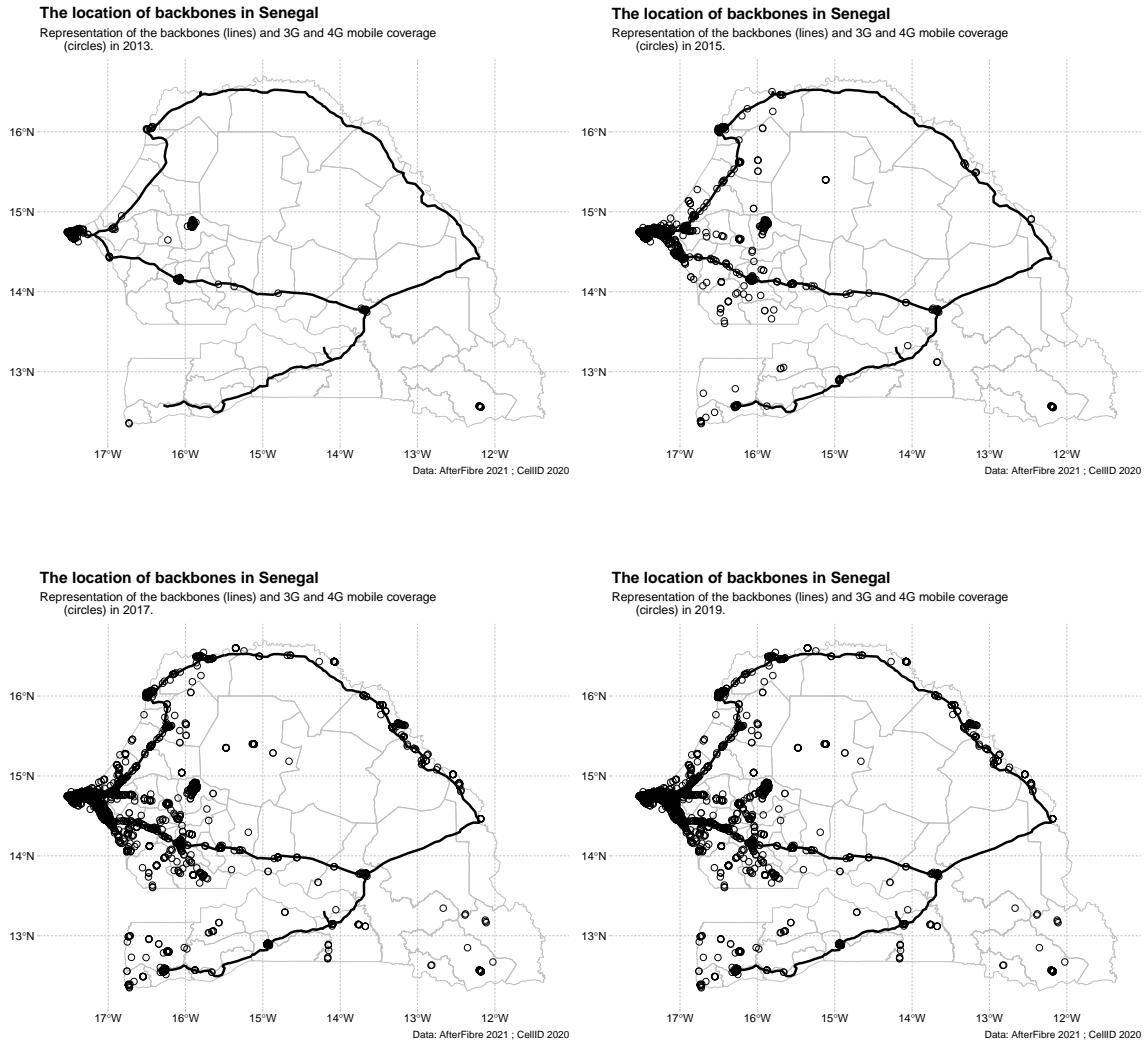


Figure 1.13: Location of 3G and 4G antennas in Senegal between 2012 and 2019 (Source: OpenCellID).

Table 1.16: Submarine Cable Arrival and Chances to Participate in a Protest (remove countries one by one with controls)

	BEN	GHA	KEN	MDG	MOZ	NAM	NGA	SEN	ZAF	TZA
SubCableXConnected	0.030** (0.015)	0.038** (0.016)	0.036** (0.015)	0.041*** (0.014)	0.046*** (0.014)	0.028* (0.015)	0.038*** (0.014)	0.039*** (0.014)	0.044*** (0.015)	0.035** (0.014)
CountryxYear	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
GADM2xConnected	No	No	No	No	No	No	No	No	No	No
CellxConnected	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Num.Obs.	30 211	28 599	28 551	30 107	29 269	28 882	29 498	29 595	25 137	30 185
R2	0.119	0.111	0.117	0.110	0.114	0.126	0.112	0.115	0.093	0.109

* p < 0.1, ** p < 0.05, *** p < 0.01

Note: The sample includes Benin, Ghana, Kenya, Madagascar, Mozambique, Namibia, Nigeria, Senegal, South Africa and Tanzania. Countries are removed from the sample one by one, and the Eq (1) is estimated. Time FE are years. Location FE are Grid-cells of 0.1*0.1 decimal degrees, which is roughly 10*10 km. Individuals are considered connected if they are closer than 1.2 km to the backbone network. Robust standard errors clustered at the level of location FE.

Table 1.17: Submarine Cable Arrival and Chances to Participate in a Protest

	Without 800-1600		Without 1200-1600		Without 800-1200	
	(1)	(2)	(3)	(4)	(5)	(6)
SubCableXConnected	0.037** (0.016)	0.034** (0.016)	0.036** (0.014)	0.037** (0.015)	0.039** (0.016)	0.035** (0.015)
CountryxYear	Yes	Yes	Yes	Yes	Yes	Yes
GADM2xConnected	Yes	No	Yes	No	Yes	No
CellxConnected	No	Yes	No	Yes	No	Yes
Num.Obs.	27 654	27 654	30 076	30 076	29 804	29 804
R2	0.083	0.116	0.082	0.115	0.081	0.114

* p < 0.1, ** p < 0.05, *** p < 0.01

Note: The sample includes Benin, Ghana, Kenya, Madagascar, Mozambique, Namibia, Nigeria, Senegal, South Africa, and Tanzania. Individuals are considered connected if they are closer than 1.2 km to the backbone network. The outcome of all models is a dummy variable indicating if the individual have participated in a protest in the last 12 months. Time FE are years. Location FE for the model (1), (3) and (5) are the reported location at the level GADM (Database of Global Administrative Areas) level 2. Location FE for the model (2), (4) and (6) are the reported location at the 10*10 Cell level. All Models include control variables: night-time lights intensity, urban, age, female, primary education. Robust standard errors clustered at the level of location FE. For each regression, I specify which individuals are excluded from the sample on the basis of their distance from the backbone.

Table 1.18: Submarine Cable Arrival and Chances to Participate in a Protest

	Controls: 1200-5000m		Controls: 1200-15000m		Controls: > 1200m	
	(1)	(2)	(3)	(4)	(5)	(6)
SubCableXConnected	0.032** (0.013)	0.038*** (0.014)	0.036*** (0.013)	0.034** (0.014)	0.029** (0.012)	0.030** (0.013)
CountryxYear	Yes	Yes	Yes	Yes	Yes	Yes
GADM2xConnected	Yes	No	Yes	No	Yes	No
CellxConnected	No	Yes	No	Yes	No	Yes
Num.Obs.	24 967	24 967	36 444	36 444	64 959	64 959
R2	0.084	0.110	0.079	0.115	0.082	0.129

* p < 0.1, ** p < 0.05, *** p < 0.01

Note: The sample includes Benin, Ghana, Kenya, Madagascar, Mozambique, Namibia, Nigeria, Senegal, South Africa, and Tanzania. Individuals are considered connected if they are closer than 1.2 km to the backbone network. The outcome of all models is a dummy variable indicating if the individual have participated in a protest in the last 12 months. Time FEs are years. Location FEs for the model (1), (3) and (5) are the reported location at the level GADM (Database of Global Administrative Areas) level 2. Location FEs for the model (2), (4) and (6) are the reported location at the 10*10 Cell level. All Models include control variables: nighttime lights intensity, urban, age, female, primary education. Robust standard errors clustered at the level of location FEs. For each regression, I specify which individuals are excluded from the sample on the basis of their distance from the backbone.

Table 1.19: Submarine Cable Arrival and Chances to Participate in a Protest (Precision test)

	(1)	(2)	(3)	(4)
SubCableXConnected	0.033** (0.014)	0.032** (0.014)	0.030** (0.014)	0.030** (0.014)
CountryxYear	Yes	Yes	Yes	Yes
GADM2xConnected	Yes	Yes	No	No
CellxConnected	No	No	Yes	Yes
Num.Obs.	31 012	30 765	31 012	30 765
R2	0.075	0.080	0.109	0.114

* p < 0.1, ** p < 0.05, *** p < 0.01

Note: The sample includes Benin, Ghana, Kenya, Madagascar, Mozambique, Namibia, Nigeria, Senegal, South Africa, and Tanzania. Individuals are considered connected if they are closer than 1.2 km to the backbone network. The outcome of all models is a dummy variable indicating if the individual have participated in a protest in the last 12 months. Time FEs are years. Location FEs for the model (1) and (2) are the reported location at the level GADM (Database of Global Administrative Areas) level 2. Location FEs for the model (3) and (4) are the reported location at the 10*10 Cell level. Models (2) and (4) include control variables: nighttime lights intensity, urban, age, female, primary education. Robust standard errors clustered at the level of location FEs.

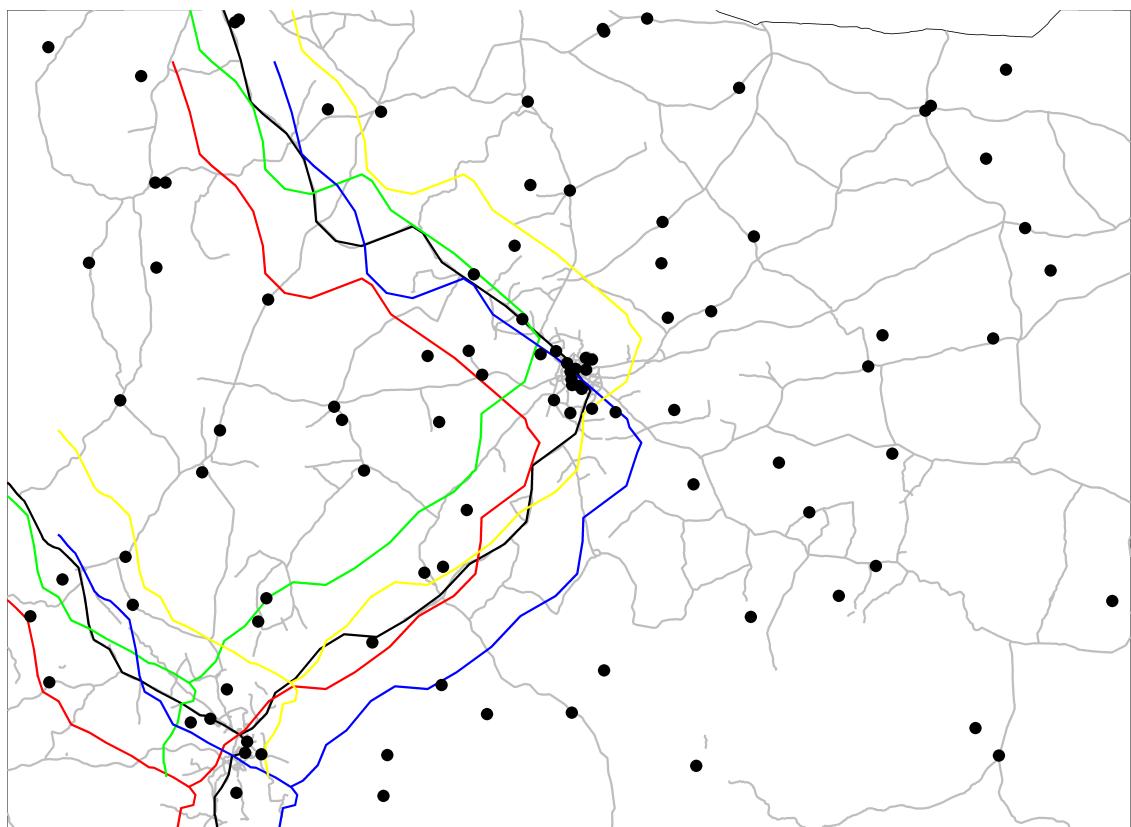


Figure 1.14: This map details the placebo test conducted for the study, centered on Kano, Nigeria. The black line marks the actual location of the existing backbone cable. Surrounding this, the other colored lines illustrate hypothetical displacements of the backbone cable, each shifted by 12.5 degrees in four different directions. Following these simulated shifts, the treatment and control groups were redefined based on the new positions to assess the robustness of the original findings.

Table 1.20: Submarine Cable Arrival and Chances to Participate in a Protest (Placebo test)

	(-0.125, -0.125)		(-0.125, 0.125)		(0.125,-0.125)		(0.125, 0.125)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
SubCableXConnected	-0.024 (0.029)	-0.025 (0.033)	0.032 (0.025)	0.019 (0.026)	0.007 (0.039)	0.006 (0.032)	0.029 (0.023)	0.019 (0.023)
CountryxYear	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
GADM2xConnected	Yes	No	Yes	No	Yes	No	Yes	No
CellxConnected	No	Yes	No	Yes	No	Yes	No	Yes
Num.Obs.	20 253	20 253	18 727	18 727	18 250	18 250	17 717	17 717
R2	0.084	0.122	0.086	0.128	-0.512	0.132	0.089	0.131

* p < 0.1, ** p < 0.05, *** p < 0.01

Note: The sample consists of Benin, Ghana, Kenya, Madagascar, Mozambique, Namibia, Nigeria, Senegal, South Africa, and Tanzania. Connectivity is defined based on proximity to a 'false' backbone network, which is displaced by the degree values specified above each column. The primary outcome for all models is a dummy variable that indicates whether an individual has participated in a protest within the last 12 months. Temporal fixed effects (Time FEs) are included for each year. Spatial fixed effects (Location FEs) for models (1), (3), (5), and (7) are determined at the GADM level 2, while for models (2), (4), (6), and (8), they are determined at the 10x10 km cell level. All models control for nighttime lights intensity, urban status, age, gender (female), and primary education. Robust standard errors clustered at the level of location FEs.

Chapter 2

Valuing the Virtual: The Impact of Fiber to the Home on Property Prices in France

Published in Telecommunications Policy

2.0.1 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.

JEL Classifications: L96 ; R31 ; R38

Keywords: *Very high-speed Internet ; FTTH ; Hedonic pricing model ; House market ; Spatial discontinuity design*

2.1 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 Internet³ 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 et al. 2011; Briglauer and Gugler 2019), notably bolstering employment growth (Kolko 2012; Whitacre, Gallardo, and Strover 2014a), household income levels (Whitacre, Gallardo, and Strover 2014b ; Gallardo and Whitacre 2018) and productivity (Mack and Faggian 2013; Gallardo et al. 2021). However, the relationship between these investments and economic inequalities remains ambiguous (Forman, Goldfarb, and Greenstein 2012; Houngbonon and 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, and Buysse 2023). Given broadband's potential impact on economic wealth, this proactive European policy initiative necessitates rigorous scrutiny. This paper explores the implications of FTTH rollout, directly addressing the pivotal question of its household valuation.

This study focuses on the case of France, which has made significant investments in FTTH network deployment with the objective of generalizing 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 con-

¹The 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.

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

³ARCEP, 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.

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

nectivity (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, and Valletti 2017; Liu, Prince, and 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 assessing the wider societal and economic impacts of making very high-speed internet widely available.

One way to estimate the value households place on infrastructure is by analyzing the housing market. In this research, I utilize a 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 and Koster 2016; Jensen et al. 2018), as well as evaluating the effects of the proximity to nuclear plants (Ando, Dahlberg, and Engström 2017; Tanaka and 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, Koutroumpis, and Valletti 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 Q2-2020⁶. In addition, a French General

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

⁶The 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

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

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.

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 most rural municipalities, and then it 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, and 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 2.2 describes the data used in this study. Section 2.3 introduces the identification strategy. Section 2.4 presents the results. Section 2.5 concludes.

2.2 The French Broadband Infrastructure

2.2.1 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

⁷ <https://www.tresor.economie.gouv.fr/Articles/2023/01/17/la-concurrence-dans-le-marche-francais>
accessed in February 2024.

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 each of these technologies can deliver: ADSL bandwidths can range from 1 to 15 megabits per second, while FTTH bandwidths can vary from 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

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

⁹Orange 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.

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

¹¹Conventionally, 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 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.

¹²https://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

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 Figure 2.1, 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 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.

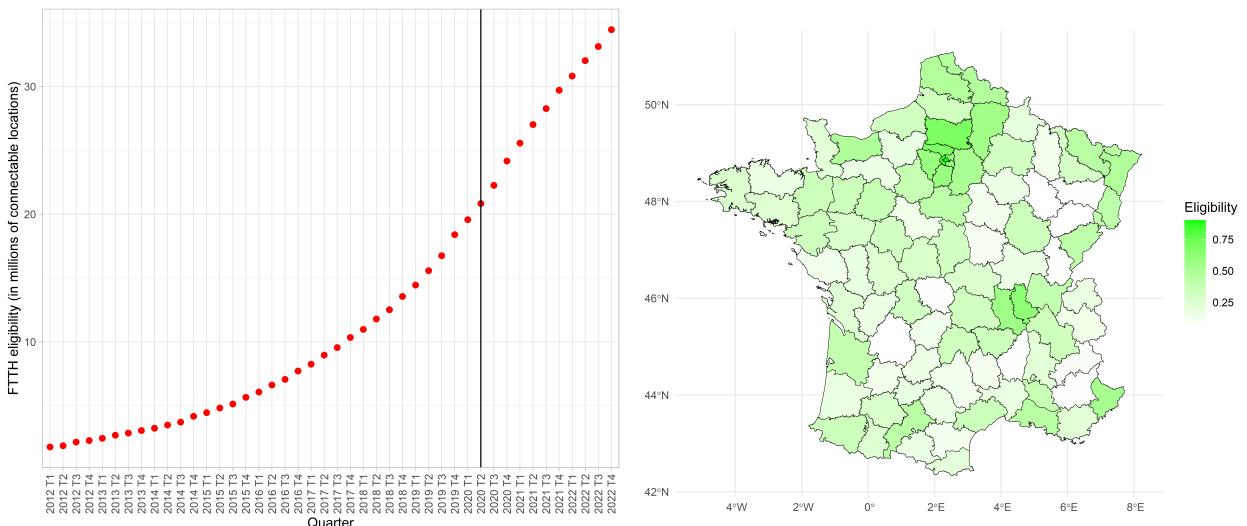


Figure 2.1: The graph on the left shows the evolution of the number of premises (in millions) eligible for fiber in France since 2012, by quarter. The black bar represents the point in time chosen for this analysis: Q2-2020. The chart on the right shows all French départements and their fiber optic eligibility rates in Q2-2020.

¹⁴<https://www.amenagement-numerique.gouv.fr/fr/actualite/raccordements-ftth-etape-determinante> accessed in February 2023

¹⁵The 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.

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,¹⁶: 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.¹⁷ This has led to the creation of tools such as “Ma connexion internet” to monitor premises that are not yet eligible for fiber regularly. 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.

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,¹⁸ highlighting a significant trend in household preferences regarding broadband services. Some studies (Grzybowski and Liang 2015; Grzybowski, Hasbi, and 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.

2.2.2 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

¹⁶<https://www.arcep.fr/nos-sujets/la-couverture-internet-fixe-a-haut-et-tres-haut-debit.html>, accessed in June 2023

¹⁷In accordance with Article L.33-13 of the French Post and Electronic Communications Code.

¹⁸Ultra-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.

entire French metropolitan territory. This analysis encompasses 90 departments.¹⁹ Figure 2.2 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 no common joining key was available, the developed method played a crucial role in facilitating the merging process.

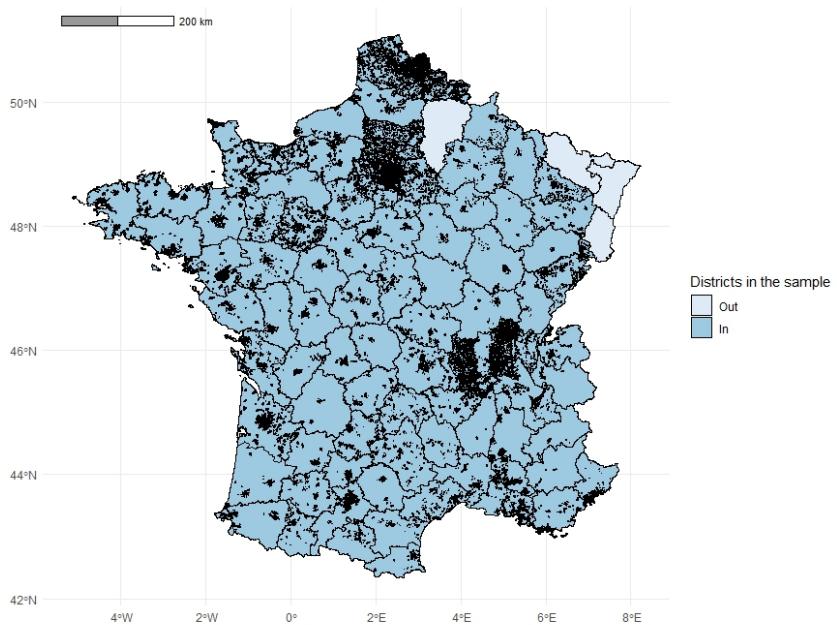


Figure 2.2: Districts in the sample and FTTH eligibility areas at the end of 2019: 90 districts are included in the analysis. Some departments shown in light blue are not included in the sample. The Direction Générale des Finances Publiques, which produces the ‘Demande de Valeurs Foncières’ data, does 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 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.

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 Figure 2.3. 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

¹⁹Excluding 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.

network characteristics such as internet speeds, fiber eligibility, and operators offering these technologies. Several steps were undertaken to achieve the first research objective of merging fiber eligibility data with geospatial data sources, as depicted in Figure 2.4. 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 reflects the properties 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 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,

²¹For 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.

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

²³This 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 ar-

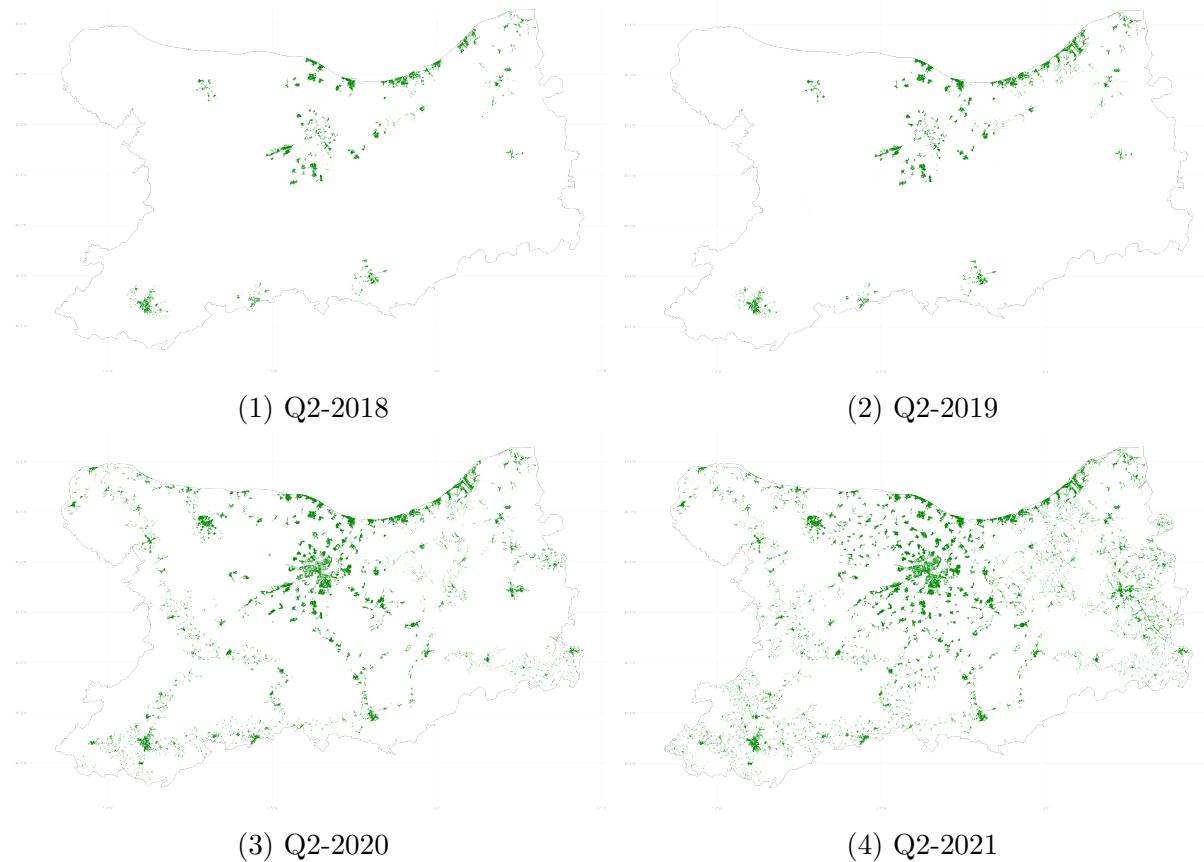


Figure 2.3: Evolution of FTTH eligibility zones in the Calvados district (14) between Q2-2018 and Q2-2021.

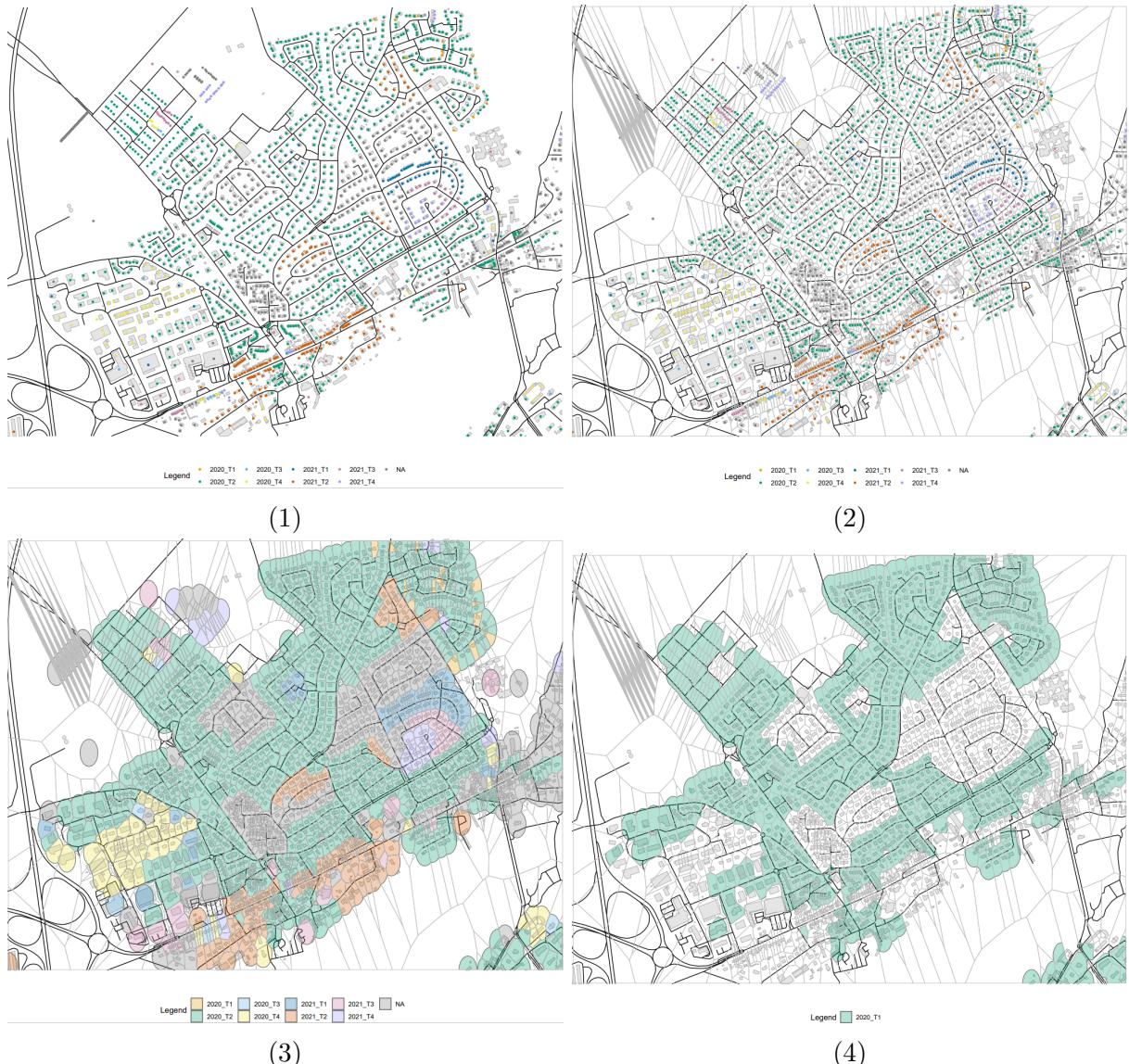


Figure 2.4: Method for constructing FTTH eligibility boundaries: The series of four maps illustrates the methodology employed to merge an exhaustive set of quarterly databases, spanning Q2-2018 to Q4-2021, at the address level for the entire metropolitan French territory, encompassing 90 departments. Given the absence of a common joining key, the study meticulously progresses through the following stages to delineate the FTTH eligibility zones: Map (1) displays 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) depicts the comprehensive FTTH eligibility zone as of Q2-2020.

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 2.7 in Appendix.

2.3 Methodology

2.3.1 Spatial Discontinuity Design

Measuring the effect of fiber eligibility on housing prices presents several challenges. This methodology aims 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.

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 (Bertanha and Imbens 2020; Chaplin et al. 2018). 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

eas 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-> accessed in January 2024.

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

the study. A non-parametric estimation approach is employed by focusing on observations in close proximity to the FTTH deployment boundary, 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 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, Koutroumpis, and Valletti (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:

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

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



Figure 2.5: 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.

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 et al. 2011](#)). To address the potential concern of non-random sorting around the threshold, I employ a Donut Regression Discontinuity estimation ([Barreca et al. 2011](#)). This involves removing observations in the immediate proximity 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 7.5m 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.

Figure 2.5 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.

2.3.2 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 2.1, 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 Figure 2.7. This suggests that these covariates exhibit a continuity at the threshold, further supporting the presence of a discontinuity only in the treatment variable (fiber eligibility) and the primary outcome (the log of the sale price). The RDD assumption assumes that variables other than the treatment and main

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

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.

Table 2.1: Table of comparison of prices and other characteristics of the properties in the eligible and non-eligible zones

	Whole sample			Within 35m of boundary		
	Non-Eligible	Eligible	SE	Non-Eligible	Eligible	SE
	(1)	(2)	(3)	(4)	(5)	(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. Only properties between 7.5 and 35 meters are selected for the three last columns. The treatment group is 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 properties sold outside of the FTTH eligibility areas, which are 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.

2.4 Results

2.4.1 Graphical Analysis

A graphical examination is conducted to initiate the analysis 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 Figure 2.6, following some of the recommendations in Korting et al. (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 linear regression of the outcome variable on the 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.

2.4.2 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 2.2 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 characteristics²⁷ (a dummy variable indicating 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

²⁷The 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 2.11, the dataset comprising transactions 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.

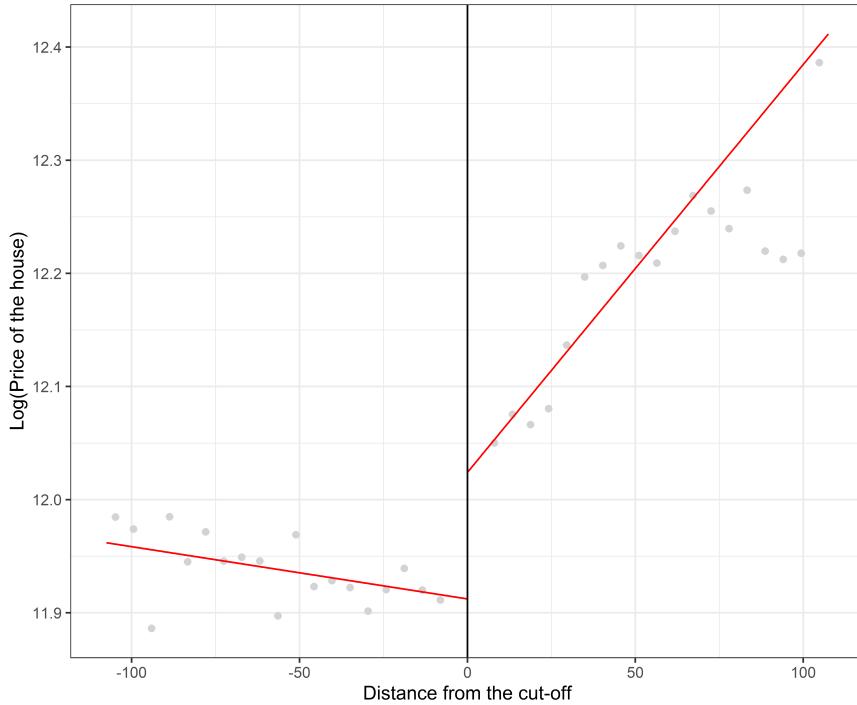


Figure 2.6: This figure illustrates the spatial discontinuities in property prices based on FTTH eligibility. Negative distances indicate locations within the boundary segment that are not eligible for FTTH technology. The dots represent the mean transaction prices within 5-meter distance bins. The sample is restricted to FTTH eligibility areas with at least one observation on each side of the boundary.

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%.²⁸ 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, Koutroumpis, and Valletti (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

²⁸According to these estimates, this is equivalent to increasing the surface area of a purchased property by around 1.11 square meters.

Table 2.2: Pricing results

	Log(price)		
	(1)	(2)	(3)
FTTH	0.016*** (0.003)	0.015*** (0.003)	0.009*** (0.003)
Quarter	Yes	Yes	Yes
PostalCode	Yes	Yes	Yes
Boundary	-	Yes	Yes
Boundary window (m)	-	0-35	7.5-35
R2	0.700	0.784	0.785
Num.Obs.	738939	257486	237299
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).

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 2.8 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.

2.4.3 Robustness

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). Figure 2.8 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 (always removing all observations between 0 and 7.5 m). 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.

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. Figure 2.9 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.

2.4.4 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.

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 2.3 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, D'Haese, and Buysse 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 and Whitacre 2019 ; Molnar, Savage, and 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.²⁹

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)³⁰ 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 2.9 and for the variable distance to the connection node in the Table 2.10 available in the 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.

²⁹However, while the coefficient is higher in rural areas, the differences between the coefficients are not statistically significant.

³⁰This 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 2.3: Pricing results by urban–rural subsamples

	Log(price)				
	(1)	(2)	(3)	(4)	(5)
FTTH	0.038** (0.019)	0.027** (0.013)	0.025*** (0.008)	-0.001 (0.007)	0.014*** (0.004)
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	24130	45424	153112
Quarter	Yes	Yes	Yes	Yes	Yes
PostalCode	Yes	Yes	Yes	Yes	Yes
Boundary	Yes	Yes	Yes	Yes	Yes
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.

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 2.4 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.

Table 2.4: Pricing results by Distance Groups

	Log(price)			
	(1)	(2)	(3)	(4)
FTTH	0.015 (0.010)	0.010 (0.012)	0.020*** (0.006)	0.026*** (0.007)
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.	26270	18302	47609	36094
Quarter	Yes	Yes	Yes	Yes
PostalCode	Yes	Yes	Yes	Yes
Boundary	Yes	Yes	Yes	Yes
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 3kms from the centroids of one of the major French cities; column (2), properties between 3 and 6kms; column (3), properties between 6 and 20kms and column (4), properties between 20 and 50kms.

Economic Disparities and FTTH Valuation

Table 2.5 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.

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. Sub-groups 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 2.6 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 2.5: Pricing results by Revenue Quartiles

	Log(price)			
	(1)	(2)	(3)	(4)
FTTH	0.022*** (0.007)	0.022** (0.009)	-0.001 (0.009)	0.001 (0.005)
Quarter	Yes	Yes	Yes	Yes
PostalCode	Yes	Yes	Yes	Yes
Boundary	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.	54595	33173	20992	100588
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 7.5-35m 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.

2.5 Conclusion

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

Table 2.6: Pricing results by Eligibility Quartiles

	Log(price)			
	(1)	(2)	(3)	(4)
FTTH	0.019** (0.007)	0.008 (0.005)	0.004 (0.007)	0.016** (0.008)
Quarter	Yes	Yes	Yes	Yes
PostalCode	Yes	Yes	Yes	Yes
Boundary	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.	36155	71012	59296	70836
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 7.5-35m 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%.

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

and resource allocation for future investment and growth potential ([Clercq, D'Haese, and Buysse 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.

2.6 References

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2.7 Appendix

Table 2.7: Descriptive Statistics

	0	1	Overall
	(N=360944)	(N=378020)	(N=738964)
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	78064 (21.6%)	82685 (21.9%)	160749 (21.8%)
2019/02	85724 (23.8%)	91900 (24.3%)	177624 (24.0%)

2019/03	101093 (28.0%)	107761 (28.5%)	208854 (28.3%)
2019/04	96063 (26.6%)	95674 (25.3%)	191737 (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 2.8: Pricing results

	Log(price)		
	(1)	(2)	(3)
FTTH	0.012*** (0.004)	0.006* (0.004)	-0.006 (0.004)
Quarter	Yes	Yes	Yes
PostalCode	Yes	Yes	Yes
Boundary	Yes	Yes	Yes
R2	0.796	0.785	0.770
Num.Obs.	126754	149303	113741

* 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 7.5-35m distance window are provided. Standard errors (enclosed in parentheses) are clustered at the boundary level.

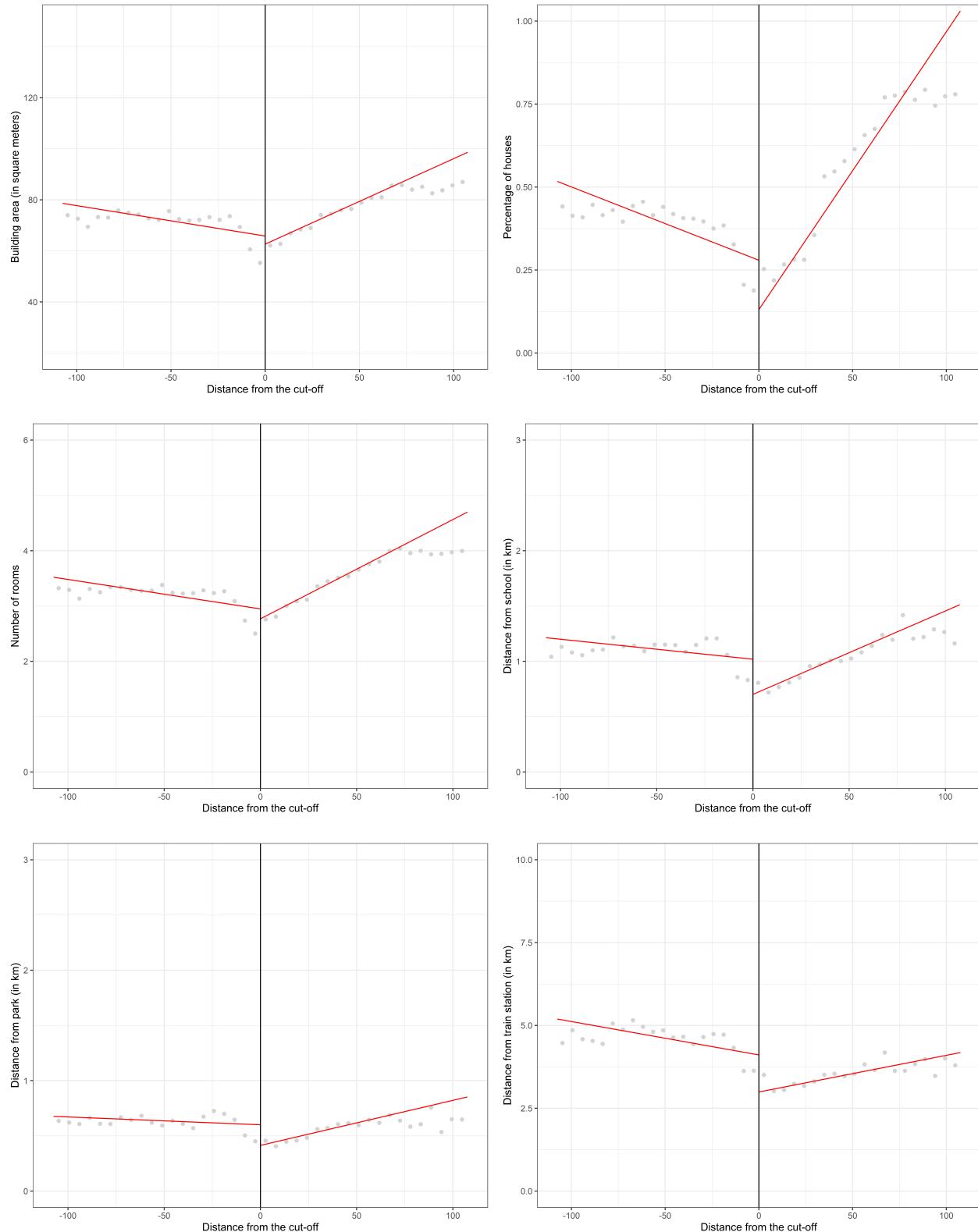


Figure 2.7: This figure illustrates the spatial discontinuities in property covariates (building and land area, number of rooms and distance from the nearest school) based on FTTH eligibility. Negative distances indicate locations within the boundary segment that are not eligible for Fiber to the Home (FTTH) technology. The dots represent the mean transaction prices within 5-meter distance bins. The red lines depict the predicted values obtained by linearly regressing the outcome variables against the distance to the boundary.

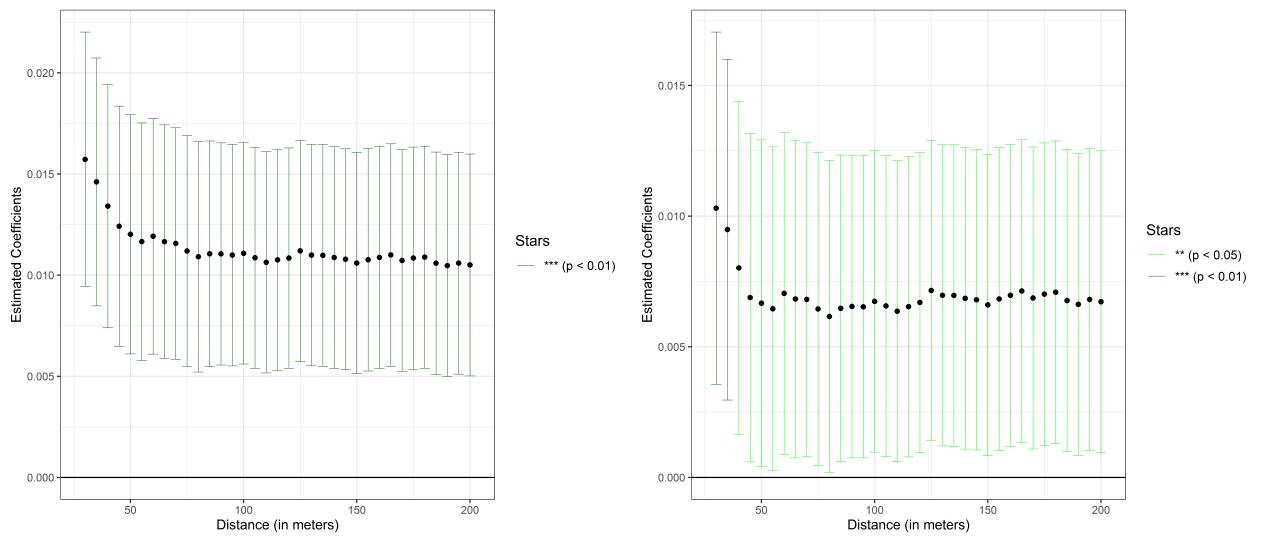


Figure 2.8: Sensitivity Analysis of FTTH Impact on Property Prices: This figure demonstrates the variability of the coefficient associated with FTTH eligibility and its effect on property transaction values. The analysis window is systematically adjusted in five-meter increments, ranging from 30m to 200m. 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.

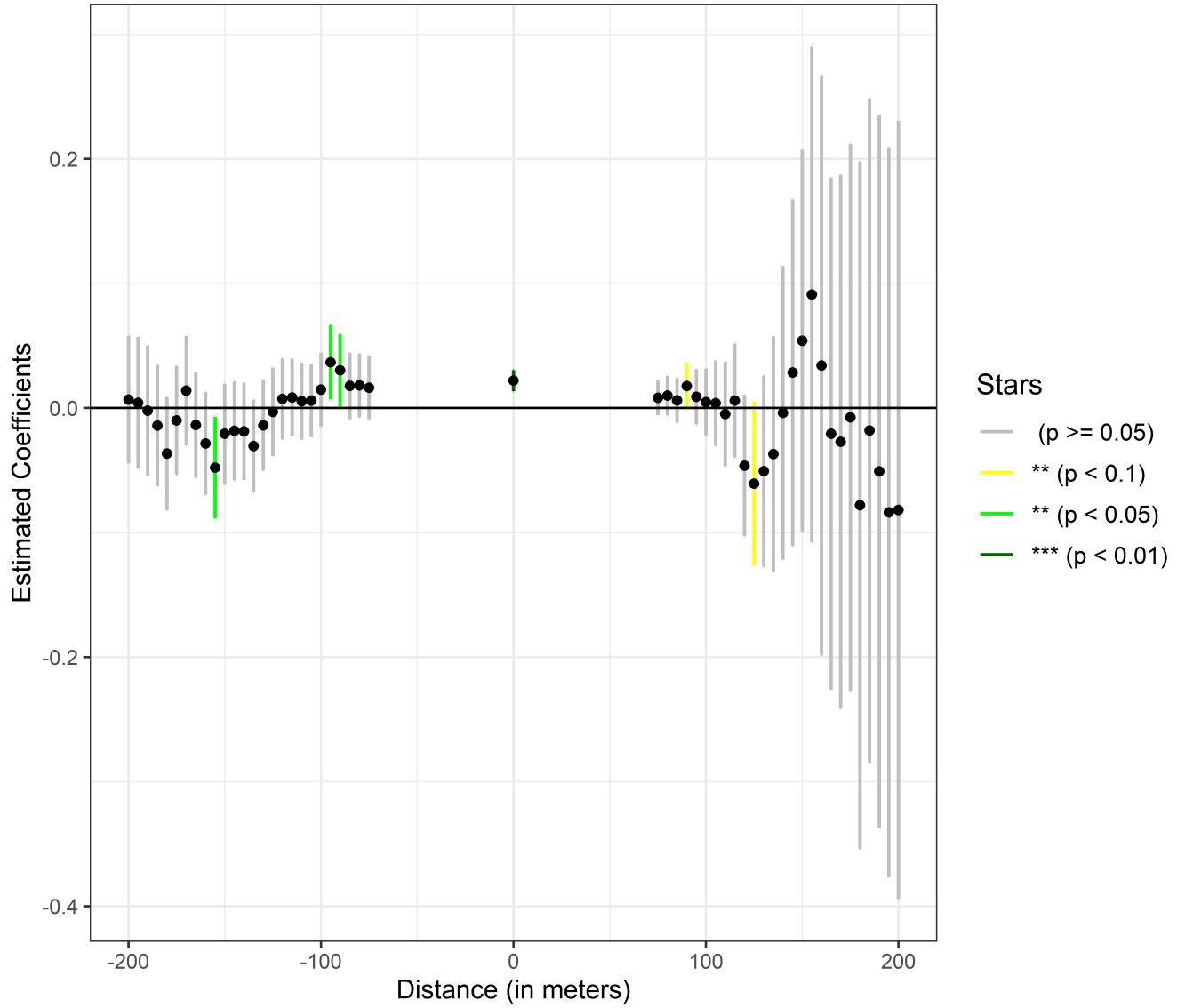


Figure 2.9: Placebo test: each estimation is estimated by shifting the cut-off on both sides of the border and performing the same estimation procedure as in Table (2), but this time assigning either a false treatment or a false control group (with a 35m boundary window on both side of the false cut-off). The coloration of the error bars denotes the levels of statistical significance.

Table 2.9: 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 (0.021)	0.030** (0.013)	0.023** (0.010)	-0.002 (0.008)	0.019*** (0.005)
bad_ADSL	-0.042 (0.046)	0.075* (0.041)	-0.007 (0.017)	0.008 (0.014)	-0.003 (0.010)
FTTH × bad_ADSL	0.077** (0.037)	-0.023 (0.038)	0.015 (0.017)	-0.002 (0.014)	-0.011 (0.010)
Quarter	Yes	Yes	Yes	Yes	Yes
PostalCode	Yes	Yes	Yes	Yes	Yes
Boundary	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	24099	45063	151619

* 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 7.5-35m 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 2.10: 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 (0.041)	-0.014 (0.027)	0.022 (0.022)	0.008 (0.017)	0.023** (0.011)
distance_NRA	-0.024 (0.035)	0.017 (0.017)	0.020* (0.011)	0.010 (0.010)	-0.008 (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	Yes	Yes	Yes	Yes	Yes
PostalCode	Yes	Yes	Yes	Yes	Yes
Boundary	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	24130	45424	153112

* 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 7.5-35m 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 2.11: Pricing results (with control of the date of construction of the dwelling)

	Log(price)		
	(1)	(2)	(3)
FTTH	0.016*** (0.003)	0.015*** (0.003)	0.010*** (0.003)
Recent	0.091*** (0.008)	0.098*** (0.014)	0.097*** (0.014)
Quarter	Yes	Yes	Yes
PostalCode	Yes	Yes	Yes
Boundary	-	Yes	Yes
Boundary window (m)	-	0-35	7.5-35
R2	0.700	0.784	0.785
Num.Obs.	738939	257486	237299
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 0-35m window are showcased in column (2), while those for a 7.5-35m window are provided in column (3). Results for boundary windows spanning from 30m to 200m 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).

Chapter 3

From Bytes to Business: Mobile Broadband, Firm Creations and Digital Divide in Tunisia

This paper investigates the impact of mobile broadband Internet on business creation in Tunisia. Using a rich dataset of Tunisian delegations, the study employs a count model and fixed effects panel data estimation to assess the influence of mobile broadband Internet quality and delegation characteristics on firm creation. The empirical findings demonstrate a robust positive relationship between the density of 4G antennas per 10,000 inhabitants and the number of new business creations (and a positive impact on net business creations). Notably, this relationship is stronger and exhibits later effects in rural areas, particularly on the peripheries of major urban centers, suggesting varying rates of technology adoption and challenging the hypothesis of the "death of distance" that broadband Internet was expected to bring. This research highlights the potential role of mobile broadband in stimulating local economic growth and sheds nuanced light on the economic implications of the digital divide.

JEL Classification: L96 ; O18 ; O33 ; O47 ; R32

Keywords: *Mobile broadband internet ; Firm creation ; Local economic growth ; Digital divide ; Tunisia*

3.1 Introduction

Digital technology is revolutionizing business operations by dramatically reducing operational costs, including search, reproduction, transportation, tracking, and verification (Goldfarb and Tucker 2019). Broadband Internet¹, recognized as a general-purpose technology, has the potential to have a profound impact on the entire economy (Bresnahan and Trajtenberg 1995, Carlaw and Lipsey 2006, Liao et al. 2016). This technology has been recognized to have a major impact in developed countries (Czernich et al. 2011, Kolko 2012, Briglauer and Gugler 2019), exceeding the influence of other Information and Communications Technologies (Vu 2011). The reduction in costs due to broadband technology not only enhances market efficiency but also broadens the market for firm outputs (Jensen 2007, Aker and Mbiti 2010, Aker 2010). By facilitating better coordination with suppliers and consumers, broadband enables businesses to reach distant markets, improving the matching between firms and markets (Autor 2001). High-speed Internet also accelerates the acquisition of market information, which is essential for swift business decisions and learning. The advent of e-commerce further exemplifies broadband's capacity to revolutionize traditional business models, allowing firms to operate more efficiently and competitively.

The Internet has significant potential to reshape territorial morphology and influence spatial inequalities, primarily by diminishing the importance of geographical distance in economic activities. While one might expect broadband Internet to diminish the significance of agglomeration effects—where the clustering of economic activity offers firms benefits from proximity (**glaeser2000new**)—this assumption is uncertain. Among the sources of agglomeration, urbanization economies, which refer to the advantages firms gain from being located in large, diverse cities, could see their importance reduced with the advent of the Internet (**frenken2007related**). Early theorists such as Toffler and Alvin, 1980 and Naisbitt, 1996 predicted a reduced dependency on urban centers, positing that advances in information technology could mitigate traditional urban functions by lowering transportation and communication costs, thereby reducing the necessity for face-to-face interactions (Gaspar and Glaeser 1998). For instance, Internet users can access many of the benefits typically associated with urban locations without physically residing in them. This has led to the emergence of theories such as the “death of distance” or the “death of cities,” which speculate on the potential reduction of spatial inequalities (**haefner2020spatial**).

However, these potential effects of digitalization are contested. **camagni2005icts** argue

¹The definition of broadband encompasses high-speed Internet access that is faster than traditional dial-up access. Broadband Internet provides access to high-speed Internet through several types of technologies, including fiber, wireless, cable, DSL, and satellite. The FCC - Federal Communications Commission - technically defines broadband Internet with a minimum speed of 25 Mbps downstream and 3 Mbps upstream.

that digitalization fosters both centrifugal and centripetal forces, leading to what **moriset2009organ** describe as the "paradoxical geographies of the digital economy." These dynamics suggest that instead of eliminating agglomeration effects, the Internet may, in fact, reinforce them, particularly in larger cities, thereby exacerbating regional inequalities (**wu2024future**). Consequently, it is crucial to consider these agglomeration effects when examining the impact of broadband Internet on firm creation. The Internet may serve as a complement to agglomeration economies, particularly in large urban areas, which could lead to increased regional disparities (**chen2023heterogeneous**).

ICTs are reducing coordination and communication costs in developing countries as well (Aker and Mbiti [2010](#)), particularly cell phones, which are the predominant means of Internet access in Africa (Manacorda and Tesei [2020](#), Aker and Cariolle [2023](#)). In imperfect markets characterized by asymmetric information, cell phones have been shown to enhance the welfare of both producers and consumers (Jensen [2007](#)), and they are even posited as a potential tool for poverty reduction (Corbett [2008](#)). The broadband Internet is increasingly acknowledged for its ability to foster sustainable economic growth, job creation, skill development, and socio-democratic transformation in developing countries (Hjort and Poulsen [2019](#)). However, some specific characteristics of developing countries introduce uncertainty regarding the economic impact of the broadband Internet, as it is unclear whether their economic structure and functioning are well suited to integrate and maximize the benefits of the digital revolution. Additionally, challenges such as a more pronounced digital divide and various infrastructural constraints may further limit the transformative potential of broadband in these regions.

In this paper, we explore the economic impact of mobile high-speed Internet on Tunisia's economy through the lens of business creation. Our hypothesis is that new firms may increasingly seek locations with better connectivity to harness potential competitive effects. We also aim to uncover any thresholds of broadband density under which broadband has no impact on business creation. Finally, we aim to highlight any heterogeneous effects, particularly between rural and urban areas, and their consequence on the digital divide.

Despite the existing disparities in Internet speeds relative to developed countries², Tunisia represents an interesting case due to its high Internet penetration rates and substantial investments in telecommunications infrastructure. Demonstrated by its role in hosting the second phase of the World Summit on the Information Society (ITU)³, Tunisia has positioned ICTs as a central pillar in its development strategy. This commitment is further underscored

²https://www.gsma.com/get-involved/gsma-membership/gsma_resources/internet-speeds-in-north-africa-are-rapidly-improving-but-still-lag-behind-much-of-the-world/ accessed in May 2024

³<https://www.itu.int/net/wsis/tunis/index.html> accessed in May 2024

by the launch of the Tunisia National Digital Strategy 2021-2025, which aims to amplify digital integration across various sectors⁴. Tunisia ranks among the leaders in Internet use within Africa and the MENA region, with 79% of individuals connected to the Internet⁵. However, its Internet speed performance is limited; the country is ranked 101st globally in mobile broadband performance trailing behind Egypt, Morocco, and Senegal in Africa according to Ookla⁶. Despite widespread Internet engagement by both society and the economy in Tunisia, the availability of broadband-enabled services and applications remains comparatively limited (Sadok, Chatta, and Bednar 2016). Additionally, Africa exhibits a significant digital divide, especially notable in the disparity in 4G antenna coverage between rural and urban areas — 93% in urban versus 43% in rural areas in 2023⁷ — as well as Tunisia for which it is a major challenge as highlighted by the ongoing efforts in the government's white zone coverage program⁸. The particularities of the Tunisian context pave the way for assessing the transformative potential of mobile broadband on Tunisia's economic activities, in particular through the creation of new businesses.

New business creation is crucial for regional economic development and often indicates future growth potential better than current employment data (Carlton 1983, Audretsch, Keilbach, and Lehmann 2006). Using data from the Tunisian national firm census (*Registre National des Entreprises* (RNE)) from 2017 to 2021, we examine the determinants that influence formal business creation in Tunisia⁹, focusing on the role of mobile broadband telecommunications infrastructure. We seek to dissect the nuanced effects of mobile broadband on firm creation, highlighting potential disparities influenced by firm-specific attributes and contextual variables. Existing firms, often established before the advent of widespread broadband access, base their location decisions on factors unrelated to current telecom infrastructure quality, and they face higher costs and lower incentives to relocate for better connectivity. In contrast, new firms are more acutely responsive to the current state of local infrastructure, including the availability and quality of mobile broadband. By focusing on new business creations, our study seeks to unravel how the quality of mobile broadband shapes the economic landscape locally, offering insights into how technological infrastructure can be important for regional development. The core of our analysis rests on a count model

⁴<https://www.gsma.com/publicpolicy/policy-spotlight-tunisia> accessed in May 2024.

⁵<https://data.worldbank.org/indicator/IT.NET.USER.ZS?locations=TN>, accessed May 2024.

⁶<https://www.speedtest.net/global-index/tunisia#mobile>, accessed in May 2024

⁷<https://www.itu.int/itu-d/reports/statistics/2022/11/24/ff22-mobile-network-coverage/> accessed in May 2024.

⁸"Tenders for coverage of white areas for high-capacity communications," Ministry of Communication Technologies and Digital Economy, Republic of Tunisia, July 26, 2017, [https://www.mtcen.gov.tn/index.php?id=119&L=1&tx_ttnews\[tt_news\]=3438&cA=1](https://www.mtcen.gov.tn/index.php?id=119&L=1&tx_ttnews[tt_news]=3438&cA=1)

⁹We do not capture informal businesses, which by definition are not registered.

approach estimated through a Poisson model. We focus on the role of mobile broadband, using the number of 4G antennas per 10,000 inhabitants as a proxy for broadband quality. Beyond the impact on business creation, we analyze the effect of internet access on net business creation to determine whether mobile broadband Internet leads to net destruction or net creation of firms. To this end, we estimate a fixed effects panel data model.

Our findings show a robust positive impact of the density of 4G infrastructure on the rate of new business creation, with a notably stronger effect observed in rural areas. The spatial distribution of this effect is particularly significant: regions located on the peripheries of major urban centers exhibit the most substantial benefits from enhanced 4G infrastructure, while the impact diminishes in areas farther away from these centers. This pattern suggests that a critical minimum threshold of infrastructure density may not be met in more isolated regions, potentially inhibiting the facilitation of new enterprises. Additionally, our results suggest an ambiguous effect on the creation of firms with more than six employees, implying that mobile internet alone may not be a sufficient factor for the establishment of larger firms, which might instead value robust fixed infrastructure. It also appears that an increase in 4G antenna density leads to a net increase in business creation.

The remainder of the paper is organized as follows: Section 3.2 provides a literature review on our research question. Section 3.3 outlines the data used to construct variables capturing the determinants of firm creation, particularly emphasizing the role of mobile broadband infrastructure in Tunisia. Section 3.4 details the methodology employed in the study. Section 3.5 presents the empirical results, analyzing the differential impact of mobile broadband antenna density on the number of firm creations, with a particular focus on the persistence of the digital divide. Finally, Section 3.6 concludes.

3.2 Literature Review

Goldfarb and Tucker 2019 survey the papers dealing with the effects of ICT adoption on the economy, highlighting various channels and encompassing four different levels of impact (country, regional, firm, and consumer). In our brief literature review, we focus on the economic impact of ICT development, particularly broadband technology at the firm and region levels.

3.2.1 Broadband, firm performance and employment

First, our paper is related to the strand of the literature examining the impact of technological infrastructure on economic growth (Vu, 2011; Czernich et al., 2011; Kolko, 2012) and job

creation (Atasoy, 2013; Hjort and Poulsen, 2019). As stated above, we limit our survey to papers dealing with the impact of ICT on firm performance (productivity and employment). Surveys by Brynjolfsson and Saunders 2009 and Draca, Sadun, and Van Reenen 2009 find a positive effect of ICT on firm performance, although Bloom, Sadun, and Reenen 2012 highlight substantial heterogeneity across countries. Using a fuzzy regression discontinuity DeStefano, Kneller, and Timmis 2023 show that broadband increases firm size, particularly in urban areas, but does not affect labor productivity in the UK. Conversely, Canzian, Poy, and Schüller 2019 and Chen, Liu, and Song 2020 find positive effects of broadband upgrades on firms' productivity, respectively, in rural areas in Italy and in China. Their methodologies rely on difference-in-difference frameworks. Furthermore, Cariolle and Le Goff, 2023, analyzing a dataset of 44,073 manufacturing firms across 109 developing countries, demonstrated that the internal adoption of email technology within industries (as opposed to inter-industry usage) has significantly enhanced sales.

Using the same methodology for 12 African countries, Hjort and Poulsen 2019 show that fast internet favors high-skilled job creation. In countries for which the authors have firm surveys, they show that the positive effect of high-speed internet on productivity and firm entry are among the main explanatory factors. Similarly, Atasoy 2013 finds broadband's positive effects on employment, mainly due to firm growth. Calderola et al. 2023 also find positive effects of mobile internet diffusion in Rwanda. Using differential intensities in lightning strikes across districts as an instrument for mobile coverage, the authors show mobile internet induces skill-biased structural change.

3.2.2 High-speed internet and firm creation

Given the relatively more isolated nature of rural areas, particularly in large countries, most studies on the impact of broadband on firm creation were concentrated in the rural world. The idea is to test explicitly or implicitly the "death of the distance" hypothesis Cairncross, 1997. Studying the case of Ohio, Mack 2014 highlights a positive correlation between broadband speed and business location in rural areas. Kim and Orazem 2017 confirm these results through a difference-in-difference framework, allowing us to conclude that broadband availability has an impact on establishments' locations in North Carolina. Deller, Whitacre, and Conroy 2022 find similar results using US non-metropolitan county-level data. The authors simultaneously address the availability and quality of broadband aspects, deal with thresholds, and show that the results vary by business industry.

Hasbi 2020 studied the case of the impact of high-speed broadband on business establishments in urban areas in France. Using a count model, she highlights positive, although

heterogeneous, effects across sectors and territory, depending on the population's education level. Similarly, using a count framework, McCoy et al. 2018 highlight the existence of a threshold of local education attainment below which we do not observe a significant effect of broadband on firm establishment in Ireland. Bourreau et al. 2022 address the issue of spatial heterogeneity in France. Using a difference-in-difference framework, they show that greater municipalities benefit relatively more from high-speed broadband than commuter municipalities in terms of firm creation, while rural municipalities are not impacted. A dynamic effect is also highlighted in urban areas.

3.2.3 ICT, inequality and digital divide

Given the positive effect of broadband on productivity, Akerman, Gaarder, and Mogstad 2015 wonder why it does not attract more public investment. They show, in the case of Norway, that broadband growth induces skill-biased technical change. Polarization issues in developed countries may discourage more public involvement in broadband development.

The disparities in the impact of high-speed internet, as analyzed through geographical economics methods, illuminate the prevalent inequalities known as the "digital divide." For instance, research by Wu, Wang, and Sun, 2022 using data from China between 2003 and 2015 demonstrated that variations in Internet penetration rates among cities significantly influence their economic growth rates. These disparities often manifest between urban and rural areas. Whitacre, Gallardo, and Strover, 2014 found that in the USA, from 2001 to 2010, rural areas with higher levels of broadband internet adoption experienced notable positive impacts on economic growth and reductions in unemployment. However, they noted that the availability of broadband had less influence than its actual adoption. As Fox and Porca, 2001 explained, investing in infrastructure in rural areas not only boosts productivity levels but also attracts additional resources, fostering development. Moreover, the impact of such investments tends to be more pronounced in rural areas that are economically integrated. This pattern also holds true for broadband infrastructure, with findings from Kim and Orazem, 2017 indicating that while broadband availability boosts new firm start-ups, the effect is significantly stronger in rural areas that are relatively more populated and closer to metropolitan centers. More recently, **wu2024future** show that the internet favors the agglomeration of producer services in large cities due to their higher intensity in knowledge industries.

3.3 Data

The number of business creations in an administrative zone results from a series of decisions regarding business location. The decision on where to establish a new business is a strategic choice that significantly influences its success and potential for growth. When companies decide where to locate, they incur fixed costs, making the selection process heavily influenced by cost factors and potential market demand. Key cost factors include the local tax environment, the availability of essential infrastructure like transportation and broadband services, and the cost and availability of labor.

Table 3.1: Data Table

Variable type	Variable	Spatial Level	Frequency	Source
Firm	Firm location, sector, entry year	Delegation	Annual	Registre National des Entreprises (RNE)
Mobile Broadband	Antennas (2G, 3G, 4G)	Geocoordinates	Annual	OpenCellID
Agglomeration / Competition	Localization - Distance from the nearest biggest urban/economic center	Geocoordinates	2021	OpenStreetMap
	Sector share of total employment	Delegation	Annual	RNE
	Spatial HHI	Delegation	Annual	RNE
Accessibility and outlets	Distance from the nearest post office	Geocoordinates	2021	OpenStreetMap
	Distance from the nearest bank	Geocoordinates	2021	OpenStreetMap
	Population	Delegation	2014, 2020	Census
Labor offer/market (Human capital, labor cost)	Mean level of education	Gouvernorat	2015-2019	Enquête Emploi
	Distance to the nearest university	Geocoordinates	2021	OpenStreetMap
	Mean wage	Gouvernorat	2015-2019	Enquête emploi

To investigate this topic, we have constructed a panel database that aggregates the number of new firms along with various characteristics of the areas in which they are located,

for each administrative unit over a five-year period from 2017 to 2021. We specifically focus on assessing the quality of mobile broadband infrastructures, using mobile antenna data, to discern their influence on firm creation. Table 3.1 summarizes the variables used in our estimates, and Table 3.2 provides some basic descriptive statistics for these variables.

3.3.1 Firm Creations

231,056 companies have been created between 2017 and 2021 in Tunisia, according to the RNE which is a “public database for collecting data and information relating to Tunisian companies and making them available to the public as well as to state institutions”. This RNE is managed by the Tunisian Institut National des Statistiques (INS). Our main outcome variables are based on the national business register. The RNE collects detailed information on various firm characteristics, including sector, number of employees, sales, and the legal and financial conditions at the time of registration, such as the date and location of company creation. This database facilitates comprehensive monitoring of all new company registrations within the formal sector over our study period. Figure 3.1 displays the distribution of these new businesses by year and sector from 2010 to 2021 (but our study is limited to the years between 2017 and 2021). The data indicates that a significant proportion of new enterprises are predominantly found in the commerce sector, with services and manufacturing following closely. For our analysis, we have defined two types of outcome variables: the first measures the total number of firm creations per administrative unit and year, and the second tracks the number of firm creations by sector within each administrative unit over the same period. The main outcome is shown in Figure 3.5 for all firm creations in 2018.

A second outcome variable has been constructed to measure the change in the stock of operating firms within each delegation for each year. This variable is calculated using the following formula:

$$Y'_{it} = N_{it} - N_{it-1}$$

Where N_{it} represents the number of active firms in delegation i during year t , and N_{it-1} represents the number of active firms in delegation i during the previous year $t - 1$. A negative value of Y'_{it} indicates a decline in the number of active firms in the delegation, suggesting a net reduction in business activity. Conversely, a positive value implies a net increase in the number of firms, indicating net firm creation within the delegation.

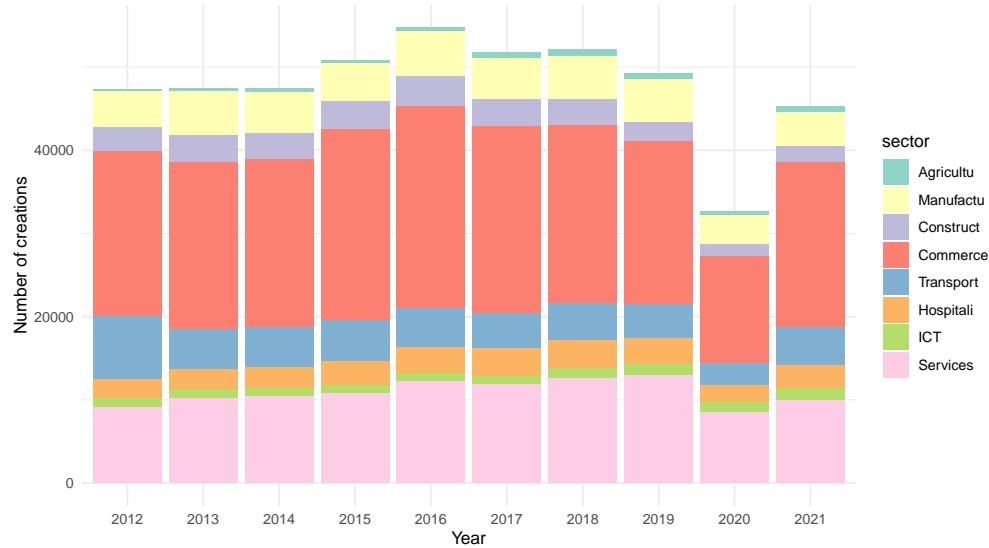


Figure 3.1: Number of business creation by year and sector

The unit of analysis: the delegation

At the time of their creation, each firm declares an address¹⁰. The available database specifies the region and delegation to which the address corresponds. As shown in Figure 3.2, there are 24 regions (or governorates) in Tunisia, divided into 264 delegations (or *mutamadiyat*). The delegation covers a limited area in terms of population (on average, 43,406 inhabitants by delegation) and size (on average, the size of a delegation is 575 km²). The delegation covers a limited area, which is designed to be easily accessible to regional population centers, facilitating access to both public and private services such as hospitals, dispensaries, and secondary schools. Thus, the 264 delegations in Tunisia correspond to as many possible locations for a firm at the time of its creation in our model. For each delegation, we have identified characteristics that business owners might consider when selecting a location. We have classified them into four categories: variables relating to the labor market (human capital and labor costs), variables relating to the functioning of the market at the delegation level (agglomeration and competition), variables relating to accessibility and outlets, and finally variables relating to the quality of the mobile broadband telecom's infrastructure.

Labor market (Human capital, labor cost)

To measure the human capital and labor costs that can influence an entrepreneur's profitability and, hence, his choice of location, we rely on two questions from the employment survey (carried out every year in Tunisia). The geographical precision we have access to

¹⁰Only governorate and delegation IDs are available in the RNE.



Figure 3.2: Map of Tunisia's Governorates and Delegations.

does not go beyond the governorates.

So, for each governorate (24), we can compute the average level of education of the population (over 25 years old), which appears as a proxy for human capital in the area (an alternative measure is to measure the proportion of the population in each area with a tertiary degree). In parallel, at the level of each governorate, we can calculate an average monthly wage for each year between 2015 and 2019. This provides a proxy for the average labor cost at the area level that an entrepreneur may face.

Agglomeration and competition

We used data from the RNE to measure the effects of agglomeration and competition. To capture these phenomena, we constructed two primary variables: The first variable represents the pre-existing number of firms operating in each delegation per year. This variable aims to capture competitive effects, where a higher concentration of firms may signal market saturation, and agglomeration effects, where clustering yields spillover benefits. The second variable measures the degree of specialization within each delegation using a spatial Herfindahl-Hirschman Index (HHI). The spatial HHI is computed by summing each delegation's squared sectoral employment shares. The sectoral employment share in each delegation is calculated as follows:

Table 3.2: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Creation Year	1,320	2019	1.41475	2017	2021
Number of creations	1,320	175.875	223.2817	0	1786
Distance Big Cities	1,310	52535.48	43409.89	267.5029	239076.6
Distance Banks	1,310	16703.65	15768.33	21.32966	90352.16
Distance Posts	1,310	11298.03	10966.32	139.1864	62334.18
Distance University	1,310	23450.11	22575.99	107.6569	100747.4
Population	1,310	43406.65	27349.06	4102.995	146760.8
GSM Antennas	1,310	73.56412	85.9777	0	637
LTE Antennas	1,310	9.678626	24.34947	0	239
UMTS Antennas	1,310	124.5076	163.2406	0	1048
Urban Rate	1,310	.653678	.215079	.2708181	1
Mean Year of Education	1,310	8.864475	.8055027	7.602976	10.89026
Mean Wage	1,310	634.4573	82.31041	449.5959	990.1528
Mean Unemployment	1,310	.1529381	.0607076	.0370855	.3573184
Rate Diploma Superior	1,310	.0412125	.0266942	.0011971	.1073173
Spatial HHI	1,320	42.95	20.32	17.35	93.9
No. living firms	1,320	3042.246	4038.783	134	36022
Area	1,310	575.6785	1846.432	1.507246	27171.66
Dens 2G	1,320	16.16642	14.74379	0	102.3643
Dens 3G	1,320	25.39955	26.59269	0	196.615
Dens 4G	1,320	1.816077	4.548814	0	54.25253

$$s_{jit} = \frac{LF_{jit}}{\sum_{j=1}^J LF_{jit}} \quad (3.1)$$

LF_{jit} is the labor force (or number of employees) in sector j in delegation j at year t and $\sum_{j=1}^J LF_{jit}$ is the total labor force in all sectors in delegation i at year t . The spatial HHI is then calculated by summing the squared sectoral employment shares in each delegation:

$$HHI_{it} = \sum_{j=1}^J (s_{ jit})^2 \quad (3.2)$$

The index ranges from 0 to 100. An index approaching zero indicates a relatively diversified employment structure across sectors, whereas a value approaching 100 signifies significant concentration in a particular sector. This allows us to gauge the extent of specialization and agglomeration in each delegation.

Using these measures, we can distinguish between competitive pressures discouraging new entrants and agglomeration economies attracting new firm formation.

Accessibility and outlets

Access to local markets and outlets is assessed through a series of distance and population variables. Proximity to major urban centers is crucial for leveraging their infrastructure and market access.¹¹ The distance to these urban centers is calculated from the centroid of each delegation to the centroid of the nearest major city. The distance to the nearest post office (which serves as a proxy for the nearest urban center/markets) is also calculated, as is the distance to the nearest university.

The size of the local market where a company is located can also be crucial. We employ one primary measure for market size: population. Population data are derived from the national censuses conducted in 2014 and 2020.

3.3.2 Mobile Broadband in Tunisia

Since the 2000s, Tunisia, along with many other developing countries, has undergone a liberalization of its telecom market. This process, closely linked to the privatization of former state monopolies and the establishment of independent regulators, has fostered greater competition and improved services¹². The origins of the Tunisian telecommunications market traced back to the promulgation of Law No. 36 on April 17, 1995, which established the

¹¹Tunisia's six largest urban areas include Tunis, Sfax, Sousse, Kairouan, Gabès, and Bizerte.

¹²This process has had significant positive effects on the rate of fixed and mobile equipment usage and the quality of service in countries benefiting from a truly competitive environment (Wallsten 2001)

Office National des Télécommunications¹³, known as Tunisie Télécom, and came into effect on January 1 of the following year. In 1998, Tunisie Télécom launched its first GSM line. In 2002, the first private competitor, Tunisiana (now Ooredoo), entered the market. Initially launched as a mobile phone operator, Tunisiana transitioned under the Qatari flag in 2014 and expanded its services by acquiring Internet service provider Tunet in 2011. Orange Tunisie became the third major player in mobile telephony after acquiring a global license in 2009. Upon commencing commercial operations in 2010, the company provided mobile telephony, mobile data, fixed telephony, and fixed data services.

New Mobile Network Operators (MNOs) can only operate in a market once the regulator grants them a license, which often coincides with the introduction of a new generation of mobile technology. These licenses facilitate the allocation of spectrum, a scarce resource shared among operators. The deployment of mobile antennas is primarily guided by economic profitability factors, including the market size served, the cost of licenses, and access costs to civil engineering and fiber optic infrastructure¹⁴. As shown in Figure 3.4, 4G antennas are located where the population is most concentrated. For this reason, the allocation process of licenses is typically accompanied by a series of regulatory obligations, such as a minimum percentage of population coverage or mandatory coverage of specific rural areas.

In Tunisia, mobile phones appear to prevail over fixed-line broadband Internet access. The disparity between mobile Internet penetration (76.1% in 2020) and fixed Internet penetration (11.5% in 2020) suggests a clear preference for mobile data in Tunisia, possibly due to the low penetration of fixed-line phones for ADSL and optic fiber networks limiting fixed broadband use¹⁵. Following the issuance of 4G licenses in 2015, the rollout of 4G antennas was rapid, covering 54% of the population by 2016 and reaching 70.4% by 2021¹⁶. Additionally, the number of 4G antennas in Tunisia recorded in OpenCellID increased significantly, rising from 2,129 antennas in 2016 to 4,344 in 2020, as illustrated in Figure 3.3.

¹³<https://www.pist.tn/jort/1995/1995F/Jo03395.pdf>, accessed in May 2024.

¹⁴<https://intt.tn/upload/files/Consultation%20publique%204G%20-%20Synth%C3%A8se%20des%20contributions.pdf>, accessed in May 2024

¹⁵Two surveys conducted by the National Telecommunications Authority (INT) support this observation. The first survey, conducted in 2019 and titled "Field Survey on the Level of Satisfaction and Use of Telecommunications Services in Tunisia," covered a sample of 5,112 individuals, representative at the delegation level. The survey found that 70.8% of respondents used the Internet, meaning that the portion of the study focused specifically on Internet usage covered 3,621 individuals. Among this sub-sample, 74.2% accessed the Internet via mobile data offers (3G and 4G), far surpassing ADSL and 3G/4G dongles, which were used by 27.5% and 24.7% of respondents, respectively. The second survey, conducted in 2021 and titled "Survey on Internet and Social Media Usage in Tunisia," followed a similar methodology and covered a sample of 5,816 individuals. According to the survey, 73.7% of respondents used the Internet. In this sub-sample, mobile data (3G and 4G) accounted for 70% of access types, while Wi-Fi and ADSL were present in 50.2% and 47.8% of responses, respectively.

¹⁶<https://www.speedchecker.com/products/cellular-coverage-datasets.html>, accessed in May 2024

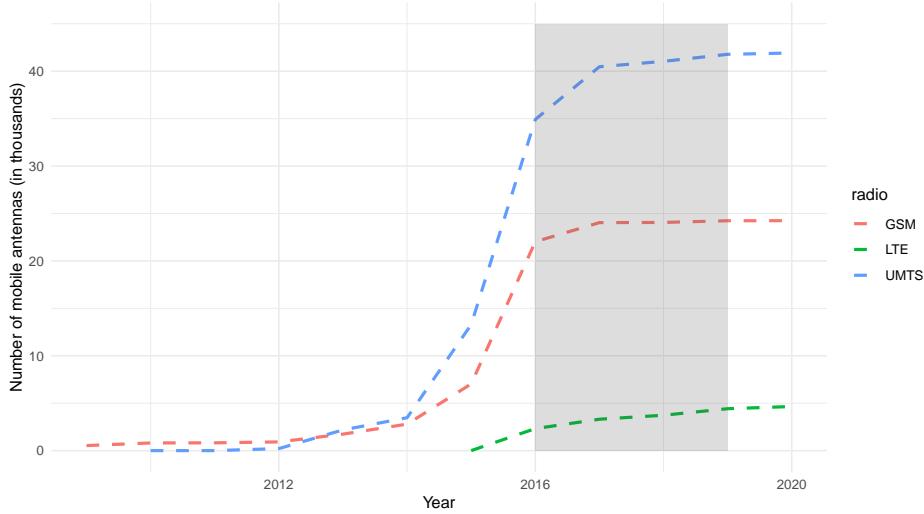


Figure 3.3: Evolution of the number of antennas by technology and year in Tunisia (OpenCell-ID). Each curve shows the cumulative growth of new antennas referenced in the OpenCellID database, categorized by technology. GSM (Global System for Mobile Communications) represents 2G technology, UMTS (Universal Mobile Telecommunications System) represents 3G technology, and LTE (Long Term Evolution) represents 4G technology.

Data on mobile broadband Internet in Tunisia

For each business created, we cannot know the quality of the mobile network to which it has access. To answer this question, we have constructed one indicator of the availability and quality of mobile broadband infrastructures. This measure aims to capture the main sources of variation in the quality and cost of broadband Internet access across Tunisia. The main data source required to construct the mobile broadband quality indicator was OpenCell-ID.

OpenCell-ID¹⁷ is an open cellular dataset where the data is obtained from project contributors; it gives the location of antennas and the creation of new antennas. This database, in addition to giving the date of entry of the antenna in the database, which can be used as a proxy for the date of commissioning, allows us to know the technology of the antenna (GSM, UMTS, LTE¹⁸) and the owner operator. The quality of the mobile broadband infrastructure is measured by the number of 4G mobile antennas per 10,000 inhabitants by delegation i at time t , following this formula :

$$MBB_{it} = \frac{\text{Number of 4G antennas}_it}{\text{Population}_{it}/10,000} \quad (3.3)$$

This measure is predicated on the rationale that a greater number of antennas is indicative

¹⁷<https://opencellid.org/>

¹⁸GSM (Global System for Mobile Communications) to 2G technology, UMTS (Universal Mobile Telecommunications System) to 3G technology, and LTE (Long Term Evolution) to 4G technology.

of enhanced network coverage, increased data transmission capacity, and higher connection speeds, which are crucial for robust broadband service. The quantity of spectrum by technology and by operator being limited, a higher density of antennas typically leads to better mobile network signal coverage, ensuring that more people in a given area have access to a stable and strong connection. This is particularly significant for maintaining service quality in areas with high network demand, as more antennas can alleviate congestion and improve the overall user experience through reduced latency and fewer dropped connections.

However, this proxy has limitations. While the number of antennas is a useful indicator of network availability and potential quality, it does not directly measure user experience or the actual speed and reliability of the broadband service. Factors like maintenance quality, network architecture, and the physical environment can also affect service quality, aspects not captured by antenna density alone. Furthermore, the proxy may not fully reflect the network's readiness for future technological advancements and increasing data demands. Despite these constraints, this proxy provides a valuable, albeit indirect, metric to assess the quality of mobile broadband infrastructure, which is a key determinant in the location choices of new firms, especially in areas where direct measures of network performance are challenging to obtain.

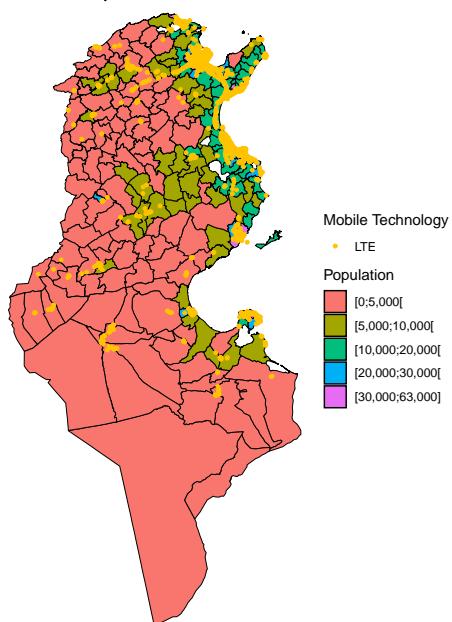


Figure 3.4: Population by Delegations and 4G antennas location

3.4 Methodology

The economic literature has two main methods of analyzing firm location: discrete choice models and count models. Our study employs count models, a preferred methodology for analyzing firm location when dealing with a high frequency of zeros in the outcome variable and a large choice set. Count models are particularly relevant in scenarios where the outcome of interest is the occurrence of an event, such as the establishment of new businesses.

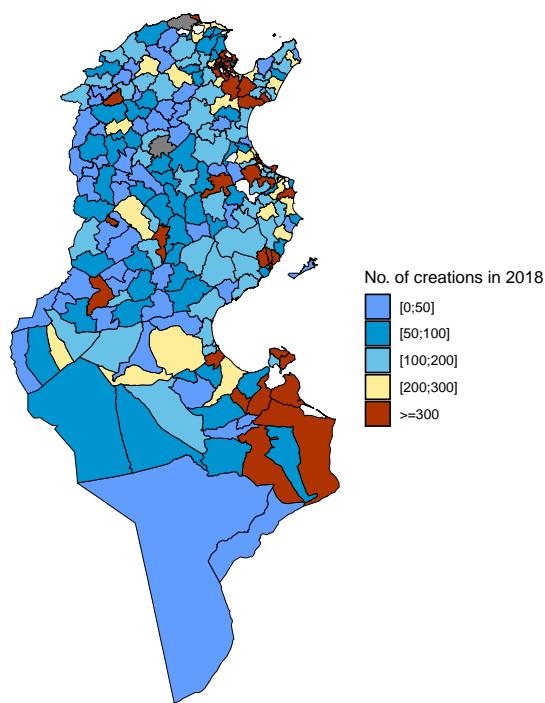


Figure 3.5: Number of firm creations by delegations in Tunisia in 2018

In this research, we analyze the influence of mobile broadband telecommunications infrastructure on new business creation. Our unit of analysis is geographical areas (the delegations) over specific time periods (years from 2017 to 2021). The model aims to predict the number of new firms in these areas based on their characteristics, including location, time-fixed effects, and factors like agglomeration forces, accessibility, and labor market dynamics (human capital and labor costs).

This approach has been used in developed countries to understand the role of broadband Internet infrastructure in firm creations (Jofre-Monseny, Marín-López, and Viladecans-Marsal 2011, Bhat, Paleti, and Singh 2014, McCoy et al. 2018, Hasbi 2020). Our study focuses on Tunisia, counting the annual number of new formal businesses established in each delegation and sector. This count assumes that firms prefer locations offering the highest

profit potential¹⁹.

We confront several methodological issues. Primarily, we estimate our model using a Poisson regression, which is well-suited for discrete and non-negative data, like our count of new business creations. The Poisson model effectively captures the likelihood of new business creation in various areas. To ensure a thorough understanding of the distribution of our dependent variable (firm creation), we included histograms in Figure 3.9 in the Appendix that depict the distribution of firm creations across two categories (firms with less than 6 workers and those with 6 workers or more).²⁰ A critical challenge in our analysis is the potential endogeneity of broadband's impact on firm creation and economic growth. To mitigate this, we argue that broadband networks more significantly affect existing businesses than new startups (McCoy et al. 2018). Therefore, our model focuses on new firms, considering the existing business landscape in each area. We also address potential reverse causality by lagging our explanatory variables by two years, acknowledging that household migration and recruitment opportunities may influence firm location choices.

Additionally, we opt for a Poisson model with fixed effects over the Negative Binomial with Fixed Effects (NBFE) model [Allison and Waterman 2002, Guimarães 2008, bosquet2014applying].²¹ The Poisson model is robust to various relationships between variance and mean and doesn't require overdispersion correction²². This choice also helps tackle another endogeneity concern: omitted variables. For instance, mobile operators might prefer to deploy infrastructure in areas with higher demand or favorable tax regimes. Our methodology is thus designed to provide a nuanced understanding of how mobile broadband impacts business creation in Tunisia, considering various economic and demographic factors.

Our empirical analysis exploits a comprehensive database covering 262 delegations across Tunisia over a five-year period from 2017 to 2021 and involves the estimation of the following a Poisson model:

$$\log(Y_{it}) = \alpha + \beta MBB_{it-2} + X_{it-2} + Z_{it-2} + \mu year_t + \eta_i + \epsilon_{it} \quad (3.4)$$

Y_{it} represents the count of new establishments created in delegation i at time t . MBB_{it-2}

¹⁹The information available in the national business register corresponds to the delegation in which the company has registered. However, it is important to note that the company may conduct its activities partially or entirely outside of this delegation, which introduces a potential bias that should be considered.

²⁰These histograms reveal the characteristics of the data, particularly the distribution of the number of firm creations. The observed distributions, skewed with a significant number of zeros and a heavy right tail, align with the typical assumptions of count data models. This justified our choice to employ Poisson model estimation, which is well-suited for modeling count data where the variance is roughly equal to the mean.

²¹The Negative Binomial with Fixed Effects model is used as a robustness test.

²²<https://www.statalist.org/forums/forum/general-stata-discussion/general/1539401-testin-overdispersion-in-negative-binomial> accessed in March 2024.

is the variable of interest, serving as a proxy for the quality of mobile broadband Internet in delegation i at time $t - 2$.²³ The primary outcome measure is the number of 4G antennas per 10,000 inhabitants. X_{it-2} is a matrix of location-specific characteristics for delegation i at time $t - 2$, which includes variables related to agglomeration, competition, and accessibility. Z_{it-2} comprises a matrix of labor market characteristics for municipality i at time t , incorporating proxies for human capital and labor costs. μ denotes fixed effects that capture year-specific influences. η_i represents time-invariant fixed effects that control for inherent differences across delegations. Finally, ϵ_{it} is the standard error clustered at the delegation level, capturing unobserved factors.

To conduct our sectoral analysis, we estimate the following Poisson model using the same dataset:

$$\log(Y_{sit}) = \alpha + \beta MBB_{it-2} + X_{sit-2} + Z_{it-2} + \mu year_t + \eta_i + \epsilon_{sit} \quad (3.5)$$

In this specification, Y_{ist} represents the count of new establishments in sector s created in delegation i at time t . MBB_{it-2} is the variable of interest, serving as a proxy for the quality of mobile broadband Internet in delegation i at time $t - 2$. The primary outcome measure is the number of 4G antennas per 10,000 inhabitants. X_{ist-2} is a matrix of location-sector-specific characteristics for delegation i at time $t - 2$, which includes variables related to agglomeration, competition, and accessibility and particularly the number of existing firms in sector s and sector share of employment of sector s in delegation i in $t - 2$. Z_{it-2} comprises a matrix of labor market characteristics for municipality i at time t , incorporating proxies for human capital and labor costs. μ denotes fixed effects that capture year-specific influences. η_i represents time-invariant fixed effects that control for inherent differences across delegations. Finally, ϵ_{it} is the standard error clustered at the delegation level, capturing unobserved factors.

For a more detailed analysis of the effects of mobile broadband on economic activity, we estimated a second panel data model with fixed effects for both location and year.

$$Y'_{it} = \alpha + \beta MBB_{it-2} + X_{it-2} + Z_{it-2} + \mu year_t + \eta_i + \epsilon_{it} \quad (3.6)$$

In this model, Y'_{it} represents the change in the stock of active businesses in delegation i during year t . This approach allows us to capture the dynamic impact of mobile broadband quality on the net creation or destruction of firms over time, taking into account both fixed-location characteristics and year-specific effects.

²³Other lags of this variable are utilized as a robustness test.

3.5 Results

3.5.1 Main findings

Our study's findings reveal several key insights into the factors influencing new business establishment, with a particular focus on the influence of mobile high-speed broadband connectivity. As illustrated in Table 3.3, the study explains the link between the availability and quality of mobile high-speed broadband and the creation of new firms in Tunisia depending on the size of the firms. Column (1) summarizes the analysis conducted across the entire sample.²⁴

The results from the first column of Table 3.3 elucidate a significant positive relationship between the proliferation of 4G antennas — as a proxy for mobile high-speed broadband quality — and the rate of new business creation. Specifically, a unit increase in the density of 4G antennas per 10,000 inhabitants increases by 0.9% the rate of new business establishment, as represented by the incidence rate ratio ($e^{0.009}$).²⁵ To ensure the robustness of these findings, we employed several estimation methods. As documented in Table 3.9 in the Appendix, we utilized two additional methods: a panel data model with fixed effects in column (2) and a negative binomial model with fixed effects in column (3). Across these methods, the results consistently demonstrate significant and similar impacts. We also controlled for the density of 2G antennas per 10,000 inhabitants. As shown in Table 3.10 in the Appendix, the results remain robust, and the impact of 4G antenna density continues to be significant and positive.²⁶ By estimating the model (3.6), it also appears that there is a positive effect of 4G antenna density on net business creation. Specifically, increasing the density of 4G antennas by one unit per 10,000 inhabitants in a delegation results in an average increase of 7.13 in the number of active businesses in that delegation. These findings suggest that improving mobile telecommunications infrastructure can play a significant role in local entrepreneurial dynamism, promoting not only the creation of new businesses but also the sustainability of existing ones. These finding underscores the critical importance of high-quality mobile broadband networks in influencing the creation of new businesses.

²⁴In these principal analyses, the effect of mobile broadband telecom infrastructure quality, along with all other explanatory variables, is assessed using a two-period lag.

²⁵The incidence rate ratio converts regression coefficients into more interpretable percentages.

²⁶Incorporating the density of 2G antennas as a control variable serves to isolate the specific impact of 4G infrastructure on firm creation. This approach allows us to account for the potential influence of existing older-generation mobile networks, ensuring that the observed effects can be more confidently attributed to the quality of 4G broadband infrastructure rather than to broader telecommunications coverage. By controlling for 2G density, we mitigate the risk of omitted variable bias, thereby reinforcing the validity and robustness of our findings concerning the economic impact of 4G technology.

Table 3.3: Summary of Estimation Results from Different Models

Variables	(1)	(2)	(3)
4G Density	0.009*** (0.002)	0.009*** (0.002)	0.017*** (0.006)
Mean Educ	0.087** (0.040)	0.088** (0.040)	-0.050 (0.217)
Mean Wage (100 dinars)	-0.086*** (0.023)	-0.087*** (0.023)	-0.002 (0.120)
Mean Unemployment	0.022*** (0.004)	0.022*** (0.004)	0.061** (0.027)
Population (1000 hab)	-0.0004 (0.005)	-0.004 (0.005)	-0.018 (0.028)
N. Firms (1000 firms)	-0.071*** (0.021)	-0.070*** (0.021)	-0.213* (0.112)
Spatial HHI	0.00001 (0.00002)	0.0014 (0.0015)	0.0162 (0.0124)
Year FE	Yes	Yes	Yes
Delegation FE	Yes	Yes	Yes
N. Obs	1310	1310	770
Delegations	262	262	154

Note: The first column represents results from the Poisson Fixed Effects model for all delegations. The second column provides estimates for firms with less than 6 workers using the same model. The third column includes results for firms with more than 6 workers. Standard errors clustered at the delegation level are presented in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

We also observe that the positive effect of 4G antenna density is recognized by both small firms with fewer than six employees—many of which are individual enterprises— (column 2) and larger firms with more than six employees (column 3). Specifically, a one-unit increase in 4G antenna density per 10,000 inhabitants within a delegation results in a 4.6% increase in the rate of new firm creation for firms with more than six employees ($e^{0.0173}$). However, as shown in table 3.10 in Appendix, when the density of 2G antennas is included as a vari-

able, the effect of 4G antenna density on the creation of firms with more than six employees becomes non-significant. This suggests that for larger firms, the quality of mobile telecommunications infrastructure alone may not be sufficient; the quality of fixed infrastructure also plays a crucial role.

Table 3.4: Net Firm Creations

Variables	(1)	(2)	(3)
4G Density	7.131*** (2.343)	-0.347 (0.338)	7.219*** (2.430)
Mean Educ	155.691*** (21.560)	-1.536 (1.643)	156.495*** (22.000)
Mean Wage (100 dinars)	-17.942** (9.024)	-0.870 (0.646)	-17.246* (8.860)
Mean Unemployment	2.442 (1.540)	0.221** (0.095)	2.328 (1.537)
Population (1000 hab)	26.014*** (3.625)	0.141 (0.381)	25.330*** (3.754)
N. Firms (1000 firms)	-241.081*** (30.837)	-340.314*** (75.366)	-230.670*** (31.576)
Spatial HHI	0.525 (0.541)	-0.086** (0.035)	0.643 (0.530)
N. Obs	1310	1268	1310
Delegations	262	259	262

Note: The table presents the first column from each of the three original tables, summarizing the results for the mean, firms with more than 6 workers, and firms with less than 6 workers. Standard errors clustered at the delegation level are presented in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

To conduct a threshold analysis and reinforce our initial findings, we replaced the continuous measure of 4G antenna density per 10,000 inhabitants with several binary variables representing different ‘treatment levels’ within our model. Figure 3.6 illustrates how the coefficient of interest evolves across varying density levels. This analysis reveals that firms require a minimum threshold of mobile broadband infrastructure quality to assign it a positive value. Specifically, on average, a baseline density of more than two 4G antennas per 10,000 inhabitants significantly impacts firm creation, with this impact intensifying as an-

tenna density increases²⁷. For instance, when the density exceeds 2.25 4G antennas per 10,000 inhabitants, the number of new businesses rises by 5.45% ($e^{0.0531}$) on average. Furthermore, surpassing a density of 3.25 4G antennas per 10,000 inhabitants leads to an 8.39% increase in the number of new firms ($e^{0.0805924}$). Our analysis supports the findings of Kim and Orazem, 2017, McCoy et al., 2018, and Hasbi, 2020, reinforcing the notion that, on average, regions outfitted with broadband infrastructure tend to be more attractive. These findings also underscore the pivotal role of high-quality mobile broadband networks in stimulating economic development, as they significantly contribute to the growth and expansion of business activities across various regions.

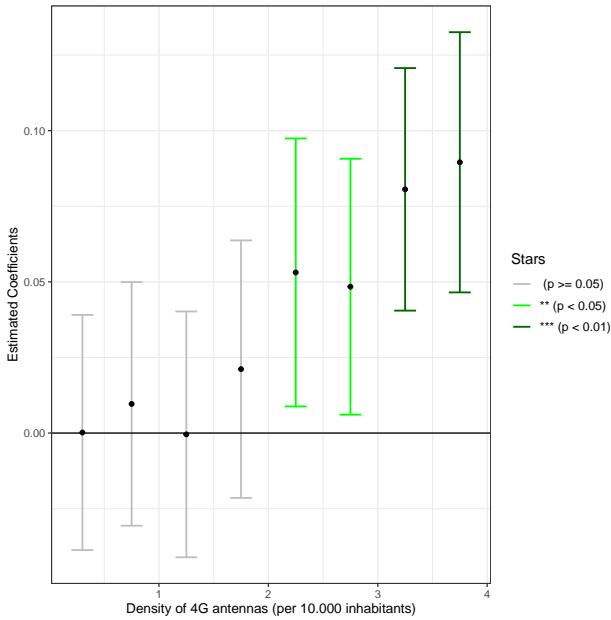


Figure 3.6: Estimations by 4G antennas density

We can go further by analyzing the coefficients associated with other variables. If we look at the variables we have identified as agglomeration variables, we notice that firms negatively value the prospect of strong competition when establishing their operations. Indeed, it appears that delegations with a large number of pre-existing firms are less attractive to new firms. As measured by population, market size does not seem to affect firm creation when the whole sample is considered, suggesting that this factor may be captured within the fixed effects. Moreover, the average number of years of education plays an important role in firm creation. Increasing the average number of years of education in a delegation by one unit increases the rate of new firm creation by 9%. It appears that human capital is key for

²⁷This indicates that a certain threshold must be reached for companies to recognize and value the benefits of 4G mobile infrastructures at the time of their establishment, with their valuation progressively increasing as infrastructure density grows.

entrepreneurship, and then the choice of location of new firms. Finally, labor costs emerge as a significant determinant as well. The relative cost of labor, assessed via the average income within a delegation, appears to have a negative impact on business creation (Delbecque, Méjean, and Patureau 2014). Conversely, higher unemployment rates are observed to affect business creation positively. This finding aligns with the research presented by McCoy et al., 2018, yet stands in contrast to Hasbi, 2020’s conclusions. The positive correlation with unemployment may reflect a potential downward pressure on wages, making starting a business a more attractive option in areas with higher unemployment rates. One possible explanation for the significant role of the unemployment rate in influencing firm creation is that, for some unemployed individuals, starting a business may be a viable solution to escape unemployment. When examining column 3 of table 3.3, which presents estimates for firms with more than six employees, it becomes evident that although the significance of the unemployment coefficient is somewhat reduced when considering only the creation of larger firms, the coefficient remains significant. This suggests that larger firms may indeed be motivated by the pursuit of lower labor costs.

3.5.2 Exploring the Digital Divide

Our research primarily concentrates on one level of the digital divide, which addresses the economic and social inequalities in access to ICT equipment and infrastructure²⁸. To address the variability in rural and urban contexts, columns (2) and (3) of Table ?? partition the data into two distinct sub-samples, categorized by the degree of ‘rurality’ of the regions examined. The second column analyzes regions characterized by a predominantly rural population — specifically, areas where less than 65% of the inhabitants are urban. Conversely, the third column explores regions with a predominantly urban demographic, where over 65% of the population is urban. When estimating model 3.6 for the rural and urban sub-samples, Table 3.7 shows that there is no significant effect of 4G antenna density on net business creation in rural areas, while the effect is significant in urban areas. Rural areas may not yet have reached the threshold where mobile broadband can significantly drive net business creation, either due to lower demand for digital services or due to other infrastructural and economic limitations.

The comparison between these columns reveals the difference in valuation between rural and urban areas. Columns 2, 4, 6 focuses on a subset of rural delegations. Here, an expansion in the density of 4G antennas per 10,000 inhabitants by one unit increases the rate of

²⁸According to Ben Youssef, 2004, there are four degrees of digital divide: the first is linked to ICT equipment; the second is linked to usage, which refers to digital literacy; the third concerns the effectiveness of usage; and finally, the fourth concerns learning methods in a knowledge-based economy.

Table 3.5: Digital Divide: Comparison Between Rural and Urban Areas

Variables	(1)	(2)	(3)	(4)	(5)	(6)
4G Density	0.049*** (0.009)	0.005*** (0.001)	0.049*** (0.009)	0.005*** (0.001)	0.162** (0.071)	0.018*** (0.005)
Mean Educ	0.057 (0.096)	0.090** (0.044)	0.053 (0.096)	0.091** (0.044)	1.966*** (0.641)	-0.188 (0.223)
Mean Wage (100 dinars)	-0.192*** (0.027)	-0.041* (0.024)	-0.191*** (0.027)	-0.041* (0.025)	-0.769*** (0.207)	0.104 (0.121)
Mean Unemployment	0.021*** (0.006)	0.028*** (0.005)	0.021*** (0.006)	0.028*** (0.005)	0.128** (0.050)	0.052* (0.030)
Population (1000 hab)	0.031* (0.017)	-0.011** (0.004)	0.031* (0.017)	-0.011** (0.004)	0.084 (0.054)	-0.036 (0.030)
N. Firms (1000 firms)	-0.187*** (0.038)	-0.036* (0.019)	-0.187*** (0.038)	-0.034* (0.019)	-0.117 (0.229)	-0.306*** (0.097)
Spatial HHI	-0.000006 (0.000002)	0.000045 (0.000028)	-0.0007 (0.0016)	0.0045 (0.0027)	0.024 (0.018)	0.013 (0.019)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Delegation FE	Yes	Yes	Yes	Yes	Yes	Yes
N. Obs	600	710	600	710	235	535
Delegations	120	142	120	142	47	107

Note: The table presents the estimation results focusing on rural (columns 1, 3, 5) and urban (columns 2, 4, 6) areas. Rural areas only include delegations in governorates where less than 65% of inhabitants are considered urban, and urban areas include delegations in governorates where more than 65% of inhabitants are considered urban. The results are shown for the entire sample (columns 1 and 2), for firms with fewer than 6 workers (columns 3 and 4), and for firms with more than 6 workers (columns 5 and 6). Standard errors clustered at the delegation level are presented in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

business creation by 4.9%. We further find that regardless of firm size, as indicated in table 3.5, the impact of 4G antenna density remains consistently stronger in rural areas compared to urban areas. This observation gains further support from the threshold analysis illustrated in Figure 3.7, indicating a critical density level of 4G antennas of 1.5 per 10,000 inhabitants at the density of 4G antennas starts to positively impact firm creation. These results may be interpreted through the lens of the “death-of-distance” or “death-of-cities” hypothesis (Toffler and Alvin 1980; Cairncross 1997 ; Naisbitt 1996; Gaspar and Glaeser 1998), which posits that broadband Internet enables rural firms to function as substitutes for

urban centers by significantly reducing communication and transaction costs. Indeed, these findings highlight the pivotal role of mobile telecom infrastructure in rural development, mirroring the observations of Kim and Orazem, 2017, who found a positive correlation between broadband accessibility and the tendency for new firms to establish in rural areas of the U.S. The substantial impact of mobile broadband infrastructure in rural settings can be attributed to its amplified benefits in these regions. For instance, Bahia et al., 2020 demonstrated the profound influence of broadband on rural labor markets in Nigeria. Similarly, Kolko, 2012 found a stronger effect of broadband Internet on local growth in sparsely populated areas. Moreover, these findings align with Atasoy, 2013, who observed a more pronounced impact of broadband services on employment in rural and remote areas. Likewise, research by Canzian, Poy, and Schüller, 2019 revealed that broadband positively affects revenue and productivity in rural areas.

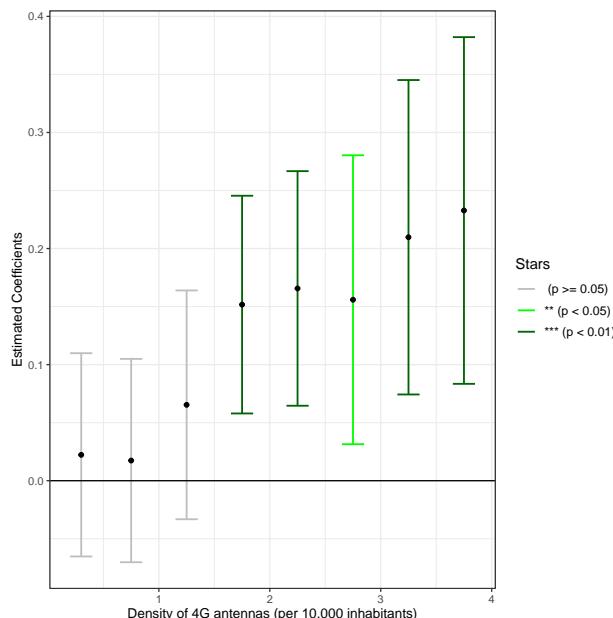


Figure 3.7: Estimations by 4G antennas density in Rural Areas

The influence of mobile broadband infrastructure on business establishment may be particularly pronounced in rural areas near urban centers. To explore this, we defined the centroids for Tunisia's six largest urban areas: Tunis, Sfax, Sousse, Kairouan, Gabès, and Bizerte.²⁹ Surrounding each centroid, we established three concentric buffer zones to delin-

²⁹The major urban agglomerations are as follows: Tunis has a population of 728,453, which expands to 2,083,000 when including the Greater Tunis area; Sfax is home to 265,131 residents, growing to 500,000 with the inclusion of Greater Sfax; Sousse has 173,047 inhabitants, increasing to 400,000 in Greater Sousse; Kairouan includes 117,903 residents; Gabès consists of 116,323 inhabitants, which rises to 170,000 for Greater Gabès; and Bizerte has 114,371 residents, expanding to 150,000 when including Greater Bizerte.

eate varying degrees of urban influence: the “center” zone, a 20 km radius circle encapsulating the urban agglomeration; the “periphery” zone, which includes all delegations situated between 20 and 50 km from the centroid; and a third zone that encompasses all delegations beyond 50 km from the centroid.

Table 3.6: Digital Divide (Groups of distances)

variables	(1)	(2)	(3)
4G density	0.006*** (0.001)	0.030*** (0.006)	0.014 (0.014)
Mean Educ	0.073 (0.054)	0.200** (0.096)	0.034 (0.104)
Mean Wage (100 dinars)	-0.057* (0.033)	-0.267*** (0.063)	-0.143*** (0.044)
Mean Unemployment	0.022*** (0.646)	0.031*** (0.814)	0.029*** (0.824)
Population (1000 hab)	-0.006 (0.005)	0.0346* (0.020)	-0.0002 (0.026)
N. Firms (1000 firms)	-0.056*** (0.021)	-0.303*** (0.096)	-0.072 (0.131)
Spatial HHI	0.000087* (0.000044)	.000019 (0.000031)	0.000006 (0.000018)
Year FE	Yes	Yes	Yes
Delegation FE	Yes	Yes	Yes
N. Obs	345	310	635
Delegations	69	62	127

Note: Column (1) includes only delegations located within 20 km of the centers of Tunisia’s six biggest cities (Tunis, Sfax, Sousse, Kairouan, Gabès, and Bizerte). Column (2) includes delegations between 20 km and 50 km from these economic centers, while Column (3) encompasses delegations farther away. Standard errors clustered at the delegation level are presented in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

As depicted in Table 3.6, when we applied the same model estimations as in model (3.4) to these three sub-samples, we found that the impact of mobile broadband infrastructure

density is significant only within the “center” and “periphery” zones, with no observable effects in regions beyond 50 km. Importantly, the influence is particularly substantial in the “periphery” areas: a one-unit increase in the density of 4G antennas per 10,000 inhabitants correlates with a 3% increase in the rate of business creation. This aligns with the observations by Fox and Porca, 2001, who noted that infrastructure investments tend to yield the most substantial impacts in economically integrated and intermediate rural areas. This can also be attributed to the high concentration of knowledge in large cities, where the synergy between online and offline interactions is more pronounced (**wu2024future**), facilitated by proximity to markets and suppliers. Furthermore, when we varied the lags associated with the proxy variable for mobile broadband infrastructure quality, the average effect remained significant and positive on business creations. However, the analysis reveals a nuanced effect between rural and urban areas. Specifically, when the lag is limited to one year, the positive impact in rural areas is no longer significant, as shown in column (2) in Table 3.11. This suggests potential challenges such as market incompleteness and the relative difficulty of establishing businesses in rural settings. To investigate this, we introduced an interaction term between the density of 4G antennas per 10,000 inhabitants and the distance to the nearest post office. As illustrated in Table 3.13, the interaction term is negative for a one-year lag, indicating that the value attributed to high-speed mobile broadband diminishes as one moves farther from urban centers, where essential services like banks and administrative offices are more readily accessible. Similarly, Kim and Orazem, 2017 documented that local broadband availability significantly promotes new firm establishment, especially in rural counties proximate to urban agglomerations. These findings emphasize the vital role of geographic proximity to urban centers in maximizing the efficacy of mobile broadband infrastructure to foster business activity. Consequently, our results suggest that the “death-of-distance” hypothesis, which posits that geographic distance becomes irrelevant in the face of digital connectivity, does not hold universally. The significant locational distinctions in the effectiveness of broadband infrastructure underscore the continued relevance of geographical proximity to urban economic centers.

3.5.3 Sectorial Analysis

To deepen our understanding of mobile broadband’s impact on local economies, we analyzed new business creation across different sectors, categorized according to the Nomenclature d’Activités Tunisiennes (NAT).³⁰ We constituted eight distinct sectors: agriculture and min-

³⁰This classification aligns with the International Standard Industrial Classification of All Economic Activities (ISIC Rev3) by the United Nations and the Statistical Classification of Economic Activities in the European Community (NACE Rev 1).

Table 3.7: Digital Divide: Net Firm Creations (All, Urban, Rural)

Variables	All (1)	Urban (2)	Rural (3)
4G Density	7.131*** (2.343)	8.209 (5.810)	7.447*** (2.674)
Mean Educ	155.691*** (21.560)	93.023*** (17.727)	180.618*** (29.873)
Mean Wage (100 dinars)	-17.942** (9.024)	-21.704*** (6.848)	-4.229 (14.688)
Mean Unemployment	2.442 (1.540)	-0.027 (1.451)	6.919** (2.919)
Population (1000 hab)	26.014*** (3.625)	33.814*** (9.482)	24.055*** (4.105)
N. Firms (1000 firms)	-241.081*** (30.837)	-232.966*** (50.727)	-246.253*** (39.574)
Spatial HHI	0.525 (0.541)	0.411 (0.650)	0.643 (1.229)
N. Obs	1310	600	710
Delegations	262	120	142

Note: The table presents the estimation results for net firm creations across all delegations (Column 1), urban delegations (Column 2), and rural delegations (Column 3). Standard errors clustered at the delegation level are presented in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

ing, manufacturing, construction, commerce, transport, hospitality, ICTs, and services.³¹

The sectoral breakdown presented in Figure 3.8 highlights the varying impacts of mobile broadband network quality on business creation across different sectors. These results are derived from estimating model (3.5) using a Poisson estimate, which incorporates sector-specific variables, particularly the number of firms already operating in sector s within delegation i at time $t - 2$, as well as the employment share of sector s in delegation i during the same period.

The tertiary sector, which includes transport, commerce, ICT, and services, is expected to derive the most significant benefits from robust mobile broadband infrastructure. Figure 3.8 illustrates a positive and significant impact for the creation of establishments in the

³¹Utilizing the first two digits of the NAT sectoral codes, which are typically assigned at the creation of most companies, allowed us to form these sectoral groups. See: <https://ins.tn/nomenclatures/nomenclature-dactivites-tunisiennes-nat> for more information.

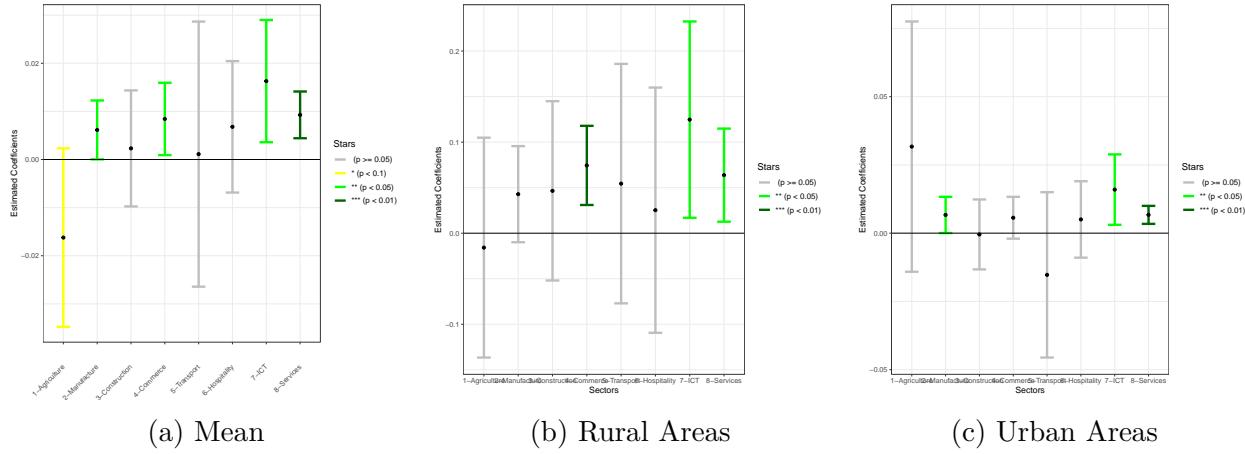


Figure 3.8: Estimation by sector

manufacture, commerce, ICT and services sectors. The commerce, ICT and services sectors intrinsically depend more on ICT for their operations. Specifically, in the commerce and services sectors, a one-unit increase in the density of 4G antennas per 10,000 inhabitants boosts the establishment of new businesses by 0.85% in commerce and by 0.9% in services. The ICT sector experiences an even more pronounced effect; here, the same increase in 4G antenna density leads to a 1.7% rise in the rate of new ICT business establishments. This is also the finding of Kolko, 2012, who identifies that the relationship between broadband and local growth is stronger in industries that are more dependent on information technology. This effect is in line with what had already been observed by Freund and Weinhold, 2002 and Kneller and Timmis, 2016. The positive and significant effect of mobile broadband antenna density on the creation of manufacturing firms can be attributed to the increasing reliance of the manufacturing sector on digital technologies for improving operational efficiency, supply chain management, and accessing broader markets, but we can see that this effect is only significant in urban areas.

Furthermore, the observed negative effect of mobile broadband density on business creation in the agricultural sector when considering the whole sample can be attributed to several sector-specific economic factors. First, the agricultural sector is typically less reliant on digital technologies, then the benefits of mobile broadband may not translate directly into increased agricultural business creation. Instead, mobile broadband may facilitate the consolidation of existing agricultural operations or encourage efficiency improvements that reduce the need for new enterprises. Additionally, mobile broadband can open up more lucrative opportunities in non-agricultural sectors, leading to a reallocation of entrepreneurial efforts and resources away from agriculture.

These findings underscore the significant role that robust digital infrastructure plays in

sectors heavily reliant on information and communication technologies, such as commerce, ICT, and services. Conversely, the limited or negative effects observed in agriculture suggest that mobile broadband alone may not be sufficient to drive new business creation in sectors less dependent on digital technologies.

3.6 Conclusion

In this study, we employed a count model methodology and a panel fixed effects estimation to evaluate the impact of mobile broadband Internet on firm creation at the delegation level in Tunisia, analyzing data from 2017 to 2021. We categorized these delegations by their rurality or proximity to major urban centers and estimated these models for each category. We assessed the impact of mobile broadband on firm creation and net creation depending on the size of firms and across eight different sectors of the Tunisian economy.

Our findings indicate that the density of 4G mobile antennas significantly influences firm creation overall, with a notably stronger impact in rural areas, albeit with delayed effects. Specifically, a unit increase in the density of 4G antennas per 10,000 inhabitants results in a 0.9% increase in the rate of new business establishment on average (this effect is stronger for firm creations with more than 6 workers), while in rural areas, this effect rises to 4.9%. However, when examining the impact on net business creation, this effect remains significant only for urban delegations. Also, a more pronounced effect near major urban centers challenges the ‘death of distance hypothesis.’ Additionally, the impact of 4G mobile infrastructure density on firm creation varies across sectors, showing positive and significant effects, particularly in the manufacturing, services, commerce, and ICT sectors. The findings also suggest that certain minimum density thresholds are necessary for mobile broadband telecom infrastructures to impact business creation rates significantly.

While our research provides valuable insights, it also encounters certain limitations. While useful, our proxy for broadband quality, the number of 4G antennas per 10,000 inhabitants, may not fully capture the nuances of network quality and user experience. Future research could employ alternative proxies, such as data from network performance testing platforms like Ookla. One key area for improvement is the exploration of other potential sources of heterogeneity in the broadband-economic growth relationship. This could include examining variations in broadband’s impact based on different demographic or socio-economic factors.

Our study underscores several implications for public policy. We have demonstrated that while robust mobile broadband infrastructure is crucial for some sectors, it alone is insufficient for fostering firm creation without the additional support of proximity to urban centers

and access to essential services. Furthermore, our findings suggest a necessary minimum level of investment in mobile infrastructure to influence local economic growth significantly. While our analysis focuses on mobile infrastructures predominantly utilized in Tunisia, we anticipate that the impact of high-quality fixed broadband infrastructures, such as fiber optics, could be even more substantial (Sadok, Chatta, and Bednar 2016). Addressing the digital divide, as highlighted in our research, requires more than merely closing the infrastructure gap. It also necessitates tackling other related issues, such as enhancing digital literacy. By addressing these multifaceted challenges, policymakers can harness the potential of mobile broadband to promote sustainable and inclusive economic growth across Tunisia.

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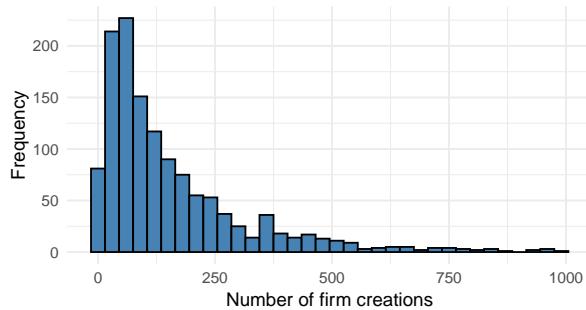
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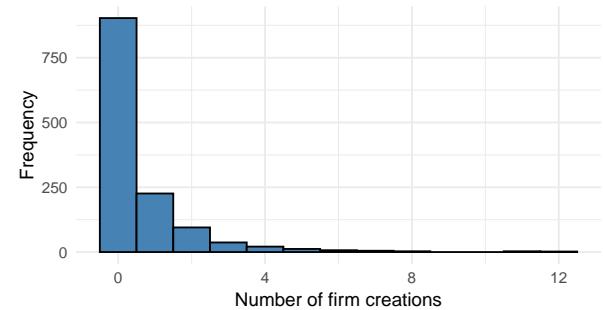
3.8 Appendix

Table 3.8: Number of firm creation by Year and Sector (2010-2021)

Year	Agriculture	Manufacturing	Construction	Commerce	Transport	Hospitality	ICT	Services	Total
2010	376	5,131	2,688	20,981	5,136	2,191	1,282	10,927	48,712
2011	344	4,702	2,769	17,676	7,859	2,191	1,177	8,153	44,871
2012	312	4,250	2,850	19,931	7,523	2,332	1,080	9,094	47,372
2013	366	5,235	3,244	20,048	4,906	2,326	1,097	10,198	47,420
2014	366	4,972	3,183	20,106	4,782	2,608	932	10,426	47,375
2015	353	4,622	3,325	23,021	4,877	2,970	894	10,813	50,875
2016	444	5,449	3,616	24,217	4,661	3,207	991	12,165	54,750
2017	608	5,046	3,164	22,497	4,223	3,354	973	11,863	51,728
2018	889	5,162	3,109	21,370	4,504	3,344	1,240	12,556	52,174
2019	657	5,110	2,372	19,631	4,011	3,189	1,269	12,971	49,210
2020	417	3,554	1,446	12,807	2,641	1,994	1,306	8,469	32,634
2021	715	4,079	1,902	19,933	4,521	2,807	1,464	9,889	45,310



(a) Firm Creation with Less Than 6 Workers



(b) Firm Creation with 6 Workers or more

Figure 3.9: Distribution of the outcomes

Table 3.9: Various estimation methods (Poisson FE, Panel FE, Negative binomial FE)

variables	(1)	(2)	(3)
4G density	0.009*** (0.002)	2.824*** (0.924)	0.005* (0.003)
Mean Educ	0.087** (0.040)	21.415*** (6.496)	0.163*** (0.031)
Mean Wage (100 dinars)	-0.086*** (0.023)	-9.957*** (2.664)	-0.173*** (0.014)
Mean Unemployment	0.022*** (0.371)	0.027*** (52.526)	0.016*** (0.288)
Population (1000 hab)	-0.004 (0.005)	-2.571* (1.376)	0.002 (0.002)
N. Firms (1000 firms)	-0.07*** (0.021)	-84.073*** (11.245)	0.03** (0.014)
Spatial HHI	0.014 (0.015)	-0.463 (1.757)	0.015 (0.012)
Year FE	Yes	Yes	Yes
Delegation FE	Yes	Yes	Yes
N. Obs	1310	1310	1310
Delegations	262	262	262

Note: The sample consists of 262 delegations over a 5-year period. Column (1) presents the estimation results of the Poisson model for the entire sample. Column (2) uses the same sample but applies a panel data estimation with fixed effects. Finally, column (3) shows the estimation results using a Negative Binomial model. Standard errors clustered at the delegation level are presented in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 3.10: 2G Density Variable

Variables	(1)	(2)	(3)
4G Density	0.010*** (0.002)	0.010*** (0.002)	0.004 (0.007)
2G Density	-0.001 (0.001)	-0.001 (0.001)	0.012* (0.006)
Mean Educ	0.094** (0.039)	0.095** (0.039)	-0.130 (0.240)
Mean Wage (100 dinars)	-0.082*** (0.024)	-0.082*** (0.024)	-0.063 (0.149)
Mean Unemployment	0.022*** (0.004)	0.022*** (0.004)	0.055** (0.026)
Population (1000 hab)	-0.005 (0.005)	-0.005 (0.005)	-0.014 (0.029)
N. Firms (1000 firms)	-0.067*** (0.021)	-0.066*** (0.021)	-0.255** (0.127)
Spatial HHI	0.001 (0.001)	0.001 (0.001)	0.018 (0.013)
N. Obs	1310	1310	770
Delegations	262	262	154

The sample includes 262 delegations observed over a 5-year period. Column (1) presents results for all delegations using the total count of firm creations as the outcome. Column (2) focuses specifically on firm creations with fewer than 6 workers, while Column (3) examines firm creations with 6 or more workers as the outcome. Standard errors clustered at the delegation level are presented in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 3.11: One year-lag (All, Rural, Urban)

variables	(1)	(2)	(3)
4G density	0.007*** (0.003)	-0.004 (0.017)	0.004* (0.002)
Mean Educ	0.076* (0.041)	0.024 (0.094)	0.084* (0.044)
Mean Wage (100 dinars)	-0.074*** (0.023)	-0.143*** (0.031)	-0.031 (0.023)
Mean Unemployment	0.021*** (0.004)	0.019*** (0.006)	0.028*** (0.005)
Population (1000 hab)	-0.009* (0.05)	0.013 (0.024)	-0.014*** (0.004)
N. Firms (1000 firms)	-0.043** (0.021)	-0.112** (0.048)	-0.015 (0.015)
Spatial HHI	0.015 (0.016)	-0.002 (0.015)	0.046 (0.028)
Year FE	Yes	Yes	Yes
Delegation FE	Yes	Yes	Yes
N. Obs	1310	600	710
Delegations	262	120	142

Note: The sample consists of 262 delegations over a 5-year period. The 4G density variable is one year lagged. Column (1) includes all delegations, while column (2) includes only delegations in governorates where less than 65% of inhabitants are considered urban, classified as rural delegations. Column (3) includes only delegations in governorates where more than 65% of inhabitants are considered urban, classified as urban delegations. Standard errors clustered at the delegation level are presented in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 3.12: Three years lagged Digital Divide (All, Rural, Urban)

variables	(1)	(2)	(3)
4G density	0.006*** (0.002)	0.025** (0.010)	0.003** (0.001)
Mean Educ	0.098** (0.040)	0.037 (0.096)	0.096** (0.045)
Mean Wage (100 dinars)	-0.079*** (0.021)	-0.16*** (0.029)	-0.034 (0.023)
Mean Unemployment	0.022*** (0.004)	0.021*** (0.005)	0.029*** (0.005)
Population (1000 hab)	-0.006 (0.005)	0.024 (0.019)	-0.012*** (0.005)
N. Firms (1000 firms)	-0.057*** (0.02)	-0.16*** (0.045)	-0.023 (0.018)
Spatial HHI	0.000014 (0.015)	-0.005 (0.016)	0.045 (0.028)
Year FE	Yes	Yes	Yes
Delegation FE	Yes	Yes	Yes
N. Obs	1310	600	710
Delegations	262	120	142

Note: The sample consists of 262 delegations over a 5-year period. The 4G density variable is three years lagged. Column (1) includes all delegations, while column (2) includes only delegations in governorates where less than 65% of inhabitants are considered urban, classified as rural delegations. Column (3) includes only delegations in governorates where more than 65% of inhabitants are considered urban, classified as urban delegations. Standard errors clustered at the delegation level are presented in parentheses: ***
 $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 3.13: Digital Divide (All, Urban, Rural) - Interaction 4G Density and distance to post

variables	(1)	(2)	(3)
4G density × Distance Post	-0.0019*** (0.0005)	-0.0029** (0.0014)	-0.0009 (0.0009)
Mean Educ	0.084** (0.040)	0.032 (0.093)	0.087* (0.045)
Mean Wage (100 dinars)	-0.072*** (0.023)	-0.145*** (0.030)	-0.032 (0.023)
Mean Unemployment	0.021*** (0.371)	0.018*** (0.553)	0.028*** (0.490)
Population (1000 hab)	-0.007 (0.005)	0.019 (0.021)	-0.013*** (0.004)
N. Firms (1000 firms)	-0.048** (0.021)	-0.138*** (0.041)	-0.017 (0.016)
Spatial HHI	0.0167 (0.0156)	-0.0911 (0.0016)	0.0461 (0.0282)
Year FE	Yes	Yes	Yes
Delegation FE	Yes	Yes	Yes
N. Obs	1310	600	710
Delegations	262	120	142

Note: The sample consists of 262 delegations over a 5-year period. The interaction term represents the one-year lagged 4G density variable interacted with the distance to the nearest post office (in kms). Column (1) includes all delegations, while column (2) includes only delegations in governorates where less than 65% of inhabitants are considered urban, classified as rural delegations. Column (3) includes only delegations in governorates where more than 65% of inhabitants are considered urban, classified as urban delegations. Standard errors clustered at the delegation level are presented in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

General Conclusion

This thesis has examined the subjective value of high-speed Internet from the perspectives of three critical economic agents: households, businesses, and citizens. Through three distinct chapters, each applying rigorous impact evaluation methodologies, the research has highlighted the multifaceted impact of broadband internet on economic and social outcomes.

The first chapter explored how high-speed internet influences political participation in Sub-Saharan Africa, particularly in the context of protests. The analysis demonstrated that access to broadband internet significantly increases the likelihood of participating in protests and the frequency of such events. This effect is particularly pronounced in countries where political rights and civil liberties are actively exercised. The study's findings suggest that broadband internet enhances access to information and facilitates coordination among individuals, making collective action more feasible and effective.

In the second chapter, the focus shifted to households, examining the impact of high-speed internet access on property values in France. The research found that Fiber to the Home (FTTH) eligibility leads to a significant increase in property prices, with a more substantial effect observed in rural areas. This suggests that households place a high subjective value on enhanced connectivity, especially in regions where existing infrastructure may be less reliable. The variation in property value appreciation underscores the importance of local context in determining the economic benefits of broadband deployment, a crucial factor that we need to be aware of in our efforts to maximize the impact of high-speed internet.

The third chapter analyzed the role of high-speed internet in fostering economic growth in Tunisia. The study revealed a robust positive correlation between the density of 4G antennas and the number of new business establishments, with stronger effects observed in rural areas. This challenges the 'death of distance' hypothesis, highlighting the role of mobile broadband in fostering economic growth even in less densely populated regions. The findings emphasize the critical role of digital infrastructure in supporting business creation and economic diversification, particularly in developing countries, and should encourage us about the potential of high-speed internet in driving economic growth.

The implications of these findings are significant for policymakers, investors, and stake-

holders in the digital economy. The demonstrated importance of broadband internet in enhancing political participation, economic welfare, and business creation highlights the need for continued investment in digital infrastructure. For policymakers, this means prioritizing expanding high-speed internet access, particularly in underserved rural areas, to ensure equitable economic development and social inclusion.

Moreover, the research underscores the need for a nuanced approach to digital infrastructure development. The varying impacts of broadband internet across different regions and economic agents suggest that one-size-fits-all policies may not be effective. Instead, tailored strategies that consider local contexts and specific needs are essential to maximize the benefits of digital connectivity.

In conclusion, this thesis contributes to the understanding of high-speed internet's economic and social value, providing evidence of its critical role in modern economies. The insights gained from this research can guide future efforts to harness digital technologies' full potential, ensuring that connectivity's benefits are widely shared and contribute to sustainable development across diverse contexts.

Résumé de la thèse

Les avancées des technologies numériques ont profondément transformé nos sociétés et nos économies. Leur rôle dans la stimulation de la croissance économique et l'amélioration de divers biens sociaux est largement documenté dans la littérature économique (Draca, Sadun, and Van Reenen 2006, Goldfarb and Tucker 2019, Hjort and Tian 2021). Au-delà de ces effets sur la richesse, les technologies de l'information et de la communication (TIC) peuvent favoriser un avenir socialement plus durable (OECD, 2004). En conséquence, des investissements massifs dans les infrastructures ont été effectués et sont en cours, tant dans les pays développés que dans les pays en développement, pour exploiter le potentiel transformateur de ces technologies.

Les concepts, méthodes et outils associés aux technologies numériques sont en constante évolution. Les technologies de l'information et de la communication³² englobent tous les services permettant aux utilisateurs d'accéder, d'extraire, de stocker, de transporter et de manipuler l'information sous forme numérique via les télécommunications. Selon Goldfarb and Tucker 2019, la caractéristique principale et distinctive des technologies numériques, qui représentent l'information sous forme de bits, réside dans leur capacité à traiter l'information avec une efficacité sans précédent. Ce traitement numérique permet une réduction substantielle des coûts de stockage, de calcul et de transfert d'informations. Puisque ces coûts peuvent restreindre les choix et les actions des agents économiques et sociaux, l'économie numérique, domaine auquel cette thèse se rattache, examine les impacts économiques, sociaux et politiques qui découlent de cette réduction des coûts, lesquels peuvent parfois tendre vers zéro.

Le discours autour des technologies numériques met fréquemment en lumière leur potentiel à engendrer des bénéfices économiques et sociaux substantiels. Cette thèse met en exergue, en particulier, le rôle de l'internet haut débit³³. L'internet haut débit, souvent

³²Les TIC désignent l'ensemble des technologies de communication, y compris Internet, les téléphones mobiles, les ordinateurs, les logiciels, les réseaux sociaux et les applications. <https://aims.fao.org/fr/information-and-communication-technologies-ict>, consulté en août 2024

³³L'Internet peut être défini comme un vaste système interconnecté d'applications logicielles et de dispositifs informatiques. Voir <https://www.broadbandsearch.net/definitions/internet> consulté en août 2024.

défini comme un accès offrant des débits d'au moins 25 Mbps en téléchargement et 3 Mbps en débit montant, permet un transfert rapide des données et un accès fluide aux contenus numériques³⁴. Ainsi, l'internet, et en particulier l'internet haut débit, constitue un atout majeur pour les économies, les sociétés et les systèmes politiques à l'échelle mondiale en facilitant l'échange d'informations et de services, en soutenant les activités économiques, les transactions commerciales, les loisirs et l'engagement politique.

La littérature économique a largement exploré l'impact de l'Internet haut débit sur la croissance économique, en établissant des parallèles avec les effets plus larges des TIC. Tout comme il a été démontré que les TIC réduisent les coûts de recherche dans les marchés financiers (Barber and Odean 2001), le marché du travail (Autor 2001) et les marchés de détail (Borenstein and Saloner 2001; Bakos 2001), l'Internet haut débit a aussi des effets sur ces coûts, ce qui engendre des conséquences économiques significatives. L'Internet haut débit est reconnu comme une General Purpose Technology (Bresnahan and Trajtenberg 1995; Carlaw and Lipsey 2006; Liao et al. 2016), une catégorie de technologie à même de stimuler une croissance économique durable en améliorant la productivité des entreprises, en facilitant l'innovation et en créant de nouvelles opportunités de marché. Par exemple, Koutroumpis, 2009, Czernich et al., 2011, Kolko, 2012, et Briglauer and Gugler, 2019 ont tous démontré que l'Internet haut débit contribue de manière significative à la croissance économique, souvent à un degré supérieur à celui des autres TIC, comme l'a souligné Vu, 2011. Au niveau microéconomique, l'impact positif sur la productivité a également été mis en évidence dans des études menées par Chen, Liu, and Song, 2020 et Haller and Lyons, 2015, soulignant encore davantage le rôle transformateur de l'Internet haut débit dans les performances économiques. L'Internet entraîne des mutations profonds de l'économie en permettant l'émergence de nouvelles activités et modèles d'affaires.³⁵

L'impact de l'Internet haut débit sur le développement a été particulièrement significatif dans les pays les plus pauvres, où ses effets économiques dépassent souvent ceux observés dans les pays plus riches (Appiah-Otoo and Song 2021). Les effets positifs de la réduction des coûts d'information, induite par les technologies numériques, ont été largement étudiés dans les pays en développement. Par exemple, les recherches de Jensen, 2007, Aker and Mbiti, 2010, et Aker, 2010 ont démontré comment les technologies numériques peuvent améliorer l'efficacité des marchés, réduire la dispersion des prix et accroître le bien-être dans ces ré-

³⁴FCC, 2015. <https://www.fcc.gov/reports-research/reports/broadband-progress-reports/2015-broadband-progress-report> consulté en août 2024.

³⁵Ces dernières années, la prolifération des smartphones et la disponibilité généralisée de l'Internet haut débit mobile et fixe ont alimenté la croissance d'une vaste gamme de nouvelles entreprises dans l'économie du partage, telles qu'Uber, Lyft et Airbnb. Ces technologies ont également soutenu l'expansion des services d'information mobile, y compris les réseaux sociaux, la billetterie, les plateformes de messagerie, et d'innombrables autres applications (Greenstein 2020).

gions. Une revue systématique par Oloyede et al., 2023 consolide ces conclusions. De plus, l'impact de l'accès à Internet sur la croissance économique dans les pays en développement a été étudié par Goldbeck and Lindlacher, 2021 et Hjort and Poulsen, 2019 par exemple. Ces études soulignent comment l'introduction et l'expansion de l'Internet haut débit peuvent engendrer une croissance substantielle en améliorant l'accès à l'information, en augmentant la productivité, et en favorisant l'innovation. Ces effets sont particulièrement cruciaux dans des contextes où les infrastructures traditionnelles sont faibles, et où le potentiel de "saut numérique" offre une opportunité unique pour un développement accéléré.

Les ménages bénéficient d'opportunités d'emploi et d'éducation accrues grâce à l'accès à l'information et aux services en ligne, améliorant ainsi leur bien-être et leur niveau de vie (Greenstein and McDevitt 2011) et ceci est également vrai dans les pays en développement (Bahia et al. 2024). L'Internet peut également promouvoir l'égalité des chances en fournant un accès équitable à des informations et services essentiels et en renforçant les liens sociaux, notamment dans les zones rurales, à travers les réseaux sociaux. En outre, l'Internet est souvent perçu comme un catalyseur de la démocratie et de la participation civique. Il permet aux citoyens de s'informer, de s'organiser et de s'exprimer plus librement, facilitant ainsi la mobilisation sociale et la transparence gouvernementale (Diamond 2010).

Cependant, la fracture numérique peut exacerber les inégalités économiques existantes, laissant les populations rurales (Forman, Goldfarb, and Greenstein 2012) et les pays en développement en retard par rapport aux zones urbaines et aux pays développés. L'impact des TIC sur le développement fait l'objet de débats. Selon Rodrik, 2018, les TIC peuvent freiner le développement économique dans certains contextes en réduisant la croissance à long terme de l'emploi par l'automatisation ou en déplaçant les emplois du secteur manufacturier. En outre, les dangers de l'isolement social, qui diminuent les interactions en face-à-face, peuvent avoir des effets négatifs sur la santé mentale (Braghieri, Levy, and Makarin 2022) et affaiblir le capital social (Geraci et al., 2022). La propagation de la désinformation et des fausses nouvelles via les réseaux sociaux peut polariser les sociétés et compromettre la cohésion sociale (Allcott and Gentzkow 2017). Politiquement, les régimes autoritaires peuvent utiliser Internet pour surveiller et réprimer les dissidents (Morozov 2012), et la manipulation des élections par des campagnes de désinformation constitue peuvent menacer la démocratie (Diamond and Plattner 2012).

Cette thèse examine trois agents économiques majeurs : les ménages, les entreprises et les citoyens. Pour ces trois agents il s'agit de mesurer la valeur subjective de l'internet haut débit accordée par ces trois agents. En s'appuyant sur le cadre théorique de l'école marginaliste, nous pouvons définir la valeur subjective comme la valeur attribuée à un bien ou un service par un individu, en fonction de ses préférences, besoins, désirs et caractéristiques spécifiques.

Cette valeur subjective peut être appliquée à la connectivité haut débit.

Les ménages peuvent attribuer une valeur subjective élevée à l'internet haut débit pour plusieurs raisons. L'internet haut débit peut offrir un accès rapide à une vaste quantité d'informations, de contenus et de services de streaming, améliorant ainsi leur qualité de vie. Il permet également le télétravail, les téléconsultations et un accès plus facile à diverses opportunités. De plus, l'internet haut débit peut jouer un rôle dans l'intégration sociale en facilitant l'accès aux réseaux sociaux, en renforçant les liens sociaux et en permettant la participation à des communautés en ligne. Le deuxième chapitre de cette thèse vise à quantifier cette valeur subjective en mesurant la disposition à payer pour l'internet très haut débit.

Au-delà de la mesure de la valeur subjective de l'internet haut débit pour les ménages, il est également crucial de considérer les changements en matière de bien-être global qui peuvent découler des évolutions de la consommation d'internet, et qui ne sont pas capturés par les mesures traditionnelles de la valeur subjective. Plus précisément, la valeur subjective de la connectivité haut débit pour les individus en tant que citoyens revêt une grande importance, notamment dans le contexte de l'exercice de la liberté politique. L'internet haut débit peut renforcer la capacité à exercer ses droits, à exprimer ses opinions et à se mobiliser pour des causes démocratiques. Par conséquent, évaluer sa valeur à travers le prisme de ses bénéfices potentiels pour la démocratie, tels que l'augmentation des chances de participer à des manifestations et de faire entendre sa voix, est l'objectif du premier chapitre de cette thèse.

Enfin, la valeur subjective de l'internet haut débit est cruciale pour les entreprises, car elle influence directement leur performance et leur compétitivité. L'internet haut débit améliore l'efficacité opérationnelle, favorise l'innovation et permet aux entreprises de s'étendre sur de nouveaux marchés. De plus, une connectivité haut débit fiable est essentielle pour une communication efficace et une meilleure coordination. Le troisième chapitre de cette thèse vise à mesurer cette valeur subjective pour les entreprises, qui cherchent à maximiser leurs profits, en analysant l'impact de l'internet haut débit sur la création d'entreprises et en examinant comment il modifie les effets d'agglomération et l'allocation des entreprises.

Ainsi, l'étude de la valeur subjective de l'internet haut débit pour les ménages, les entreprises et les citoyens, à travers les infrastructures de l'internet haut débit, est essentielle car elle permet de comprendre les besoins et les priorités des différents agents économiques. Cette compréhension aide à orienter les politiques publiques et les investissements en infrastructures numériques afin de maximiser le bien-être social et économique. En quantifiant la valeur subjective, nous pouvons mieux évaluer l'impact économique global du déploiement de l'internet haut débit et justifier les investissements nécessaires. Reconnaître la valeur

perçue par les agents économiques permet de concevoir des stratégies pour réduire la fracture numérique et garantir un accès équitable aux avantages de l'internet haut débit. En fin de compte, il s'agit d'aider à mieux comprendre et à maximiser les impacts positifs de la numérisation sur la société et l'économie.

L'objectif principal est de mesurer l'impact de l'infrastructure de l'internet haut-débit sur divers aspects économiques et sociaux en fonction du contexte géographique et socio-économique. La thèse est structurée en trois chapitres, chacun explorant une dimension différente de l'impact de l'internet haut-débit permettant finalement de mesurer la valeur de la connectivité haut-débit pour chacun de ces agents.

Le premier chapitre s'intéresse à l'effet de l'accès à l'internet haut-débit sur la participation politique, notamment à travers la participation aux manifestations en Afrique subsaharienne. Ce chapitre teste l'hypothèse selon laquelle l'accès à l'internet haut-débit, qui permet l'accès à de nouveaux contenus et plateformes (comme les réseaux sociaux), augmente la probabilité de participation à des manifestations ainsi que la fréquence de celles-ci. Pour évaluer cet impact, une méthode des doubles différences (DiD) est employée, s'appuyant sur l'arrivée progressive des câbles sous-marins de fibre optique entre 2009 et 2014. Cette méthode permet de mesurer l'exposition à l'internet haut-débit en fonction de la proximité des câbles terrestres, servant de proxy pour l'accès à la connectivité haut-débit. Les résultats montrent que l'exposition à l'internet, qu'il soit mobile ou fixe, accroît la probabilité de participation aux manifestations et la fréquence des manifestations dans les zones exposées. Cette relation est particulièrement significative dans les pays où les droits politiques et les libertés civiles sont activement exercés. Aussi les résultats suggèrent que le mécanisme de coordination, plutôt que le simple accès à l'information, joue un rôle prédominant dans l'incitation à la mobilisation politique.

Le deuxième chapitre de la thèse explore comment les ménages en France valorisent l'accès à l'internet très haut-débit en particulier le FTTH (Fiber to the Home) et comment cette valorisation affecte les prix de l'immobilier. La méthode employée ici est un modèle de prix hédonique, associé à un design de régression en discontinuité spatiale. Ce modèle permet d'estimer la disposition à payer des ménages pour une connectivité améliorée à l'internet. Les données telecom utilisées dans ce chapitre proviennent du régulateur français des télécommunications (ARCEP), qui fournit des informations détaillées sur l'éligibilité à la fibre optique au niveau des adresses en France métropolitaine. En comparant les transactions immobilières situées de part et d'autre des zones d'éligibilité à la FTTH, les résultats montrent que l'éligibilité à la fibre optique entraîne une augmentation significative des prix de l'immobilier, avec une augmentation moyenne de 0,9%. Cet effet est particulièrement marqué dans les zones rurales, où la performance des réseaux fixes préexistants (comme l'ADSL)

est souvent médiocre, ce qui rend la connectivité haut-débit d'autant plus précieuse pour les ménages.

Le troisième chapitre aborde l'impact de la qualité de l'internet haut-débit mobile sur la création d'entreprises en Tunisie. Cette étude utilise un modèle de comptage et des estimations de panel avec effets fixes, en exploitant des données sur la densité des antennes 4G et les données de créations de firmes formelles en Tunisie pour analyser comment l'infrastructure mobile haut-débit influence la dynamique de création d'entreprises. Les résultats montrent une relation positive robuste entre la densité des antennes 4G et le nombre de nouvelles créations d'entreprises. Cet effet est particulièrement notable dans les zones rurales et en périphérie des grands centres urbains. Ces résultats remettent en question l'hypothèse de la "mort de la distance", soulignant que l'internet mobile joue un rôle essentiel dans la stimulation de la croissance économique locale, tout en exacerbant les disparités économiques entre les zones urbaines et rurales.

Cette thèse apporte des contributions, principalement grâce à l'utilisation de jeux de données diversifiés—en particulier les données d'infrastructures télécoms—and de méthodologies avancées d'évaluation d'impact, soutenues par une expertise technique substantielle en matière de fonctionnement des réseaux télécoms.

La collecte, le traitement et l'utilisation de ces données d'infrastructure télécom sont au cœur des méthodes et des arguments déployés tout au long de cette thèse. La variété des données relatives aux infrastructures internet haut débit est clairement mise en évidence dans les différents chapitres. Le Chapitre 1 utilise des données sur les réseaux centraux, permettant de pallier les problèmes de disponibilité de données précises en Afrique. Cela inclut des informations sur les câbles sous-marins en fibre optique reliant l'Europe à l'Afrique, les points de connexion et les dates de mise en service, ce qui permet de déterminer à quel moment la connectivité internationale haut débit est devenue disponible dans chaque pays d'Afrique subsaharienne. De plus, des données sur les câbles terrestres de backbone sont utilisées pour construire un proxy de l'exposition à l'internet haut débit. Plus un individu est éloigné de ces câbles terrestres, plus la probabilité d'accéder à des vitesses de connexion suffisantes diminue.

Le Chapitre 2 exploite des données relatives aux infrastructures fixes d'internet haut débit, principalement une compilation d'adresses éligibles à la fibre, avec l'indication du trimestre d'éligibilité. Cette base de données, fournie par l'ARCEP, permet de déterminer l'éligibilité à la fibre optique au niveau de l'adresse sur l'ensemble du territoire métropolitain. Ces données sont utilisées pour construire des zones d'éligibilité afin de déterminer le statut des propriétés (éligible ou non à la fibre) au moment de la vente. La distance par rapport à la frontière d'éligibilité soutient la méthodologie de régression en discontinuité spatiale pour

l'identification causale. Des données supplémentaires sur les vitesses maximales de l'ADSL, également compilées par l'ARCEP, aident à comprendre pourquoi l'impact de la fibre sur les prix immobiliers pourrait être plus marqué dans les zones moins denses, où les vitesses ADSL préexistantes sont plus faibles.

Le Chapitre 3 se concentre sur les infrastructures mobiles d'internet haut débit, en utilisant des données d'OpenCellID pour localiser les antennes de téléphonie mobile, leur génération (2G, 3G, 4G), leur propriétaire et leurs dates de mise en service. Dans le contexte tunisien, ces données sont utilisées pour créer des indicateurs tels que la densité des antennes 4G pour 10 000 habitants dans chaque délégation tunisienne et la couverture mobile. Ces indicateurs mesurent la qualité de l'internet mobile haut débit au niveau des unités administratives et sont utilisés pour analyser comment la qualité des infrastructures mobiles haut débit influence la création d'entreprises en Tunisie.

La diversité des données utilisées dans cette thèse s'accompagne de l'application de plusieurs méthodologies d'évaluation d'impact. Chaque chapitre est consacré à une évaluation d'impact approfondie en utilisant des approches méthodologiques distinctes, adaptées aux questions de recherche spécifiques. Le premier chapitre emploie une approche de différence en différences (DiD), en utilisant l'arrivée du câble sous-marin à fibre optique comme date de traitement et comme choc exogène. Le deuxième chapitre adopte un design de régression en discontinuité spatiale (RDD), un outil puissant pour estimer les impacts causaux en exploitant les frontières géographiques comme expérience naturelle. De plus, cette thèse utilise diverses autres techniques économétriques dans le Chapitre 3, incluant des méthodes de données de panel avec des estimations de modèle de Poisson à effets fixes et des techniques d'économétrie spatiale. Ces méthodologies fournissent des estimations robustes des impacts étudiés et contribuent à la littérature méthodologique en démontrant leur application dans des contextes variés.

L'utilisation des données d'infrastructures télécom dans cette thèse est éclairée par une expertise du fonctionnement des réseaux internet fixes et mobiles, ce qui guide et justifie plusieurs choix méthodologiques. Par exemple, cette expertise a conduit à une réévaluation critique de la méthodologie utilisée par Hjort and Poulsen, 2019 dans le Chapitre 1. La préférence pour les données collectées de manière participative par rapport aux sources traditionnelles, en particulier le choix d'utiliser les données OpenCellID au lieu des données GSMA, a été motivée par une compréhension détaillée des opérations des réseaux mobiles et la granularité supérieure qu'offre OpenCellID. De même, l'analyse des réseaux fibre est enrichie par une compréhension approfondie de leur fonctionnement technique et de la régulation des réseaux de télécommunications, ce qui permet une application des données plus précise et pertinente. Cette expertise technique garantit que les méthodologies employées

sont à la fois théoriquement solides et pratiquement alignées avec les dynamiques réelles des infrastructures télécoms haut débit.

En conclusion, cette thèse souligne le rôle central de l'internet haut-débit dans les économies contemporaines et propose des recommandations pour orienter les politiques publiques et les investissements, afin de garantir un accès équitable aux bénéfices de la connectivité numérique tout en tenant compte des disparités géographiques et socio-économiques.

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