PhD Pre-Defense of Jean-Baptiste GUIFFARD

Essays in Digital Economics: Three Impact Evaluations of Broadband Internet

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Ph.D Pre-Defense in Paris-1

Objectives of the PhD Pre-Defense

- Mandatory Before the Final Defense
- Conducted privately with the jury members:
  - Jenny Aker, Tufts University (Reviewer)
  - Marc Bourreau, Telecom Paris - Polytechnic Institute of Paris (President)
  - Joël Cariolle, FERDI (Examiner)
  - François Combarnous, University of Bordeaux (Reviewer)
  - Georges Houngbonon, World Bank (Examiner)
  - Mohamed Ali Marouani, University of Paris 1 Panthéon-Sorbonne (Supervisor)
  - François Roubaud, Research Institute for Development (Supervisor)
- Goal: Collect feedback and critiques from the jury members

Objectives of the PhD Pre-Defense

At the End of the Pre-Defense:

- The jury provides approval for the final defense and sets a date (minimum 3-month lead time)

After the Pre-Defense:

- The doctoral candidate writes a pre-defense report summarizing the jury's feedback
- Potential coverage of expenses related to the jury

General Introduction

The Big Question

Essays in Digital Economics: Three Impact Evaluations of Broadband Internet

- At the intersection of digital and development economics, this thesis focuses on the "value" of high-speed Internet access.
- I consider the subjective conception of value, which measures an agent's interest in a good or service, resulting from an evaluation process.
- I focus on three different agents in three different contexts: households, firms, and citizens:
  - For **citizens**, measuring social and political value through the ability to mobilize (access to information and democratic participation).
  - For **households**, measuring the "Willingness to Pay" for very high-speed Internet.
  - For **firms**, the strategic value attributed to the Internet by entrepreneurs seeking to maximize their profits.

Structure of the chapters

Three main hypotheses are tested:

- Chapter 1: **From Connection to Coordination: High-Speed Internet and Protests in Africa**

  "Access to broadband internet, which allows access to new content and platforms (such as social networks), increases the likelihood of participating in a protest and the frequency of protests in Sub-Saharan Africa."

- Chapter 2: **Valuing the Virtual: The Impact of Fiber to the Home on Property Prices in France**

  "Households positively value access to very high-speed internet, but this valuation varies according to socio-economic contexts in France."

- Chapter 3: **From Bytes to Business: Mobile Broadband, Firm Creations and Digital Divide in Tunisia** (with Mohamed Ali Marouani)

  "New firms increasingly seek locations with better connectivity to harness potential competitive effects in Tunisia, but this effect can vary according to context."

Contributions of this thesis

- Multiple methods, data sources, and econometric techniques are used to address the methodological challenges of endogeneity, data availability, and the identification of causal effects when considering the impact of the deployment of broadband infrastructures.
- The thesis aims to contribute to the literature on the impact of broadband Internet on economic and social outcomes in both developed and developing countries, focusing on Sub-Saharan Africa, France, and Tunisia.
- This thesis provides technical insights into the functioning of telecommunications networks, which justify certain methodological choices.
- Additionally, heterogeneity analyses are conducted to examine the variation in the impact of broadband according to different contexts and the characteristics of economic agents.

Chapter 1

Chapter 1 - From Connection to Coordination: High-Speed Internet and Protests in Africa

Research Question and Motivations

Research Question: How does exposure to broadband internet, encompassing both fixed and mobile connections, influence political mobilization and, specifically, protest activities in Sub-Saharan Africa?

1. Impact of broadband Internet exposure on the **likelihood to participate in a protest** $\rightarrow$ Address two methodological issues:
   - Limited data availability in Sub-Saharan Africa;
   - Endogeneity due to non-random allocation of telecom infrastructure.
2. Enhancing the Hjort and Poulsen (2019) method: Incorporating an additional before and after period for trend analysis and improved technical support for the treatment
3. Unveiling the **underlying mechanisms**: Analyzing the interplay between information dissemination and coordination.
4. Objective analysis of these effects: the effect on the **frequency of protests** (through a cell analysis).

Literature

- Impact of ICTs in Developing Countries: R. Jensen (2007), Aker (2010), Aker, Ksoll, and Lybbert (2012), Jack and Suri (2014), Hjort and Poulsen (2019). . .

ICT and Governance and Political Outcomes

- Trust in institutions: Miner (2015), Guriev, Melnikov, and Zhuravskaya (2021);
- Electoral Fraud: Gonzalez (2021);
- Internet Use and Supply and Demand of Democracy: J. Cariolle, Elkhateeb, and Maurel (2022).

ICT and Mass Mobilization

- Protests: Pierskalla and Hollenbach (2013), Manacorda and Tesei (2020);
- Social networks and protests: Fergusson and Molina (2019), Qin, Strömberg, and Wu (2021).

Data

- **Backbone's location and submarine cables' activation date**
  - Infrapedia: Gives the date of arrival of the submarine cable in each country.
  - Afterfibre: Gives the route of each terrestrial Internet cable, the country where it has been deployed, and the owner telecom operator.
- **Political Attitude and Behavior: Individual Level Data from Afrobarometer**
  - Opinion polls on democracy, governance and social and economic issues;
  - Set of variables on political mobilization;
  - Control variables : age, sex, education, rural/urban.
  - Geocoded data
- **Cell-Level Characteristics**
  - VIIRS: Night lights data accurate to predict economic activity and spatial inequality in urban and rural areas.
- **Tracking Protests with Objective Data**: ACLED
- **Assessing Freedom and Democracy in Selected Countries**: Freedom House Proxy

Data

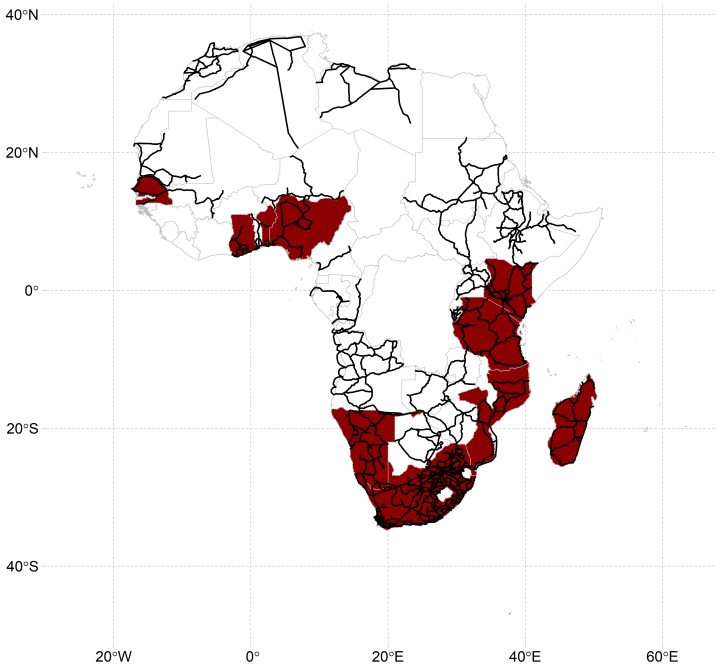


Figure 1: Countries in the sample

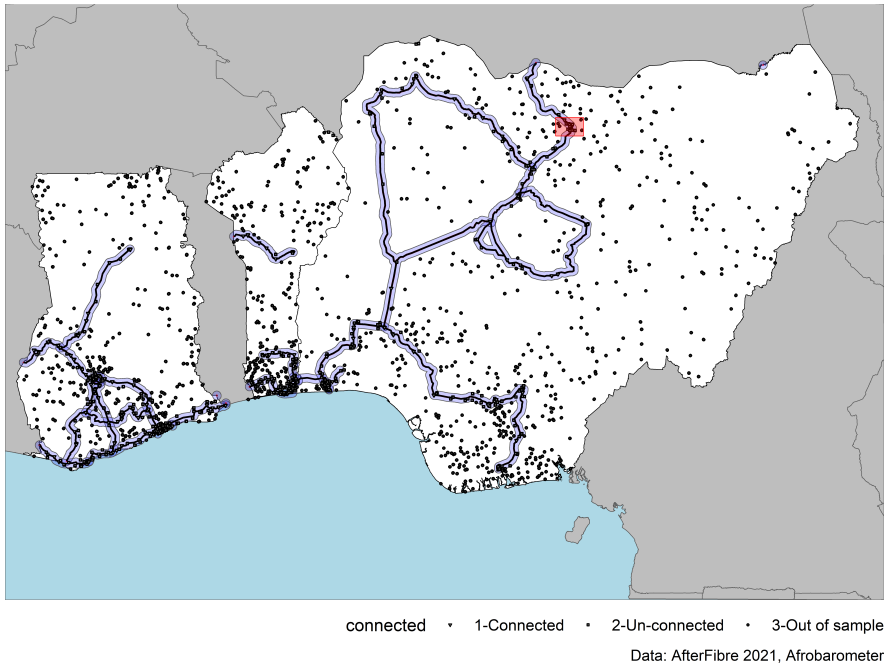


Figure 2: Focus on the gulf of guinea

Design I

Difference-in-Difference design (Hjort and Poulsen 2019):

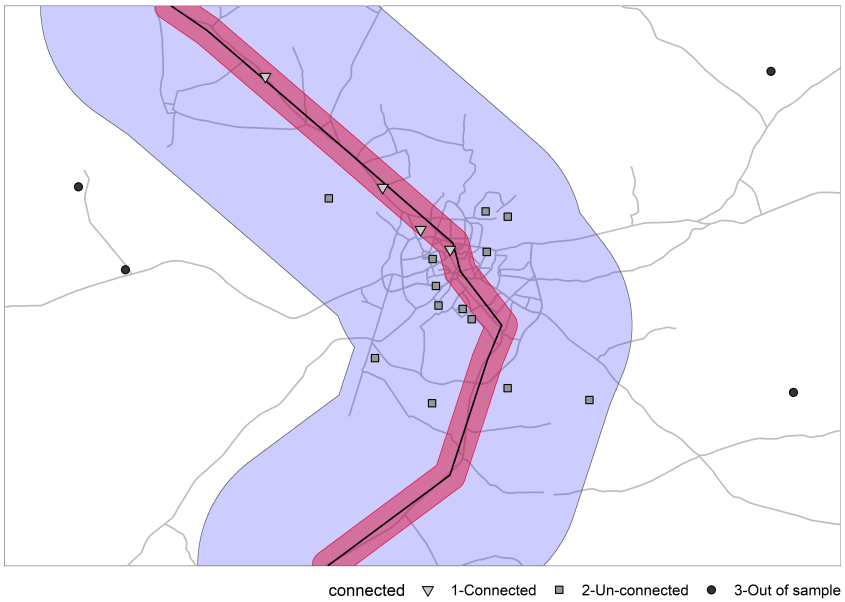


Figure 3: An illustration of the methodology with a zoom on Kano, Nigeria

- **Date of treatment**: the date of arrival of the first fiber-optic submarine cable in the country
- **Treatment**: The distance from the nearest backbone cable.
  - The treatment group consists of individuals located within 1200 meters of the nearest backbone.
  - The control group consists of those located between 1200 meters and 10kms.

Model

$$Y_{ijt} = \alpha + \beta * SubCables_{ict} * Connected_i + \delta_j * Connected_i + X_{ij} + \gamma_{ct} + \epsilon_{ijct} \quad (1)$$

where:

- Y_{ijt}: a governance outcome for individual i in cell j in country c, and time period t;
- $SubCables_{ict}$: a dummy variable indicating whether the submarine cable was in service in country c and thus whether fast Internet was available in the country at time t;
- $Connected_i$: the treatment and control group variable, based on the distance with backbone cables;
- X_{ij}: a vector of individual and cell level controls including nighttime lights intensity, urban/rural, age, gender, primary education;
- δ_j coefficient: captures time-invariant differences in governance outcomes between treatment and control groups;
- γ_{ct} gives country-specific time period fixed effect.
- ϵ_{ijct} : the error term (clustered standard error at the Cell level).

Results - The effect on Internet Use

Table 1: Submarine Cable Arrival and Internet Use

	Daily Internet Use (0/1)	
	(1)	(2)
SubCableXConnected	0.029**	0.029**
	(0.015)	(0.015)
Num.Obs.	25 402	25 402
R2	0.166	0.196
Country×Year	Yes	Yes
GADM2×Connected	Yes	-
Cell×Connected	-	Yes

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

- The arrival of the submarine cables in Subsaharan Africa increases the probability that a person will use the internet every day in the connected areas by 3pp (confirming Joël Cariolle 2021).

Results - The effect on Protests

Table 2: 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

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

- The arrival of submarine cables allowing a significant increase in the availability of broadband internet increases the probability that a treated individual will participate in a protest by about 3.8pp.

Objective measure of protests: estimating a model at the cell level, I showed that the arrival of optic-fiber submarine cables increased by 2.2 pp the chances that a protest or a riot occurred in connected cells.

Results - Mechanisms

Table 3: Estimates of the effect on the arrival of submarine cables on political attitudes

Outcomes	Estimates
Perception corruption Police	0.030*** (0.011)
Satisfied with Democracy	0.004 (0.018)
Radio	0.025* (0.013)
TV	0.004 (0.021)
Newspaper	0.004 (0.021)
Chances to Join Others to Raise an Issue	0.029* (0.016)
Interest in Public Affairs	-0.017 (0.018)
Active Member of community group	0.026* (0.015)

Information VS Coordination

- No negative effects on perception of democracy or use of traditional media (Traditional media and content available on the Internet are not substitutes)
- Positive impact on coordination for raising issues and to be an active member of a community group
- Importance of coordination (rather than information?) in explaining effects of high-speed Internet on political mobilization

Heterogeneity analysis: The findings reveal that the positive impact of increased Internet availability on protest participation is significantly positive only in countries classified with "free" traditional media (Freedom House).

Chapter 2

Chapter 2- Valuing the Virtual: The Impact of Fiber to the Home on Property Prices in France

Research Question

Research Question: How do households value access to very high-speed Internet in France?

1. Evaluate the **impact of FTTH eligibility on property prices in France** using a hedonic price model → This analysis allows for the estimation of the economic value (WTP) associated with improved broadband access.
2. Analyze **heterogeneity in household valuations** based on different factors such as the rural or urban context of the property's location, and local socioeconomic characteristics.
3. Address two methodological issues:
   - **Endogeneity**: FTTH eligibility is endogenous to factors that determine very high-speed Internet demand and are likely correlated with property prices (high levels of income, education levels...)
   - **Data challenges**: Absence of a common joining key between property transactions and FTTH eligibility datasets.

Literature

The impact of broadband Internet deployment and associated benefits:

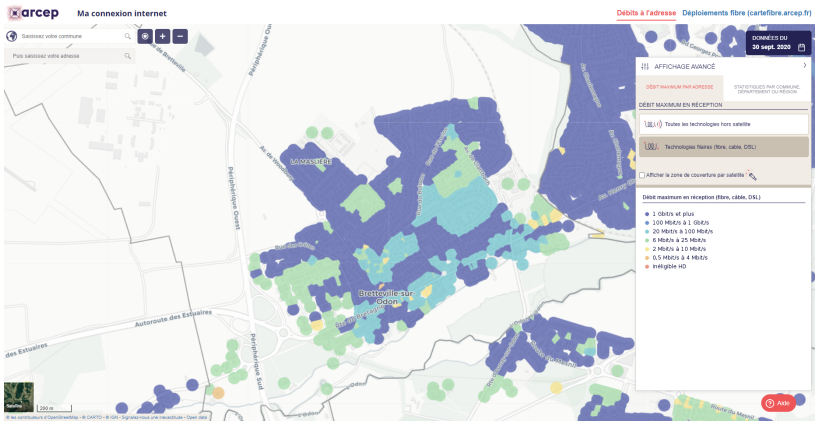
- On economic activity: Czernich et al. (2011), Kolko (2012), Briglauer and Gugler (2019).
- On inequality: Forman, Goldfarb, and Greenstein (2012), Houngbonon and Liang (2021).
- On addressing the digital divide: Clercq, D'Haese, and Buysse (2023).

The measurement of demand for high-speed Internet and FTTH consumer valuation: Ahlfeldt, Koutroumpis, and Valletti (2017), Liu, Prince, and Wallsten (2018), Grzybowski and Liang (2015), Grzybowski, Hasbi, and Liang (2018).

Capitalization effects of local public goods or nonmarket externalities (such as wind turbines and nuclear plants): Gibbons (2015), Dröes and Koster (2016); C. U. Jensen et al. (2018), Ando, Dahlberg, and Engström (2017), Tanaka and Zabel (2018).

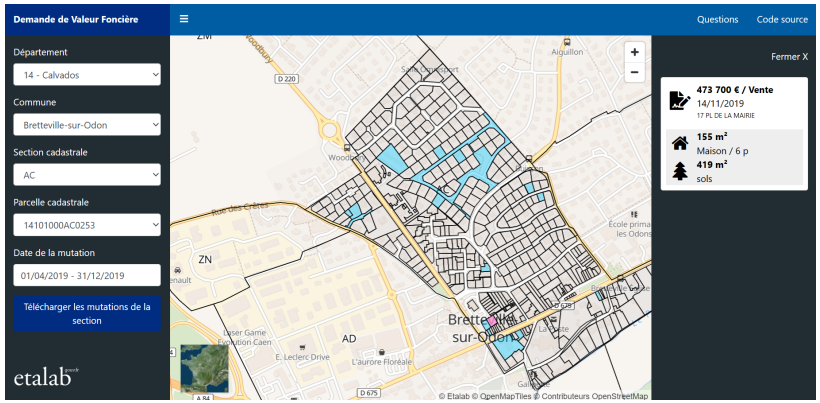
Data

Ma connexion internet



- ARCEP
- Information on fiber eligibility dates at the address level ;

Demande de Valeurs Foncières



- French General Directorate of Public Finance
- Information on property transactions that have occurred over the last five years in metropolitan France.

⇒ Addressing the absence of a common joining key: I present a method for reconstructing the FTTH eligibility areas by period

Methodology

The use of fiber eligibility zones makes it possible to use a **Spatial Discontinuity Design**.
Since the assignment rule is deterministic, this regression discontinuity adopts a sharp design (the treatment probability changes from 0 to 1 at the cutoff).

- **Hedonic regression model**: it aims at explaining the price of a good based on its intrinsic and situational characteristics.
- **Non-parametric estimation**: Naive bandwidth (35m for baseline estimates).
- **Donut RD estimation**: Addresses concerns regarding non-random sorting at the threshold and deals with issues related to the method based on maps that determines the treatment.

Figure 4: Map illustrating the methodology - Focus on eligibility zone in Bretteville-sur-Odon (14760).

Model

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

With:

- Y_{ijt}, the log price of the property at postcode i and time t associated with boundary j;
- $FTTH_{ij}$, a binary indicator that signifies whether the property sold in postcode i associated with boundary j falls within the FTTH "eligible" zone;
- X_i, a vector 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, and distance from the nearest park);
- γ_t, the time fixed-effects (quarterly);
- μ_i accounts for unobserved time-invariant effects at the postcode level.
- η_j captures the effect of proximity to the nearest boundary j of FTTH deployment at the time of the study.
- ϵ_{ijt} denotes the error term (clustered at the boundary level).

Results - The impact of FTTH eligibility on property prices

Table 4: 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

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

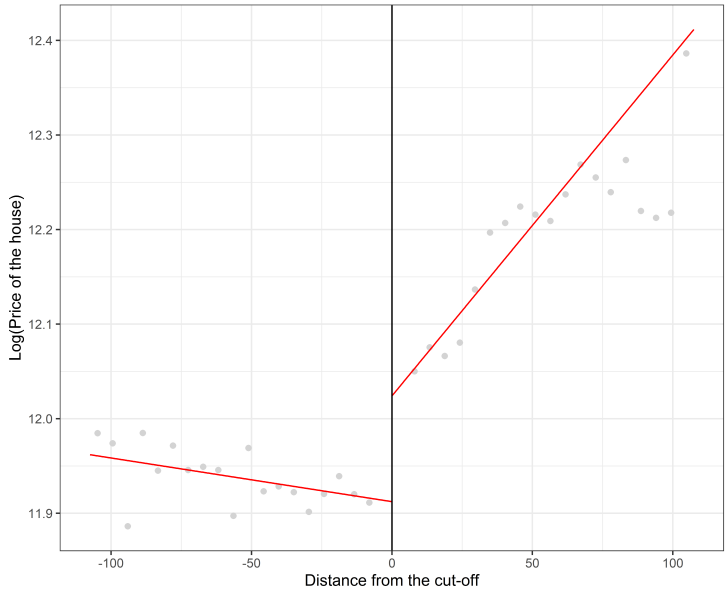


Figure 5: Graphical Analysis

- On average, FTTH-eligible properties see a price increase of 0.9% → highlighting the tangible benefits households are seeing from improved broadband infrastructure.

Results - Heterogeneity Analysis

Table 5: 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

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

- I find a stronger FTTH impact in rural areas (also I find that the poorer the pre-existing quality of ADSL speeds, the higher the value of FTTH eligibility, explaining this stronger effect).
- The impact of FTTH is notably stronger in peripheral areas compared to city centers.

Chapter 3

Chapter 3- From Bytes to Business: Mobile Broadband, Firm Creations and Digital Divide in Tunisia

Research Question and Motivations

Research Question: What is the impact of mobile high-speed Internet on business creation in Tunisia?

1. **Location Determinants**: Explore the factors influencing firms' location decisions within the unique context of a MENA country.
2. **Mobile Broadband Telecom impact**: Examine the role played by broadband telecom infrastructures in shaping firms' location choices and their subsequent growth.
3. **Contextual Heterogeneity**: Analyze heterogeneous effects of mobile broadband networks on firm creation at the local level (depending on contexts and firms characteristics) $\rightarrow$ Test the hypothesis of the **"death of distance"** (Cairncross 1997) by analyzing the implications of the digital divide.

Literature

- **Broadband, Firm Performance, and Employment**:
  - Impact of broadband Internet access on economic growth (Czernich et al. 2011; Kolko 2012; Briglauer and Gugler 2019), surpassing the influence of other ICTs (Vu 2011).
  - On employment and productivity Brynjolfsson and Saunders (2009); Draca, Sadun, and Van Reenen (2009); Atasoy (2013); Hjort and Poulsen (2019); Chen, Liu, and Song (2020); Joël Cariolle and Le Goff (2023).
- **High-Speed Internet and Firm Creation**: Kim and Orazem (2017), Deller, Whitacre, and Conroy (2022).
  - By employing **geographical economics methods to evaluate the determinants of firms' location choices**, particularly the role of broadband connectivity (McCoy et al. 2018 ; Hasbi 2020 ; Bourreau et al. 2022).
- **ICT, Inequality, and the Digital Divide**: Research indicates a stronger economic impact of public investment in integrated rural areas (Fox and Porca 2001), especially regarding broadband Internet (Whitacre, Gallardo, and Strover 2014; Kim and Orazem 2017), which can help narrow regional economic disparities (Wu, Wang, and Sun 2022).

Data

Firm location decision process? Factors influencing area attractiveness:

Variable type	Variable	Spatial Level	Frequency	Source
Firm	Firm location, sector, entry year	Delegation	2017-2021	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

Data

The quality of the mobile broadband infrastructure is measured by the number of 4G mobile antennas per 10,000 inhabitants:

$$MBB_{it} = \frac{Number\ of\ 4G\ antennas_{it}}{Population_{it}/10000} \quad (2)$$

→ This choice is based on the assumption that more antennas correspond to better network coverage and higher data transmission capacity.

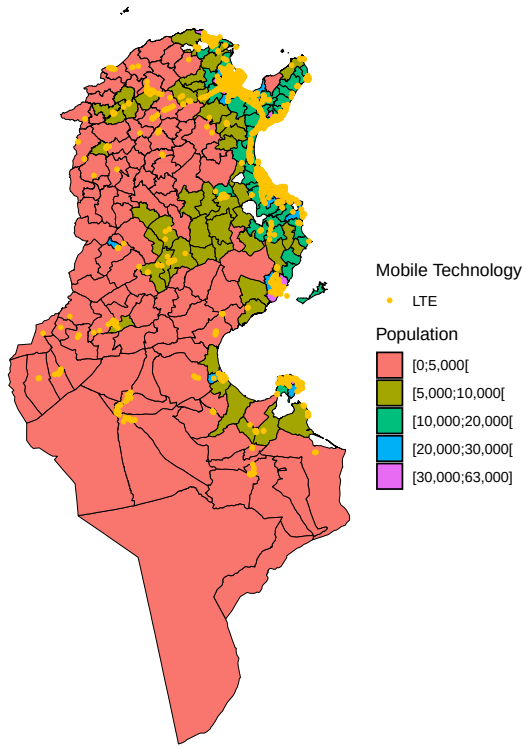


Figure 6: 4G antennas and population

Methodology

We estimate a count model where the number of new firms in a particular area in each period is modeled as a function of the characteristics of the geographical area.

- **Discrete and non-negative nature of the data**: The count data model estimated using a **Poisson model**.
- **Endogeneity**: looking at the flow of new firm formation (and not the stock of existing companies), is a way to reduce the risk of endogeneity (McCoy et al. 2018).
- **Reverse causality**: All explaining variables are 2-year lagged variables.
- **The fixed effects** are a way to control for **omitted variables** i.e. operators can have higher incentives to deploy mobile antennas in areas with favorable tax regimes or with higher demand for mobile broadband quality.

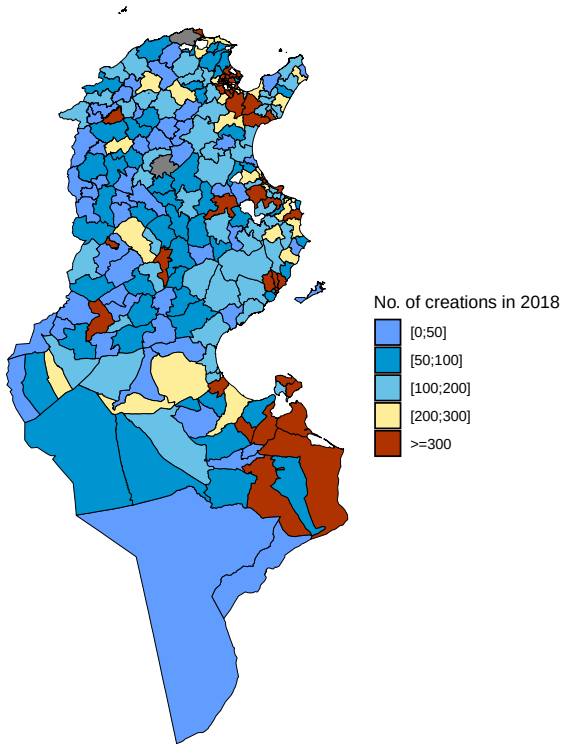


Figure 7: Number of creations of firms by delegations in 2018

Model

$$Y_{it} = \alpha + \beta MBB_{it-2} + X_{it-2} + Z_{it-2} + \mu year_t + \eta_i + \epsilon_{it} \quad (3)$$

With:

- Y_{it}: the count of new establishments created in delegation i at time t.
- MBB_{it-2}: proxy for the quality of mobile broadband Internet in delegation i at time $t-2$.
- X_{it-2}: 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.
- ϵ_{it} is the standard error clustered at the delegation level, capturing unobserved factors.

Results - The impact of mobile broadband antennas density on firm creation

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

- Impact of high-quality mobile broadband networks in influencing the locational decisions of new businesses: A unit increase in the density of 4G antennas per 10,000 inhabitants increases by 0.9% the rate of new business establishments in Tunisia.
- In rural areas, an expansion in the density of 4G antennas per 10,000 inhabitants by one unit increases the rate of business creation by 4.9%.

Results - Death of Distance?

Table 6: 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

- The impact of mobile broadband infrastructure density is significant only within the "center" and "periphery" zones, with no observable effects in regions beyond 50 kms.
- Most substantial impacts in economically integrated and intermediate rural areas.

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