University of Warsaw
Faculty of Economic Sciences

Working Papers
No. 24/2025 (487)

State Aid for Broadband and Crowding Out of Private Investment: Evidence from the French Market

Marc Bourreau
Lukasz Grzybowski
Ángela Muńoz-Acevedo

Warsaw 2025

ISSN 2957-0506

University of Warsaw
Faculty of Economic Sciences

WORKING PAPERS

State Aid for Broadband and Crowding Out of Private Investment: Evidence from the French Market

Marc Bourreau[1], Lukasz Grzybowski[2], Ángela Muñoz-Acevedo[3]*

[1] *Telecom Paris, Institut Polytechnique de Paris, CREST, France, and CESifo*
[2] *Faculty of Economic Sciences, University of Warsaw*
[3] *Deloitte Finance*
[*] *Corresponding author: lgrzybowski@wne.uw.edu.pl*

Abstract: In this paper, we investigate the potential crowding out of private investment by public subsidies in the deployment of broadband fiber networks. We estimate a model of fiber entry using a rich dataset on fiber deployment for more than 34,000 municipalities in mainland France from 2014 to 2019. We then assess whether private investment would have occurred in subsidized municipalities in the absence of state aid. We find that in 36% of cases, public subsidies were allocated to municipalities where private entry would have occurred within three years. We estimate that about 902 million euros of the total 2,203 million euros in total subsidies disbursed by the end of 2019 may have crowded out private investment. However, we also show that the French broadband plan accelerated fiber coverage in subsidized municipalities in the early stages of deployment.

Keywords: State Aid, Ex-Post Evaluation, Broadband, Entry, Coverage, Crowding Out

JEL codes: D22, L1, L4, L33, L96, H44

Acknowledgements: This paper was written as part of the state aid ex-post evaluation program undertaken by France Stratégie, from which we acknowledge financial support. Lukasz Grzybowski was supported by the grant from the National Science Centre in Poland (Project No. 2021/43/P/HS4/03115) and the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No. 945339. We thank our audiences at the 2021 Digital Economics Summer School, organized by the Association Francophone de Recherche en Economie Numérique (AFREN), the 2021 Doctoral Workshop on the Economics of Digitization at Telecom Paris, CRESSE 2023, APIOC 2023, BECCLE 2023, EARIE 2023, ACER Week 2023, the FCC, ARCEP, COMCOM, France Stratégie, and Orange for helpful comments and discussions. We are grateful to Zichuan Li for his research assistance.

1 Introduction

Since the launch of the Digital Agenda for Europe in 2010,[1] the European Union (EU) has set targets for nationwide broadband coverage with next-generation access (NGA) networks providing ultra-fast access to the Internet. These networks are considered strategic for consolidating the EU's digital single market, fostering economic and social development, and bridging the digital and economic divide in rural areas.[2] However, deploying broadband infrastructure involves high fixed costs, which may not be recoverable in areas with low or uncertain demand. As a result, some regions may remain unserved by private operators.

Member States of the European Union can provide public subsidies to support the deployment of broadband networks, subject to compliance with EU State aid rules.[3] Such financial support must not substitute for private investment, but should be targeted at areas where private operators lack the incentive to deploy broadband infrastructure, thereby bringing significant social and economic benefits.

In this context, France proposed the *Plan France Très Haut Débit* (hereafter the "French Broadband Plan") to the European Commission in 2013. This national high-speed broadband plan aims to provide broadband connections of at least 30 Mbps for all by the end of 2022 and fiber connections for all by 2025, with a total budget of 3 billion euros.[4]

In this paper, we examine the potential crowding out effect of state aid granted to local authorities under the French Broadband Plan. Crowding out occurs when public funds are directed to areas where private operators would have invested profitably in the absence of subsidies. To investigate this question, we develop a model of entry by a fiber operator to assess whether private investment would have taken place in a given area in the absence of state aid. This approach allows us to identify the areas where state aid enabled fiber deployment as well as those where private investment would likely have occurred without public funding. We also examine the impact of state aid on fiber coverage (the intensive margin), accounting for the endogeneity of fiber entry.

[1] See 'A digital agenda for Europe,' COM(2010)245 final, Brussels, 19 May 2010.

[2] High-speed broadband infrastructure is expected to stimulate growth and job creation by enhancing productivity and stimulating innovation in products and services. For empirical evidence on the positive impact of broadband infrastructure on growth and job creation, see, among others, Czernich, Falck, Kretschmer, and Woessmann (2011) and Ahlfeldt, Koutroumpis and Valletti (2017).

[3] See: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:C:2013:025:0001:0026:EN:PDF

[4] See: https://agence-cohesion-territoires.gouv.fr/france-tres-haut-debit-53; https://www.arcep.fr/demarches-et-services/collectivites/le-plan-france-tres-haut-debit-pfthd.html

We use panel data over the period 2014-2019 with information on fiber deployment, the number of infrastructure operators, state aid and socio-demographic characteristics of more than 34,000 municipalities in mainland France.[5] We adopt a two-step empirical approach. In the first step, we estimate a model of fiber entry by infrastructure operators in local municipalities and find that local market characteristics, such as market size and income, are important determinants of fiber entry. We also find evidence of a "replacement effect" from the legacy copper network in fiber entry decisions.[6] Prior investment in neighboring municipalities is also a very strong determinant of investment, suggesting that cost factors are more important than demand factors in driving deployment decisions.

Based on the estimates from the entry model, we calculate entry thresholds, that is, the minimum market size required to support fiber entry in a given municipality at a given time. We find that the entry threshold decreases over time for all municipalities, suggesting that fiber entry becomes progressively easier. We then use these entry thresholds to assess whether private entry might have occurred in municipalities that received state aid.

In its *State Aid Broadband Guidelines*, the European Commission considers an area eligible for state aid if there is no prospect of private investment within the next three years.[7] Therefore, to determine whether there is a prospect of private entry at the time of the state aid decision, we compare the market size of each municipality to its entry threshold over the next three years. Using this approach, if a municipality that received state aid has a market size below the entry threshold in that time frame, we consider that the plan has efficiently addressed the lack of private investment. Otherwise, we consider that the plan has crowded out potential private investment. We find that state aid was allocated efficiently in 64% of the cases. In the remaining 36%, state aid may have crowded out private investment. Based on our estimates, the cost associated with crowding out amounts to 902 million euros, or 41% of total expenditure.[8]

The allocation of state aid in municipalities with potential private investment could reflect the impatience of local authorities to accelerate fiber deployment, or their limited ability to anticipate

[5] Our analysis does not include Corsica and overseas territories of France.

[6] Following Arrow (1962), an operator has less incentive to invest in a new technology (e.g., fiber) if it is already earning revenues from an old technology (e.g., DSL). In the French broadband market, all fiber entrants are potentially subject to a replacement effect as they all offer DSL services nationwide.

[7] See "EU Guidelines for the application of state aid rules in relation to the rapid deployment of broadband networks," 2013/C 25/01), 26 January 2013, Article (75). As we will explain, the terms of reference of the French Broadband Plan also indicate that the prospects for private entry must be assessed in a three-year window.

[8] This figure represents an upper bound because in the calculation we use the total number of lines in municipalities and the maximum amount of aid.

future technological developments, or demand evolution, and the decline of entry thresholds. If we assess the prospect of private entry in the same year that public investment began, we find that for 93% of the aided municipalities, private investment would not have occurred.

Once fiber networks are deployed with the support of state aid, it is important to evaluate how coverage in these areas compares to municipalities with private investment. Although 36% of public subsidies were directed toward areas where private investment would likely have occurred within three years (according to our findings), such funding may not be entirely inefficient if it results in substantially higher coverage levels. To this end, we use a two-stage Heckman selection model to account for the endogeneity of fiber entry. We find that the French Broadband Plan allowed for higher fiber coverage in aided municipalities compared to unaided municipalities, especially in the early stages of the period under analysis. However, this effect diminishes over time. One possible interpretation is that aided municipalities may have included coverage targets in their contracts with private partners, accelerating deployment and resulting in higher coverage than in unaided municipalities. However, as the demand for ultra-fast broadband grows, private operators eventually catch up and close the gap.

In sum, our results suggest that the French Broadband Plan was relatively successful in helping to achieve the objectives of ultra-fast broadband deployment set by the EU, enabling deployment in areas that would otherwise not have been covered by the private sector and stimulating overall coverage. Additionally, broadband deployment under the plan may have generated spillover effects and facilitated investment in neighboring areas, as suggested by our results. However, we also find evidence of crowding out, with some subsidies going to municipalities where private investment would likely have occurred in the absence of public support.

The remainder of the paper is organized as follows. In Section 2, we review the relevant literature and outline our contribution. In Section 3, we discuss the objectives of the Digital Agenda for Europe, provide an overview of the EU state aid regime, and describe the main features of the French Broadband Plan as well as the French broadband market. Section 4 presents our datasets. Section 5 introduces the econometric framework, and Section 6 discusses the estimation results. Section 7 concludes.

2 Literature Review

This paper contributes to three strands of the empirical literature on (i) entry in telecommunications markets, (ii) investment in next-generation broadband networks, and (iii) the impact of state aid on broadband deployment.

First, the paper relates to the literature on entry into local telecommunications markets. Using a latent variable representation of market profitability, this literature examines the market characteristics that influence entry. In addition to the demand and cost shifters influencing entry (e.g., market size and population density), the literature highlights the role of differentiation (Greenstein and Mazzeo, 2006), sunk costs (Xiao and Orazem, 2011), managers' strategic ability (Goldfarb and Xiao, 2011), and entry threats (Wilson, Xiao and Orazem, 2021).

While these papers rely on data from the U.S., two recent papers focus on European markets. In the first paper, Nardotto, Valletti, and Verboven (2015) use an entry model as a first stage to study the effect of entry of alternative operators on broadband penetration in the UK between 2005 and 2009. They find that entry did not foster broadband adoption but did increase service quality to the benefit of consumers. In the second paper, Bourreau, Grzybowski, and Hasbi (2019) use a similar approach to study the impact of competition in the legacy copper network on the deployment of high-speed broadband in France. They find that a higher number of local competitors in a municipality reduces the incentives to deploy and expand broadband coverage at speeds of 30Mbps or higher.

Our first contribution to this literature is to use an entry model to assess the potential crowding out effect of state aid. Since the entry model can identify where a private operator would have found it profitable to enter, we can identify areas where public subsidies have effectively addressed the lack of private investment and those where they may have crowded it out. Our second contribution is to consider fiber entry in local markets where legacy broadband (DSL) services are already available, thus accounting for the competition between "old" and "new" broadband technologies.

Second, our paper contributes to the empirical literature on investment in next-generation access (NGA) fiber networks. This literature examines the impact of sectoral regulation on the deployment of fiber networks (see, e.g., Bacache, Bourreau and Gaudin (2014), Briglauer (2015), and Briglauer, Cambini and Grajek (2018)). In particular, Briglauer et al. (2018) use data on incumbent telecom operators and cable operators for 27 European member states from

2004 to 2014, and show that stricter regulation of access to the legacy copper network hurts fiber investment by incumbent telecom operators. Similarly, Fabritz and Falck (2013) find that deregulation stimulated fiber deployment by incumbents in the UK during 2007-2013. Briglauer, Cambini, Gugler and Stocker (2023) study the impact of net neutrality regulations on fiber and cable infrastructure investment and subscriptions. Using data from 32 OECD countries for the years 2003-2019, they find that these regulations have reduced investment and subscriptions. We contribute to this literature by considering the role of state aid –another form of public intervention– and its impact on the deployment of NGA fiber networks.

Finally, our paper is related to the literature on the impact of state aid on broadband deployment. Briglauer, Dürr, Falck, and Hüschelrath (2019) evaluate the effect of a state aid program introduced by the German state of Bavaria in 2010 and 2011 on improving broadband availability in rural areas. Using a difference-in-differences (DiD) model, they show that subsidized municipalities have higher broadband coverage at higher speeds than non-subsidized (matched) municipalities. Similarly, Duso, Nardotto, and Seldeslachts (2024) study the impact of state aid broadband plans implemented in Germany between 2011 and 2013 on broadband coverage and competition. Using a DiD approach, they find that state aid has significantly improved broadband coverage in the aided municipalities without distorting local competition. Briglauer and Grajek (2023) use cross-country data to study the effectiveness of state aid programs for the deployment of new fiber broadband networks. Using data from 32 OECD countries for 2002-2019, they find that the availability of a state aid program to support broadband deployment significantly increases broadband coverage. Finally, Wilson (2024) studies the impact of public investment in broadband infrastructure on private investment using U.S. data at the zip code level. He estimates a discrete choice model of demand for Internet access and a dynamic oligopoly model in which private and public firms make entry and investment decisions. He finds that public investment crowds out private investment to some extent, while increasing fiber availability and consumer surplus.

We contribute to this literature in two ways. First, we use an entry model to evaluate the extent of crowding out associated with a state aid program. Our estimates of entry thresholds for each municipality allow us to determine whether a private operator would likely have entered a local market in the absence of state aid. Second, we assess the impact of state aid on coverage (the intensive margin) using a control function approach to correct for potential sample selection bias.

3 State Aid for Broadband and the French Broadband Plan

In this section, we provide background information on state aid for broadband in the European Union. We then describe in more detail the French broadband state aid plan and how state aid is allocated to municipalities. Finally, we briefly describe the market structure of the French broadband industry.

3.1 EU Digital Agenda and State Aid for Broadband

In May 2010, the European Union (EU) announced its Digital Agenda to boost Europe's economy and consolidate the EU Digital Single Market. At the time, Europe was lagging behind other regions in terms of fast and reliable digital networks.[9] Moreover, coverage with very high capacity fiber networks[10] capable of delivering ultra-fast broadband was much lower in rural areas than in urban areas, revealing a persistent digital divide.[11]

Several factors may explain the slow transition from basic to ultra-fast broadband. First, on the supply side, deploying very high-capacity networks requires large fixed and sunk costs. Operators may also face an opportunity cost in deploying next-generation networks due to their revenues from legacy broadband networks based on the digital subscriber line (DSL) technology (the so-called "replacement effect"). Finally, operators deploying fiber networks face competition from Internet service providers using other technologies (e.g., DSL and cable). On the demand side, switching costs may discourage basic broadband users from subscribing to new ultra-fast broadband offers. Moreover, their willingness to pay for higher speeds may be low, at least in the early stages of the diffusion of the new technology.

Most importantly, there may be a lack of private investment in the provision of ultra-fast broadband in rural and less densely populated areas due to high deployment costs and low uncertain demand. At the same time, covering these areas may be socially desirable due to the high economic and social benefits that are not internalized by market players.

As the demand for fast and reliable connectivity increases and the digital divide becomes more visible, the need for widespread deployment of very high-capacity networks has become a

[9] See: European Commission, "The EU explained: Digital Agenda for Europe," November 2014.

[10] Very high capacity networks (VHCN) correspond to "any network providing a fixed-line connection with fiber roll out at least up to the multi-dwelling building" or any network providing the same quality of service (BEREC, 2020). Ultra-fast broadband, which enables connection speeds of 100 Mbps or more, requires VHCNs.

[11] In 2011, 10% of households in the EU were covered by very high capacity networks but only 2% in rural areas. See European Commission, "Digital Economy and Society Index (DESI)," 2020, p. 10-11.

key policy objective. The 2010 Digital Agenda for Europe set a target of providing at least 50% of European households with access to ultra-fast broadband by 2020. In 2016, the EU updated this target, with the objective that all EU households should have access to ultra-fast broadband by 2025.[12]

To foster the deployment of very high-capacity networks, the European Commission has issued recommendations on next-generation access networks and revised its state aid guidelines for broadband deployments. Of particular relevance to our analysis, the 2013 Broadband State Aid Guidelines[13] emphasize that the Digital Agenda targets cannot be achieved without public funding, and that "well-targeted State intervention in the broadband field" can help reduce the digital divide. However, state aid would be "counterproductive" if it is granted in "areas where market operators would normally choose to invest or have already invested." Therefore, a "balancing test" must be conducted to ensure that the overall effect of state aid is positive, "compared with what would have happened without the aid." In the context of broadband, this means that "the aid leads to the rollout of a new infrastructure which would not have been there otherwise." More specifically, the Guidelines stipulate that an area is eligible for state aid for next-generation access (NGA) networks if such networks do not currently exist and are not likely to be built within the next three years.

3.2 The French Broadband Plan

In April 2013, the French government launched the French Broadband Plan. This plan aims to support the design and financing of high-speed broadband infrastructure in France, primarily through fiber-to-the-home (FTTH) networks. Its primary objective is to provide FTTH coverage to all households and businesses by 2025.

Under this program, the French territory is divided into two types of zones: private initiative zones and public initiative zones. The private initiative zones include a list of very densely populated areas defined in 2009 by the sectoral regulator, ARCEP (*"Autorité de régulation des communications électroniques, des postes et de la distribution de la presse"*), where it was expected that multiple operators could deploy fiber and infrastructure-based competition could

[12]See: European Commission, "Connectivity for a Competitive Digital Single Market - Towards a European Gigabit Society," COM(2016) 587 final.

[13]EU Guidelines for the application of state aid rules in relation to the rapid deployment of broadband networks (2013/C 25/01).

develop.[14] These zones also include less densely populated areas where, in 2011, major telecommunications operators expressed their intention to deploy fiber without public funding within 5 years.[15] In total, the private initiative zones cover 20.7 million households. They are not eligible for public funding.

The public initiative zones simply correspond to the rest of the country. In these zones, private investment in fiber networks was not expected shortly following the 2011 call for expressions of interest to invest in fiber. Therefore, local authorities were allowed to partner with private operators to deploy fiber with financial support from both the French government and the European Union (EU). These zones cover 16.5 million households. It is important to note that private investment remains possible in public initiative zones.

Figure 1 shows the distribution of private and public initiative zones as of the fourth quarter of 2020. Private initiative zones are urban areas, while public initiative zones are mostly suburban and rural.

Public authorities estimated that a total investment of 21 billion euros over 10 years, from both public and private sources, would be needed to achieve the objectives set by the French Broadband Plan. Of this total, approximately 3 billion euros are allocated from the State budget to support the deployment of public initiative networks (*"Réseaux d'initiative publique"* or "RIP" by its French acronym). Additional funding can also be provided by municipalities and the European Union.[16]

In November 2016, the European Commission approved the French Broadband Plan. As of January 2021, 82 RIP projects were eligible for state aid (74 in mainland France). Table A.1 in the Appendix lists these projects, along with the departments or regions concerned. Note that in some departments, the public initiative zone represents only a small part of the total territory.[17]

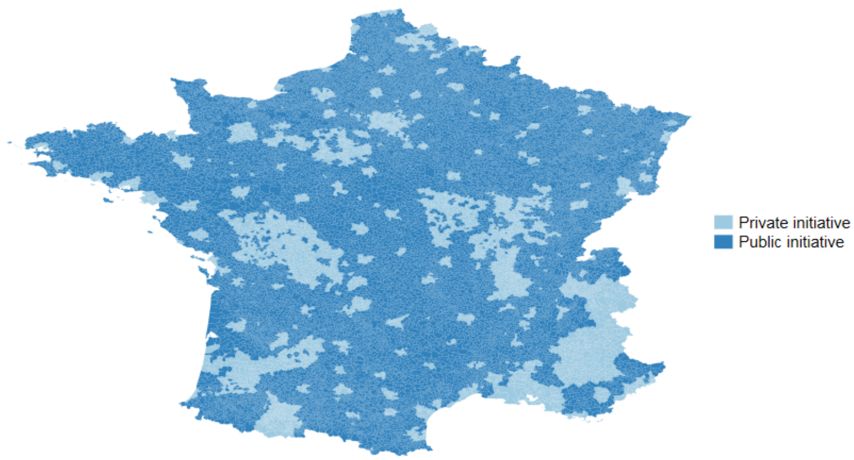
[14] In 2009, ARCEP defined the "very dense areas" as a list of 148 municipalities (Decision no 2009-1006). In 2013, it reduced this list to 106 municipalities due to some municipalities' lack of deployment or infrastructure-based competition (Decision no 2013-1475).

[15] In 2011, the French government launched a call for expressions of interest to invest in fiber ("Appel à manifestations d'intentions d'investissement"). Two operators (the historical operator, Orange, and an alternative operator, SFR) expressed interest in investing in 3,600 municipalities outside of very densely populated areas over the next five years. The government launched another similar call for expressions of interest in 2017, identifying 2,600 municipalities in the public initiative zones where private operators were willing to invest.

[16] As of the third quarter of 2022, state aid represented 3.51 billion euros, funding from municipalities 8.84 billion euros, while EU funding provided an additional 0.55 billion euros. See: France Stratégie (2020), "Déploiement du très haut débit et Plan France très haut débit. Evaluation socioéconomique", Technical report.

[17] For example, the RIP in the Val-de-Marne department covers only 1% of dwellings, while in the Manche department, 100% of dwellings are covered by the plan.

Figure 1: Public and private initiative zones for fiber coverage in France (2020Q4).



Source: own elaboration based on data from AVICCA.
Note: 27,566 municipalities are categorized as public initiative zones and 6,877 as private initiative zones.

3.3 Allocation of State Aid in the French Broadband Plan

Eligibility for state aid is subject to review by a dedicated government agency, the *"Agence Nationale de la Cohésion des Territoires"* (ANCT, formerly *"Agence du Numérique"*).

A project to deploy a public initiative network (RIP) must be designed at the departmental or regional level by local authorities,[18] and then submitted to the ANCT.[19] To be considered eligible, projects must meet certain technical and legal criteria set out in the terms of reference (*"cahier des charges"*). Only municipalities located in public initiative zones are eligible for funding. In addition, the applicant must provide evidence that no private investment is expected within three years, in line with EU state aid rules for broadband. Specifically, the 2013 *cahier des charges* stipulates that the RIP project must publish its deployment plan on ARCEP's website, specifying the areas it intends to cover with state aid. Private operators then have two months to notify the RIP project that they have an investment plan for the next three years that overlaps

[18] In practice, 80% of public initiative networks (RIP) operate at the departmental level.
[19] Private firms cannot apply for state aid. Only local authorities within a RIP project can apply for state aid.

in whole or in part with the RIP holder's plan.[20]

RIP projects are then evaluated based on their technical and financial components. If they meet the criteria, a preliminary agreement (*"accord préalable de principe"*) is issued, allowing the project leader to seek a private partner.[21]

RIP projects have flexibility in choosing their public-private partnership model. Most RIPs have adopted the concession model, which delegates the construction and operation of the fiber network to a private partner selected through an open tender. Once the private partner is selected, a final financing decision (*"décision de financement"*) can be requested from the government agency. Note that there may be a few years between the initial agreement and the final funding decision.

The amount of subsidy granted depends on several rules. First, only the costs of passive network elements are eligible for state aid. Second, state aid must not exceed 61.6% of the total project funding, with municipalities required to fund at least 33% of the project. Additionally, the subsidy per line must not exceed a maximum amount per line calculated for each department based on rurality and population dispersion.[22]

Subsidies are paid in several installments, spread over several years, according to the rate of network construction and after verification that the network has been built according to current regulations and technical specifications. Therefore, subsidies will only be granted if the fiber network is properly deployed.

Subsidized networks are subject to access obligations. Access to the subsidized network must be open and non-discriminatory, with oversight by the French regulator, ARCEP. Access obligations for subsidized networks are the same as for private networks; in particular, access prices must be similar. These symmetric access obligations are intended to promote uniform retail prices throughout the territory.

[20]Operators must provide a detailed investment plan with precise planning and all the elements to substantiate that their investment plan is credible.

[21]While no projects have been formally rejected, some are modified during the review process or canceled due to private investment in the area.

[22]In the 2013 *cahier des charges*, the average maximum subsidy was €425 per line, ranging from €180 (in Seine Saint Denis and Hauts-de-Seine) to €694 (in Creuse).

3.4 Market Structure of the Broadband Industry

In France, during our observation period, there are two potential substitutes to fiber for consumers: (i) DSL, based on the legacy copper network, and (ii) broadband cable, offered by only one operator, SFR, in some municipalities.

DSL offers lower speeds than fiber and is available almost everywhere in the territory.[23] It is provided by the four main telecom operators in France: Orange, SFR, Bouygues Télécom, and Free, which are active both in the fixed broadband market (with DSL and fiber offers) and in the mobile market (as mobile network operators, MNOs).[24] Cable is only offered by SFR in some municipalities.[25] Since 2014 (the start of our period), SFR has operated both a cable network and a fiber network, but it invests primarily in fiber.

Regarding the identity of the fiber entrants, we need to distinguish between private initiative zones and public initiative zones. In the private initiative zones, the main infrastructure operators in 2019Q4 were Orange (11.9 million lines), SFR (2.3 million lines), and Free (0.3 million lines), with other operators (including Bouygues Télécom) accounting for about 0.5 million lines (source: ARCEP). In other words, the fiber entrants in these zones are the main telecom operators offering DSL services to consumers. In the public initiative zones, there is more diversity, with deployments by Orange (0.6 million lines), SFR (0.6 million lines), Altitude (0.9 million lines), Covage (0.6 million lines), and others (0.3 million lines) in 2019Q4.

4 Data

We combine data from several sources. First, we use data on fiber-to-the-home (FTTH) infrastructure provided by the sectoral regulator, ARCEP. Second, we build a database on state aid at the municipality level using information from the ANCT. Third, we collect information on the socio-economic and geographic characteristics of municipalities from INSEE (French National Institute for Statistics and Economic Studies). Fourth, we use information from AVICCA (*"As-*

[23]It was available for 99.4% of lines in 2014Q1, at the beginning of our period, and for 99.5% of lines in 2019Q4, at the end of our period (source: ARCEP)

[24]SFR, Bouygues Télécom, and Free rely mainly on local loop unbundling to offer DSL services.

[25]Historically, there was only one cable operator in France, Numericable, which covered approximately 30% of the population, mainly in urban areas. In 2007, Numericable began upgrading its cable network to the DOCSIS 3.0 standard to offer broadband services. Between 2007 and 2014, Numericable did not deploy any new cable infrastructure. As of 2014, Numericable was present in 756 municipalities in mainland France (Bourreau, Grzybowski and Hasbi, 2019). In 2014, Numericable merged with SFR.

sociation des Villes et Collectivités pour les Communications électroniques"), which is a French association of local authorities involved in electronic communications, to identify the type of zone of each municipality (public or private). Fifth, we use information on the quality of the French legacy copper network provided by the incumbent operator Orange.

Data on fiber-to-the-home infrastructure. We obtained data from ARCEP on the geographic location, deployment status, and identity of the fiber infrastructure operator for more than 16 million buildings in France as of June 2020. The fiber infrastructure operator deploys the fiber network in a given area and offers services to residential and business customers. It may also lease access to its network to other "commercial" operators who in turn offer services to consumers.

We aggregate this data at the municipality level using the geographic location of each building. The data includes information on the availability date of each building's mutualization point (MP). The MP is the interface between the core fiber network of the operator and the fiber optic lines that connect consumers' premises. We use the MP availability date as the fiber entry date, as it indicates that the most expensive part of the fiber network has been deployed.[26]

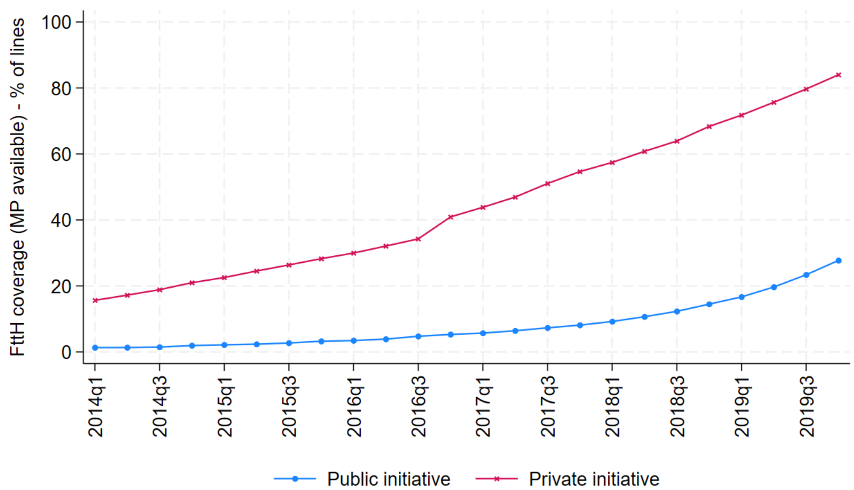
Thus, for each quarter between 2014 and 2019, we observe the number of fiber operators and the number of FTTH lines deployed in each municipality in mainland France. To estimate the fiber coverage rate in each municipality, we use publicly available data from ARCEP on the total number of dwellings (hereafter "lines") in each municipality in 2020.[27] We define the fiber coverage rate as the ratio between the number of fiber lines deployed and the total number of lines (dwellings) in the municipality.

Figure 2 shows the evolution of FTTH deployment in France in public and private initiative zones. By the end of 2019, more than 60% of French households were covered by fiber (i.e., the mutualization point of the building was available). However, while coverage exceeds 80% in private initiative zones, it is less than 30% in public initiative zones.

[26] For some buildings, the MP availability date is missing. In this case, we replace the missing information with the availability date of the first optical access point (*"Point de branchement optique"* in French) deployed in the building.

[27] ARCEP's data was retrieved on 20 May 2021 from the following website: https://www.data.gouv.fr/en/datasets/ma-connexion-internet/. We compare this information with the number of lines provided by AVICCA. For a few municipalities, the total number of lines according to ARCEP is different from the one provided by AVICCA. We keep the source that gives the number of lines closer to the number of households in the municipality reported by INSEE. In a few cases, the number of installed lines is higher than the total number of lines in the municipality, in which case we set the former equal to the latter.

Figure 2: Evolution of fiber deployment in France.



Source: ARCEP.

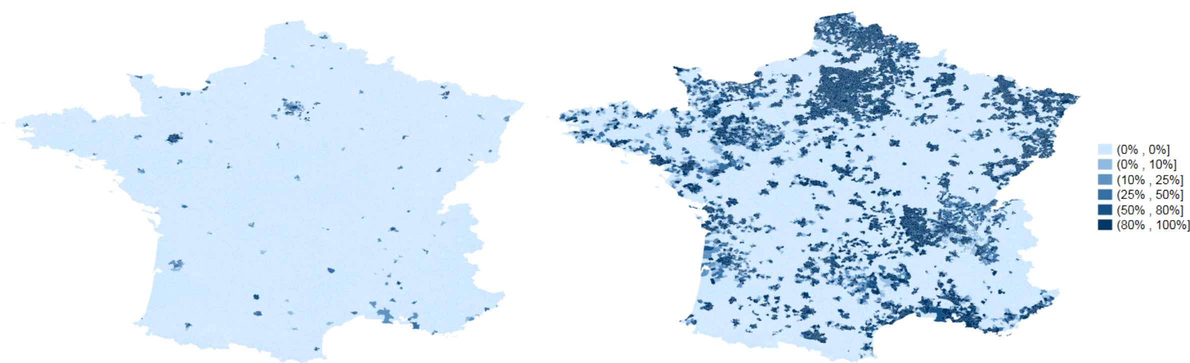
Panels (a) and (b) of Figure 3 show the geographic location of fiber deployments in the first period (2014Q1) and the last period (2019Q4) covered by our data. The first deployments occur in the main urban areas, and then tend to expand around the initially covered municipalities in a cluster. To account for any geographic dependence in fiber deployments and potential spillover effects, we calculate for each municipality the average fiber coverage in neighboring municipalities in the previous quarter.[28]

Table 1 shows the number of municipalities with different numbers of infrastructure operators for the period 2014-2019. Only a few municipalities have two or more infrastructure operators. Moreover, Table A.3 in the appendix shows that there is a large number of entries and no exits of fiber infrastructure operators in mainland France during this period.

Data on state aid. We received two datasets from the ANCT on state aid in the context of the French Broadband Plan. The first dataset contains information on the decisions taken

[28]Neighboring municipalities are those that share a border with a given municipality. The list of neighboring municipalities as of January 2021 in mainland France was retrieved on 22 June 2021 from the following website: www.data.gouv.fr/en/datasets/liste-des-adjacences-des-communes-françaises.

Figure 3: Fiber coverage in mainland France municipalities (share of connected lines - 2014Q1 and 2019Q4).



(a) 2014Q1 (b) 2019Q4

Table 1: Number of municipalities with the presence of infrastructure operators and municipalities with state aid.

	Number of operators						State aid
Year	0	1	2	3	4	5	
2014	33,827	495	73	37	10	1	23
2015	33,404	905	77	41	15	1	191
2016	32,271	1,983	112	60	16	1	560
2017	30,838	3,301	191	89	22	2	1,451
2018	27,905	6,054	326	132	24	2	3,564
2019	22,840	10,875	522	169	34	3	6,771

by the Prime Minister on projects submitted by local authorities requesting state aid. For each project, we have information on (i) the departments involved; (ii) the type of decision (preliminary agreement, final decision, other); (iii) the date of the decision; (iv) the reference number of the decision; (v) the amount of aid granted; and (vi) a dummy variable indicating whether the decision is valid as of January 2021. We only consider projects for which a final decision has been issued, as only in this case can public funds be released.[29] Second, for each project, we obtained a "proxy" file used by the ANCT to calculate the amount of the aid. Each proxy file contains an approximation of the number of eligible lines in each municipality covered by the project.

We combine these two datasets to construct a database that identifies the municipalities in mainland France that receive state aid. Municipalities receive state aid as a reimbursement when they provide proof of network deployment. Therefore, for our analysis, we make the simplifying assumption that state aid is effective when the first FTTH line is deployed in the municipality.[30]

As of January 2021, there are 74 projects in mainland France with a valid state aid decision (either preliminary or final). Among them, the state aid projects that have been confirmed by the Prime Minister through a final decision represent an aid amount of 2.58 billion euros.

Table 1 shows the cumulative number of municipalities receiving state aid in mainland France during the period 2014-2019. By the end of 2019, 6,771 municipalities had received state aid.[31] Figure 6 in the appendix shows the geographic location of aided municipalities. Figure 4 shows the distribution of average state aid per line (in euros) across 6,771 municipalities that received state aid as of Q4 2019.

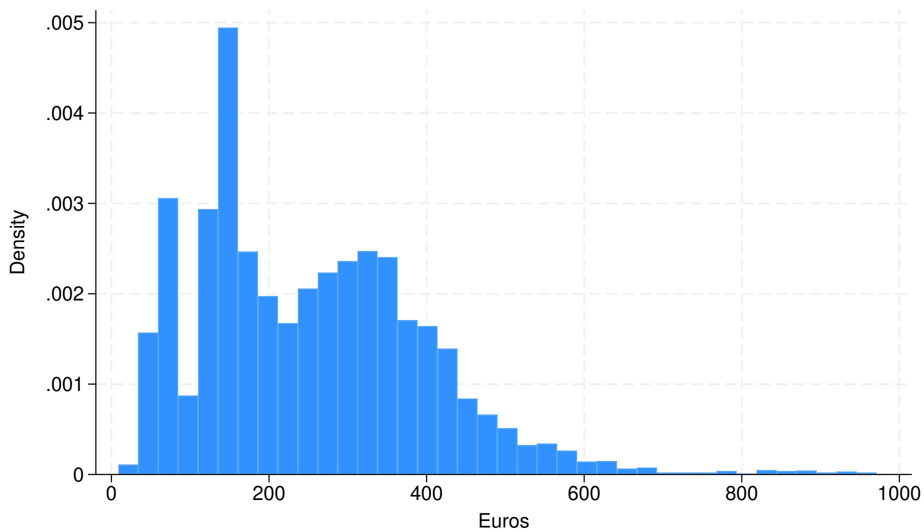
Data on socio-demographic characteristics of municipalities. We obtained socio-demographic information at the municipality level from the French National Institute for Statistics and Economic Studies (INSEE). In particular, we have municipal-level data on the population size (defined as the number of households). This information is published with a two-year lag and is only available until 2017. Since firms do not have access to more recent statistics, we consider that they make their entry decisions based on demographic information with a two-year lag. In

[29]Preliminary decisions can be subject to change throughout the ANCT review process and may not lead to disbursements.

[30]On average, we observe the first deployment in an aided municipality four quarters (one year) after the date of the Prime Minister's decision to grant aid.

[31]In 2019, out of the 27,153 municipalities located in public initiative zones, 17,326 were covered by a project for which a final decision had been taken. However, only about a quarter of them (6,771) had begun fiber deployment.

Figure 4: State aid per line in Euros



Source: Own calculation for 6,771 municipalities that received state aid as of Q4 2019. The number of lines used in the calculation is based on data reported by ARCEP.

addition, we have information on the median household income per municipality for the years 2014-2017.[32]

Data on zone types. We obtained data from AVICCA on the type of zone of each municipality in mainland France.[33] This information allows us to identify whether a municipality belongs to a public or private initiative zone in the context of fiber deployment.[34] At the end of 2020, 80% of the municipalities in mainland France (40% of the population) were located in public initiative zones.

[32]This information comes from the *Dispositif Fichier localisé social et fiscal (Filosofi)* and is missing for municipalities with less than 30 households. We replace missing values with the median household income in the department.

[33]The information corresponds to the fourth quarter of 2020 and was collected from the following website: www.avicca.org/content/open-data-avicca.

[34]AVICCA also identifies what it calls "mixed initiative zones" where municipalities have both public and private network deployment. There are only 85 municipalities in these mixed initiative zones, which is less than 0.25% of the 34,443 municipalities in our database. Therefore, we consider them as private initiative zones in our analysis.

Data on the quality of the copper network. We obtained information on the quality of the legacy copper network in each municipality from the French incumbent operator Orange. We use this information to proxy for the opportunity cost that operators may face in deploying fiber due to their revenues from the legacy copper network (the "replacement effect"). Indeed, as explained in Section 3.4, the main operators investing in fiber in France offer DSL services based on the copper network throughout the country.

In general, broadband signals suffer attenuation as they travel along a copper line from an exchange point to a customer's premises. This is called *copper loss*, and it translates into a reduction in speed for DSL access. The further a customer is from the exchange point, the more copper loss they may experience. We consider that the revenues from legacy DSL networks are lower when copper loss is higher, due to a lower quality of broadband experience.[35] The quality of copper networks generally remains unchanged over time because it is controlled by the incumbent operator, Orange, which does not invest in improving copper networks due to the availability of fiber technology.

In our data, municipalities are assigned to the following categories based on the average quality (attenuation) of copper lines measured in decibels (dB): 20dB and below (outstanding); 20-30dB (excellent); 30-40dB (very good); 40-50dB (good); 50-60dB (poor and may experience connectivity problems); and 60dB or above (bad, will experience connectivity problems).

We merged the different datasets using the unique INSEE code for each municipality. After merging, we have information on 34,443 municipalities in mainland France for the years 2014-2019, quarterly, for a total of 826,632 observations.[36] Table 2 reports summary statistics for the variables used in the analysis.

5 Empirical Analysis

State aid is allowed in the EU if it alleviates a market failure or addresses another objective of common interest. Moreover, state aid should be well-targeted with limited distortion of competition. In our context, state aid serves the common interest and does not distort competition

[35] While there may be variations in copper loss within a municipality, we believe that our data on average copper loss is a reasonable proxy for the revenues that operators can generate with legacy broadband.

[36] In 2020, there were 34,479 municipalities in mainland France. Due to administrative changes in the years 2014-2019 (some municipalities split, and others merged) and a lack of information for some small municipalities in the different data sources, we removed 36 small municipalities from the data.

Table 2: Summary statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max
Number of infrastructure operators	826,632	0.11	0.36	0	5
Number of households (thousands)	826,632	0.76	3.37	1	100
Fiber coverage (%)	826,632	0.07	0.23	0	1
State aid (dummy)	826,632	0.04	0.21	0	1
Income (euros)	826,632	20,327	3,419	9,958	48,310
Public initiative zone (dummy)	826,632	0.80	0.40	0	1
Private initiative zone (dummy)	826,632	0.20	0.40	0	1
Copper line quality - outstanding	826,632	0.18	0.39	0	1
Copper line quality - excellent (dummy)	826,632	0.16	0.37	0	1
Copper line quality - very good (dummy)	826,632	0.14	0.35	0	1
Copper line quality - good (dummy)	826,632	0.18	0.39	0	1
Copper line quality - poor (dummy)	826,632	0.16	0.37	0	1
Copper line quality - bad (dummy)	826,632	0.17	0.37	0	1

Note: The maximum values of number of households were truncated to 100,000 due to a few extreme cases. There are 34,443 municipalities and 24 quarters in our database.

if private operators would not have found it profitable to build a fiber network without public funding.

To determine whether there was a prospect of private investment at the time the public funding was provided, we start by building a model of fiber entry in the next subsection. In this model, a private operator decides to enter a given area with fiber if and only if its expected net profit from entry is positive. Then, we use the estimates from the entry model to calculate entry thresholds, i.e., the minimum number of households required for private entry to occur. If the number of households in a municipality that received state aid is below the threshold, we conclude that state aid has efficiently addressed the lack of private investment. Otherwise, if it is above the threshold, we conclude that state aid may have inefficiently crowded out potential private investment.

Finally, we compare fiber coverage (the intensive margin) between municipalities with and without state aid. To do so, we develop a reduced-form model of fiber coverage that accounts for the endogeneity of fiber entry through a control function approach.

5.1 Model of Fiber Entry

We build a model of fiber entry by infrastructure operators. We assume that at the end of each period, operators decide whether to enter into "new" local markets and deploy fiber in the next period. They form expectations about market demand, costs, and competition from other operators. These expectations are fulfilled in equilibrium, and the marginal operator enters the market. We make inferences about the profit determinants assuming a free entry equilibrium, where operators enter a local market if, and only if, it is profitable for them to do so, i.e., expected gross profits exceed entry costs. As noted earlier, we do not observe exits in our data, and thus entry is a final decision.[37]

The number of fibre infrastructure operators present in municipality i at time t is denoted by $N_{it} \in \{0, 1, 2, 3, 4, 5\}$. The discounted future stream of profits for an operator facing n competitors in market i at time t can be written as:

$$\bar{\pi}_{it}^{n} = \alpha S_{it} + \sum_{b_k \in B} \alpha_{b_k} S_{it} \times \mathbb{1}\{S_{it} \in b_k\} + X_{it}\beta - \mu^{n} + \epsilon_{it} \equiv \pi_{it}^{n} + \epsilon_{it}, \tag{1}$$

where S_{it} is the market size approximated by the number of households. To account for non-linear market size effects due to economies of scale in fiber deployment, we introduce differential effects by market size intervals that we call "bands". To do this, we define the vector $B = \{b_1, b_2, b_3, b_4, b_5\}$ as a set of five household size bands, with $b_1 = [0, 2,000)$, $b_2 = [2,000, 5,000)$, $b_3 = [5,000, 10,000)$, $b_4 = [10,000, 20,000)$, and $b_5 = [20,000, \infty)$. Next, we denote by X_{it} the vector of other characteristics of municipalities that are potential demand or supply determinants of profits (including income, the type of zone, the quality of the legacy copper network, and the fiber coverage in neighboring municipalities). We also include a set of year-dummy variables and department-dummy variables to account for the fact that firms' profits may differ across geographic locations due to other specific factors. Some of these variables affect the demand for fiber Internet and thus revenues, while others affect deployment costs or both demand and costs. Additionally, the year and department dummy variables may affect both demand and costs.[38] Finally, μ^n represents the negative effect on profits from the n^{th} firm, and ϵ_{it} is the error term, which has a standard normal distribution. The profits, π_{it}^{n}, are unobserved and represent a latent variable.

This reduced-form profit specification is similar to the models estimated by Xiao and Orazem

[37]Some of the fixed costs of entry into local markets may be sunk. The presence of sunk costs implies that less demand is needed for an incumbent to continue operations than to support a new entrant. Sunk costs cannot be identified in our setup, because we observe at most one entry and no exit at all. Therefore, we estimate the entry model without sunk costs.

[38]In 2021, there were 94 departments in mainland France, excluding Corsica.

(2011), Nardotto et al. (2015), and Bourreau et al. (2019), and, like those models, does not distinguish between marginal and fixed costs, as in Bresnahan and Reiss (1991). Our model does not account for firm heterogeneity, which may arise from differences in size, geographic coverage, cost structures, and ownership of broadband networks based on other technologies. However, this assumption may be justified by the fact that, as of Q4 2019, the former incumbent operator Orange had deployed 69% of all fiber lines (see Section 3.4).

Since there is only a small number of markets with two or more infrastructure operators, as shown in Table 1, we truncate the number of entrants to one, which simplifies our entry model. In equilibrium, in market i and at time t, there is entry of at least one fiber network ($N_{it} = 1+$) when the condition $\bar{\pi}^1_{it} > 0$ is satisfied, which yields, using the profit specification (1):

$$\alpha S_{it} + \sum_{b_k \in B} \alpha_{b_k} S_{it} \times \mathbb{1}\{S_{it} \in b_k\} + X_{it}\beta - \mu^1 + \epsilon_{it} > 0. \tag{2}$$

The probability of observing $N_{it} = 1+$ entrants in market i at time t is thus given by:

$$Pr(N_{it} = 1+) = \Phi(\alpha S_{it} + \sum_{b_k \in B} \alpha_{b_k} S_{it} \times \mathbb{1}\{S_{it} \in b_k\} + X_{it}\beta - \mu^1), \tag{3}$$

where $\Phi(.)$ denotes the cumulative normal distribution function. The parameter vector $\theta = (\alpha, \alpha_{b_2}, \ldots, \alpha_{b_5}, \beta, \mu^1)$ is estimated by maximizing the following log-likelihood function:

$$\hat{\theta} = \arg\max \sum_{i=1}^{M} \sum_{t=1}^{T} [y_{it} \ln(Pr(N_{it} = 1 + |\theta)) + (1 - y_{it}) \ln(Pr(N_{it} = 0|\theta))], \tag{4}$$

where y_{it} takes the value of 1 when $N_{it} = 1+$, and 0 otherwise. The estimated model is a simple probit model, or an ordered probit model if we consider the entry of one, two, or more fiber infrastructure operators.

5.2 Entry Thresholds and State Aid Granting Decision

Using the estimates $\hat{\theta}$ from the entry model described above, we define the entry threshold $\hat{S}_{it}$ as the number of households in municipality i at time t necessary to allow the entry of $N_{it} = 1+$

fiber networks. It is calculated as follows:

$$\hat{S}_{it} = \frac{\hat{\mu}^1 - X_{it}\hat{\beta}}{\alpha + \sum_{b_k \in B} \alpha_{b_k} \mathbb{1}\{S_{it} \in b_k\}}. \tag{5}$$

We use these entry thresholds to assess whether state aid under the French Broadband Plan was targeted to municipalities where private investment would not have occurred. We consider the policymaker's decision as follows. At a given time t, the policymaker must decide whether to grant public funds for the deployment of a high-speed network in a municipality i. According to the European Broadband State Aid Guidelines and the *Cahier des charges* (terms of reference) of the French Broadband Plan, the policymaker should only grant public funding if no private operator is likely to invest in the municipality within the next three years (see Section 3.2). The policymaker therefore needs to assess the likelihood of a private operator entering the market with fiber in this time horizon.

According to our entry model, a private operator can enter the market if the size of the municipality is larger than the entry threshold. Therefore, we compare the size of the municipality under consideration at time t, S_{it}, with the estimated entry thresholds $\hat{S}_{it'}$ for the same municipality in the next three years ($t' \in \{t, \cdots, t+3\}$).

5.3 Fiber Coverage

Once fiber networks have been deployed with the support of state aid, it is important to assess how coverage in these areas compares to municipalities with private investment. Indeed, even if state aid is allocated to areas where private investment would likely have occurred, the subsidies may not be entirely inefficient if they result in substantially higher coverage levels.

To this end, we use a two-stage Heckman selection model to account for the endogeneity of fiber entry. In particular, we estimate the following reduced-form equation for the share of households in a given municipality with access to ultra-fast broadband over fiber:

$$y_{it} = \rho SA_{it} + \gamma Z_{it} + u_{it}, \tag{6}$$

where y_{it} denotes the share of households in municipality i and period t with fiber coverage (i.e., the mutualization point is available in the household's building); SA_{it} is an indicator variable for state aid in municipality i and period t; and Z_{it} is a set of control variables that may determine coverage, including demand and cost shifters.

When estimating equation (6), we need to correct for a potential sample selection bias. Indeed, fiber coverage y_{it} is only observed when there is at least one infrastructure operator in the municipality ($N_{it} = 1+$ in our entry model). To take this into account, we follow Heckman (1979) and estimate the model in two stages using a control function approach. Specifically, in the first stage, we estimate the entry model discussed in the previous section (Model I). Then, the hazard function (inverse Mills ratio) denoted by $\lambda(S_{it}, X_{it}; \theta)$ is defined using the entry model estimates as follows:

$$\lambda(S_{it}, X_{it}; \hat{\theta}) \equiv E(\epsilon_{it} | \hat{\pi}^n_{it} > -\epsilon_{it}) = \frac{\phi(\hat{\pi}^n_{it})}{\Phi(\hat{\pi}^n_{it})}. \tag{7}$$

Assuming that the error terms of the two models of fiber entry and fiber coverage, ϵ_{it} and u_{it}, are multivariate normally distributed, one can show that:

$$\begin{aligned} E(y_{it}|X_{it}, S_{it}, Z_{it}) &= \rho SA_{it} + \gamma Z_{it} + E(u_{it}|N_{it} > 0), \\ &= \rho SA_{it} + \gamma Z_{it} + \sigma_{u\epsilon}\lambda(S_{it}, X_{it}; \theta), \end{aligned} \tag{8}$$

where $\theta = (\alpha, \alpha_{b_2}, \dots, \alpha_{b_5}, \beta, \mu^1)$ is the parameter vector from the entry model, and $\sigma_{u\epsilon}$ is the covariance between u_{it} and ϵ_{it}. In the second stage, we estimate the following modified coverage equation for the sample of municipalities with positive coverage:

$$y_{it} = \rho SA_{it} + \gamma Z_{it} + \sigma_{u\epsilon}\lambda(S_{it}, X_{it}; \hat{\theta}) + \varepsilon_{it}. \tag{9}$$

In this equation, we exploit the fact that the error term u_{it} can be decomposed into the sum of two terms and written as $u_{it} = \sigma_{u\epsilon}\lambda(S_{it}, X_{it}; \hat{\theta}) + \varepsilon_{it}$, where by construction ε_{it} is mean zero conditional on S_{it}, X_{it} and Z_{it}.[39]

The municipality characteristics included in the estimation of equation (9) are the same as in the model of fiber entry, except for market size and the dummy variable identifying municipalities with no fiber coverage in neighboring municipalities in the previous period. These are our exclusion restrictions, which are required in the Heckman selection model.

[39] We acknowledge that the estimation error from the entry model should ideally be accounted for in the coverage equation in the inverse Mills ratio. However, given the strong significance of the entry estimates, as discussed below, and the added computational burden, we have not implemented the correction.

In particular, we need at least one variable that determines the entry of fiber operators but is not correlated with the error term in the fiber coverage equation. Market size makes markets more attractive for fiber deployment, but it should not affect the share of the population covered by fiber. In other words, the share of the population covered by fiber should be comparable in smaller and larger municipalities, conditional on the presence of infrastructure fiber operators in those municipalities. Moreover, fiber deployment in neighboring municipalities influences entry, as the roll-out of a fiber backbone facilitates entry into adjacent municipalities. However, it should not directly impact the level of coverage in the municipality. We consider that only the level of coverage in neighboring municipalities in the previous period can influence the current level of coverage in a given municipality. This is because the coverage level reflects how far the overall roll-out work has progressed in a given area.

Although we do not expect the market size to have a direct impact on fiber coverage, it may be correlated with omitted municipality-specific characteristics. To mitigate this problem, we use in the estimation a set of municipality characteristics and department dummy variables, as well as year dummy variables. For comparison, we first estimate equation (9) using ordinary least squares (OLS) without a correction term and then use the Heckman two-stage procedure described above.

6 Estimation Results

Our estimation is done in the following steps. First, we estimate the fiber entry model using the maximum likelihood estimator in equation (4). The estimated model is a simple probit model. Second, we use the estimates from the entry model to compute entry thresholds, as described in equation (5). We use them to assess the potential for private entry into aided municipalities. Third, we use the estimates from the entry model to compute the correction term (7). Fourth, we use ordinary least squares to estimate the coverage equation (9). This equation includes the number of fiber entrants and the correction term from the entry model (7). We also include local market characteristics, as well as time and department dummy variables in the estimation as discussed above.

6.1 Fiber Entry

Table 3 shows the estimation results of our model of fiber entry using panel data for 34,406 municipalities over the period 2014-2019.[40] In practice, there are few municipalities with two or more infrastructure operators (e.g., only 2.1% of municipalities are in this case in the fourth quarter of 2019). Since there is little variation in the number of infrastructure operators, we focus on the presence of at least one infrastructure operator in the municipality. Therefore, our dependent variable is either 0 if there is no infrastructure operator in the municipality or 1 if there is one or more infrastructure operators. As a robustness check, we also estimated the model for the entry of only one operator and two or more operators. Our results concerning the determinants of entry, as well as model predictions, remain almost unchanged. The only difference is that we can estimate entry thresholds for one and for two or more fiber operators.

Some municipalities with at least one infrastructure operator received state aid. However, there are no aided municipalities without any deployed infrastructure, as we consider a municipality to have received state aid only once the first fiber lines are deployed. In other words, state aid perfectly predicts entry. Therefore, to identify the effect of state aid, we estimate three alternative entry models under different assumptions about the municipalities that received state aid.

Model I is estimated using a restricted sample of 27,601 out of 34,406 municipalities that never received state aid during the analysis period, including municipalities in both private and public initiative zones. Notably, we observe some unaided entries even within public initiative zones. This approach assumes that state aid is randomly allocated within public initiative zones—an assumption that may not be fully justified. Model II, by contrast, is estimated using a sample of 6,840 municipalities classified as private initiative zones. These municipalities differ in systematic ways from those in public initiative zones, yet the approach implicitly assumes that the determinants of entry are the same across both types of zones. Finally, Model III is estimated using the full sample of municipalities. Since state aid perfectly predicts entry, this variable is excluded from the estimation. This approach implicitly assumes that entry would have occurred in aided municipalities regardless of the presence of state aid.[41]

[40]Fiber entry occurred before the start of the period in all municipalities in the departments of Hauts-de-Seine and Paris. Since our model includes department dummies, they must be excluded from the analysis, reducing the initial sample of 34,443 municipalities to 34,406 municipalities.

[41]In an earlier version of the paper, we also estimated a model in which the number of infrastructure operators was set to zero in municipalities that received state aid, based on the assumption that no entry would have taken

Table 3: Fiber entry in municipalities – entry of at least 1 infrastructure operator.

Dep. Var: Number of operators (0,1+)	(I)	(II)	(III)
Nb Households	0.510***	0.697***	0.522***
	(0.0682)	(0.0565)	(0.0576)
Nb Households interactions (ref: <2,000)			
Nb Households * [2,000 ; 5,000)	-0.153***	-0.244***	-0.180***
	(0.0439)	(0.0357)	(0.0372)
Nb Households * [5,000 , 10,000)	-0.268***	-0.405***	-0.280***
	(0.0584)	(0.0481)	(0.0485)
Nb Households * [10,000 ; 20,000)	-0.339***	-0.493***	-0.349***
	(0.0636)	(0.0514)	(0.0539)
Nb Households * (>20,000]	-0.418***	-0.594***	-0.431***
	(0.0650)	(0.0526)	(0.0552)
Log(Income)	0.631***	0.934***	0.405***
	(0.175)	(0.181)	(0.144)
No coverage in neighbor dummy t-1	-0.871***	-1.013***	-0.822***
	(0.0414)	(0.0564)	(0.0376)
Level of coverage in neighbor t-1	3.254***	3.017***	3.262***
	(0.216)	(0.166)	(0.111)
Year dummies (ref 2014)			
2015	0.208***	0.211***	0.241***
	(0.0528)	(0.0387)	(0.0495)
2016	0.514***	0.585***	0.542***
	(0.0692)	(0.0586)	(0.0622)
2017	0.686***	0.955***	0.728***
	(0.0937)	(0.0629)	(0.0706)
2018	0.829***	1.200***	0.967***
	(0.121)	(0.0660)	(0.0790)
2019	1.018***	1.444***	1.183***
	(0.172)	(0.0832)	(0.0918)
Type of initiative zone (ref: public)			
Private initiative	0.942***		0.202**
	(0.139)		(0.0971)
Copper loss (ref: <=20dB)			
20dB–30dB excellent	0.0873*	0.169**	0.0952***
	(0.0477)	(0.0666)	(0.0356)
30dB–40dB very good	0.203***	0.289***	0.170***
	(0.0544)	(0.0760)	(0.0432)
40dB–50dB good	0.278***	0.419***	0.267***
	(0.0624)	(0.0708)	(0.0430)
50dB–60dB poor	0.340***	0.556***	0.337***
	(0.0529)	(0.0705)	(0.0421)
>=60dB bad	0.272***	0.457***	0.340***
	(0.0671)	(0.0941)	(0.0487)
μ	9.467***	11.85***	5.993***
	(1.815)	(1.851)	(1.473)
Department fixed effects	Yes	Yes	Yes
Observations	663,240	164,160	825,744
LL	-50279	-25723	-102617

Note: Robust standard errors in parentheses (clustered at the department level). Symbols *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

The results of these three models are qualitatively similar. We find that the market size (measured as the number of households in the municipality) significantly and positively affects fiber entry. The effect is non-linear and decreases with market size, as suggested by the coefficients of the interactions between market size and market size bands. We also find that a higher income level has a positive and statistically significant effect on fiber entry, suggesting a higher demand for broadband in wealthier municipalities.

In the estimation, we also include two variables to capture the geographic spillovers of fiber entry suggested by the graphical analysis of deployments (see Section 4). First, we include a dummy variable that identifies municipalities with no fiber coverage in neighboring municipalities in the previous period. The coefficient on this variable is negative and statistically significant, indicating that the absence of fiber coverage in neighboring areas reduces the likelihood of entry. Second, we include a continuous variable measuring the average fiber coverage in neighboring municipalities in the previous period. This variable is positive and statistically significant, suggesting that higher coverage in neighboring municipalities increases the likelihood of entry. We interpret these results as evidence of geographic dependence in fiber deployment. In practice, infrastructure operators must deploy a fiber backbone, which serves as the core of the network. Once a sufficiently large share of municipalities in a given area is covered, the backbone has likely been deployed, reducing the marginal cost of expanding coverage to adjacent municipalities.

Spillovers emerge as the most important predictor of entry in our model. The accuracy of entry prediction over the full 2014–2019 period declines significantly by several percentage points across all three models. This highlights the importance of accounting for geographic interdependence in fiber deployment decisions. The presence of strong spillovers implies that the benefits of state aid are not confined to the municipalities receiving public support directly; neighboring municipalities may also experience increased entry as a result. Accordingly, when spillovers are included in the estimation, the model predicts a higher degree of crowding out of private investment, since entry becomes more likely in areas adjacent to those receiving aid. While regulators may not be able to fully anticipate the extent of these spillovers, they are partially captured in the state aid application process, which is typically coordinated and submitted by groups of neighboring municipalities.

The coefficients on the year dummies are positive, statistically significant, and increasing over

---

place in the absence of public subsidies. The results were qualitatively similar.

time. This pattern suggests that market entry is becoming progressively easier, possibly due to technological progress and declining deployment costs. Notably, the year coefficients increase the most in Model II, which is estimated on the sample of municipalities located in private initiative zones. This suggests that entry in these municipalities has become significantly easier over time than in public initiative zones, where a mix of unaided and aided entry is observed. Demand for fiber may also grow as the need for higher speeds and connection reliability increases. Unsurprisingly, entry is more likely in private initiative zones than in public ones. Furthermore, municipalities with a lower quality of the legacy copper network experience more entry than municipalities with a higher quality. This reflects the opportunity cost that operators may face in deploying next-generation networks due to their revenues from the legacy copper network (the "replacement effect"). Finally, we include in the estimation a set of department dummy variables that are highly significant. They control for other factors that determine the attractiveness of municipalities belonging to the same department and do not vary over time. Moreover, as discussed in Section 3.3, state aid subsidies are also designed at the departmental level.

In alternative specifications of our model (not reported due to space constraints), we included population density, which is expected to influence the cost of fiber deployment. However, this variable was consistently insignificant when added to the current set of entry determinants. This may be due, in part, to the inclusion of department fixed effects, which likely absorb some of the variation in population density, as well as the private initiative zone dummy. We also tested an extended model with richer controls for municipal heterogeneity, allowing department fixed effects to interact with a dummy for urban municipalities. However, this specification did not improve the model's predictive performance. Further alternative specifications included additional demand- and cost-related variables, such as surface area, employment rate, number of jobs, demographic age groups, and the share of active population by socio-professional category. None of these variables showed a significant effect on fiber entry. Notably, their significance disappears once we control for coverage in neighboring municipalities.

In another specification, we also account for the presence of a cable network, which was deployed by a single firm before 2014 and was not expanded thereafter, as discussed in Section 3.4. The deployment of the cable network can therefore be considered exogenous. Nevertheless, the dummy variable indicating the presence of cable in a municipality is not statistically significant, possibly because cable deployment is concentrated in a limited number of departments, and department fixed effects are included in the regressions.

In summary, our estimation results confirm the role that market size and other local market characteristics play in determining fiber entry. In particular, our results suggest that fiber entry is driven more by cost factors than demand factors, as deployment in neighboring areas appears to play an important role in entry decisions.

Our data consists of a panel of more than 34,000 municipalities over the period 2014-2019. Since we cannot account for this number of fixed effects, the observations for the same municipality are treated as a cross-section in the estimation, where the increasing likelihood of entry over time is accounted for by the year dummies. The estimated coefficients are averages over the entire period, and the error terms are clustered by department, as the error terms for municipalities belonging to the same department may be correlated.

The three models we estimate may be subject to different sources of bias. In Model I, we assume that state aid is granted randomly across municipalities, an assumption that may not hold in practice. In reality, the timing and allocation of state aid are likely influenced by varying levels of engagement and initiative on the part of local authorities. In Model II, the estimation sample excludes the municipalities categorized as public initiative zones, rendering the sample unrepresentative of the full population of municipalities. Finally, Model III assumes that fiber entry would have occurred in aided municipalities regardless of whether state aid was received, which is not realistic.

The predictive performance of all three models is broadly comparable in terms of overall accuracy, as reported in Table A.2. Predictions are based on a threshold rule: entry is predicted when the estimated probability exceeds or equals 0.5, and no entry otherwise. Prediction rates are then computed as the proportion of correct predictions (either for entry only, or for both entry and non-entry) relative to the total number of observations.[42] Our preferred specification to assess the efficiency of the French Broadband Plan is Model I, which achieves the highest overall prediction accuracy—97% for the period 2014-2019 for both entry and non-entry cases. However, Model I performs slightly worse than Models II and III in predicting entry events specifically (with an accuracy of 65.4%).

[42] These ratios are calculated for the 27,601 municipalities that did not receive state aid during the 2014–2019 period.

6.2 Entry Thresholds and Crowding Out

Based on the estimates from Model I in the previous section, we compute the entry thresholds for each municipality and each year. Column (2) in Table 4 reports the average entry threshold for all municipalities in a given year, while column (4) reports the average entry threshold only for the municipalities where entry occurred in a given year. For comparison, columns (3) and (5) show the average size – in terms of the number of households – of all municipalities and of the municipalities where entry occurred in a given year, respectively.

The entry threshold of a given municipality refers to the minimum number of households required for fiber entry to be profitable, which varies based on the characteristics of the municipality. For example, fiber deployment in neighboring municipalities and higher income levels reduce the entry threshold for a given area. Additionally, the threshold decreases over time for all municipalities, as shown in Table 4. For the 27,635 municipalities that never received state aid, the average entry threshold was 7,835 in 2014, but it declined to 4,207 by 2019. In municipalities where fiber entry occurs in a given year, the number of households required to sustain fiber entry declines sharply, from 9,128 in 2014 to 1,302 in 2019. The average entry thresholds in municipalities that experience entry are lower than the thresholds for all municipalities, except 2014.[43]

The decline in entry thresholds we obtain is consistent with Xiao and Orazem (2011) and Nardotto et al. (2015), who also report decreasing entry thresholds for network deployment over time. This may be due to declining investment costs, increasing demand, or a combination of both. The decline in investment costs may itself be due to technological improvements or learning by doing in building fiber networks.[44]

To assess whether state aid allocated under the French Broadband Plan was directed to municipalities that would not have attracted private entry, we compare the entry threshold predicted by Model I with each municipality's market size. We can equivalently check whether the predicted probability of entry is above or below the 0.5 threshold.[45] However, we choose to

[43] In 2014, fiber was deployed in 498 municipalities without state aid. In 2015, new entries occurred in 217 municipalities, increasing to 1,956 by 2019, excluding state-aid-supported entries.

[44] Estimated entry thresholds are negative for a few municipalities. In particular, this is true for small municipalities with high fiber coverage in neighboring municipalities. We believe this is consistent with lower investment costs in areas where the fiber backbone is already deployed. In these cases, we consider that entry would occur almost independently of market characteristics and set the entry threshold at one household.

[45] Policymakers may require that the probability of private entry exceed a threshold higher than 0.5 to classify entry as "likely." In our framework based on entry thresholds, imposing a higher probability requirement for private

Table 4: Average entry thresholds and market size.

Year	All Municipalities				Municipalities with Entry				Entries
	(I)	(II)	(III)	Market size	(I)	(II)	(III)	Market size	
2014	7,834	5,498	6,829	757	9,128	9,598	9,607	13,235	498
2015	7,299	5,084	6,240	757	4,201	4,020	4,038	2,483	217
2016	6,504	4,369	5,478	757	5,366	5,227	5,352	4,362	637
2017	5,819	3,521	4,788	789	2,909	2,523	2,928	3,173	630
2018	5,198	2,898	4,013	789	2,211	1,398	1,719	1,190	857
2019	4,207	2,109	3,058	789	1,302	613	960	691	1,956

Note: Entry thresholds and market size are in terms of the number of households. The numbers are reported for the 4th quarter of each year. The number of entries is without state aid.

focus on entry thresholds to remain consistent with the prior literature.

As noted in Section 5.2, under EU rules, a municipality should only receive state aid if its market size is below the entry threshold within a three-year window, indicating that private entry would not be profitable in that period. If this condition is met, the plan has efficiently addressed the lack of private investment. Otherwise, it may have distorted the market by crowding out private investment. We use the year and quarter of the final decision to grant state aid as the starting point for the three-year window. In most cases, the decision date coincides with the deployment of the first lines in the municipalities.

Table 5 shows (i) the number of municipalities receiving state aid for the first time each year, (ii) the number of these municipalities with entry thresholds that exceeded market size within a three-year window, and (iii) the proportion of aided municipalities where the model predicts a lack of private investment within a three-year window, calculated as the ratio of (ii) to (i). Table 6 displays cumulative figures for these measures over time.

For 64% of the municipalities that received state aid between 2014 and 2019, our model predicts no unaided private operator entry within a three-year window. However, for the remaining 36%, we anticipate private entry within that period. As a result, public funding in these municipalities may have crowded out private investment while speeding up fiber deployment. Note that the figures for the years 2017-2019 overstate the lack of private investment, as we do not have

firms is equivalent to raising the entry thresholds. For instance, increasing the probability cutoff for private entry to 0.75 would raise the share of municipalities without private entry (as shown in Table 5) to 83% in the three-year window case and 99% in the contemporaneous case.

predictions on the evolution of entry thresholds for the entire three-year period following the entry with state aid. There was a significant decline in entry thresholds in 2019, which reduced the proportion of municipalities where we predict a lack of private investment.

As we estimate lower entry thresholds in Model II, the proportion of aided municipalities where the model predicts a lack of private investment is lower. With a three-year window, it drops significantly to only 24%. This is because there is substantial entry in the later years of the data in municipalities located in private initiative zones, resulting in higher estimated coefficients on the year dummies in Model II. When these coefficients are applied to municipalities in public initiative zones, they imply that more unaided entry would have occurred, which we do not consider realistic, given the inherent differences between the zones.

Although the Broadband State Aid Guidelines and the *Cahier des charges* of the French Broadband Plan stipulate that the prospects for private investment must be assessed in a three-year window, this window may be too wide for policymakers for several reasons. First, local authorities may have a strong preference for fast(er) fiber deployment, in other words, be *impatient*.[46] Second, policymakers may have a limited ability to anticipate future technological developments, demand evolution, and the decline of entry thresholds. Therefore, as an alternative, for each municipality and each year, we compare the size of the municipality and the contemporaneous entry threshold. This scenario corresponds to columns (iv) and (v) in Tables 5 and 6. Overall, in 97% of the cases, the market size of the municipalities receiving state aid was below the entry threshold predicted by our model in the year when state aid was granted. In other words, private operators were not expected to enter these markets in the year in question, supporting the idea of *impatient* local authorities. Our discussions with industry players also support this idea.[47]

The French Broadband Plan successfully addressed the broadband availability gap by extending fiber coverage to regions that private operators would not have entered in the "near future". However, we estimate that in 36% of cases, this public intervention led to some degree

[46]Cooper and Kovacic (2012) discuss the possible behavioral biases of regulators and in particular, myopia, which can "lead the regulator to favor policies that focus excessively on short-run considerations."

[47]For example, in 2021, the Brittany local authority responsible for FTTH deployment signed an agreement with the consortium in charge of deploying the fiber network in the region's public initiative zones. The aim was to accelerate deployment following complaints from residents and mayors about delays in access to ultra-fast broadband. See https://www.lesechos.fr/pme-regions/bretagne/les-retards-du-reseau-tres-haut-debit-breton-exaspere-entreprises-et-elus-1353384.

Table 5: Number and proportion of aided municipalities where private entry would not have occurred, for a three-year window and a contemporaneous evaluation.

Year	(i) Number of municipalities with state aid	(ii) Entry threshold higher than market size: three-year window	(iii) Lack of private investment	(iv) Entry threshold higher than market size: contemporaneous	(v) Lack of private investment
2014	23	19	83%	23	100%
2015	168	148	88%	168	100%
2016	369	221	60%	365	99%
2017	891	543	61%	890	100%
2018	2,113	1,099	52%	1,939	92%
2019	3,207	2,310	72%	3,156	98%
Total	6,771	4,340	64%	6,541	97%

Table 6: Cumulative number and proportion of aided municipalities where private entry would not have occurred, for a three-year window and a contemporaneous evaluation.

Year	(i) Number of municipalities with state aid	(ii) Entry threshold higher than market size: three-year window	(iii) Lack of private investment	(iv) Entry threshold higher than market size: contemporaneous	(v) Lack of private investment
2014	23	19	83%	23	100%
2015	191	167	87%	191	100%
2016	560	388	69%	556	99%
2017	1,451	931	64%	1,446	99%
2018	3,564	2,030	57%	3,385	95%
2019	6,771	4,340	64%	6,541	97%

of crowding out, as private operators would have likely entered these areas within a three-year window.

We then use our estimates to calculate the cost of state aid for the municipalities where we predict a lack of private investment and for those where we predict likely crowding out. For these calculations, we use the maximum amount of aid per line that a municipality can claim, and the number of lines in each municipality reported by ARCEP and AVICCA.[48] The cost per line is the same for all municipalities in the same department but differs from department to department depending on rurality and the dispersion of population. Table 7 shows the estimated cumulative costs over time for municipalities that received state aid. Note that the number of

[48]Source: "Investissements d'Avenir - Développement de l'Economie Numérique. France Très Haut Débit, Réseaux d'initiative publique," March 2017, p. 42 and 43.

lines deployed that received public subsidies is lower than the total number of lines used in the calculation. Therefore, our calculations represent an upper bound on the cost of state aid.[49] According to our estimates, in 2019, 905 million euros of state aid (41% of total expenditure) went to municipalities where we predict that private entry could have occurred in a three-year window. Note that these municipalities where we predict likely crowding out tend to be larger on average than those where we predict a lack of private investment. This explains why the crowding out effect accounts for a larger share of total expenditure (41%) than of the number of municipalities affected (36%).

Table 7: Cumulative cost of state aid for full coverage (million euros)

	Lack of private investment		Crowding out	
Year	Cost	Lines (000s)	Cost	Lines (000s)
2014	18	36	5	10
2015	68	153	26	57
2016	107	240	190	426
2017	293	679	347	815
2018	575	1,389	602	1,597
2019	1,298	3,202	905	2,351

Note: The number of lines (in thousands) corresponds to the total number of lines in municipalities reported by ARCEP and AVICCA.

In this analysis, we have considered the cost of state aid that may have led to crowding out of private investment. However, there may also be benefits to society counter-balancing this cost. For example, if access conditions to public initiative networks are more favorable than those to private networks, then *ex-post* competition could be more intense with public rather than private investment. However, as we have explained in Section 3.2, this is not the case in France, where wholesale prices for public initiative networks must be similar to those for private networks.

6.3 Fiber Coverage

Table 8 reports the estimation results for our coverage model, based on six regression specifications. We first estimate models in which the effect of state aid is assumed to be constant over

[49] Note, however, that we ignore here the cost of public funding from municipalities or the EU.

time (columns (1) to (3)). To allow for potential differences in trends between aided and unaided municipalities, we then estimate models that include interactions between the state aid variable and year dummies (columns (4) to (6)). For each specification, we report three regressions: one using OLS, and two using a Heckman selection correction to account for the non-random presence of fiber infrastructure operators (columns labeled as "Heckman"). In the Heckman regressions in columns (2) and (5), we use the correction term (inverse Mills ratio) computed from the estimates of entry Model I in Table 3. In columns (3) and (6), we use a Mills ratio computed from entry Model II in Table 3, which is estimated for municipalities in private initiative zones. For public initiative zone municipalities, where some entry occurs with state aid and some without, we estimate a separate entry model using the same set of explanatory variables. The resulting estimates are used to compute a Mills ratio for these municipalities. In this way, we account for the non-randomness of entry both with and without state aid.

The dummy variables corresponding to state aid should therefore be interpreted as classification indicators, distinguishing municipalities in which entry occurred with state aid from those in which it occurred without. In columns (1) to (3) of Table 8, the presence of state aid has a significant and positive impact on fiber coverage. Its average magnitude over the period 2014-2019 in the OLS estimation (column (1)) is 6.4%. When the correction term from the fiber entry model is included in the estimation (column (2)), the magnitude of the impact of state aid increases slightly to 6.8%. The significant estimate of the Mills ratio indicates that the OLS estimates suffer from a sample selection bias. However, the Mills ratio is not significant in our second Heckman model (column (3)).

In columns (4) to (6) of Table 8, we observe that the positive impact of state aid on fiber coverage is substantial at the beginning of the period but declines over time. However, the coefficient of the Mills ratio is positive and statistically significant at the 10% level only in column (5), and not statistically significant in column (6). We use the estimates from column (5) of Table 8 to illustrate in Figure 5 the evolution of the impact of state aid on fiber coverage over time. Since the estimated coefficients for the state aid variables are similar across the specifications in columns (4) to (6), the patterns depicted in Figure 5 would remain broadly consistent regardless of the specification chosen.

Table 8: Fiber coverage in municipalities.

Dep. Var: Fiber coverage rate	(1) OLS	(2) Heckman	(3) Heckman	(4) OLS	(5) Heckman	(6) Heckman
State aid (dummy)	0.062**	0.066**	0.060**	0.518***	0.478***	0.546***
	(0.030)	(0.030)	(0.030)	(0.043)	(0.051)	(0.050)
State aid (dummy) * 2015				-0.196***	-0.179***	-0.216***
				(0.034)	(0.033)	(0.039)
State aid (dummy) * 2016				-0.299***	-0.268***	-0.327***
				(0.042)	(0.046)	(0.044)
State aid (dummy) * 2017				-0.359***	-0.324***	-0.386***
				(0.041)	(0.048)	(0.044)
State aid (dummy) * 2018				-0.434***	-0.392***	-0.463***
				(0.037)	(0.044)	(0.044)
State aid (dummy) * 2019				-0.506***	-0.461***	-0.538***
				(0.035)	(0.045)	(0.045)
Level of coverage in neighbor t-1	0.379***	0.457***	0.364***	0.382***	0.430***	0.346***
	(0.039)	(0.029)	(0.046)	(0.037)	(0.033)	(0.044)
Log(Income)	-0.070*	-0.065*	-0.069*	-0.075**	-0.071*	-0.073**
	(0.036)	(0.038)	(0.036)	(0.036)	(0.037)	(0.036)
Type of initiative zone (ref: public)						
Private initiative	0.063**	0.082***	0.059*	0.066**	0.077**	0.055*
	(0.029)	(0.029)	(0.030)	(0.030)	(0.030)	(0.030)
Copper loss (ref: <=20dB)						
20dB-30dB excellent	0.019	0.030*	0.017	0.022	0.028*	0.018
	(0.015)	(0.015)	(0.016)	(0.015)	(0.015)	(0.015)
30dB-40dB very good	0.065***	0.073***	0.065***	0.067***	0.071***	0.064***
	(0.018)	(0.018)	(0.018)	(0.018)	(0.018)	(0.018)
40dB-50dB good	0.111***	0.119***	0.110***	0.112***	0.117***	0.110***
	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)
50dB-60dB poor	0.147***	0.155***	0.146***	0.147***	0.153***	0.145***
	(0.026)	(0.026)	(0.027)	(0.026)	(0.026)	(0.027)
>=60dB bad	0.155***	0.159***	0.154***	0.155***	0.158***	0.154***
	(0.030)	(0.030)	(0.030)	(0.030)	(0.030)	(0.030)
Year dummies (ref 2014)						
y2015	0.053***	0.049***	0.053***	0.031**	0.031***	0.031**
	(0.016)	(0.013)	(0.016)	(0.012)	(0.012)	(0.013)
y2016	0.090***	0.090***	0.089***	0.064***	0.066***	0.063***
	(0.024)	(0.023)	(0.024)	(0.021)	(0.020)	(0.022)
y2017	0.112***	0.121***	0.111***	0.093***	0.100***	0.089***
	(0.027)	(0.026)	(0.027)	(0.026)	(0.025)	(0.027)
y2018	0.164***	0.174***	0.162***	0.166***	0.172***	0.162***
	(0.029)	(0.028)	(0.030)	(0.031)	(0.030)	(0.032)
y2019	0.195***	0.208***	0.193***	0.234***	0.240***	0.231***
	(0.030)	(0.029)	(0.031)	(0.032)	(0.030)	(0.032)
Correction term entry (Mills ratio)		0.045***	-0.009		0.028*	-0.022
		(0.016)	(0.016)		(0.015)	(0.015)
Constant	0.758**	0.630	0.764**	0.769**	0.688*	0.785**
	(0.364)	(0.389)	(0.368)	(0.364)	(0.384)	(0.369)
Department dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	81,629	81,629	81,629	81,629	81,629	81,629
Adjusted R-squared	0.289	0.291	0.289	0.297	0.298	0.297

Note: Robust standard errors in parentheses (clustered at the department level). Symbols *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

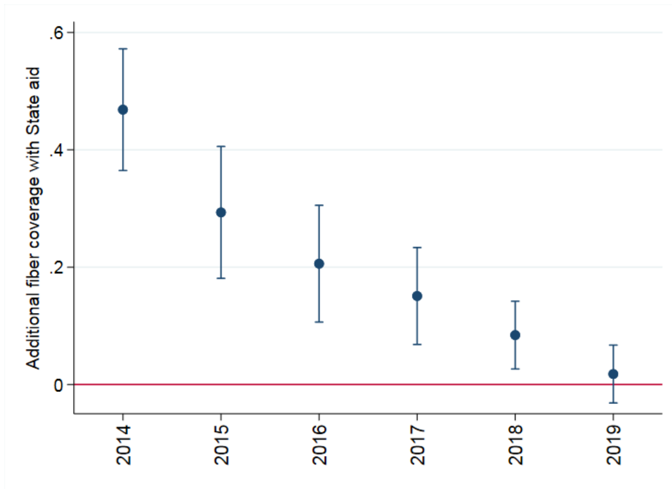
The additional coverage in aided municipalities was 48% in 2014, 30% in 2015, 21% in 2016, 15% in 2017, and 9% in 2018.[50] There is no evidence that state aid allowed for significantly higher coverage in 2019. The higher coverage observed in municipalities receiving state aid during the early years may reflect the fact that these municipalities are generally much smaller. Over time, however, private entry also occurred in public initiative zone municipalities, and the number of households became comparable between the two types of municipalities within a department.

We include in the models several control variables to account for the heterogeneity of local markets, which we expect to have a significant impact on fiber deployment. The effects are qualitatively similar across specifications, except for differences in the significance level of certain variables. In specification (4), a higher level of fiber coverage in neighboring municipalities in the previous period is associated with a higher fiber coverage in the municipality. This confirms the existence of geographic dependence in fiber deployment. The coefficient of income is negative and statistically significant at the 90% level. This suggests that income effects are dominated by cost effects. Fiber coverage is higher in private initiative zones than in public initiative zones. Moreover, coverage expands as the quality of the legacy copper network decreases. This result reinforces the evidence of a replacement effect that we also find when we estimate the entry model. The coefficients of yearly dummies are positive, statistically significant, and increasing over time. This is intuitive as deployment is an incremental process. Finally, we include department dummy variables in the estimation to control for differences in the attractiveness of the municipalities that belong to them. Most of them are highly significant.

Our results suggest that state aid to municipalities has resulted in higher fiber coverage, especially in the early part of the period. Over time, however, the gap between aided and unaided municipalities appears to have narrowed. One interpretation of this finding is that some municipalities may have included specific coverage obligations in their contracts with private partners, leading to higher observed coverage compared to similar unaided municipalities. However, as the demand for ultra-fast broadband grows, private operators tend to catch up, reducing the gap.

[50] The impact of state aid on coverage in the years 2015-2019 is calculated by adding each interaction coefficient to the coefficient of the state aid dummy.

Figure 5: Evolution of the impact of state aid on fiber coverage.



Note: Estimates from column (5) in Table 8, where the dependent variable is the fiber coverage rate at the municipality level. Each point represents the additional coverage rate in aided municipalities. For example, in 2015, aided municipalities had 29% additional coverage relative to unaided municipalities. The vertical lines represent the 95% confidence intervals.

7 Conclusion

In this paper, we investigate the potential crowding out of private investment by public subsidies in the deployment of broadband fiber networks using a rich dataset on fiber deployment, state aid, and local market characteristics in France in the context of the French Broadband Plan (*Plan France Très Haut Débit*). We first examine the determinants of fiber entry in local areas. We then use this model to assess the extent to which state aid has likely crowded out private investment. Finally, we evaluate the impact of state aid on fiber coverage (the intensive margin), controlling for the endogeneity of fiber entry.

State aid is an important policy tool for deploying broadband networks in rural and low-density areas, where private operators may lack the incentive to invest. However, state aid is subject to control, as it may distort competition or crowd out private investment. In particular, it is important to ensure that state aid is targeted at areas where private operators would not choose to invest.

Our results suggest that the French Broadband Plan was successful in covering areas that would not otherwise have been covered. In addition, broadband deployment under the plan may have generated spillovers and facilitated investment in neighboring areas. Spillovers are the most important predictor of entry in our model, and the accuracy of entry prediction drops substantially when they are not accounted for. While regulators may not be able to fully predict the magnitude of such spillovers, they are partly incorporated in the state aid application process, which is typically submitted jointly by multiple municipalities.

However, these benefits come at the cost of some crowding out. Specifically, we find that in 64% of the cases, state aid benefited municipalities where private entry would not have occurred. Yet, in 36% of the aided municipalities, private investment may have occurred within a three-year window (i.e., the time frame suggested by the EU Broadband State Aid Guidelines). Crowding out may result from the impatience of local authorities to obtain fiber coverage, or their limited ability to anticipate the evolution of the technology or demand, and the decline in entry costs. Based on the average cost of state aid per line and the total number of lines in a municipality, we estimate that the cost associated with crowding out amounts to (at most) 902 million euros in 2019, or 41% of total expenditure.

In evaluating the French broadband plan, we also examined the determinants of fiber entry in municipalities. We find that local market characteristics, such as market size and income, are important determinants of entry. Interestingly, we also find evidence of a strong geographic dependence of fiber entry and a replacement effect from the legacy copper network in fiber entry decisions. We also find that fiber entry becomes easier over time.

While the state aid plan may have crowded out private investment in some municipalities, our analysis suggests that it allowed for higher fiber coverage in aided municipalities, especially at the beginning of the period of analysis. This effect diminishes over time, so that by the end of the observation period, there is no difference between aided and unaided municipalities. Our interpretation is that some aided municipalities may have adopted ambitious fiber coverage targets, leading to a gap in coverage between aided and unaided municipalities in the early years. This gap narrowed and eventually disappeared as demand for ultra-fast broadband grew over time, increasing the returns to increased coverage for private operators.

Due to data limitations and our focus on infrastructure operators, we are unable to study the impact of state aid on competition between Internet service providers or the impact of fiber competition on deployment. The analysis of entry into the downstream market for the provision of fiber services to residential and/or business customers is an interesting avenue for future research. Moreover, we assume that there is no favoritism or capture in the granting of public subsidies in local markets. For example, there may be political factors (e.g., differences in the involvement of voters or local representatives across markets, and political orientation at the regional, departmental, and local levels) that influence the location and timing of state aid. These questions could be the subject of further research on state aid.

Moreover, our model does not account for firm heterogeneity, which may arise from differences in size, geographic coverage, cost structures, and ownership of broadband networks based on other technologies. Accounting for this would require reformulating the model as a discrete entry game, in which firms make strategic entry decisions conditional on the actions of competitors. Such models typically allow for multiple equilibria, depending on the sequencing of entry and the potential for preemption. Incorporating strategic interactions and firm-specific characteristics into our framework constitutes a valuable and promising direction for future research.

References

Ahlfeldt, G., Koutroumpis, P. and T. Valletti (2017). "Speed 2.0 – Evaluating access to universal digital highways," *Journal of the European Economic Association*, 15(3), 586–625.

Arrow, K. (1962). "Economic welfare and the allocation of resources for invention," Chapter in *The rate and direction of inventive activity: Economic and social factors.* Princeton University Press.

Bacache, M., Bourreau, M. and G. Gaudin (2014). "Dynamic Entry and Investment in New Infrastructures: Empirical Evidence from the Fixed Broadband Industry," *Review of Industrial Organization*, 44(2), 179–209.

Bourreau, M., Feasey, R., and Nicolle, A. (2020). Assessing fifteen years of State Aid for broadband in the European Union: A quantitative analysis. *Telecommunications Policy*, 44(7), 101974.

Bourreau, M., Grzybowski, L. and M. Hasbi (2019). "Unbundling the incumbent and deployment of high-speed internet: Evidence from France," *International Journal of Industrial Organization*, 67, 102526.

Bresnahan, T. and P. Reiss (1991). "Entry and Competition in Concentrated Markets," *Journal of Political Economy*, 95, 977–1009.

Briglauer, W. (2015). "How EU sector specific regulations and competition affect migration from old to new communications infrastructure: recent evidence from EU27 member states," *Journal of Regulatory Economics*, 48(2), 194–127.

Briglauer, W., Dürr, N.S., Falck, O. and K. Hüschelrath (2019). "Does state aid for broadband deployment in rural areas close the digital and economic divide?" *Information Economics and Policy*, 46, 68-85.

Briglauer, W., Cambini, C. and M. Grajek (2018). "Speeding Up the Internet: Regulation and Investment in European Fiber Optic Infrastructure," *International Journal of Industrial Organization*, 61, 613-652.

Briglauer, W., Cambini, C., Gugler, K. and V. Stocker (2023). “Net Neutrality and High-Speed Broadband Networks: Evidence from OECD Countries,” *European Journal of Law and Economics*, 55(3), 533-571.

Briglauer, W. and M. Grajek (2023). “Effectiveness and efficiency of state aid for new broadband networks: Evidence from OECD member states,” *Economics of Innovation and New Technology*, 33(5), 672-700.

Cooper, J. C., and W. E. Kovacic (2012). “Behavioral economics: implications for regulatory behavior,” *Journal of Regulatory Economics*, 41, 41–58.

Czernich, N., Falck, O., Kretschmer, T., and L. Woessmann (2011). “Broadband Infrastructure and Economic Growth,” *The Economic Journal*, 121, 505–532.

Duso, T., Nardotto, M. and J. Seldeslachts (2024). “A Retrospective Study of State Aid Control in the German Broadband Market,” DIW Discussion Papers (No. 1931), forthcoming in the *Journal of the European Economic Association*.

European Commission, Connectivity for a Competitive Digital Single Market - Towards a European Gigabit Society, COM(2016) 587 final.

European Commission, Digital Economy and Society Index (DESI) 2020.

European Commission, EU Guidelines for the application of state aid rules in relation to the rapid deployment of broadband networks, 2013/C 25/01.

European Commission, The EU explained: Digital agenda for Europe, November 2014.

Fabritz, N. and O. Falck (2013). “Investment in Broadband Infrastructure Under Local Deregulation: Evidence from the UK Broadband Market,” CESifo Working Paper No. 4277.

France Stratégie (2020), *« Déploiement du très haut débit et Plan France très haut débit. Évaluation socioéconomique »*, Technical report.

Goldfarb, A. and M. Xiao (2011). “Who Thinks about the Competition? Managerial Ability and Strategic Entry in US Local Telephone Markets,” *American Economic Review*, 101(7), 3130–3161.

Greenstein, S. and M. Mazzeo (2006). "The role of differentiation strategy in local telecommunication entry and market evolution: 1999-2002," *Journal of Industrial Economics*, 54, 323–350.

Investissements d'Avenir – Développement de l'Économie Numérique France Très Haut Débit, Réseaux d'initiative publique, March 2017.

Matteucci, N. (2019). "The EU state aid policy for broadband: An evaluation of the Italian experience with first generation networks," *Telecommunications Policy*, 43, 101830.

Nardotto, M., Valletti, T. and F. Verboven (2015). "Unbundling the incumbent: Evidence from UK broadband," *Journal of the European Economic Association*, 13, 330–362.

Wilson, K. (2024). "Does Public Competition Crowd Out Private Investment? Evidence from Municipal Provision of Internet Access," forthcoming in the *American Economic Journal: Microeconomics*.

Wilson, K., Xiao, M. and P.F. Orazem (2021). "Entry threat, entry delay, and Internet speed: The timing of the US broadband rollout," *Journal of Economics & Management Strategy*, 30(1), 3-44.

Xiao, M. and P.F. Orazem (2011). "Does the fourth entrant make any difference? Entry and competition in the early US broadband market," *International Journal of Industrial Organization*, 29(5), 547–561.

Appendices

Appendix A1 Additional Figures and Tables

Table A.1: List of projects eligible for State aid in the framework of the French Broadband Program as of January 2021.

Project code	Departments/region	Project code	Departments/region
CD01	Ain	CD40	Landes
CD02	Aisne	LIMO	Limousin
PACA	Alpes-de-Haute-Provence & Hautes-Alpes	CD42	Loire
CD06	Alpes-Maritimes	CD44	Loire-Atlantique
ALSA	Alsace	CD45	Loiret
ARDR	Ardèche & Drôme	CD41	Loir-et-Cher
CD09	Ariège	CD46	Lot
CD10	Aube	CD47	Lot-et-Garonne
CD11	Aude	CD48	Lozère
AUVE	Auvergne	CD49	Maine-et-Loire
CD12	Aveyron	CD50	Manche
CD13	Bouches-du-Rhône	C972	Martinique
BRET	Bretagne	CD53	Mayenne
CD14	Calvados	C976	Mayotte
CD16	Charente	CD57	Moselle
CD17	Charente-Maritime	CD58	Nièvre
CD18	Cher	NPDC	Nord-Pas-de-Calais
CORS	Corse	CD60	Oise
CD21	Côte-d'or	CD61	Orne
CD79	Deux-Sèvres	CD64	Pyrénées-Atlantiques
CD24	Dordogne	CD66	Pyrénées-Orientales
CD25	Doubs	C974	Réunion
CD91	Essonne	C977	Saint-Barthélémy
CD27	Eure	C975	Saint-Pierre-et-Miquelon
CD28	Eure-et-Loir	CD71	Saône-et-Loire
CD30	Gard	CD72	Sarthe
CD32	Gers	CD73	Savoie
CD33	Gironde	CD77	Seine-et-Marne
GDES	Grand Est	CD76	Seine-Maritime
C971	Guadeloupe	CD80	Somme
C973	Guyane	CD81	Tarn
CD31	Haute-Garonne	CD82	Tarn-et-Garonne
CD52	Haute-Marne	CD94	Val-de-Marne
CD70	Haute-Saône	CD95	Val-d'oise
CD74	Haute-Savoie	CD83	Var
CD65	Hautes-Pyrénées	CD84	Vaucluse
CD34	Hérault	CD85	Vendée
CD36	Indre	CD86	Vienne
CD37	Indre-et-Loire	CD88	Vosges
CD38	Isère	CD89	Yonne
CD39	Jura	CD78	Yvelines

Table A.2: Comparison of correct prediction rates across models.

	Entry only			Entry and no entry		
Year	Model I	Model II	Model III	Model I	Model II	Model III
2014	49.4%	42.8%	45.8%	98.8%	98.8%	98.8%
2015	51.3%	49.8%	50.8%	98.3%	98.4%	98.4%
2016	51.0%	49.3%	50.1%	97.0%	97.0%	97.0%
2017	64.7%	68.5%	64.5%	96.8%	96.1%	96.4%
2018	68.0%	74.3%	70.8%	95.5%	93.5%	94.2%
2019	70.2%	82.3%	76.9%	92.7%	87.6%	89.8%
All	65.4%	71.7%	68.4%	97.0%	95.9%	96.4%

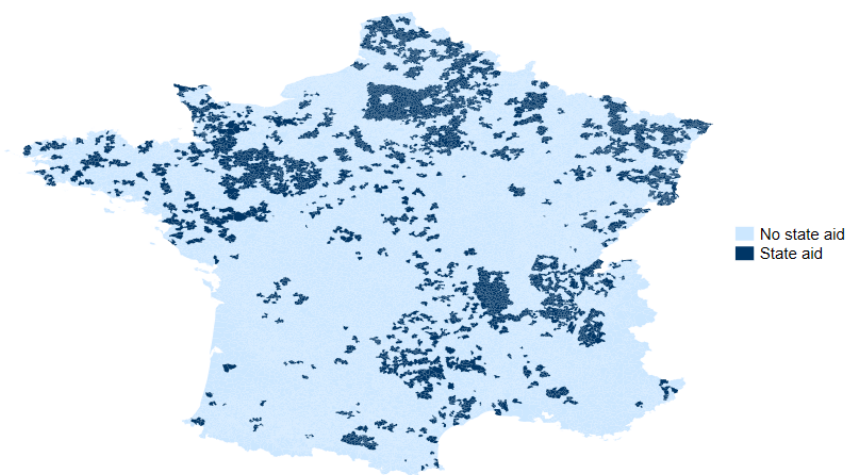
Note: Prediction rates are calculated as the ratio between the number of correct predictions (for entry and no entry) and the total number of observations. This ratio is calculated only for the 27,635 municipalities that do not benefit from state aid in the period 2014-2019.

Table A.3: Fiber entry and exit in years 2014-2019.

	Number of infrastructure operators (Nb fiber$_t$)					
Nb fiber$_{t-1}$	0	1	2	3	4	5
0	744,115	10,901	259	40	0	0
1	0	64,875	289	50	1	0
2	0	0	3,839	72	2	0
3	0	0	0	1,712	24	0
4	0	0	0	0	417	2
5	0	0	0	0	0	34

Note: 826,632 observations for 34,443 municipalities for the period 2014-2019. We observe entry, but no exit.

Figure 6: Municipalities benefiting from state aid as of 2019Q4.



Source: ANCT.

University of Warsaw
Faculty of Economic Sciences
44/50 Długa St.
00-241 Warsaw
www.wne.uw.edu.pl
ISSN 2957-0506