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

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Essays in Digital Economics: Three Impact Evaluations of Broadband Internet

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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 identified as 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 availability of mobile and fixed broadband Internet[3] 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)

[2] Dictators 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.

[3] Broadband 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 Heblich 2014; Campante, Durante, and Sobbrio 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 biases[4].

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 multifaceted 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-

[4]Only 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 specifically 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. This research extends beyond previous studies that have investigated the influence of 2G mobile networks in conflict scenarios (Pierskalla and Hollenbach 2013; Bailard 2015). For example, 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. 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 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 connectivity[5]. Submarine cables are the preferred choice 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 net-

[5]The 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)

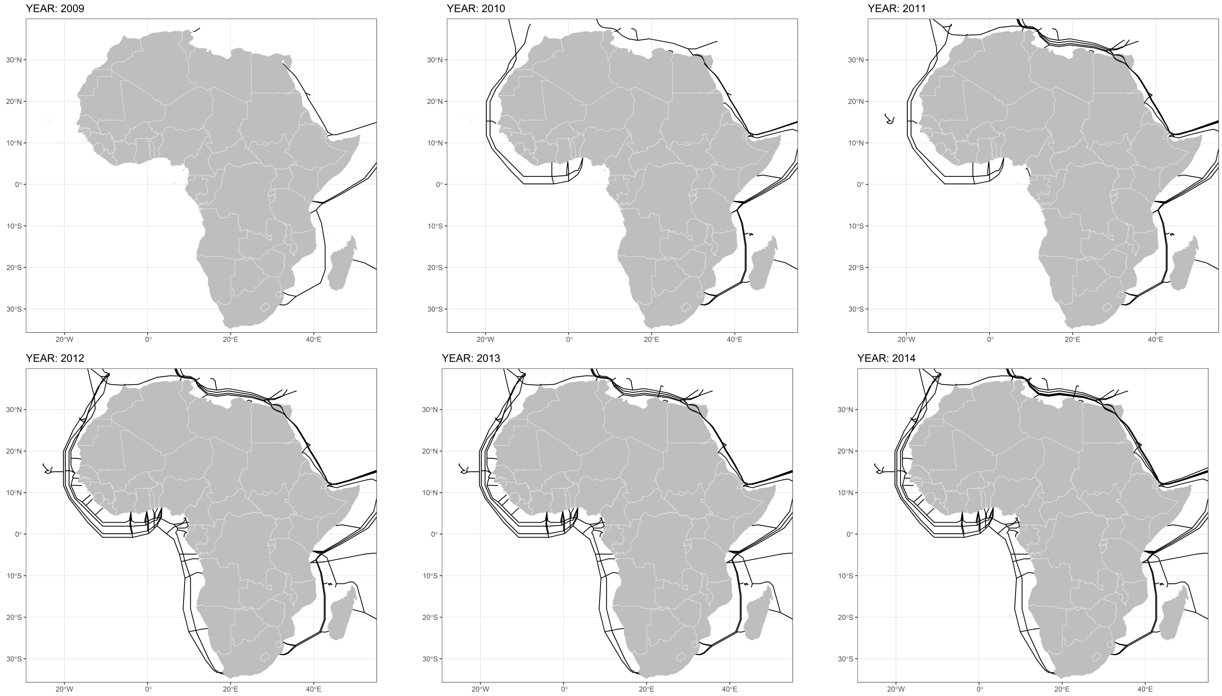

Figure 1.1: The gradual arrival of optic-fibre submarine cables in Sub-Saharan Africa

work 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 capacity[6]. The backbone network plays a crucial role in distributing Internet traffic nationwide, leveraging expansive fiber cables for the bulk of data transmission. The final phase of connectivity, known as the 'last mile', 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 used[7]. As shown in Figure 1.9 in the Appendix, the

[6]During 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.

[7]For 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

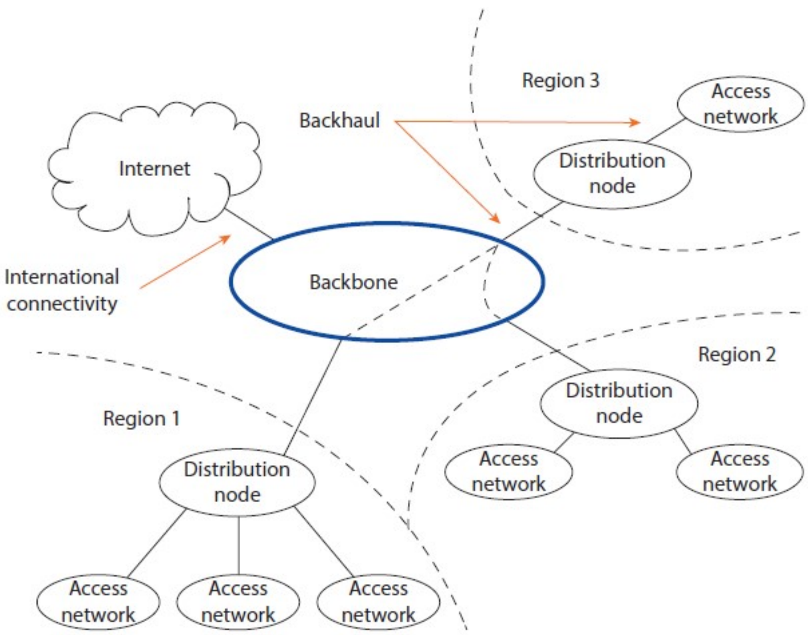

Figure 1.2: Network Components of Broadband Infrastructure (Source: World Bank, 2014)

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 antennas[8]. Figure 1.13 in the Appendix 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 technology[9].

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

signal quality decreases rapidly after a 1km distance as shown in Figure 1.10 from Karray and Jovanovic (2013).

[8]The 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 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).

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

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)

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, 2009[10]; State of the Internet Report, 2012[11]). 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 revolution[12]. Additionally, broadband Internet significantly improves content accessibility and usage patterns. 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.

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-

[10]BBC. (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

[11]Communications, 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/.

[12]Makeni, 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

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 era[13]. This enhanced connectivity is instrumental in unlocking economic potential and bolstering social dimensions such as improved communication, heightened awareness, and increased governmental transparency[14].

This connectivity fosters economic opportunities and improves aspects of social life, including communication, awareness, and governmental transparency[15]. 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.

[13] Kermeliotis, 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

[14] Funke 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.

[15] Funke 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."

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 live broadcasts we did on Facebook"* (Translated from French)[16].

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) database[17] 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

[16] Dimé, 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.

[17] https://afterfibre.nsrc.org/

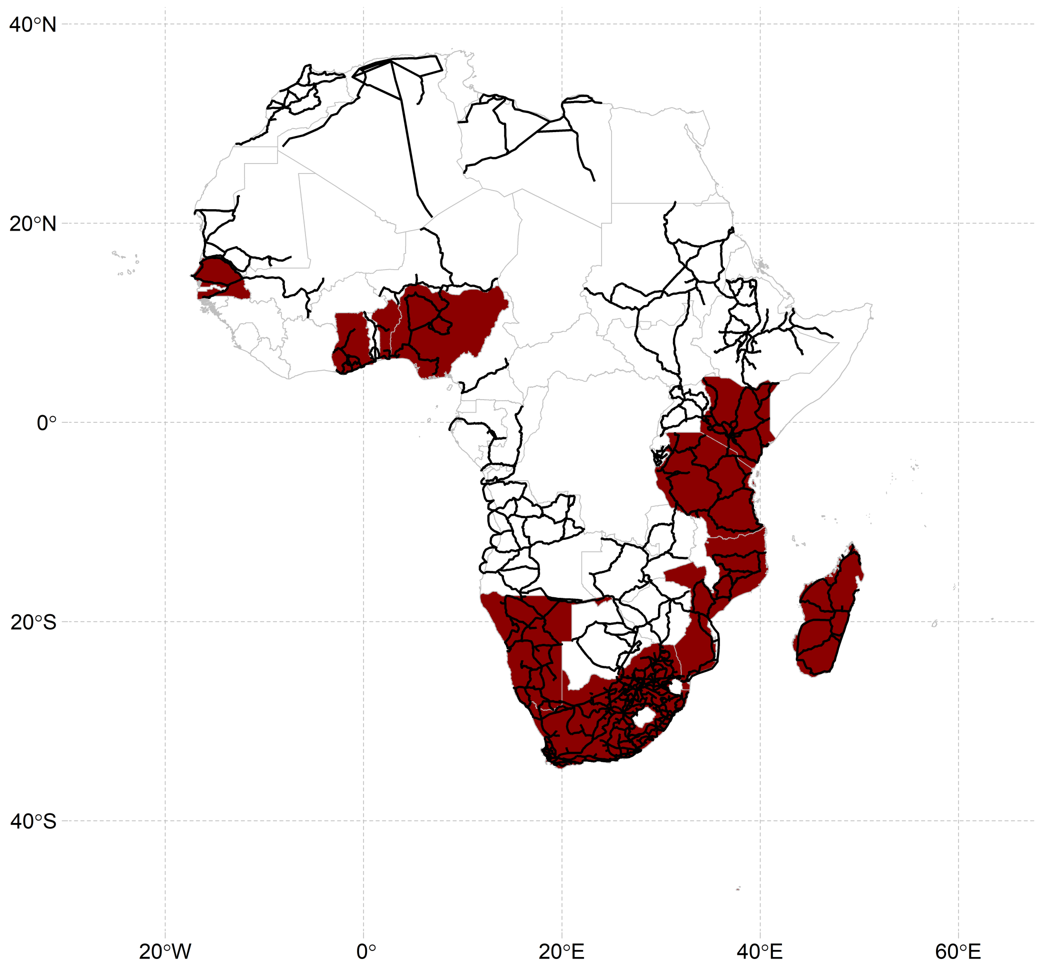

Figure 1.3: This map illustrates the ten Sub-Saharan African countries included in our study—Benin, Ghana, Kenya, Madagascar, Mozambique, Namibia, Nigeria, Senegal, South Africa, and Tanzania—highlighting the routes of existing backbone cables operational prior to the introduction of submarine cables. 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.

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 2009[18] 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.

Additionally, the arrival dates of these submarine cables in each country, as depicted in Figure 1.1, are sourced from Infrapedia[19]. 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 Afrobarometer[20], which has been systematically collecting opinion polls in multiple African countries since 1999, with the first survey wave encompassing 37 countries by 2021[21]. 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 cables[22]: 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

[18] For 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.

[19] www.infrapedia.com.

[20] The 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).

[21] Afrobarometer. (2021). Afrobarometer. Retrieved December 1, 2021, from https://afrobarometer.org/countries

[22] The 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.

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 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 × 0,1 degrees[23]. 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 VIIRS[24] night lights data, which are considered to be more accurate to predict economic activity in rural areas and spatial inequality in urban areas than DMSP[25] 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.

[23] 0.1 degrees correspond roughly 10 kms
[24] Visible Infrared Imaging Radiometer Suite
[25] Defense Meteorological Satellite Program

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 infrastructure[26]. 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 Africa[27]; and spatial variation, which is based on the proximity of respondents to the nearest backbone network, illustrated

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

[27]Following 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)

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

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	0.805	0.025***	0.793	0.782	-0.011*
	(0.004)	(0.007)		(0.004)	(0.007)	
Trust in Presidency	0.65	0.671	0.021*	0.585	0.603	0.018**
	(0.005)	(0.008)		(0.005)	(0.008)	
Preference for Democracy	0.74	0.762	0.022**	0.742	0.749	0.007
	(0.005)	(0.008)		(0.004)	(0.007)	
Satisfied with democracy	0.54	0.614	0.074***	0.534	0.537	0.003
	(0.005)	(0.009)		(0.005)	(0.008)	
Freedom of Thought	0.86	0.894	0.034***	0.869	0.883	0.014***
	(0.004)	(0.006)		(0.003)	(0.005)	
Freedom to join organisations	0.919	0.92	0.001	0.914	0.924	0.01**
	(0.004)	(0.007)		(0.003)	(0.004)	
Free vote	0.95	0.956	0.007	0.953	0.956	0.004
	(0.003)	(0.005)		(0.002)	(0.003)	

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

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.

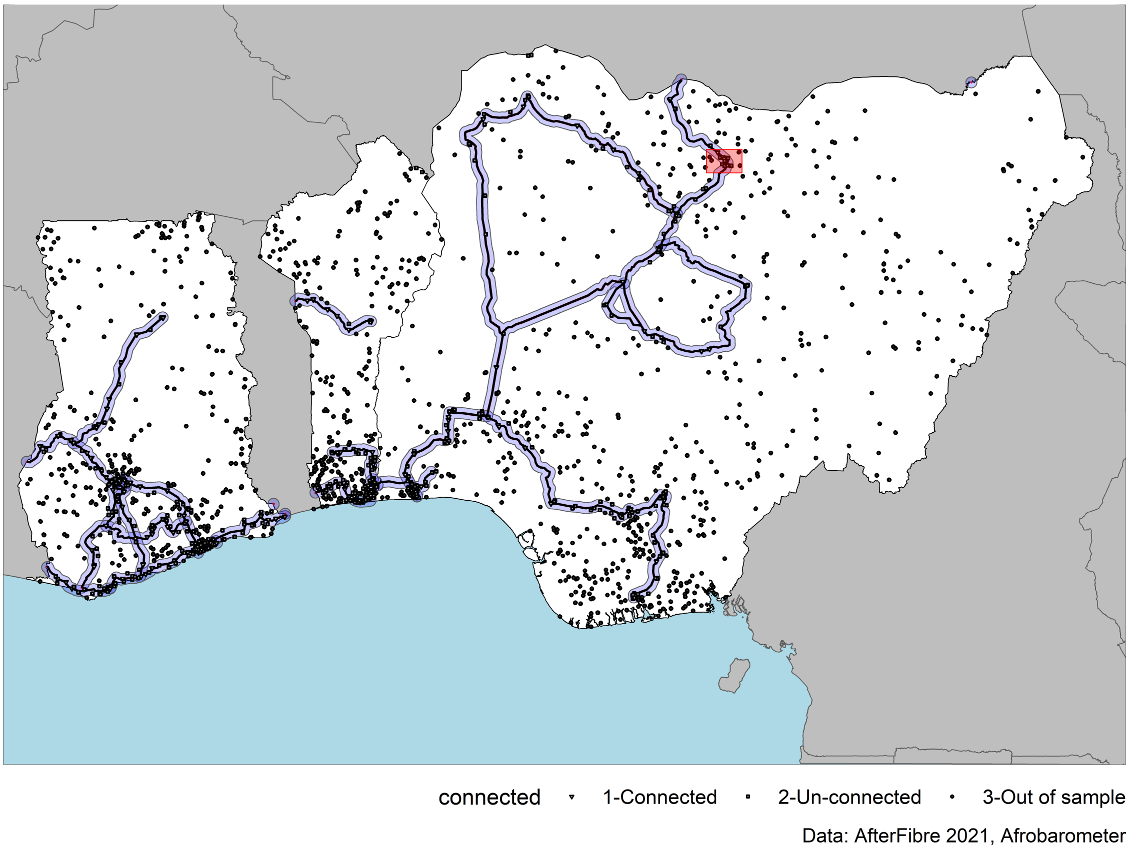

Figure 1.4: This map highlights three countries from the sample, showcasing all geolocated observations from the Afrobarometer database. Utilizing the Afterfibre database, it displays the routes of backbone cables that were in place before the introduction of submarine cables. Along these routes, two 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.

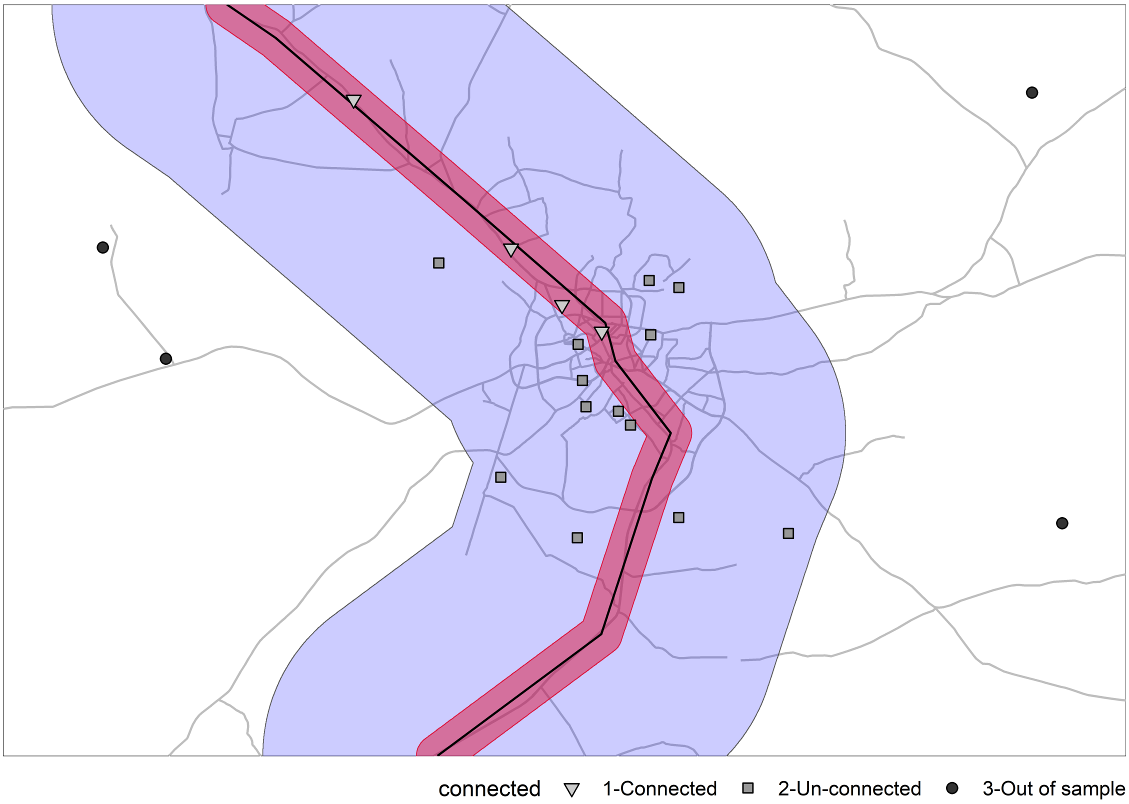

Figure 1.5: This map centered on Kano, Nigeria, details the methodology approach for this study. The black line marks the actual location of the existing backbone cable. The distance to the backbone defines the respondent's status (connected or control), and buffers have been drawn to show how individuals 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 degrees[28]. 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-

[28]Equivalent 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.

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

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.

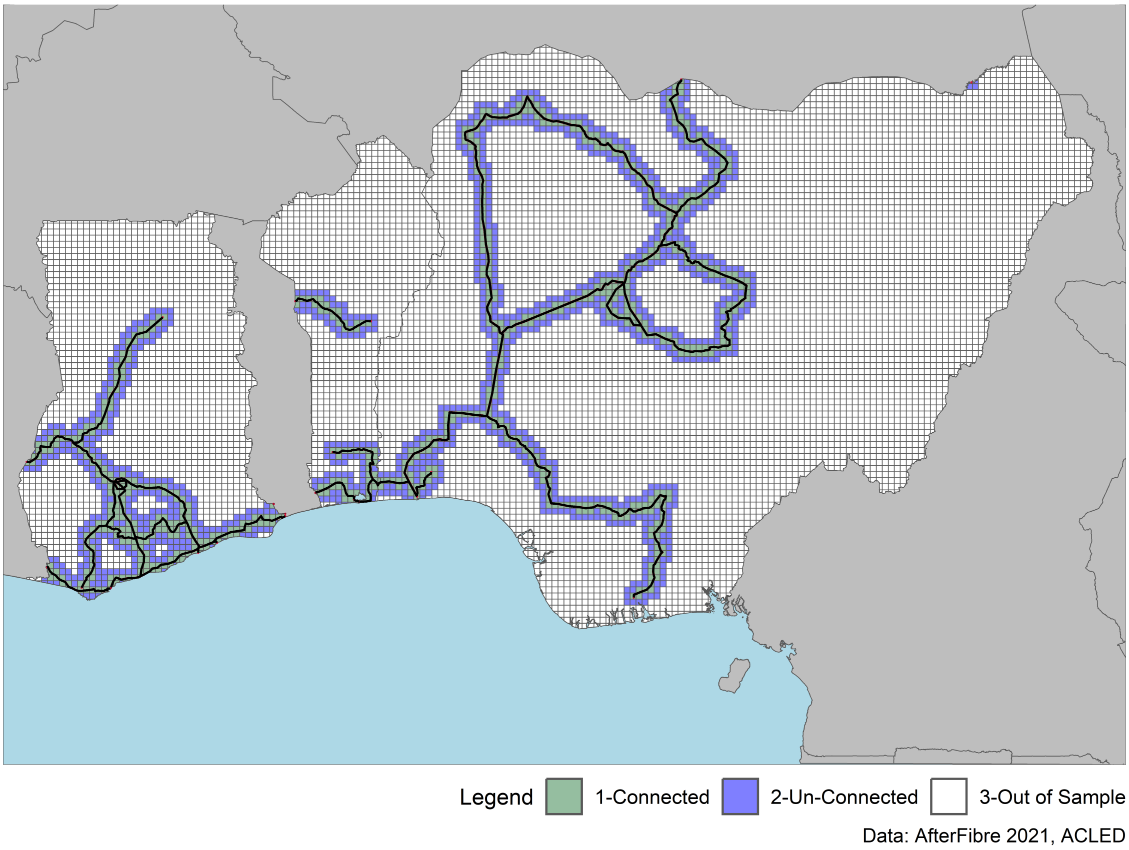

Figure 1.6: This map displays a grid of 0.1 by 0.1-degree cells covering three sample countries. Utilizing the Afterfibre database, it illustrates the routes of backbone cables existing prior to the introduction of submarine cables. Cells intersected by these terrestrial cable routes are labeled as connected. 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

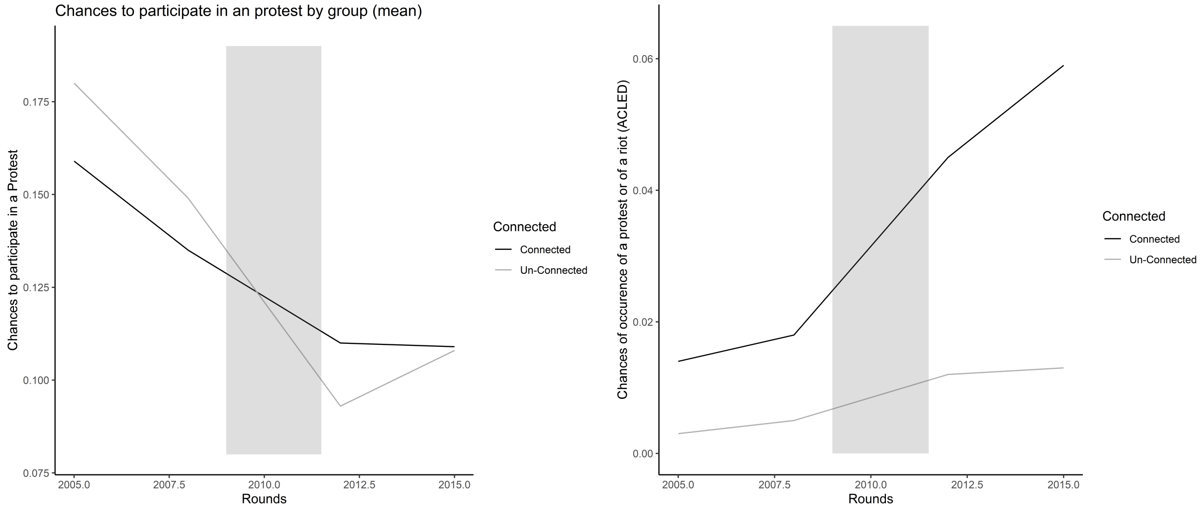

Figure 1.7: Left-hand panel displays the proportion of individuals within specified groups who participated in at least one protest over the past 12 months, across each available survey wave. The treatment group includes individuals within 1200 meters of the nearest backbone cable, while the control 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 is 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:

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

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

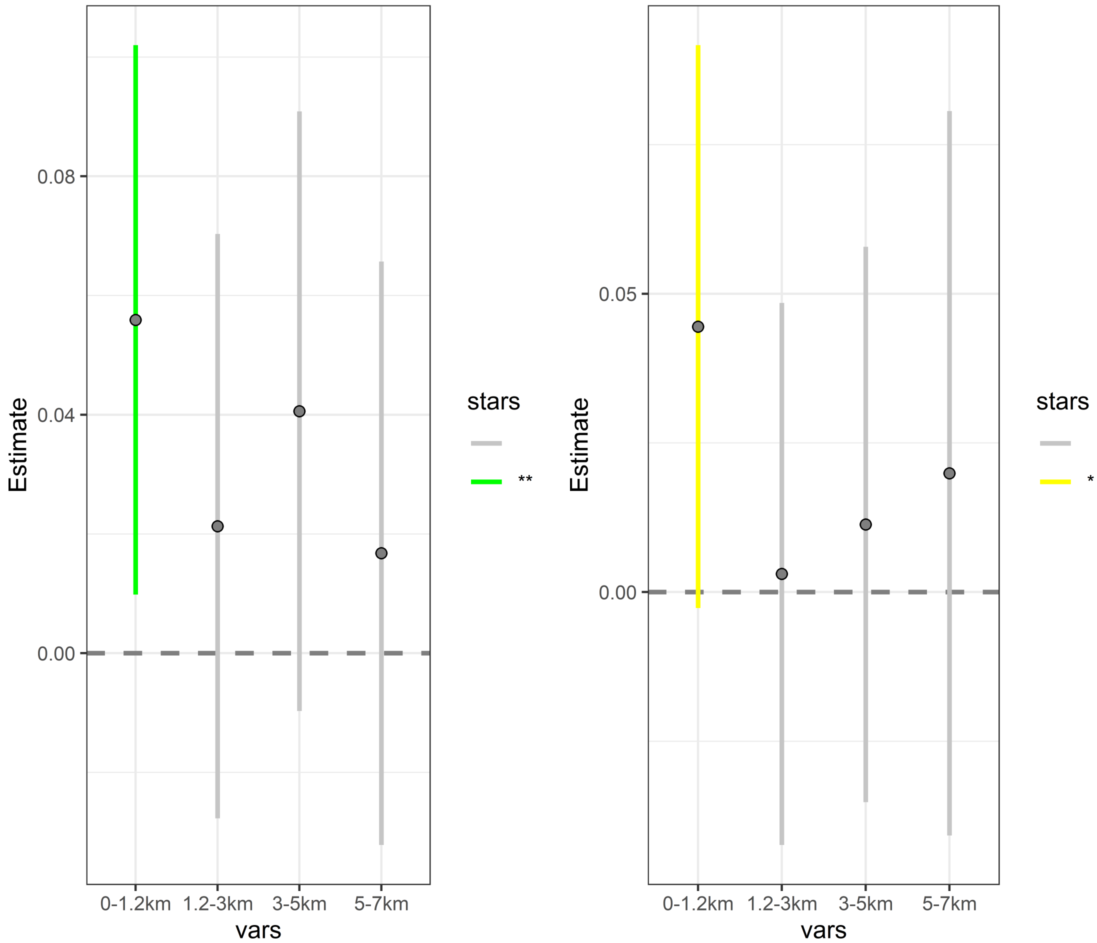

Figure 1.8: These graphs depict the evolution of interaction coefficients between various distance groups (0-1.2 km; 1.2-3 km; 3-5 km; 5-7 km; >7 km) and the introduction of fiber optic submarine cables. On the left, the plotted coefficients relate to a dummy variable indicating individuals' daily Internet 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**	0.029**	0.032*	0.036
	(0.015)	(0.015)	(0.017)	(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***	0.037***	−0.005*	0.037***	0.038***	−0.005*
	(0.013)	(0.013)	(0.003)	(0.014)	(0.014)	(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 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 2. Location FEs 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 FEs.

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 1.16, 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 1.18 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.

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 1.17, 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 1.19, 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 occurence of a protest in a Cell

	Protest Incidence		Number of Protests	
	(1)	(2)	(3)	(4)
SubCableXConnected	0.022***	0.020***	0.114***	0.110***
	(0.001)	(0.001)	(0.014)	(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 an 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 a variety of data sources use (radio, television and newspaper). As a result, I conclude that the arrival of submarine cables, which has resulted in a major rise in the availability of high-speed Internet, has a positive impact

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 FEs 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 FEs.

on the use of radio as a source of news, while having no effect on the use of other sources of information. This absence of a negative impact on the utilization of conventional sources of information implies that traditional media and content available on the Internet are not substitutes. Consequently, the role of informational dynamics appears to be non-critical in elucidating 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***	0.048***	0.016	0.018
	(0.016)	(0.016)	(0.025)	(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.

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 capabilities, 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.

1.8 References

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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 TGN-Eurasia	Fibre-optic (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; Duynefontein, 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

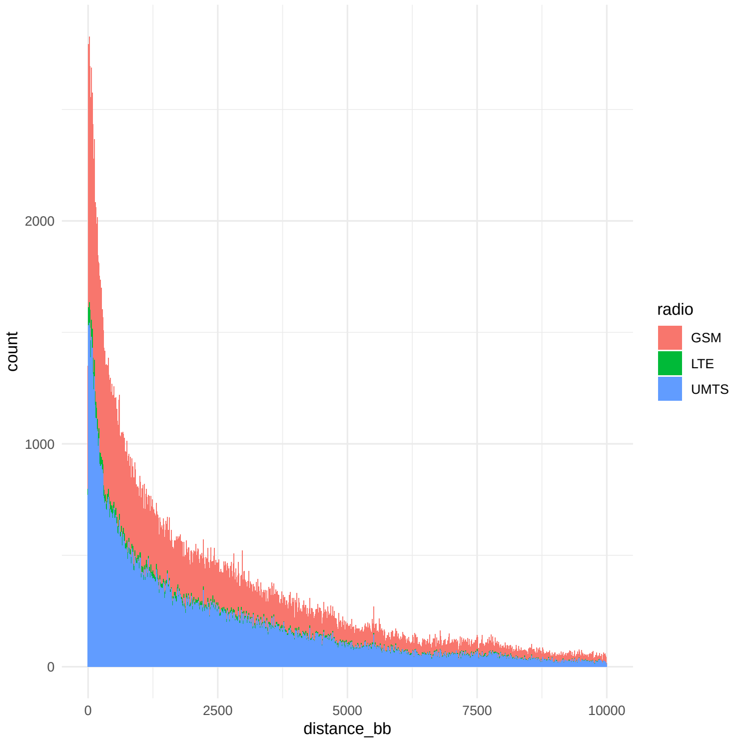


Figure 1.9: Density of the number of new antennas (2G, 3G, 4G) between 2012 and 2016 in relation to the distance to the backbone for the 10 countries in the sample.

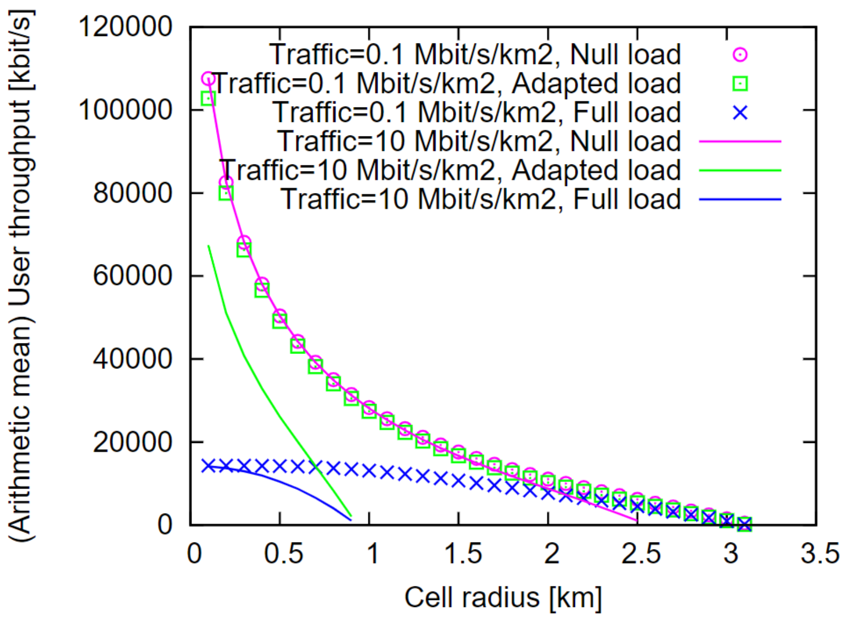


Figure 1.10: Mean user throughput as function of the cell radius for different load situations (Source: Karray and Jovanovic 2013).

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***	0.045***	0.044***	0.044***
	(0.014)	(0.014)	(0.015)	(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**	0.027*	0.025*	0.025*
	(0.014)	(0.014)	(0.015)	(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: night-time 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 (remove countries one by one)

	BEN	GHA	KEN	MDG	MOZ	NAM	NGA	SEN	ZAF	TZA
SubCableXConnected	0.030**	0.037**	0.036**	0.040***	0.047***	0.027*	0.038***	0.039***	0.044***	0.035**
	(0.015)	(0.016)	(0.015)	(0.014)	(0.014)	(0.015)	(0.014)	(0.015)	(0.015)	(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 FEs are years. Location FEs 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 FEs.

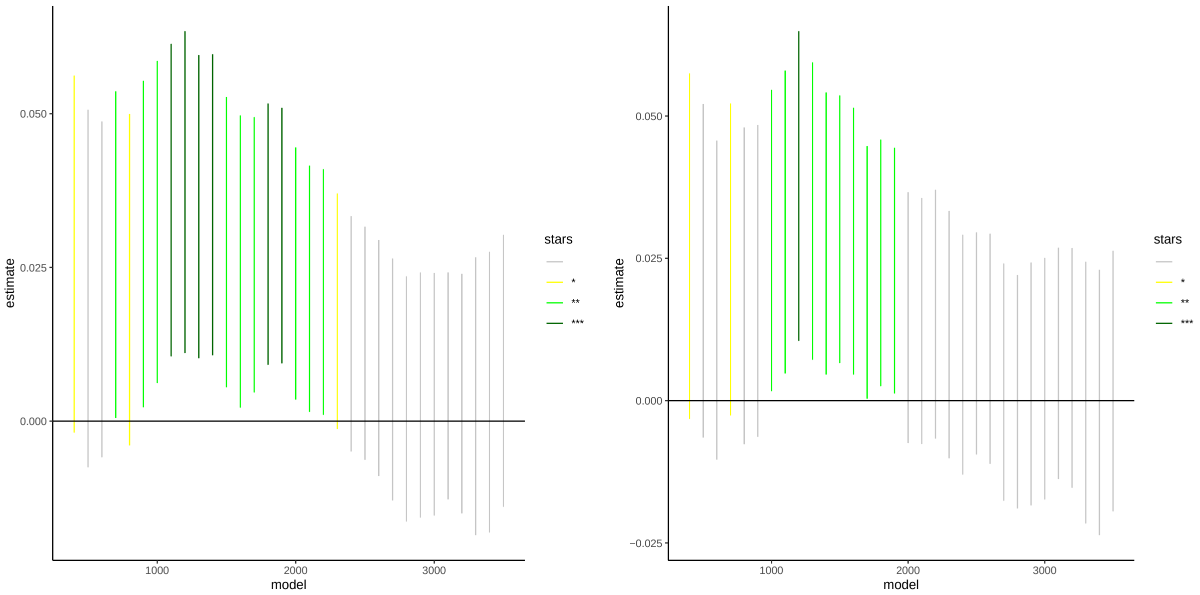


Figure 1.11: Variation of Connection Radius - Effect of the arrival of submarine cables on the chances to part.

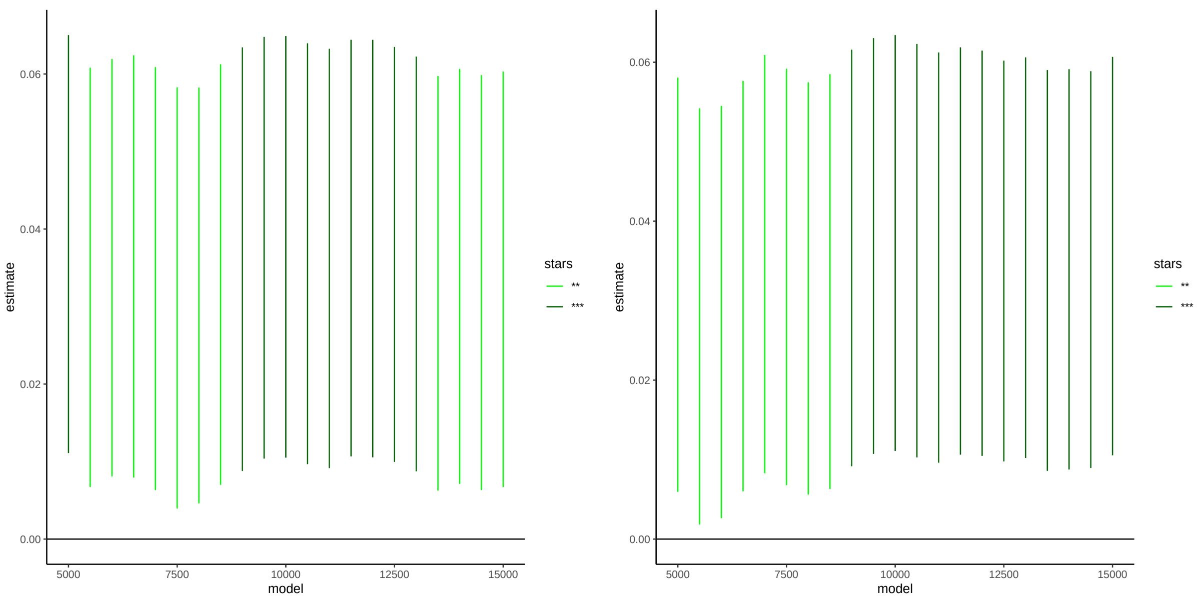


Figure 1.12: Variation of Size of the control group - Effect of the arrival of submarine cables on the chances to part.

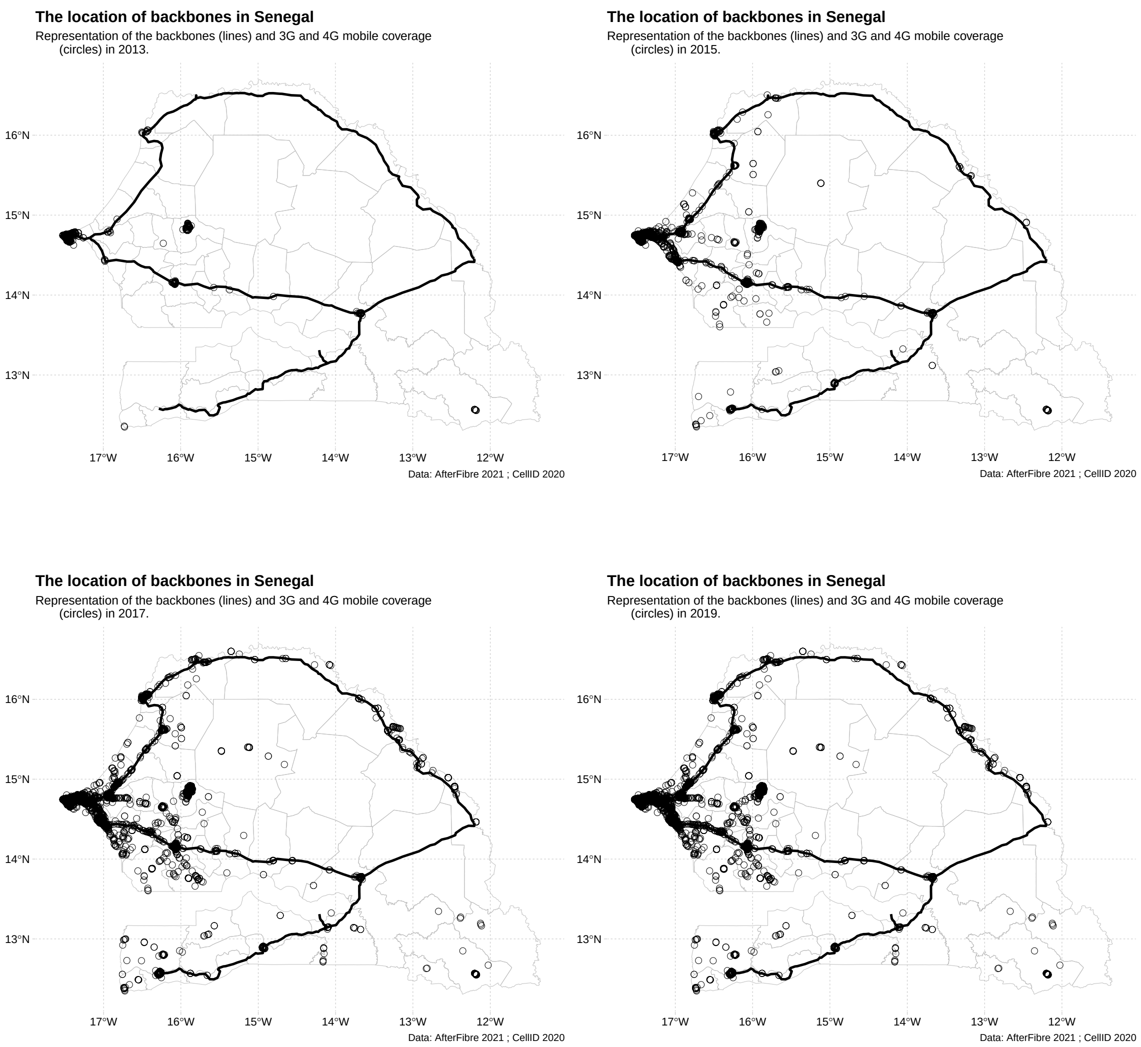


Figure 1.13: Location of 3G and 4G antennas in Senegal between 2012 and 2019 (Source: OpenCellID).

Table 1.15: 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**	0.038**	0.036**	0.041***	0.046***	0.028*	0.038***	0.039***	0.044***	0.035**
	(0.015)	(0.016)	(0.015)	(0.014)	(0.014)	(0.015)	(0.014)	(0.014)	(0.015)	(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 FEs are years. Location FEs 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 FEs.

Table 1.16: 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**	0.034**	0.036**	0.037**	0.039**	0.035**
	(0.016)	(0.016)	(0.014)	(0.015)	(0.016)	(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 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: night-time 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 1.17: 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**	0.038***	0.036***	0.034**	0.029**	0.030**
	(0.013)	(0.014)	(0.013)	(0.014)	(0.012)	(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 1.18: Submarine Cable Arrival and Chances to Participate in a Protest (Precision test)

	(1)	(2)	(3)	(4)
SubCableXConnected	0.033**	0.032**	0.030**	0.030**
	(0.014)	(0.014)	(0.014)	(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.

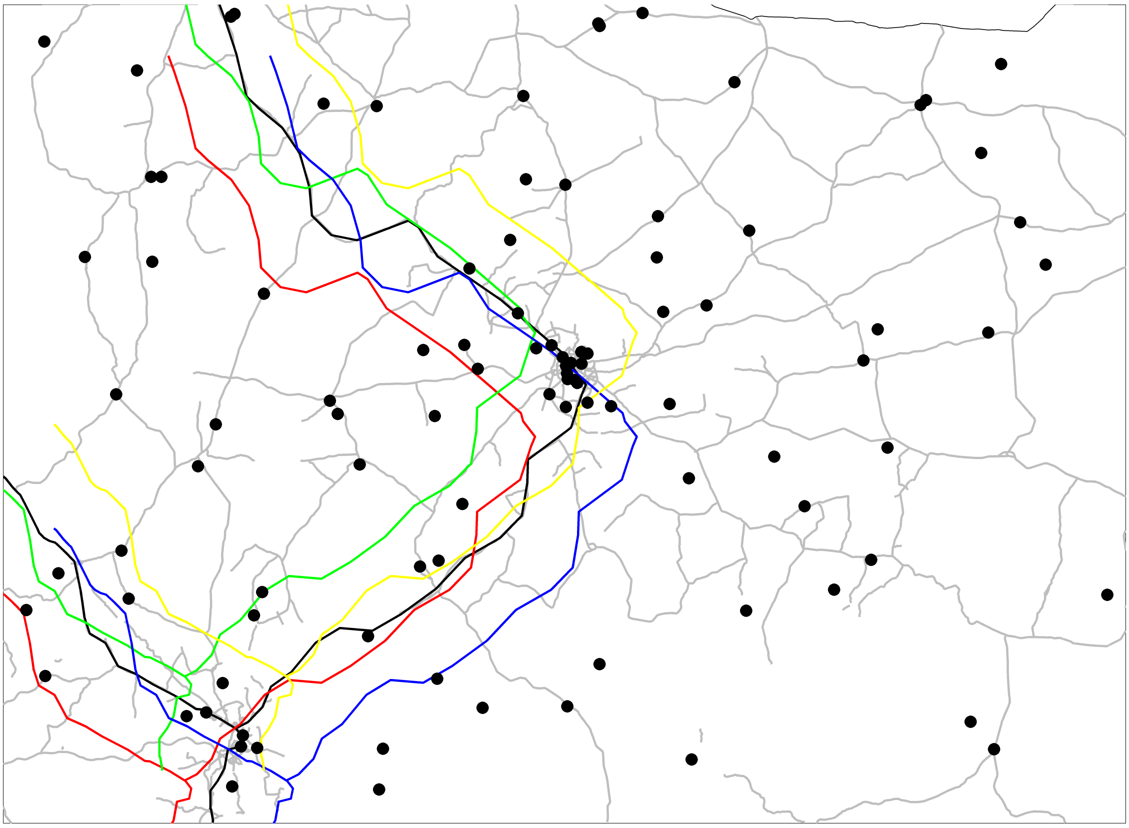


Figure 1.14: This map details the placebo test conducted for the study, centered on Kano, Nigeria. The black line marks the actual location of the existing backbone cable. Surrounding this, the other colored lines illustrate hypothetical displacements of the backbone cable, each shifted by 12.5 degrees 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 1.19: 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	−0.025	0.032	0.019	0.007	0.006	0.029	0.019
	(0.029)	(0.033)	(0.025)	(0.026)	(0.039)	(0.032)	(0.023)	(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 Internet[3] is largely based on the deployment of Fiber To The Home (FTTH) technology.[4] The deployment of broadband telecommunications infrastructure, similar to major public amenities such as high-speed train networks and highways, has been empirically linked to enhancements in economic wealth and activity (Czernich 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-

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

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

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

[4] The FTTH implies a connection by an optical fiber line from end to end to the user's home. 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 Q2-2020[6]. In addition, a French General

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

[6]The strategic choice of Q2-2020 as the reference period is pivotal, coinciding with the initiation of extensive updates in the database of fiber-eligible addresses through the "Ma connexion internet" tool. This

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

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

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

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

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

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

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

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.

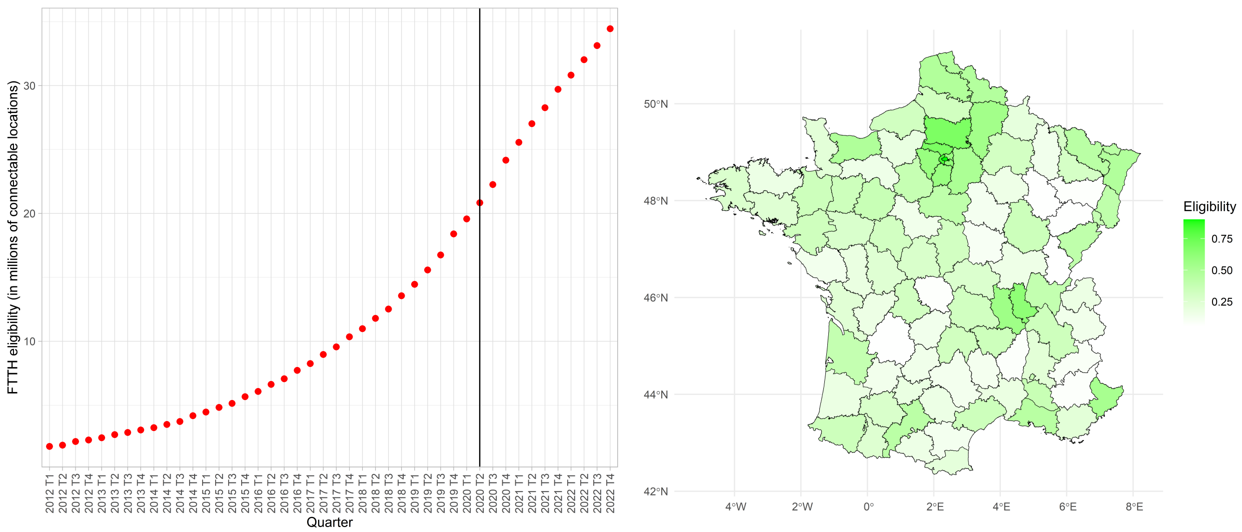


Figure 2.1: The graph on the left shows the evolution of the number of premises (in millions) eligible for fiber in France since 2012, by quarter. The black bar represents the point in time chosen for this analysis: Q2-2020. The chart on the right shows all French départements and their fiber optic eligibility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

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

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

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

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

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

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.

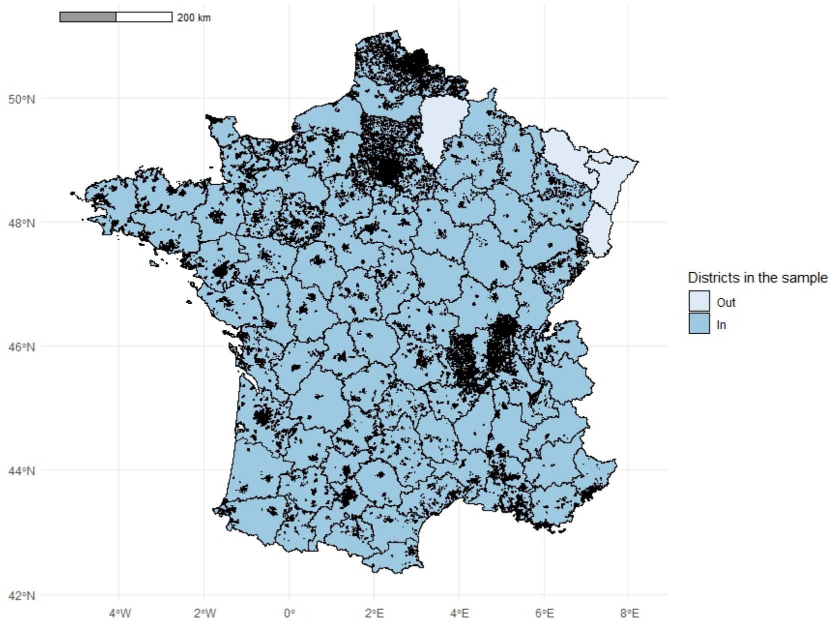


Figure 2.2: Districts in the sample and FTTH eligibility areas at the end of 2019: 90 districts are included in the analysis. Some departments shown in light blue are not included in the sample. The Direction Générale des Finances Publiques, which produces the 'Demande de Valeurs Foncières' data, does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

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

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

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.

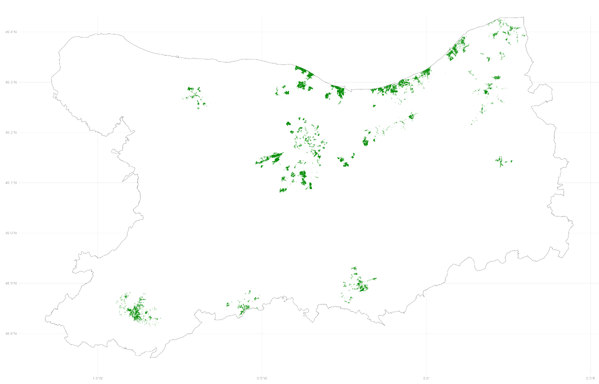
The second dataset used was the "Demande de Valeurs Foncières" (Land Value Request) database, which is published and produced by the French General Directorate of Public Finance. This database provides information on property transactions that occurred in metropolitan France over the last five years, 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,

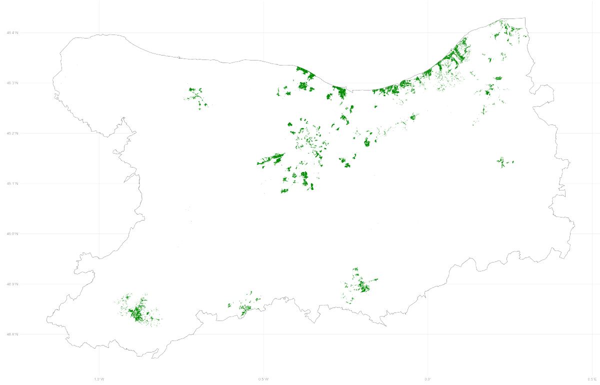
[21] For all the map processing functions, I used the package sf and the package "qgisprocess" which allows the use of the commands of the software QGIS (Open Source geographic information system) with the interface R.

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

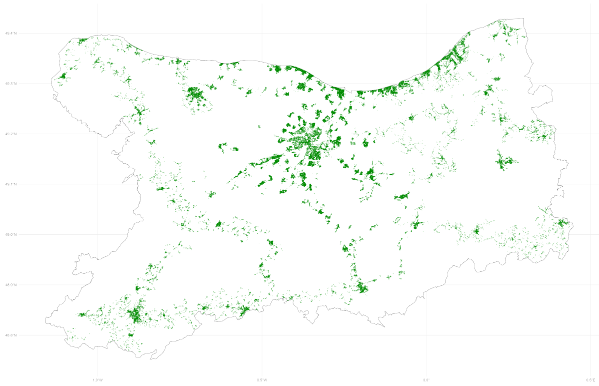
[23] This data is sourced from the OpenStreetMap project, an open-source initiative for community-driven mapping. It is provided at the departmental level, with department boundaries based on the "Contours des départements français" from OpenStreetMap. The "buildings.shp" file details built-up ar-



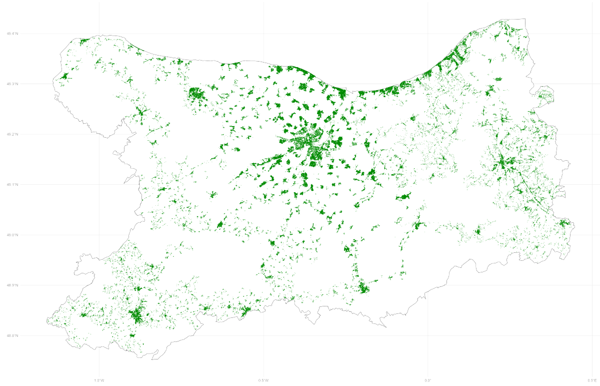
(1) Q2-2018



(2) Q2-2019



(3) Q2-2020



(4) Q2-2021

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

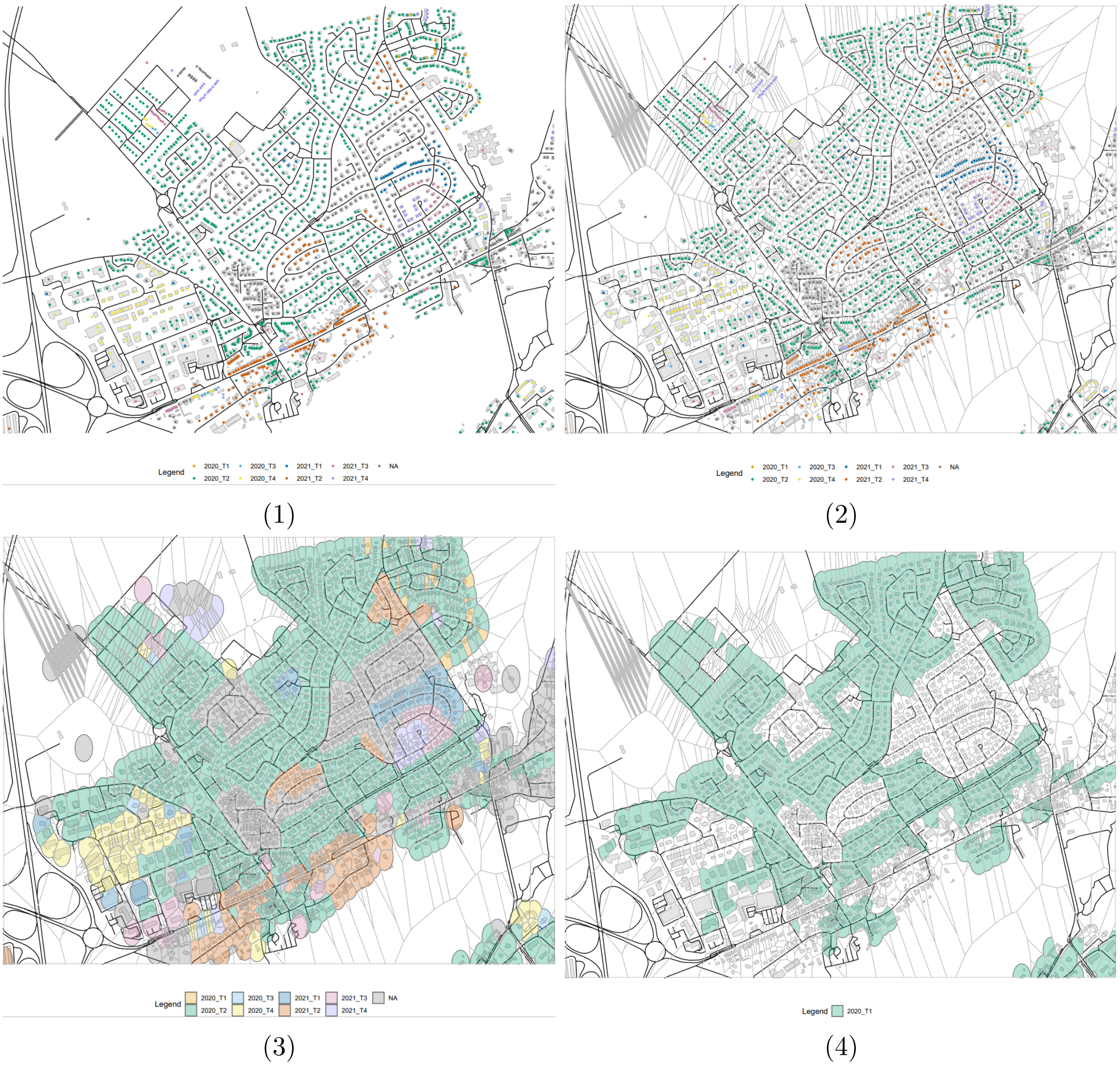


Figure 2.4: Method for constructing FTTH eligibility boundaries: The series of four maps illustrates the methodology employed to merge an exhaustive set of quarterly databases, spanning Q2-2018 to Q4-2021, at the address level for the entire metropolitan French territory, encompassing 90 departments. 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-c
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:

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

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

To summarize, this specification encompasses the logarithm of property price as a function of FTTH eligibility, along with a range of partially observed and unobserved internal property characteristics. Employing a non-parametric approach, the analysis focuses on properties located within a close proximity to the deployment boundary, explicitly leveraging the spatial discontinuities in FTTH eligibility and their impact on bandwidth speed. By

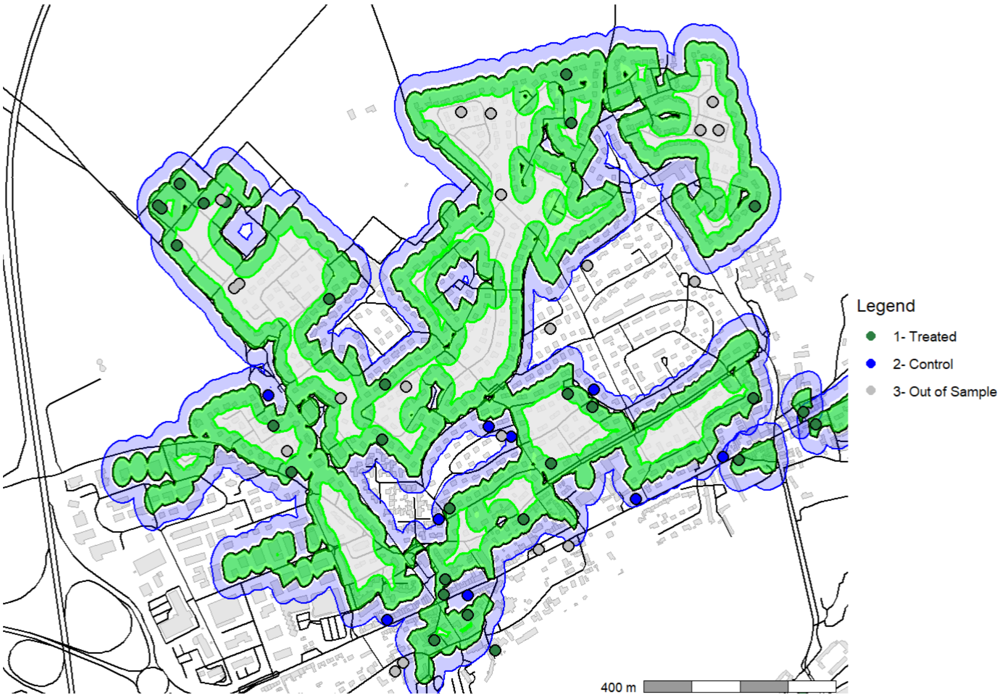


Figure 2.5: Map depicting the spatial distribution of property transactions and FTTH eligibility zones in Bretteville-sur-Odon (14760). The green zone demarcates FTTH eligibility, with the intensified green bandwidth (ranging from 7.5 m to 35 m) signifying properties incorporated into the treatment group 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

[26] To 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 characteristics[27] (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

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

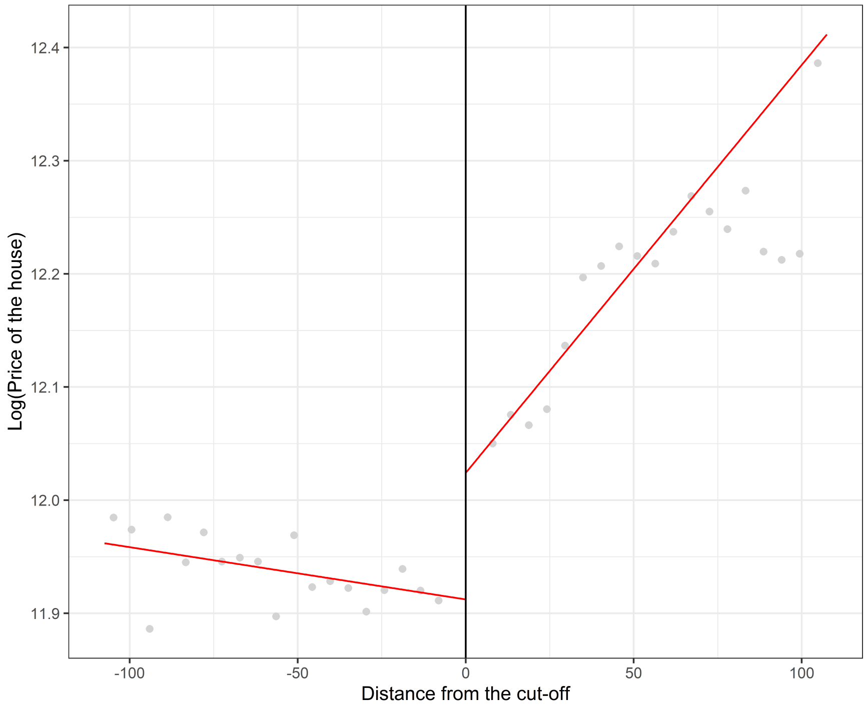


Figure 2.6: This figure illustrates the spatial discontinuities in property prices based on FTTH eligibility. Negative distances indicate locations within the boundary segment that are not eligible for FTTH technology. The dots represent the mean transaction prices within 5-meter distance bins. The sample 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%. 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 in home values attributable to fiber eligibility in Wisconsin, USA, while Whitacre (2023)

Table 2.2: Pricing results

	Log(price)		
	(1)	(2)	(3)
FTTH	0.016***	0.015***	0.009***
	(0.003)	(0.003)	(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).

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 Robusteness

I conduct some further checks to validate the positive and significant effect of FTTH eligibility on housing prices. Specifically, a sensitivity analysis was performed to ascertain that our findings remain consistent across different analytical windows, defined by varying distances from the eligibility boundary (the cut-off). 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.

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

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

Table 2.3: Pricing results by urban–rural subsamples

	Log(price)				
	(1)	(2)	(3)	(4)	(5)
FTTH	0.038**	0.027**	0.025***	-0.001	0.014***
	(0.019)	(0.013)	(0.008)	(0.007)	(0.004)
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	0.020***	0.026***
	(0.010)	(0.012)	(0.006)	(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. Subgroups of properties have been constructed according to the FTTH deployment rate in the municipality as of Q2-2020. Regression models were estimated for sub-samples with different FTTH deployment rates: less than 60% of eligible dwellings in the municipality (1), less than 80% (2), less than 90% (3), and more than 90% (4). As Table 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***	0.022**	-0.001	0.001
	(0.007)	(0.009)	(0.009)	(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**	0.008	0.004	0.016**
	(0.007)	(0.005)	(0.007)	(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***	0.006*	-0.006
	(0.004)	(0.004)	(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.

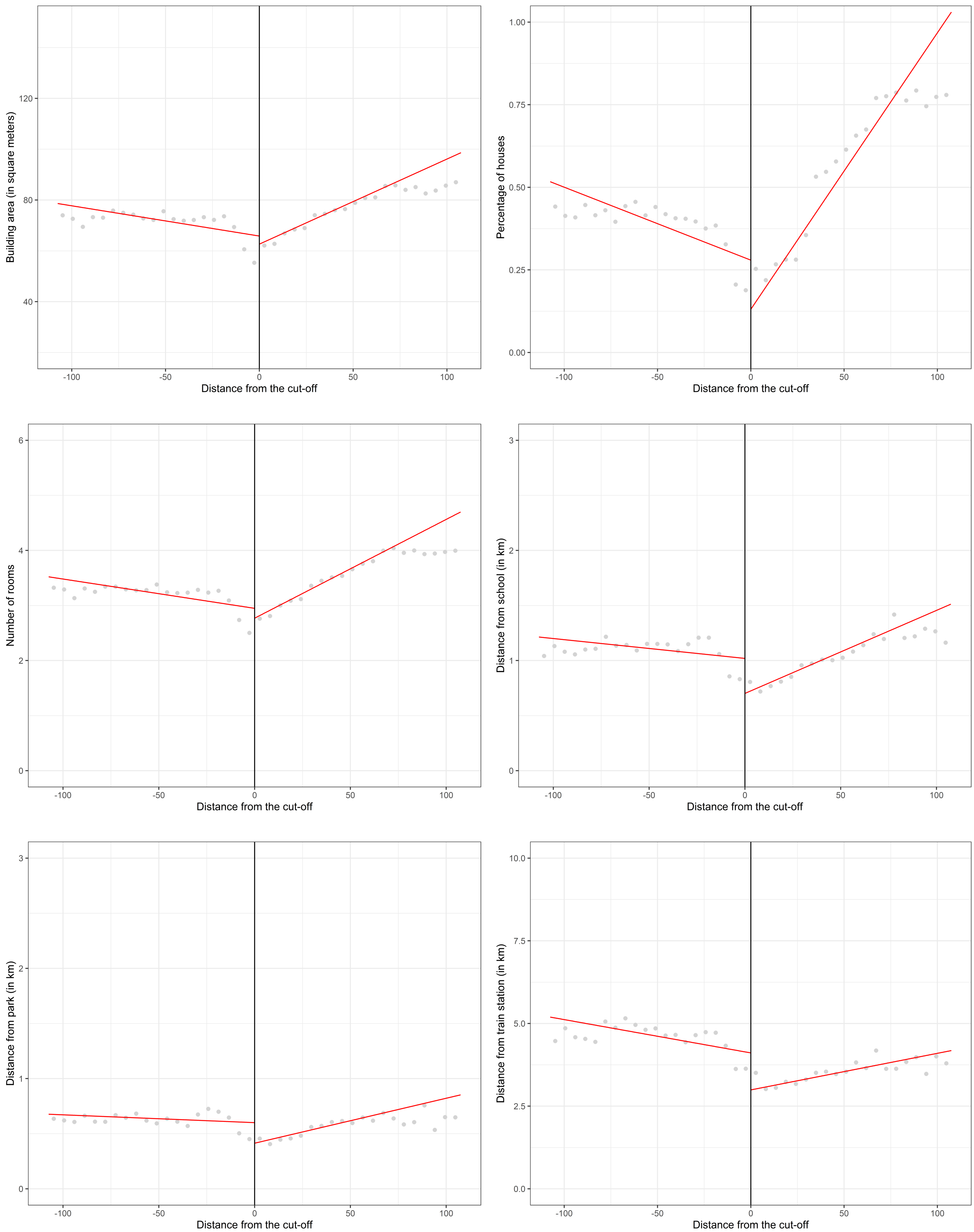

Figure 2.7: This figure illustrates the spatial discontinuities in property covariates (building and land area, number of rooms and distance from the nearest school) based on FTTH eligibility. Negative distances indicate locations within the boundary segment that are not eligible for Fiber to the Home (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.

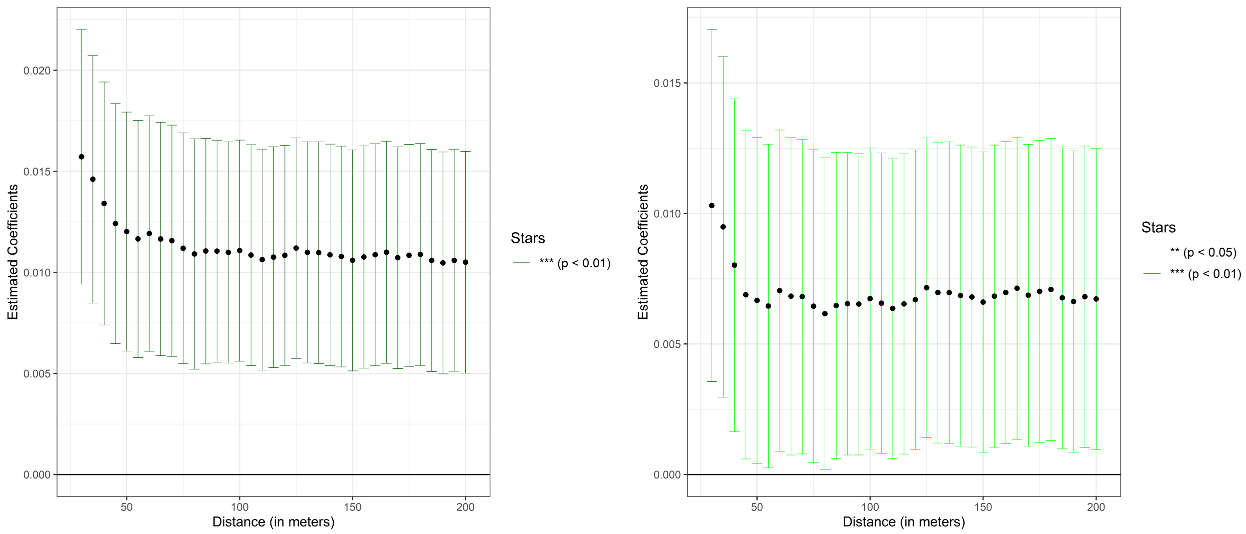

Figure 2.8: Sensitivity Analysis of FTTH Impact on Property Prices: This figure demonstrates the variability of the coefficient associated with FTTH eligibility and its effect on property transaction values. The analysis window is systematically adjusted in five-meter increments, ranging from 30m to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

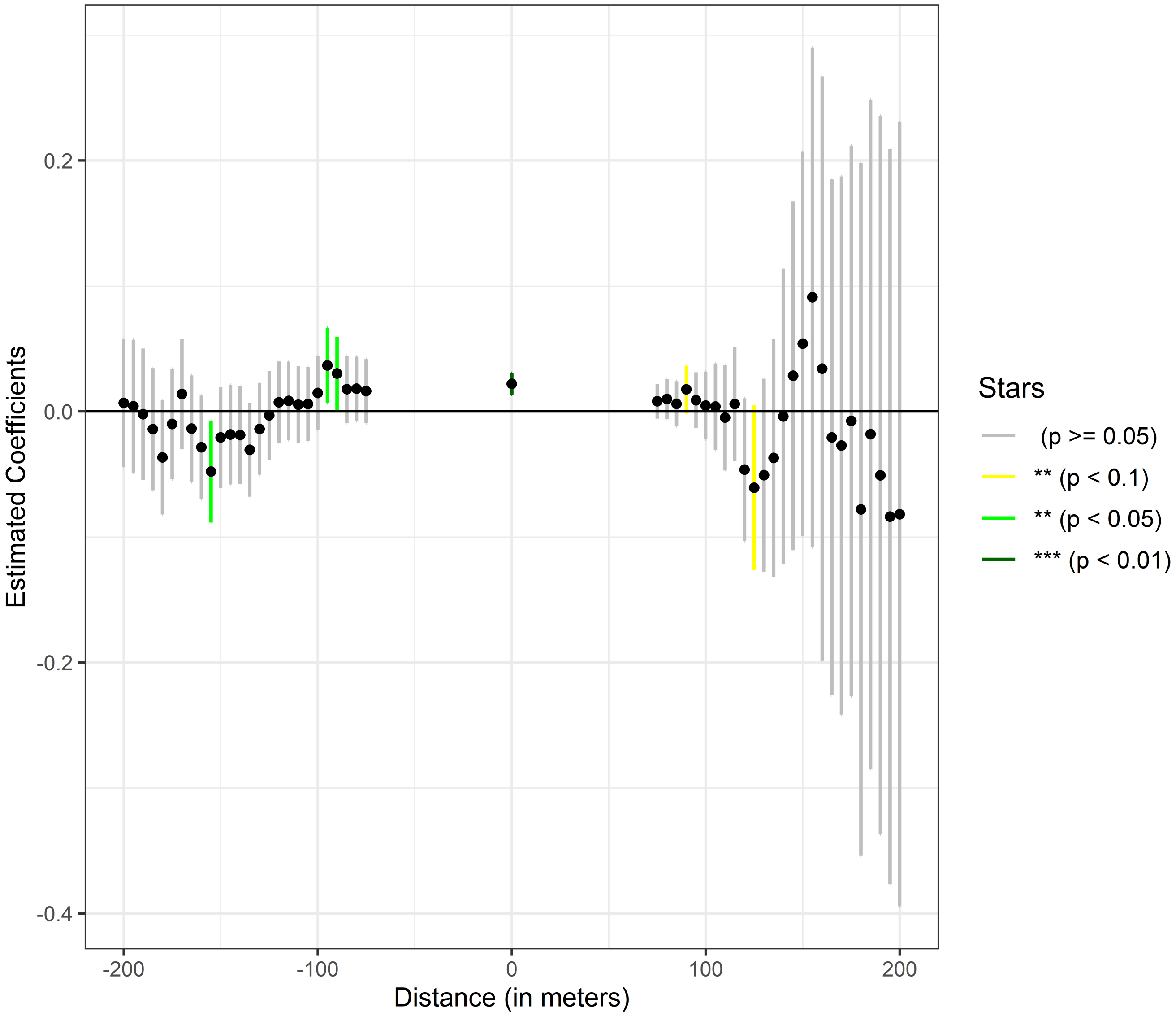

Figure 2.9: Placebo test: each estimation is estimated by shifting the cut-off on both sides of the border and performing the same estimation procedure as in Table (2), but this time assigning either a false treatment or a false control group (with a 35m boundary window on both side of the false cut-off). 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	0.030**	0.023**	-0.002	0.019***
	(0.021)	(0.013)	(0.010)	(0.008)	(0.005)
bad_ADSL	-0.042	0.075*	-0.007	0.008	-0.003
	(0.046)	(0.041)	(0.017)	(0.014)	(0.010)
FTTH × bad_ADSL	0.077**	-0.023	0.015	-0.002	-0.011
	(0.037)	(0.038)	(0.017)	(0.014)	(0.010)
Quarter	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	-0.014	0.022	0.008	0.023**
	(0.041)	(0.027)	(0.022)	(0.017)	(0.011)
distance_NRA	-0.024	0.017	0.020*	0.010	-0.008
	(0.035)	(0.017)	(0.011)	(0.010)	(0.010)
FTTH × distance_NRA	0.001*	0.000*	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Quarter	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***	0.015***	0.010***
	(0.003)	(0.003)	(0.003)
Recent	0.091***	0.098***	0.097***
	(0.008)	(0.014)	(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 to assess the influence of mobile broadband Internet quality and other infrastructure and delegation characteristics on firm location decisions. 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. 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 location ; 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 Internet[1], 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 also has significant potential to reshape territorial morphology and influence spatial inequalities. Specifically, its capabilities could reduce the importance of geographical distance in economic activities. Toffler and Alvin, 1980 and Naisbitt, 1996 anticipated a reduced dependency on urban centers, suggesting that advances in information technology could mitigate many traditional urban functions by lowering transportation and communication costs and potentially reducing the need for face-to-face interactions (Gaspar and Glaeser 1998). For example, Internet users can access many of the benefits typically associated with urban locations without physically residing in them.

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

[1] The 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.

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 location. 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 countries[2], 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 by the launch of the Tunisia National Digital Strategy 2021-2025, which aims to amplify digital integration across various sectors[4]. Tunisia ranks among the leaders in Internet use within Africa and the MENA region, with 79% of individuals connected to the Internet[5]. 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 Ookla[6]. 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 2023[7] — as well as Tunisia for which it is a major challenge as highlighted by the ongoing efforts in the government's white zone coverage program[8]. The particularities of the Tunisian context pave the way for

[2] https://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

[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

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)), we examine the determinants that influence business location in Tunisia, focusing on the role of mobile broadband telecommunications infrastructure. We seek to dissect the nuanced effects of mobile broadband on firms' location choices, 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 the location decisions of these newly established firms, our study seeks to unravel how the quality of mobile broadband shapes the economic landscape at a local level, offering insights into how technological infrastructure can be utilized for regional development. This methodological shift addresses the issue of endogeneity arising from the non-random allocation of telecom infrastructures.

The core of our analysis rests on a count model 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.

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.

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 firms' location choices, 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

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&câĂę

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 seeking to analyze how technological infrastructure affects 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 shows 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 shows 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. Caldarola et al. 2023 also finds positive 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 highlights 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.

3.3 Data on firms' location choices and their determinants and the role of mobile broadband infrastructures

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 both 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.

To investigate this topic, we have constructed a panel database that aggregates the number of new firms alongside various characteristics of the area they choose to locate in for each administrative unit over several years. We specifically focus on assessing the quality of mobile broadband infrastructures using available data, aiming to discern their influence on firms' locational decisions. 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 The Firms' Location Choices

231,056 companies have been created between 2017 and 2021 in Tunisia, according to the Registre National des Entreprises (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,

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

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. 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.

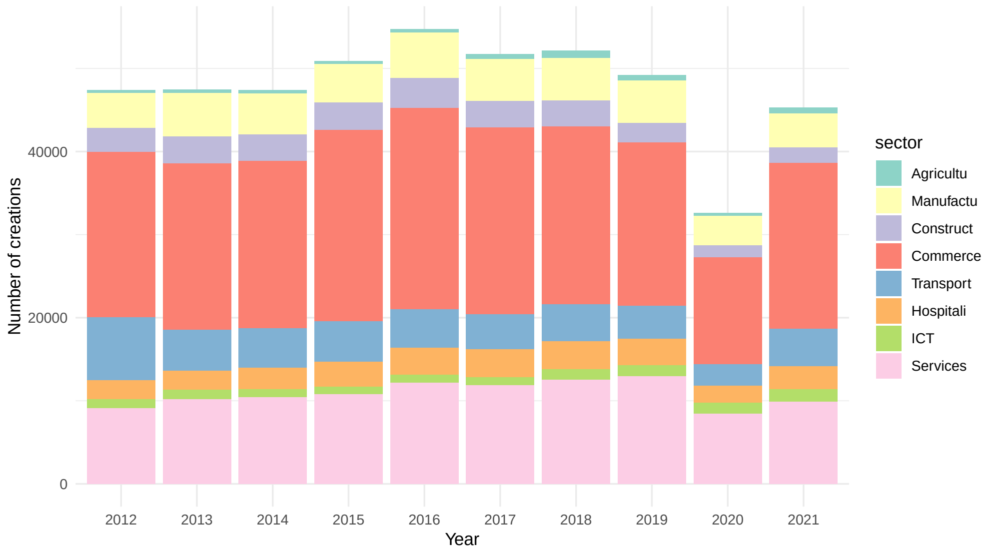

Figure 3.1: Number of business creation by year and sector

The unit of analysis: the delegation

At the time of their creation, each firm declares an address[9]. 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

[9]Only governorate and delegation IDs are available in the RNE.

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.

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

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 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.

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	4294.969	2031.792	1734.666	9389.617
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

Agglomeration and competition

We used data from the Registre National des Entreprises (RNE) to measure agglomeration and competition effects. We constructed two primary variables to capture these phenomena: The first variable represents the pre-existing number of firms operating in each delegation per year. This variable aims to capture both 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:

$$s_{jit} = \frac{LF_{jit}}{\sum_{j=1}^{J} LF_{jit}} \tag{3.1}$$

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:

$$HHI_{it} = \sum_{j=1}^{J} (s_{jit} \times 100)^2 \tag{3.2}$$

The index ranges from 0 to 10,000. An index approaching zero indicates a relatively diversified employment structure across sectors, whereas a value approaching 10,000 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.[10] 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) 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

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

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 services[11]. The origins of the Tunisian telecommunications market traced back to the promulgation of Law No. 36 on April 17, 1995, which established the Office National des Télécommunications[12], 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 infrastructure[13]. 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 use[14]. Following the issuance of 4G licenses in 2015, the rollout of 4G antennas

[11] This 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)

[12] https://www.pist.tn/jort/1995/1995F/Jo03395.pdf, accessed in May 2024.

[13] https://intt.tn/upload/files/Consultation%20publique%204G%20-%20Synth%C3%A8se%20des%20contributions.

accessed in May 2024

[14] Two surveys conducted by the National Telecommunications Authority (INT) support this observation.

was rapid, covering 54% of the population by 2016 and reaching 70.4% by 2021[15]. 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.

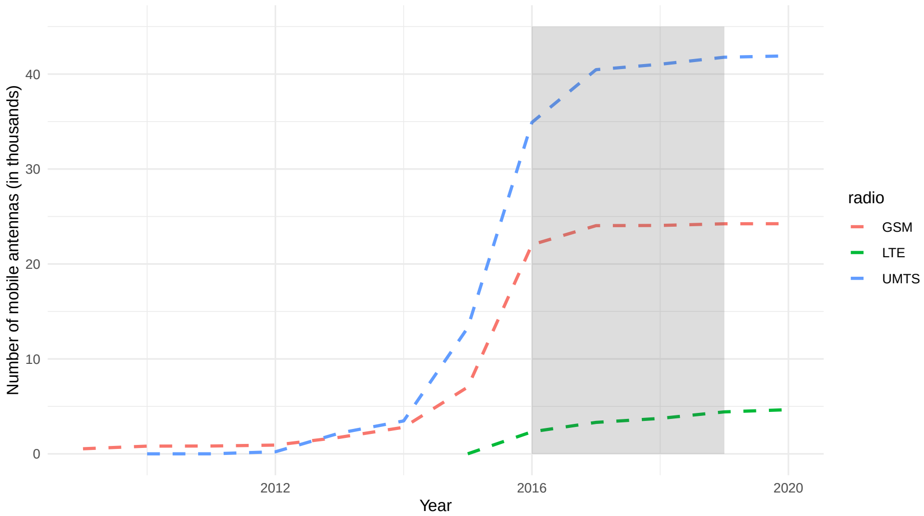

Figure 3.3: Evolution of the number of antennas by technology and year in Tunisia (OpenCellID). Each curve shows the cumulative growth of new antennas referenced in the OpenCellID database, categorized by technology. GSM (Global System for Mobile Communications) represents 2G technology, UMTS (Universal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

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.

[15] https://www.speedchecker.com/products/cellular-coverage-datasets.html, accessed in May 2024

OpenCell-ID[16] 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, LTE[17]) 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 :

$$MBB_{it} = \frac{Number\ of\ 4G\ antennas_{it}}{Population_{it}/10000} \tag{3.3}$$

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

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

[16]https://opencellid.org/

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

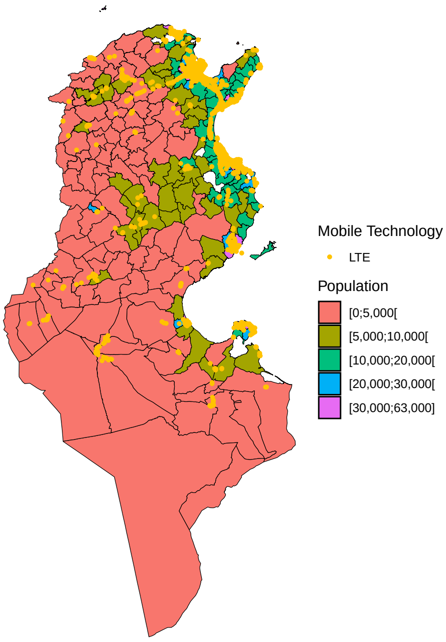

Figure 3.4: Population by Delegations and 4G antennas location

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.

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 location decisions (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 potential[18].

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. A critical challenge in our analysis is the potential endogeneity

[18]The information available in the national business register corresponds to the delegation in which the company has registered.

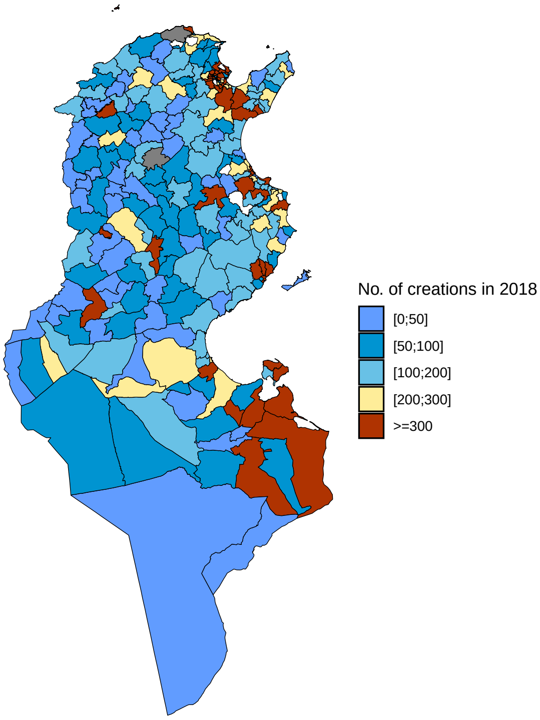

Figure 3.5: Number of firm creations by delegations in Tunisia in 2018

of broadband's impact on firm creation and economic growth. To mitigate this, we adopt the argument 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].[19] The Poisson model is robust to various relationships between variance and mean and doesn't require overdispersion correction[20]. 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 location decisions in Tunisia, considering various economic and demographic factors.

Our empirical analysis exploits a comprehensive database covering 262 delegations across

[19] The Negative Binomial with Fixed Effects model is used as a robustness test.

[20] https://www.statalist.org/forums/forum/general-stata-discussion/general/1539401-testin-overdispersion-in-negative-binomial accessed in March 2024.

Tunisia over a five-year period from 2017 to 2021 and involves the estimation of the following model:

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

Y_{it} represents the count of new establishments created in delegation i at time t. MBB_{it-2} is the variable of interest, serving as a proxy for the quality of mobile broadband Internet in delegation i at time $t-2$.[21] The primary outcome measure is the number of 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.

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. Column (1) summarizes the analysis conducted across the entire sample. In these principal analyses, the effect of mobile broadband telecom infrastructure quality, along with all other explanatory variables, is assessed using a two-period lag.

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 formation. 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 ($e^{0.009}$).[22] This finding underscores the critical importance of high-quality mobile broadband networks in influencing the locational decisions of new businesses. As a robustness test, we used several estimation methods. To

[21] Other lags of this variable are utilized as a robustness test.

[22] The incidence rate ratio converts regression coefficients into more interpretable percentages.

ensure the robustness of these findings, we employed several estimation methods. As documented in Table 3.6 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.

Table 3.3: Digital Divide (All, Rural, Urban)

variables	**(1)**	**(2)**	**(3)**
4G density	0.009***	0.049***	0.005***
	(0.002)	(0.009)	(0.001)
Mean Educ	0.087**	0.057	0.090**
	(0.040)	(0.096)	(0.044)
Mean Wage (100 dinars)	-0.086***	-0.192***	-0.041*
	(0.023)	(0.027)	(0.024)
Mean Unemployment	0.022***	0.021***	0.028***
	(0.004)	(0.006)	(0.005)
Population (1000 hab)	-0.0004	0.031*	-0.011**
	(0.005)	(0.017)	(0.004)
N. Firms (1000 firms)	-0.071***	-0.187***	-0.036*
	(0.02.1)	(0.038)	(0.019)
Spatial HHI	0.000014	-0.000006	0.000045
	(0.000015)	(0.0000016)	(0.000028)
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. 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: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

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 levels of density. 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 is necessary for companies to recognize and value the benefits of 4G telecom infrastructures at the time of their establishment, with their valuation progressively increasing as infrastructure density grows. 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.

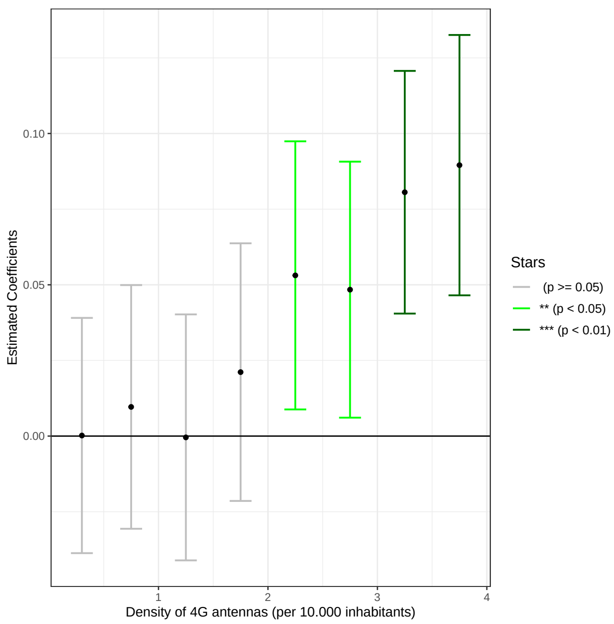

Figure 3.6: Estimations by 4G antennas density

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. Market size, as measured by population, does not seem to have any effect on firms' location choices 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 the choice of location. 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 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.

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 infrastructure[23]. To address the variability in rural and urban contexts, columns (2) and (3) of Table 3.3 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. The comparison between these columns reveals the difference in valuation between rural and urban areas. Column (2) 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 business creation by 4.9%. 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 which companies start to value positively. 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 cen-

[23]According 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.

ters 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.

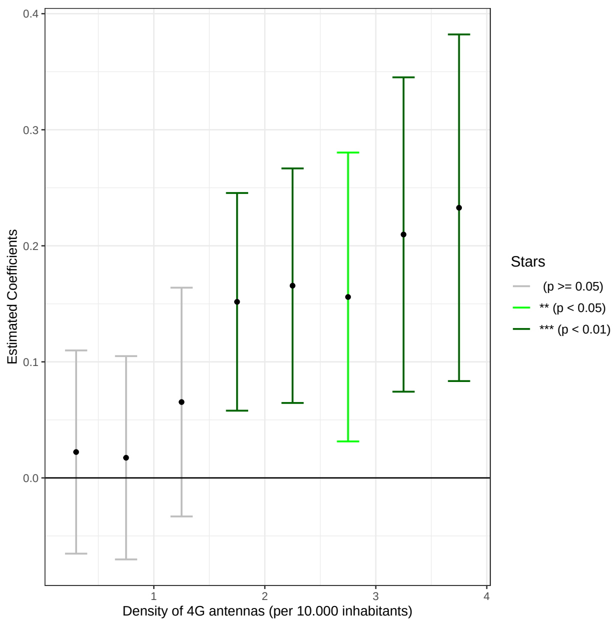

Figure 3.7: Estimations by 4G antennas density in Rural Areas

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.[24] Surrounding each centroid, we established three concentric buffer zones to delin-

[24]The 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 3.4: Digital Divide (Groups of distances)

variables	**(1)**	**(2)**	**(3)**
4G density	0.006***	0.030***	0.014
	(0.001)	(0.006)	(0.014)
Mean Educ	0.073	0.200**	0.034
	(0.054)	(0.096)	(0.104)
Mean Wage (100 dinars)	-0.057*	-0.267***	-0.143***
	(0.033)	(0.063)	(0.044)
Mean Unemployment	0.022***	0.031***	0.029***
	(0.646)	(0.814)	(0.824)
Population (1000 hab)	-0.006	0.0346*	-0.0002
	(0.005)	(0.020)	(0.026)
N. Firms (1000 firms)	-0.056***	-0.303***	-0.072
	(0.021)	(0.096)	(0.131)
Spatial HHI	0.000087*	.000019	0.000006
	(0.000044)	(0.000031)	(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 3.4, 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. 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 3.7. 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 3.9, 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).[25] We constituted eight distinct sectors: agriculture and min-

[25] This 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).

ing, manufacturing, construction, commerce, transport, hospitality, ICTs, and services.[26]

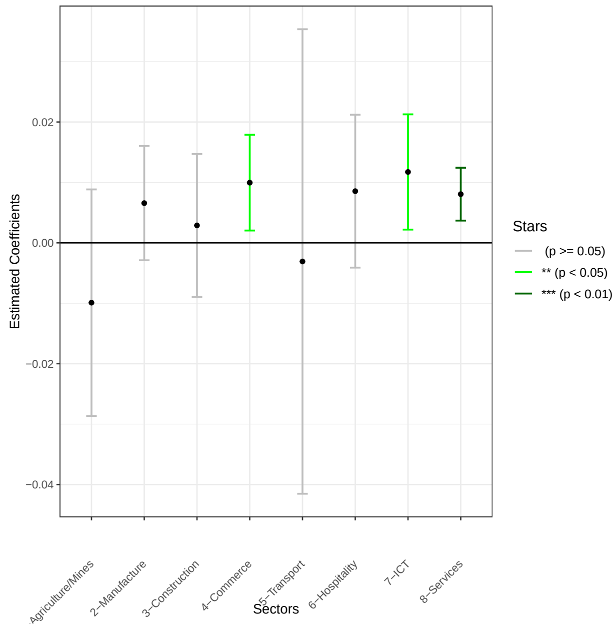

Figure 3.8: Estimation by sector

This sectoral breakdown reveals the differential impacts of mobile broadband network quality on business creation across sectors. 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 only for the creation of establishments in the commerce, ICT and services sectors. These 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 0.9% in commerce and by 0.8% in services. The ICT sector experiences an even more pronounced effect; here, the same increase in 4G antenna density leads to a 1.1% rise in the rate of new ICT business establishments. We see no significant effect for other sectors. 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. Detailed results for each sector-level regression are given in the appendix in Table 3.10 and Table 3.11.

[26]Utilizing 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.

3.6 Conclusion

In this study, we employed a count model methodology 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 the count model for each category. Furthermore, we assessed the impact of mobile broadband on firm creation 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, while in rural areas, this effect rises to 4.9%. 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 services, trade, 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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3.8 Appendix

Table 3.5: Number of firm creations 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

Table 3.6: Various estimation methods (Poisson FE, Panel FE, Negative binomial FE)

variables	**(1)**	**(2)**	**(3)**
4G density	0.009***	2.824***	0.005*
	(0.002)	(0.924)	(0.003)
Mean Educ	0.087**	21.415***	0.163***
	(0.040)	(6.496)	(0.031)
Mean Wage (100 dinars)	-0.086***	-9.957***	-0.173***
	(0.023)	(2.664)	(0.014)
Mean Unemployment	0.022***	0.027***	0.016***
	(0.371)	(52.526)	(0.288)
Population (1000 hab)	-0.004	-2.571*	0.002
	(0.005)	(1.376)	(0.002)
N. Firms (1000 firms)	-0.07***	-84.073***	0.03**
	(0.021)	(11.245)	(0.014)
Spatial HHI	0.000014	-0.000463	0.000015
	(0.000015)	(0.001757)	(0.000012)
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 3.7: One year-lag (All, Rural, Urban)

variables	**(1)**	**(2)**	**(3)**
4G density	0.007***	-0.004	0.004*
	(0.003)	(0.017)	(0.002)
Mean Educ	0.076*	0.024	0.084*
	(0.041)	(0.094)	(0.044)
Mean Wage (100 dinars)	-0.074***	-0.143***	-0.031
	(0.023)	(0.031)	(0.023)
Mean Unemployment	0.021***	0.019***	0.028***
	(0.004)	(0.006)	(0.005)
Population (1000 hab)	-0.009*	0.013	-0.014***
	(0.05)	(0.024)	(0.004)
N. Firms (1000 firms)	-0.043**	-0.112**	-0.015
	(0.021)	(0.048)	(0.015)
Spatial HHI	0.000015	-0.000002	0.000046
	(0.000016)	(0.000015)	(0.000028)
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 3.8: Three years lagged Digital Divide (All, Rural, Urban)

variables	**(1)**	**(2)**	**(3)**
4G density	0.006***	0.025**	0.003**
	(0.002)	(0.010)	(0.001)
Mean Educ	0.098**	0.037	0.096**
	(0.040)	(0.096)	(0.045)
Mean Wage (100 dinars)	-0.079***	-0.16***	-0.034
	(0.021)	(0.029)	(0.023)
Mean Unemployment	0.022***	0.021***	0.029***
	(0.004)	(0.005)	(0.005)
Population (1000 hab)	-0.006	0.024	-0.012***
	(0.005)	(0.019)	(0.005)
N. Firms (1000 firms)	-0.057***	-0.16***	-0.023
	(0.02)	(0.045)	(0.018)
Spatial HHI	0.000014	-0.000005	0.000045
	(0.000015)	(0.000016)	(0.000028)
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 3.9: Digital Divide (All, Urban, Rural) - Interaction 4G Density and distance to post

variables	**(1)**	**(2)**	**(3)**
4G density × Distance Post	-0.0000019***	-0.0000029**	-0.0000009
	(0.0000005)	(0.0000014)	(0.0000009)
Mean Educ	0.084**	0.032	0.087*
	(0.040)	(0.093)	(0.045)
Mean Wage (100 dinars)	-0.072***	-0.145***	-0.032
	(0.023)	(0.030)	(0.023)
Mean Unemployment	0.021***	0.018***	0.028***
	(0.371)	(0.553)	(0.490)
Population (1000 hab)	-0.007	0.019	-0.013***
	(0.005)	(0.021)	(0.004)
N. Firms (1000 firms)	-0.048**	-0.138***	-0.017
	(0.021)	(0.041)	(0.016)
Spatial HHI	0.0000167	-0.0000911	0.0000461
	(0.0000156)	(0.0000016)	(0.0000282)
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 meters). 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 3.10: Establishment creation in the agricultural, manufacturing, construction, and commerce sectors

	(1)	(2)	(3)	(4)
4G Density	-0.010	0.007	0.003	0.010**
	(0.010)	(0.005)	(0.006)	(0.004)
Mean Educ	0.477	-0.107	-0.073	0.235***
	(0.456)	(0.092)	(0.158)	(0.090)
Mean Wage (100 dinars)	0.186	-0.114**	-0.203**	-0.172**
	(0.211)	(0.046)	(0.084)	(0.073)
Mean Unemployment	0.013***	0.082***	0.063***	0.039***
	(3.332)	(0.862)	(1.495)	(1.018)
Population (1000 hab)	-0.093	-0.023*	-0.043**	0.012
	(0.07)	(0.013)	(0.017)	(0.011)
N. Firms (1000 firms)	-0.219	-0.006	-0.066	-0.111**
	(0.165)	(0.051)	(0.061)	(0.047)
Spatial HHI	0.000469**	0.000039	0.000026	-0.000063*
	(0.000225)	(0.000034)	(0.000091)	(0.000033)
Year FE	Yes	Yes	Yes	Yes
Delegation FE	Yes	Yes	Yes	Yes
N. Obs	1310	1310	1310	1310
Delegations	262	262	262	262

Note: The sample consists of 262 delegations over a 5-year period. In each column, the outcome corresponds to the number of firm creations within a specific sector. Column (1) represents agriculture and mining, column (2) industry, column (3) construction, and column (4) commerce. Standard errors are clustered at the delegation level in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 3.11: Establishment creation in the transport, hospitality, ICT and services sectors

	(5)	(6)	(7)	(8)
4G density	-0.003	0.009	0.012**	0.008***
	(0.020)	(0.006)	(0.005)	(0.002)
Mean Educ	0.146	0.102	0.137	0.004
	(0.216)	(0.134)	(0.119)	(0.070)
Mean Wage (100 dinars)	-0.0006	-0.0916	0.0471	-0.121***
	(0.0014)	(0.089)	(0.065)	(0.044)
Mean Unemployment	0.023	0.063***	0.019	0.027***
	(1.715)	(1.591)	(1.730)	(0.702)
Population (1000 hab)	-0.026	-0.014	0.016	-0.009
	(0.057)	(0.022)	(0.017)	(0.01)
N. Firms (1000 firms)	-0.002	-0.128*	-0.025	-0.014
	(0.204)	(0.070)	(0.039)	(0.023)
Spatial HHI	0.000184**	0.000055	-0.000007	0.000022
	(0.000082)	(0.000058)	(0.000097)	(0.000038)
Year FE	Yes	Yes	Yes	Yes
Delegation FE	Yes	Yes	Yes	Yes
N. Obs	1310	1310	1310	1310
Delegations	262	262	262	262

Note: The sample consists of 262 delegations over a 5-year period. In each column, the outcome corresponds to the number of firm creations within a specific sector. Column (5) represents transport, column (6) hospitality, column (7) ICT, and column (8) services. Standard errors are clustered at the delegation level in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.