Unbundling the Incumbent and Entry into Fiber: Evidence from France

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Abstract

We use panel data on 36,080 municipalities in metropolitan France over the period 2010-2014 to estimate two models of entry into local markets by: (i) the incumbent and two other operators using fibre technology and (ii) operators seeking wholesale access to the legacy telecommunications network via local loop unbundling (LLU). We find that local market presence of LLU operators has a positive impact on entry by fibre operators. We observe in the data that the deployment of fibre is always proceeded by the entry via LLU. Based on the estimation results the decision to deploy fibre by the incumbent and competitors is also positively influenced by the presence of other LLU operators. High speed fiber broadband allows firms to differentiate their offer from DSL-based services. Moreover, the presence of cable operator stimulates deployment of fibre. Firms using DSL technology fear losing consumers and being preempted by cable operator and deploy fibre technology in areas covered by cable. We also find that the deployment of VDSL technology which allows higher Internet speed on copper network slows down the deployment of fibre. Thus, firms choose to upgrade copper lines on the legacy network instead of investing in fibre networks. We use the estimates to calculate entry thresholds into local markets, which are much lower for broadband provision via LLU than via fibre and decrease over time. The deployment of fibre becomes cheaper over time but is unprofitable for the vast majority of municipalities in France.

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1 Introduction

Investments in next generation access networks are a priority for policymakers in all industrialized countries. The roll-out of fiber-optic networks delivering superfast broadband access to the Internet is expected to improve productivity and stimulate growth and job creations (see Röller and Waverman 2000; Czernich et al. 2011; Ahfeldt et al. 2015). In the US, the National Broadband Plan aims at providing 100 Mbit/s connections to 100 million American households by 2020.[1] In Europe, the European Commission has set as a target that half of European households should have the ability to access the Internet at speeds of 100 Mbit/s or more by 2020.[2] The roll-out costs of next generation access networks are, however, significant. For example, the European Commission has estimated that it would cost between 181 and 268 billion euros to achieve its target.[3] Private operators deploying fiber also face the competition from the previous broadband technology, which has been promoted in Europe through specific regulations.

Telecommunications have been subject to regulation since the opening to competition in the 1990's, to limit the exercise of market power by incumbent operators and allow competition to emerge. In particular, to foster entry and competition in the broadband market, Europe has implemented in the early 2000's wholesale access to the incumbents' local network, a regulatory policy known as "local loop unbundling" (or LLU). LLU requires incumbents to grant access to their physical local copper infrastructure, at regulated prices, to enable entrants to provide DSL ("digital subscriber line") broadband services.

The introduction of LLU has generated heated policy debates. While LLU can facilitate entry of alternative operators and allow the new entrants to acquire market experience progressively, some (in particular incumbent) operators have argued that it may undermine investment incentives for both incumbent and entrant operators.

Recently, the regulatory debate has centered on the impact of LLU on firms' incentives to roll-out next generation access networks. Due to their high deployment costs, fiber-optic access infrastructures are likely to coexist with the legacy copper networks for some time. A report commissioned by the European Competitive Telecommunication Association (WIK 2011) argued

[1] "Connecting America: The National Broadband Plan, Federal Communications Commission," March 2010
[2] "A Digital Agenda for Europe," European Commission, COM(2010) 245.
[3] See COM(2010) 472 final.

that promoting LLU via low access prices would foster investments in fiber, while another report written for European Telecommunications Network Operators (Plum 2011) concluded that it would rather discourage fiber deployment.

Therefore, governments and regulators face a complex trade-off between encouraging competition on the legacy copper network via LLU and providing industry players with the proper incentives to roll-out fiber networks. However, even though this question is critical for both policymakers and academics, so far there exist only limited and a very high level empirical evidence on the impact of regulation of legacy network on the roll-out of fiber networks.

In this paper, we analyze the impact of LLU on fiber investments using panel data on 36,080 municipalities in metropolitan France in years 2010-2014. The French market is interesting for such analysis for the following reasons. First, the regulation of wholesale broadband access via LLU in France has encouraged entry and competition since early 2000's. Second, in the last years fibre broadband has been deployed by the former telecommunications incumbent Orange and its two main rivals, SFR and Free, which are also active in the provision of mobile services. Third, there is a single cable network operator, Numericable, which has been upgrading its network to a hybrid fiber-coaxial architecture allowing for Internet speeds comparable to fibre. Fourth, since 2013 Orange and other DSL operators have been upgrading copper network towards VDSL technology, which is more advanced than ADSL and provides consumers with Interne speed up to 50 Mbp/s.

Following Xiao and Orazem (2011) and Nardotto, Valletti and Verboven (2015) we use panel data on 36,080 municipalities in metropolitan France over the period 2010-2014 to estimate two models of entry into local markets by: (i) the incumbent and two other operators using fibre technology and (ii) operators seeking wholesale access to the legacy telecommunications network via local loop unbundling (LLU). We estimate the role of sunk costs in entry decisions using reduced form specification of profit function. In the model of fiber entry, we allow the entry decision to depend on the local market presence of competing LLU operators, which entered in the earlier periods and therefore may be considered as exogenous. We also consider the impact of local market presence of cable operator on both fibre and LLU entry. When estimating the models we take into account the role of observable local market characteristics which are represented by population size, density of population, income, etc. and unobservable characteristics represented by market-specific random effects.

We find that local market presence of LLU operators has a positive impact on entry by fibre operators. We observe in the data that the deployment of fibre is always proceeded by the entry via LLU. Based on the estimation results the decision to deploy fibre by the incumbent and competitors is also positively influenced by the presence of other LLU operators. High speed fiber broadband allows firms to differentiate their offer from DSL-based services. Moreover, the presence of cable operator stimulates deployment of fibre. Firms using DSL technology fear losing consumers and being preempted by cable operator and deploy fibre technology. This also suggests that firms recognize that consumers care about the speed of connection and at the same time being first in the market matters for building consumer base and recouping the cost of investment. We also find that the deployment of VDSL technology which allows higher Internet speed on copper network slows down the deployment of fibre. Thus, firms choose to upgrade copper lines on the legacy network instead of investing in fibre networks.

We also find that market characteristics significantly impact the mode of entry. The main variable influencing entry is the market size measured by the number of households in the local market. Also, population density has a positive impact on fiber investment but its impacts decreases over time, which means that operators are able to enter less densely populated markets with time. We also find that the share of flats influences positively the probability of deploying fiber, reflecting the lower cost of connecting a block of flats rather than single houses. Besides, we show a positive effect of the quality of demand, in terms of purchasing market power, with the positive impact of the income. We use the estimates to compute the entry thresholds for fibre and LLU operators and how they change over time. The entry thresholds for LLU operators are much smaller than for fibre operators, which reflects the scale of investment needed to enter the market. Since LLU operators to a large extent rely on incumbent's infrastructure the scale of investment is much smaller.

Our results have important policy implications as they show that LLU regulation does not impede fiber entry. Moreover, we show that the main variable that influences fiber deployment is the market size. The market size required for an operator and for an additional operator to enter the market is decreasing over time, which makes entry easier to enter less densely populated municipality easier. However, fibre provision will remain unprofitable in the vast majority of smaller municipalities in France. There is a critical role for public policy to foster operators' incentives to deploy fiber and enter less densely populated municipalities by means of co-investment or cost-sharing.

The remainder of the paper is organized as follows. In Section 2, we review the relevant literature on regulation and investment in the telecommunications industry. Section 3 introduces the broadband industry in France. Section 4 presents the data. Section 5 introduces the econometric framework. Section 6 presents the estimation results. Finally, Section 7 concludes.

2 Literature Review

Universal access to superfast broadband is on top of the public policy agenda in the European Union. The contribution of this paper is to analyze how broadband provision on the incumbent's legacy copper network via local loop unbundling (LLU) influences entry and deployment of fiber infrastructures. To the best of our knowledge, this is the first paper which at a granular local level analyzes the deployment of fiber infrastructures and the impact of legacy broadband networks on the deployment of next generation access infrastructures. Our results shed light on the ongoing debate on the impact of LLU and the optimal policies to achieve universal access to high speed broadband.

The linkage between access regulation and investment incentives has long been recognized in the theoretical literature (see, for example, Valletti 2003; Hori and Mizuno 2006; Klumpp and Su 2010).[4] A few recent studies look more specifically at the effect of access regulation on investment incentives when the new infrastructure coexists with the legacy infrastructure (Inderst and Peitz 2012; Bourreau, Cambini and Doğan 2012 and 2014). They show that regulation of access to the legacy network (via LLU, for example) has ambiguous effects on the incentives to roll-out new infrastructures.

[4] See also Guthrie (2006) and Cambini and Jiang (2009) for comprehensive surveys. The relation between access and investment has generated heated policy debates, and a large number of policy papers have also addressed this question; see, among others, Crandall, Ingraham and Sidak (2004), Hausman and Sidak (2005) and Hazlett and Bazelon (2005).

The empirical literature on fiber investments is rather scant. Many studies have analyzed the effects of regulation and competition between technologies on the diffusion of the previous generation of broadband using aggregate country-level data.[5] Only few studies rely on more fine-grained data; Dauvin and Grzybowski (2014) use NUTS 1 level data for the EU countries, while Nardotto, Valletti and Verboven (2015) use microdata at the local level for the UK. In general, competition is found to have a significant and positive impact on broadband diffusion but with some differences with respect to the importance of inter- (when entrants build their own infrastructure) and intra-platform (when entrants lease access to incumbents' facilities) competition. Only very few papers analyze investments in superfast broadband infrastructures. Bacache, Bourreau and Gaudin (2014) analyze the migration from LLU to fiber in 15 European Member States over the period 2002-2010. Briglauer (2015) studies the determinants of fiber investments for the 27 EU Members over the period 2004-2013.[6] These two studies use aggregate country-level data. There are only two recent papers which use local market data. In a recent paper, Minamihashi (2012) uses municipality-level data for Japan in years 2005-2009 and finds that unbundling regulations imposed on the Japanese incumbent operator have prevented entrants from self-deploying new broadband infrastructures. According to a counterfactual exercise unbundling regulation leads to a 24% decrease in the incidence of new infrastructure builders. However, the incumbent's NGA investments were not hindered by the unbundling regulation. In another paper, Fabritz and Falck (2013) use data on local exchange areas in the UK in years 2007-2013 to analyze how the introduction of geographically differentiated regulation of the wholesale broadband access influences investment in NGA network by the incumbents. They find that deregulation has a positive effect on the roll-out of fibre.

Another growing body of literature analyzes competition between broadband technologies from a consumer perspective. For instance, Cardona, Schwarz, Yurtoglu and Zulehner (2009) use household survey data for Austria to estimate discrete choice models, and find that cable modem and mobile access are close substitutes to DSL and therefore that they are in the same market as DSL. Srinuan, Srinuan and Bohlin (2012) use survey data for Sweden to estimate

[5] See, among others, Distaso, Lupi and Manenti (2006), Denni and Gruber (2007), Lee and Brown (2008), Bouckaert, Dijk and Verboven (2010), Lee et al. (2011), Gruber and Koutroumpis (2013).

[6] See also Grajek and Röller (2012), who study the impact of pro-entry regulation on incumbents' and entrants' aggregate investments.

a discrete choice model, and find that mobile broadband and fixed broadband technologies are close substitutes when they are locally available. Finally, Grzybowski, Nitsche, Verboven and Wiethaus (2014) estimate a mixed logit model using survey data for Slovakia, and find that mobile broadband should be included in the relevant market for internet access based on fixed broadband technologies. These studies provide evidence of competition between DSL and other broadband technologies, but do not analyze how DSL regulation via LLU influences the incentives to invest into fiber or into other high speed broadband technologies.

The literature on entry is mature and was excellently reviewed by Berry and Reiss (2007). There are only few studies which analyze entry into telecommunications markets. This is due to a lack of appropriate local-level data and the fact that the opening of telecommunications to competition is relatively recent. Facility-based entry requires substantial capital investment to materialize. Most of the studies focus on entry into local telecommunications markets in the US prior to the FCC decision in 2004 to reverse its open access policy (see Greenstein and Mazzeo 2006; Economides, Seim and Viard 2008; Xiao and Orazem 2009 and 2011; Goldfarb and Xiao 2011), at a time when broadband was still in its infancy. Finally, Nardotto et al. (2015) study the deployment of the broadband technology in the last decade in the UK. However, they do not observe entry in high-speed broadband (fiber) in their period of analysis.

3 Broadband Industry in France

In France, five main operators compete in the retail broadband market: Orange, SFR, Free, Bouygues Telecom and Numericable. Orange is the historical fixed-line incumbent operator. It owns the legacy copper network, that it uses to provide voice and broadband services to its customers, using the DSL technology. SFR, Bouygues Telecom and Free are alternative operators, which do not possess their own copper network. To provide broadband services, they have to lease access to the incumbent's (Orange) local access network, via local loop unbundling (LLU).[7]

Broadband can be delivered with different technologies: DSL, fibre, cable, Wifi and mobile

[7] There is also a competitive fringe of small private or public broadband operators, which often target specific market segments (e.g., business consumers).

broadband. In 2014, the respective market shares were 88% for the DSL technology, 3.6% for fibre, 6.6% for cable modem, and 1.8% for other broadband technologies, such as WiFi, mobile broadband and satellite.[8]

3.1 DSL

In France and in the European Union, the wholesale access to the copper local loop is regulated. LLU has played a critical role in promoting broadband diffusion in France by enabling competition between the incumbent and alternative operators which do not possess developed local telecommunications infrastructure.[9] Based on the ladder of investment theory, a phase of service-based competition or intra-platform competition is a prerequisite for alternative operators to enter the broadband market. They can get information on the market, constitute their customer's databases and then they will have incentive to build their own network.

Figure (2) presents the architecture of local loop unbundling, also referred to as wholesale local access. The copper network can typically be divided into three parts: access, backhaul connections and core networks. The access network (often called local loop or "the last mile") establishes the connection between the end user's premises and a main distribution frame (MDF) at a MDF site, passing through a first network aggregation point, called street cabinet. These elements belong to the incumbent operator. In order to provide Internet services, the alternative operator builds its own backhaul connection and core network down to the incumbent's MDF. Then it connects its customers to its own broadband equipment (DSLAM) located within the MDF, next to the incumbent's DSLAM.

There are in total 16,315 Main Distribution Frames (MDFs) distributed across metropolitan France, excluding Corsica, with about 33 million copper line connections, all of which as of 2014

[8]Source: ARCEP observatory - High and very-high speed Internet Retail market; SFR-Numericable 2014 annual results.

[9]Pursuant to the 2000 European Community Regulation on unbundled access to the local loop, 'the local loop is the physical twisted metallic pair circuit in the fixed public telephone network connecting the network termination point at the subscriber's premises to the main distribution frame or equivalent facility'. Two types of unbundled access to the local loop, namely full or shared unbundling can be implemented. The first one refers to 'the provision to a beneficiary of access to the local loop or local sub loop of the notified operator authorizing the use [...] of the twisted metallic pair'. The latter one consists in 'the provision to a beneficiary of access to the local loop or local sub loop of the notified operator, authorizing the use of the non-voice band frequency spectrum of the twisted metallic pair; the local loop continues to be used by the notified operator to provide the telephone service to the public'.

are eligible to a DSL technology. In December 2014, more than half of the MDFs have been unbundled, i.e., at least one alternative operator has installed its own active equipment inside. Hence, almost 90% of the metropolitan population has access to unbundling offers. Until 2015, SFR has been the main alternative operators, in terms of unbundled MDFs. In March 2015, Free had unbundled 6,980 MDFs compared to 6,764 for SFR. In contrast, Bouygues Telecom had only unbundled 985 MDFs. Unlike SFR and Free, the third biggest alternative DSL operator, Bouygues Telecom, favored DSLAM renting. Instead of unbundling Orange local loop, it rents a broadband access to another operator, either the incumbent or an unbundling operator.

In order to increase the speed delivered through the copper network, a faster technology, called VDSL has been implemented.[10] It requires deploying fiber downstream to the sub local loop (between the MDF and street cabinet), where the DSLAM will then be located. In October 2013, the French telecommunications regulator ARCEP authorized the use of a second generation of VDSL, called VDSL2, which can deliver speed superior or equal to 30MB/s.[11] VDSL2 is cheaper to deploy than FttH network because the copper local loop or the last mile is still used, i.e. between the street cabinet and the customer's premises. See Figure 1 for better understanding. According to ARCEP in the fourth quarter of 2014, approximately 8,500 MDFs, covering 91% of the population, have been equipped with VDSL2.[12]

3.2 Optical Fiber

From 2010 onwards, DSL operators have started to invest in Fiber to the Home network (FttH) in order to provide high speed broadband services on the retail market. Fiber optic networks are rolled-out up to the customer's premises and can carry video, data, voice and interactive video-telephone services.

Orange and SFR are the most active in FttH deployment. They deploy not only in very high

[10] VDSL stands for very high bit rate digital subscriber line. This technology is also called Fiber to the Neighborhood (FttN).

[11] In 2013, the authorization to implement VDSL2 only concerned lines in direct distribution, i.e, only the lines which are directly connected to a MDF.Since October 2014, ARCEP generalized the use of VDSL2 to all eligible lines, i.e., all lines connected to a street cabinet.

[12] Another solution which has been implemented by Orange to improve broadband speed in rural areas, where some lines were not eligible to ADSL, was the creation of MDF shadow zones. The idea was to reduce the line distance by creating a new MDF next to the street cabinet, where the DSLAM would be placed. However, this solution has been stopped with the development of VDSL.

density areas, but also in less densely populated areas. In January 2010, Orange and SFR signed a co-investment agreement, mostly to deploy FttH in areas which are less densely populated.[13] In October 2014, Numericable aquired SFR threatening the viability of the 2010 co-investment agreement since some areas are also covered by the cable network of Numericable.[14]

Numericable, is the cable-operator. It provides broadband services on the retail market using its co-axial cable network. Its footprint is, however, somehow limited, as only 30% of the population, mostly located in urban area, are within its coverage. From 2007 onwards, Numericable has started to upgrade its cable network by using DOCSIS 3.0 standard. Unlike FttH operators, Numericable does not deploy a new network, instead it brings fiber downstream, until the last amplifier (Fiber to the Last Amplifier or FttLA). It keeps relying on its co-axial local loop to provide broadband services to its customers. Numericable is at present, the biggest operators on the high speed broadband segment.

Free deploys its own FttH network in very high density areas and co-invests in less densely populated areas. In July 2011, Free signed a co-investment agreement with Orange to deploy FttH in 60 agglomerations located in less densely populated areas. In 2014, another 20 municipalities have been added to the list. Since August 2012, Free has almost stopped deploying its optical distribution frames. In December 2014 it had deployed its optical distribution frames (ODF) in 230 sites as compared to 226 in August 2012. At the same time Free has intensified its unbundling strategy and transfers its DSL subscriber towards the VDSL2 protocol.

Bouygues Telecom does not deploy its own FttH network, but rather offers retail fiber services by subscribing to Numericable's bitstream offer on its ugraded cable or FttLA network. In addition, in December 2010, Bouygues Telecom has signed a co-investment agreement with SFR to cover few agglomerations in very high density areas. In January 2012, it has also signed a co-investment agreement with Orange concerning FttH deployment in both less densely populated and very high density areas. As of December 2014, Bouygues Telecom fiber offers were commercially available in 6 agglomerations, namely Paris, Lyon, Marseille, Toulouse, Bordeaux

[13] In frame of a co-investment agreement, there is one leading operator, which deploys the FttH network. The other operator participates to the financial cost in proportion of the market share it wants to obtain. However, we could not get information on the local market share targeted by the co-investors. We also do not have information on the municipalities covered by any of the co-investment agreements.

[14] In April 2014, Numericable aquired SFR. The merger has been cleared by the Competition Authority in the 27th October 2014

and Nice. Bouygues Telecom keeps also unbundling Orange's MDFs. However, due to a lack of data on the municipalities concerned by Bouygues Telecom FttH co-investment and FttLA bitstream access, it has been excluded from the scope of the study.

Other smaller private operators concentrate their investments in large municipalities or medium municipalities located in less densely populated areas. Many municipalities or departments across the country deploy FttH network or a mix of technologies, such as FttH, VDSL2, satellite or wireless local access to provide high speed Internet connection into rural areas. However, the analysis of public investment or its impact on private investment is out of the scope of the paper.

The roll-out of the horizontal segment of FttH networks is well undergone. According to ARCEP observatory, in December 2014, 4,064,000 housings were eligible to FttH and 356,000 households had subscribed to an FttH offer, i.e. a rise of 37% and 91% respectively compared to December 2013. Besides, 8,707,000 households were eligible to Numericable's FttLA offer. All fiber operators have chosen to apply a 5 euros mark up on the retail market compared to the price of broadband offers. As such, customer's migration toward FttH or FttLA Internet offers is enhanced.

3.3 Regulatory Framework

Legal certainty is of prime importance for private investments to occur. Onward 2008, with the adoption of the Law on Modernising the Economy, public authorities have adopted a series of measures to facilitate the roll-out of next generation access network, especially fiber network and achieve full coverage of the French territory by 2022.

ARCEP has contributed to define a secure and clear regulatory framework which includes both symmetrical obligations, i.e., which apply to all operators, and asymmetrical obligations, i.e. which apply only to Orange. In this respect, in its 2008 market analysis of markets 4 and 5, ARCEP has compelled Orange to provide access to its civil engineering, ducts and pole, under transparent, non-discriminatory and cost-oriented conditions and to publish a reference offer.[15]

[15] Market 4 of Wholesale (physical) network infrastructure access (including shared or fully unbundled access) at a fixed location. Market 5 of Wholesale broadband and ultra-fast broadband network access including bitstream' access at a fixed location.

Access to existing infrastructure is seen as a prerequisite to ensure dynamic competition in the deployment of FttH network. Civil engineering represents the highest costs of deployment, the FttH council has estimated, in 2014, that "about 2.5 billion Euros was saved over five years by eliminating civil works for new cables in France, and similar savings could be made in the coming five years. The huge cost savings from duct sharing can dramatically improve the return on investment for FTTH projects".[16]

In addition, to avoid the pitfall of monopolisation, ARCEP has imposed symmetrical access obligations to all operators deploying a fiber optical network.[17] Hence, any operators deploying an FttH network must grant access to its network, access prices are defined commercially by the operators and a public offer shall be published. Besides, to take account of geographical differentiation and promote investment, France has been segmented in two zones: the very high density areas and the other areas.

In very high density area, where dynamic competition already exists, ARCEP promotes infrastructure-based competition. In these areas, it is economically feasible for several operators to deploy their own network until the consumers' premises.[18] On the contrary, in less densely populated areas, ARCEP promotes co-investment for the last mile of the network from the optical distribution frame to alleviate the costs of FttH roll-out. In these areas, it is not economically feasible for several operators to deploy their own fiber network, however, network co-investment between two or more operators leads to cost-cutting and improve profitability. As a result, operators wishing to deploy an FttH network in these less densely populated areas have to publish a call for co-investment and co-invest with any operators interested.

Yet, in some sparsely populated areas, despite co-investment, private investment is unlikely to occur. In some of those non-profitable areas, where a lack of private incentive to invest has been assessed, local governments can deploy their own public network.[19] We do not address the question of public intervention in this analysis.

In December 2009, ARCEP had identified 148 municipalities located in very high density

[16]Source: White Paper: Innovative FTTH Deployment Technologies By the Deployment & Operations Committee

[17]ARCEP is enabled to define general obligations which apply uniformly to all stakeholders as soon as these obligations have been homologated by the Minister in charge of telecommunications

[18]ARCEP Decision Nr 2009-1106 from the 22nd December 2009

[19]Call for manifestation of incentive to invest 2009

areas, representing 5.54 million households.[20] In 2013, taking into account practical considerations and the technical and financial conditions surrounding fiber deployment, ARCEP removes 43 municipalities, corresponding to 547,000 households from the list of high density areas. This, in turns, strengthens the principle of co-investment or cost-sharing on these municipalities facilitating the roll-out of fiber network. On the contrary, one municipality, Poitier, has been added to the list of the very high density area, based on the deployment that had already happened. The 2013 Decision brings also a modification inside the definition of the very high density areas, by identifying low-density pockets. Inside low-density pockets, the principle of network co-investment also applies. The localization of the concentration point and the condition of vertical deployment differs from the other areas.[21]

4 The Data

The main data on optical fiber deployment constitutes a panel of fiber deployment in metropolitan France (Corsica excluded) over 5 years, from 2010 to 2014. They have been extracted from Orange's Information System and from SFR's website. Both databases provide information at the municipality level with each municipality identified by a unique geographic code (the INSEE code). We have information on 36,080 French municipalities out of the 36,192 municipalities counted in metropolitan France in 2014. The Corsican region and the French overseas territories are excluded from the database due to a lack of information. For each municipality, we know whether Orange and/or SFR has deployed an FttH network. In the original dataset from Orange's Information System, we had information on the deployment state of each concentration point. For the year 2014, the data have been extracted only when the concentration point was

[20]The list of very high density area has been defined following a socio-economic approach (instead of an administrative one) starting from the agglomeration level (instead of the municipality level). Only the principal French agglomerations densely populated, whose urban units count more than 250,000 inhabitants and where buildings of more than 12 flats represent at least 20% of housing (single houses included). 20 agglomerations representing 148 municipalities have been identified as very high density zone in 2009.

[21]As regards vertical deployment, the Law on Modernising the Economy imposes to co-invest in the last mile of the network deployed in-building. Only one operator, the building operator, deploys fiber in the building. In its 2009 decision, ARCEP imposes to building operators to deploy in very high density areas a dedicated fiber for their competitors, if they asked for and co-finance it. This solution aims at reducing the costs of deployment and remedies to the inconvenience of having multiple interventions in the same building. This regulation comes with the creation of a right of access or right of use of the vertical fiber network by commercial operators. Therefore, customers have the choice between different competing high broadband offers.

declared as "deployed". The two other states "in deployment" and "planned" have been excluded as no timeline was given for their actual deployment. However, their exclusion does not lessen the relevance of the final dataset. Indeed, for each municipality in which an FttH network is deployed, several concentration points coexist. As a result, we assume that, in a municipality where a horizontal network has been deployed, there is at least one concentration point declared as deployed.

Regarding the data extracted on SFR's website, two sources have been used. First, SFR has published on its website a map of France and a list of municipalities in which it has deployed or will deploy an FttH network. For each municipality, we know whether SFR has planned to deploy its network alone or in co-investment with another operator. However, for the year 2014, no timeline was provided for the deployment. As a result, to determine whether SFR has effectively deployed an FttH network in the municipality, we crossed these data with a press release, published on its website, listing the municipality where households can subscribe to its FttH offers as of October 2014.

Regarding Free's data, they have been extracted on an unofficial website updated by Free's users community. The data are consistent with information gathered on other websites, as well as with Free's Annual Reports. For each municipality, we know whether there are active fiber connections.

This database has been completed with four other sources. First, variables on the copper network have been taken from two databases coming from Orange's Information System for the years 2010 to 2014. They inform us on the number and identity of the unbundling operator as well as on the number of VDSL lines both at the Main Distribution Frame (MDF) and at the municipality level.

Second, data on cable upgrade to FttLA have been extracted from Numericable's website for the years 2010 to 2014. For each municipality, we know whether Numericable has upgraded its cable network to provide very high broadband services.

Third, socio-demographic characteristics come from INSEE, the French National Institute for Statistics and Economics Studies. INSEE publishes data at the municipality level such as population density, population, number of housing and economic data such as the unemployment rate. Some municipality characteristics are also extracted from INSEE databases, such as the municipal urbanization degree, the type of economic or political zones with the employments zones and the canton-ville zones. These information have all been collected by INSEE for the years 2008 to 2012 and have been published 2 years later. As such, lagged values have been created, as it could be considered that to make their decision, operators take account of the most recent information they can get. Data on the average fiscal income per municipality has been collected on the General Direction of Public Finance's website (Gouvernment Taxes Services, DGFIP) for the years 2010 to 2014.

The different databases have been merged using the INSEE code which uniquely identifies a municipality. This code was nevertheless not included in the dataset coming from SFR, Numericable and SNCF. As a substitute, we use the name of the municipality associated with the department number in the merging process.

After merging the databases, we have information on 99.7% of the French metropolitan municipalities (excluding Corsica). There are 112 municipalities out of the 36,192 counted in 2014 which are missing from the final dataset, which is due to evolution of the administrative scope of these municipalities between 2012 and 2014. In the meantime, some municipalities have been split into two different new municipalities and some others have been merged, resulting in a modification of the name and INSEE code of the municipalities. The latest socio-demographic and municipality characteristics data are from 2012, whereas the lastest data on FttH deployment, cable upgrade and on the copper network are from 2014, as reported in Table (**??**)

5 Econometric Model

In this section we derive a model of entry of providers of broadband services in France. We use the model to answer the main question of our paper which is whether LLU has an impact on the entry and deployment of FttH. Moreover, we analyze what are the determinants of entry into local markets with broadband services via FttH and LLU.

As discussed in Section (3), to provide Internet services the alternative operator builds its own backhaul connection and core network down to the incumbent's MDF and then connects customers to its own broadband equipment (DSLAM), which is located within the MDF, next to the incumbent's DSLAM. There are therefore capital investments needed to enter local markets via LLU. The deployment of FttH requires even greater capital investments because every household needs to be connected to the backbone with optical fiber. The infrastructure fixed costs can be divided into country- and local market costs. The country-level fixed entry costs are related to the deployment and maintenance of backbone infrastructure, administration, marketing, etc. The local market entry fixed costs are related to the connection of the backbone infrastructure to the local market and deployment of the network within the local market. These costs differ locally because of factors such as geographic area to be covered as well as the size and distribution of population. After the infrastructure is deployed the marginal costs are relatively small and may include modem rental expenditures and customer services. There are therefore economies of scale both on the country and local market level since the average costs decline with the number of connected consumers. The presence of economies of scale implies that only a certain number of entrants can be accommodated by a market of given size, which is more stringent when the price is fixed on the country-level.

The previous literature on entry into provision of broadband services considered that the investments made by LLU operators are sunk (see Xiao and Orazem (2011) and Nardoto et al. (2015)). We estimate two models with and without sunk entry costs. In the model with sunk entry costs, their identification is based on a comparison of entry thresholds for markets which have experienced entry to thresholds for markets experiencing no entry. There is a difference in the decision problem of the entrant and incumbent. While the entrant will only enter when market size is big enough to cover their entry costs, incumbent firms do not take entry costs into consideration when deciding whether to continue operations. The existence of sunk entry costs means that it takes less demand to sustain an incumbent than to support a new entrant. In France, we do not observe fibre operators exiting local markets but there are some exists of LLU entrants, as shown in Tables (1) and (2). Since we observe that firms always continue to operate fibre network, the fixed costs of maintaining the local network must be relatively small. In an extreme case, when fixed costs are zero, firms would never exit.

As discussed in Section 3, there are four main market players: Orange, SFR, Free and Numericable, which differ with respect to the broadband technology deployed and the timing of entry. The previous fixed-line incumbent operator, Orange, covered the whole country with xDSL technology by 2007 and deploys FttH alone or in co-investment with SFR or Free. SFR provides xDSL services based on the incumbent's copper infrastructure via LLU and deploys FttH alone or in co-investment with Orange or Free. Similarly, Free provides xDSL services via LLU and deploys fibre network alone or in co-investment with Orange or SFR. Finally, Numericable owns cable network which has been upgraded to provide broadband services and provides xDSL services via LLU. In April 2014, Numericable acquired SFR and since then these two firms should be considered as a single profit maximizer. Table (1) shows the number of municipalities in which these three operators entered with FttH and Numericable upgraded its cable network. The remaining firms on the market provide xDSL broadband via LLU or mobile broadband.

The following facts matter for the decision of broadband operators to enter local market. Operators sets nationwide prices without geographic differentiation in dependence on the number of other entrants. Since there is usually a single broadband connection to a household, the total demand in local market is defined by the number of households. Consumers can substitute between broadband access via xDSL or FttH connections, where the latter offers higher connection speed and therefore higher quality. Moreover, we observe that SFR and Free deploy fiber only in markets in which they also provide broadband services via xDSL.

First, we consider operator's decision to deploy fiber technology. Market demand is stochastic. At the end of each time period, firms decide whether to enter new local markets and whether to operate in the old ones in the next period. They form expectations about market demand, cost levels and competition with other firms. The expectations are fulfilled in equilibrium. The number of fiber entrants in municipality i at time t is denoted by $N_{it} = n$, where $n = \{0, 1, 2, 3\}$. Following Xiao and Orazem (2011) and Nardotto et al. (2015), with n-1 competitors, the discounted value of future profits of n^{th} firm in market i at time t can be written as:

$$\pi_{it}^{n} = \bar{\pi}_{it}^{n} + \epsilon_{it} \equiv \alpha_t ln S_{it} + X_{it}\beta + Z_{it}\gamma - \mu^n I(N_{it} = n) + \eta_i + \epsilon_{it} \quad (1)$$

where S_{it} is the potential market size approximated by the local population size, Z_{it} is a vector of other demographic and geographic characteristics of municipalities which are potential profit determinants, such as the density of population, share of flats in the total number of residencies, income, the rate of unemployment and the number of firms which are registered locally, μ_{nt} is a fixed effect describing the negative profit effect from the n^{th} firm and ϵ_{it} is an i.i.d. standard normal random variable, capturing unobserved profit determinants. Our model differs from Xiao and Orazem (2011) and Nardotto et al. (2015) in that we include market-specific effects denoted by ν_i, which should control for unobserved to us but observed by the firms market-specific factors which determine entry. We estimation both a model with and without market fixed effects and comment on their importance.

In addition, the profits of FttH operators are affected by substitution/complementarity with other technologies either provided by themselves or competitors, which are denoted by X_{it}. We create a variables which is the number of LLU entrants locally including SFR and Free. Since SFR and Free deploy FttH only in areas in which they are already present with LLU offer, there must be a positive effect of entry via LLU on FttH deployment by the same firm. Their effect on the FttH deployment by Orange may be negative or positive. A negative effect may be due to lower incentives of Orange to invest in areas in which it has to provide LLU access. A positive effect may be due to incentives to differentiate via provision of higher quality services. The overall effect on the FttH entry is ambiguous. The effect of competitors' LLU entry on the deployment of fibre by Orange, SFR and Free is also ambiguous. Firms may stay away from investing in markets with more competition or may invest more to differentiate their own offer from competitors. The incentives to invest will certainly depend on the position of firms in particular markets reflected in market shares on which we lack information. We consider the number of LLU entrants to be exogenous since entry via LLU by SFR, Free and other firms took place before the deployment of fibre technology. Moreover, the speed of xDSL services may impact the willingness of consumer to switch to fiber and firms may be less willing to deploy fiber in municipalities with a higher share of lines upgraded to VDSL. We have information on the share of VDSL lines in a municipality but the upgrading process started only in 2013 and the share is still too small to identify a significant effect. Instead, we create a dummy variable for municipalities with nonzero share of VDSL lines. We also treat this variable as exogenous even though firms may strategically decide not to deploy fibre and invest in upgrading xDSL lines instead.

The equation (1) is reduced form and does not allow to distinguish how the number of competitors affects the variable profits function and the fixed costs function, as in Bresnahan and Reiss (1991). The model also does not allow for simultaneous entry and exit and instead focuses on the marginal entering or existing firm's expected profitability from operating in the next period. Moreover, in the model with sunk entry costs we assume that all entrants incur the same entry costs regardless of the order of entry.

The profits π_{it}^n include the non-sunk part of fixed costs. Firms also incur a sunk cost SC to enter a market, which cannot be recouped when they exit. Profits are unobserved and π_{it}^n is a latent variable but it is still possible to draw inferences on the profit determinants by assuming a free entry equilibrium, where firms enter if and only if such move is profitable. There are three possible situations that would generate the observation of n firms in market i at time t:

(1) One or more firms have entered and there were fewer than n firms at time $t-1$, or $N_{mt} > N_{mt-1}$. For the n^{th} firm, the expected discounted value of entry exceeds sunk costs of entry,while for the $n+1^{st}$ firm not. This can be expressed as:

$$\textbf{Case 1, net entry: } N_{it} > N_{it-1} \text{ if } \pi_{it}^n \geq SC \text{ and } \pi_{it}^{n+1} < SC \tag{2}$$

(2) No firm has entered or exited a market with n firms, or $N_{mt} = N_{mt-1}$. The n^{th} firm from period $t-1$ has decided to stay because its expected discounted values of continuation exceed 0, while the $n+1^{st}$ firm has expected a loss from entry:

$$\textbf{Case 2, inaction: } N_{it} = N_{it-1} \text{ if } \pi_{it}^n \geq 0 \text{ and } \pi_{it}^{n+1} < SC \tag{3}$$

(3) One or more firms have exited and there were more than n firms at time $t-1$, or $N_{mt} < N_{mt-1}$. The market has become unprofitable when more than n firms stayed operating. The marginal $n+1^{st}$ firm expected that it would be unprofitable to stay in the market and when this firm left, the n^{th} firm expected otherwise:

$$\textbf{Case 3, net exit: } N_{it} < N_{it-1} \text{ if } \pi_{it}^n \geq 0 \text{ and } \pi_{it}^{n+1} < 0 \tag{4}$$

We do not observe Case 3 in the case of FttH entry model, which as mentioned above may be because the fixed costs component, which is not sunkm is relatively small.

Using the profit specification (1), the above inequalities can be combined to obtain the following probability of observing $N_{it} = n$ entrants in market i at time t:

$$Pr(N_{it} = n) = \Phi(\overline{\pi}_{it}^{n} - SC \cdot I_{it}^{+}) - \Phi(\overline{\pi}_{it}^{n+1} - SC \cdot (I_{it}^{+} + I_{it}^{0})) \tag{5}$$

where $\Phi(.)$ denotes the cumulative normal distribution function, and $I_{it}^{+} \equiv I(N_{it} > N_{it-1})$ are indicator variables to denote whether entry increased (+) or remained constant (0).

Notice that if there are no sunk costs, $SC = 0$, then the model is static and reduces to a standard ordered logit or probit. The parameter vector $\theta = [\alpha_t, \beta, \gamma, \mu^n, \overline{\eta}, \sigma_\eta]$ is estimated by maximizing the following log-likelihood function:

$$LL(\theta) = \sum_{i=1}^{M} \sum_{t=1}^{T} \sum_{n=1}^{N} y_{it} \ln(Pr(N_{it} = n)|\theta) \tag{6}$$

where y_{it} takes value of 1 if $N_{it} = n$ and zero otherwise.

Since as shown in Table (3) Orange is the market leader in deployment of FttH, we also estimate a model in which the 0-1 entry decision by Orange is regressed on the same set of explanatory variables.[22] In this way we analyze whether Orange is less likely to deploy FttH in areas in which there is LLU and whether upgrading DSL lines to VDSL discourages deployment of FttH.

Next, we analyze the determinants of entry via LLU, which in general took place before the deployment of fiber. Table (2) shows the number of municipalities, in which SFR, Free, Numericable and other operators entered via LLU. The discounted value of future profits may be written in analogous way to (1), but in this case $n = \{0, 1, 2, 3, 4, 5\}$. Since there was a small number of markets with more than five entries, we truncated the number of entries with

[22] In principle, whenever there is only one FttH operator in a municipality, the operator is Orange. Whenever there are two operators, with a small margin of mistake, the operators are Orange and SFR. We observe that Orange is present in 804 out of 819 municipalities, in which there are two entrants, and in 429 out of 475 municipalities with only one entrant. Furthermore, we observe that SFR is present in 781 out of 819 municipalities with two entrants and it is present alone only in 14 municipalities. Finally, Free is present in only 53 out of 819 municipalities in which there are two entrants and it is a single operator in 32 out of 475 municipalities.

five. Even though the functional forms which we use are similar for xDSL and fiber, the costs of entry are substantially lower in the case of LLU and the prices for xDSL are also lower due to lower transfer speed. In the estimation, we use the same set of demographic and geographic characteristics as determinants of profits, except the LLU-related variables denoted by X_{it}. We also do not consider that the presence of FttH and cable in a municipality had impact on the entry via LLU. In general, LLU entry took place before deployment of FttH and before cable was upgraded to broadband provision.

6 Estimation Results

Table (6) shows the estimation results for FttH entry. Model I is estimated without sunk costs (simple ordered logit model) and Model II allows for non-zero sunk cots [TO BE ESTIMATED].

The main variable which determines FttH entry is the market size, which is represented by the number of households in the municipality. Also, the population density denoted by the number of households divided by the surface has a significant positive impact on FttH entry, which decreases over time. This means that FttH is more profitable in densely populated areas but over time it becomes easier to enter less densely populated areas.

We find that the local market presence of competing technologies: xDSL, cable and VDSL has a significant impact on FttH deployment. In particular, we observe in the data that the deployment of fibre by SFR and Free is always proceeded by the entry via LLU. Overall, the local market presence of SFR and Free via LLU has a positive impact on FttH entry by these two firms and Orange. SFR and Free may have incentives to develop own fibre network to avoid paying wholesale access charges and steal consumers from competitors which utilize copper network. Thus, SFR and Free use LLU as a stepping stone into the provision of high speed broadband services. On the other hand, the main investor in fibre network, Orange, may have incentives to differentiate itself from the competitors xDSL offers of competitors. Our results support the ladder of investment (LoI) theory suggesting that the main operators start providing broadband services in selected municipalities using incumbent's infrastructure via LLU, and then follow up with FttH networks deployment. At the same time, the incumbent is not stopped from investing in fibre network. Overall, the LLU entry has also a positive impact on fibre deployment by Orange, SFR and Free. Also in this case firms have incentives to differentiate themselves by providing consumers with high speed Internet services based on fibre. In the estimation, we consider that LLU entry is exogenous, which is justified by the fact that SFR and Free entered via LLU before deploying fibre services. A situation in which LLU entry does not take place because fibre is being deployed in the local market is very unlikely. We also estimated a model with lagged LLU presence variables which yields very similar results.

We also find that FttH entry is more likely in areas in which there the sole cable operator Numericable upgraded its network to provide high speed broadband services. This result suggests that fibre operators recognize that consumers care about the speed of connection and at the same time being first in the market matters for building consumer base and recoup the cost of investment. In practice, we observe that the marketing strategy of FttH operators to gain customers is more aggressive in municipalities covered by cable. On the other hand, upgrading DSL lines to VDSL tends to reduce incentives to deploy fiber. The fibre operators which provide DSL services on the legacy network via LLU and invest in VDSL or VDSL2 technology offering Internet speed up to 30 Mbp/s have lower incentives to deploy fibre network. The negative effect suggests that FttH and VDSL connections are strategic substitutes. The deployment of cable network and VDSL lines may be endogenous and correlated with the unobserved market shocks. The endogeneity problem may be mitigated by inclusion of unobserved market specific effects. Optimally, we should use instrumental variables estimation approach.

The scope of FttH deployment is limited by the local markets demographic and geographic characteristics. The main variable influencing entry is the market size measured by the number of households in the local market. Also, population density has a positive impact on fiber investment but its impacts decreases through the years, which means that operators are able to enter less densely populated markets with time. The share of flats in the total number of residencies has a positive impact on FttH entry which may reflect lower cost of deploying fiber in areas with many apartment blocks. Furthermore, we find that a higher level of income has a positive impact on FttH entry, while unemployment is insignificant. These two variables approximate the quality of demand in terms of purchasing power.

Table (7) shows the estimation results for LLU entry. Model I is estimated without sunk costs and Model II allows for non-zero sunk costs. Based on the value of log-likelihood function the preferred model is the model with sunk costs, which we use to interpret the estimation results. Also in this case, the main variableS which determine LLU entry are the number of households and density of population represented by the number of households divided by the surface. The interaction terms of density with time dummy variables are significant but, contrary to the estimates for fibre, do not indicate a particular trend. At the same time, the coefficients of time dummies increase over time. The share of flats in the total number of residencies is not significant. Furthermore, we find that a higher level of income has a positive impact on LLU entry and surprisingly a higher unemployment rate also has a positive effect.

We use the estimates to compute entry thresholds for fibre and LLU operators and their changes over time. For each market i at period t we calculate entry threshold for $n = 1, 2, 3$ FttH operators by solving for the critical market size which sets the mean profits to zero: $S_{it}^n = exp((Z_{it}\delta - \mu_t^n I(N_{it} = n) + X_{it}\theta + \nu_i)/\gamma_t)$. The thresholds are market specific due to observed and unobserved market factors. The average thresholds are shown in Table (8). The entry thresholds for LLU entry at particular points in time are shown in Table (9). The entry thresholds for LLU operators are much smaller than for fibre operators which reflects the scale of investment needed to enter the market. Since LLU operators rely mainly on incumbent's infrastructure the investments needed for entry are much lower.

7 Conclusion

In this paper, we analyze the impact of LLU on fiber investments using panel data on 36,080 municipalities in metropolitan France in years 2010-2014. We estimate two models of entry into local markets by: (i) the incumbent and two other operators using fibre technology and (ii) operators seeking wholesale access to the legacy telecommunications network via local loop unbundling (LLU).

We find that local market presence of LLU operators has a positive impact on entry by fibre operators. We observe in the data that the deployment of fibre is always proceeded by the entry via LLU. Based on the estimation results the decision to deploy fibre by the incumbent and competitors is also positively influenced by the presence of other LLU operators. High speed fiber broadband allows firms to differentiate their offer from DSL-based services. Moreover, the presence of cable operator stimulates deployment of fibre. Firms using DSL technology fear losing consumers and being preempted by cable operator and deploy fibre technology. This also suggests that firms recognize that consumers care about the speed of connection and at the same time being first in the market matters for building consumer base and recouping the cost of investment. We also find that the deployment of VDSL technology which allows higher Internet speed on copper network slows down the deployment of fibre. Thus, firms choose to upgrade copper lines on the legacy network instead of investing in fibre networks.

We also find that market characteristics significantly impact the mode of entry. The main variable influencing entry is the market size measured by the number of households in the local market. Also, population density has a positive impact on fiber investment but its impacts decreases over time, which means that operators are able to enter less densely populated markets with time. We also find that the share of flats influences positively the probability of deploying fiber, reflecting the lower cost of connecting a block of flats rather than single houses. Besides, we show a positive effect of the quality of demand, in terms of purchasing market power, with the positive impact of the income. We use the estimates to compute the entry thresholds for fibre and LLU operators and how they change over time. The entry thresholds for LLU operators are much smaller than for fibre operators, which reflects the scale of investment needed to enter the market. Since LLU operators to a large extent rely on incumbent's infrastructure the scale of investment is much smaller.

Our results have important policy implications as they show that LLU regulation does not impede fiber entry. Moreover, we show that the main variable that influences fiber deployment is the market size. The market size required for an operator and for an additional operator to enter the market is decreasing over time, which makes entry easier to enter less densely populated municipality easier. However, fibre provision will remain unprofitable in the vast majority of smaller municipalities in France. The policy makers can stimulate deployment of FttH by allowing firms to co-invest which will reduce entry costs and by ensuring that the investment profitability will not reduced by wholesale access regulation. Private operators will be more prone to invest into fiber in less densely populated area if they set commercially the wholesale access fee and anticipate higher wholesale revenue. This finding confirms ARCEP policy, unlike the European Commission recommendation to regulated NGA infrastructure access. In other areas, where market characteristics show that the local market is not economically profitable, there is a rationale for public investment. Eventually, private operators decisions of entry into fiber are also based on the potential revenue expected from a local market and its "quality" in terms of expected demand as well as on the cost of deployment. Therefore, there are grounds for the use of demand stimulation policy, which by enhancing the demand, will indirectly enhance operators incentives to invest.

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Appendix

Table 1: Deployment of fiber in municipalities by Orange, SFR and Free

	Orange	SFR	Free	Total
2010	125	96	93	137
2011	195	156	101	206
2012	295	217	102	304
2013	452	344	104	461
2014	584	420	104	592

Table 2: Deployment of xDSL via LLU in municipalities by SFR, Free and Numericable

	SFR	Free	Numericable	Total
2010	6,395	8,473	1,857	12,809
2011	7,727	10,706	1,997	15,269
2012	9,570	12,870	2,041	17,337
2013	13,001	16,077	1,929	20,835
2014	14,119	19,463	1,937	23,179

Table 3: The number of observations (municipalities in years 2010-2014) with the presence of Orange, SFR and Free by the number of entries

Operators	Orange	SFR	Free	Total
0	0	0	0	178,785
1	404	14	20	438
2	820	792	57	835
3	427	427	427	427

Table 4: FttH entries and exists

$FttH_t$ / $FttH_{t-1}$	0	1	2	3
0	178,63	0	0	0
1	192	246	0	0
2	284	30	521	0
3	14	14	35	364

Table 5: LLU entries and exists

LLU_t / LLU_{t-1}	0	1	2	3	4	5
0	67,075	508	59	1	0	0
1	8,806	17,165	551	6	4	0
2	2,113	8,188	28,704	301	28	1
3	19	99	881	2,899	206	5
4	0	2	22	333	4,330	84
5	0	0	0	6	293	1,271
6	0	0	0	0	7	233
7	0	0	0	0	0	60

Table 6: Entry via FttH in municipalities

		2011	2012	2013	2014		2012	2013	2014	2014
trend		1.0502***	1.9485***	2.8155***	3.3105***		2.5086***	4.2590***	6.2936***	7.4097***
		(0.215)	(0.197)	(0.206)	(0.215)		(0.314)	(0.319)	(0.367)	(0.400)
loghh	1.1142***					2.7957***				
	(0.051)					(0.218)				
Logdensity	1.6803***	-0.1712	-0.6621***	-1.0698***	-1.1603***	3.6521***	-0.2606	-1.0263***	-1.6974***	-1.8840***
	(0.164)	(0.203)	(0.182)	(0.173)	(0.170)	(0.330)	(0.296)	(0.282)	(0.281)	(0.280)
Logincome	1.6730***					6.3138***				
	(0.202)					(0.866)				
Share flat	1.7410***					4.4919***				
	(0.231)					(0.915)				
Unempl	0.0102					0.0060				
	(0.020)					(0.075)				
ULL entrants	0.6411***					0.9539***				
	(0.041)					(0.121)				
VDSL	-0.3384***					-0.6854***				
	(0.104)					(0.191)				
Cable	0.3278***					0.5537***				
	(0.083)					(0.208)				
cut1	25.8177***					82.3974***				
	(2.140)					(9.239)				
cut2	26.5790***					84.0790***				
	(2.141)					(9.253)				
cut3	29.0167***					90.6530***				
	(2.150)					(9.328)				
Sigma2						22.1755***				
						(2.174)				
Observations	180,330					180,330				
LL	-3738					-2837				

Model I: ordered logit. Model II: random effects ordered logit.

Table 7: Entry via LLU in municipalities

		y2011	y2012	y2013	y2014		y2012	y2013	y2014	y2014
trend		0.3863***	0.6808***	1.0802***	1.2222***		1.3486***	2.3653***	3.7945***	4.4226***
		(0.053)	(0.052)	(0.052)	(0.051)		(0.076)	(0.079)	(0.084)	(0.086)
loghh	0.3041***					0.9543***				
	(0.007)					(0.044)				
loghhdensity_2013	1.0035***	-0.0053	-0.0081	-0.0313**	-0.0841***	3.4018***	0.0657***	0.1055***	0.1068***	-0.0108
	(0.014)	(0.014)	(0.014)	(0.014)	(0.013)	(0.052)	(0.020)	(0.021)	(0.021)	(0.021)
logincome	3.5455***					11.6056***				
	(0.041)					(0.255)				
share_flat	0.3184***					1.8457***				
	(0.046)					(0.287)				
unempl	0.0688***					0.2645***				
	(0.003)					(0.015)				
cut1	31.8784***					104.4809***				
	(0.417)					(2.607)				
cut2	33.0980***					107.9415***				
	(0.418)					(2.610)				
cut3	35.9339***					116.9341***				
	(0.419)					(2.619)				
cut4	36.6924***					121.4477***				
	(0.419)					(2.626)				
cut5	38.6533***					129.9487***				
	(0.420)					(2.638)				
cut6	41.2085***					137.3586***				
	(0.426)					(2.651)				
sigma2_u						31.6050***				
						(0.476)				
Observations	180,330					180,330				
LL	-176522					-110596				

Model I: ordered logit. Model II: random effects ordered logit.

Table 8: FttH entry thresholds

year	entrant 1	entrant 2	entrant 3
2010	85,531	111,017	307,739
2011	60,562	79,476	229,977
2012	53,328	72,722	244,500
2013	41,690	59,398	237,021
2014	33,785	48,838	206,226
Without LLU			
year	entrant 1	entrant 2	entrant 3
2010	91,701	119,026	329,941
2011	66,222	86,905	251,472
2012	59,986	81,801	275,025
2013	48,394	68,949	275,135
2014	39,982	57,796	244,053

Table 9: FttH entry thresholds

year	entrant 1	entrant 2	entrant 3	entrant 4	entrant 5	entrant 6
2010	502	1,112	8,759	24,687	173,780	952,263
2011	389	850	6,494	18,023	123,242	658,471
2012	307	667	5,005	13,765	92,526	487,029
2013	217	470	3,529	9,702	65,180	342,924
2014	168	372	2,948	8,330	58,924	324,253