A Structural Model of Local Loop Unbundling

VERY PRELIMINARY AND INCOMPLETE – PLEASE DO NOTE CIRCULATE*

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November 28, 2007

Abstract

Local loop unbundling (LLU) refers to the possibility for entrants on the broadband market to access the incumbent's local loop and provide service using their own backhaul network. While LLU allows entrants to operate under (possibly) lower marginal costs, it involves important *ex ante* investment. This paper studies the role of regulation on the unbundling decisions of alternative operators on the French broadband market. To do so, we develop and estimate a fully structural model of regulated competition with *ex ante* choice of unbundling and *ex post* price setting. In this framework, unbundling decisions are subject to strategic behavior a la Fudenberg and Tirole (1984): entrants adopt "puppy dog" strategies, i.e. under-unbundle in order to soften price competition. We show that how our model is identified and, using Central Office level data on market shares, we estimate it. To circumvent traditional endogeneity biases in demand estimations, we use cost-oriented instruments induced by each entrant's history. We then provide a quantitative assessment on the role of strategic behavior on each entrant's unbundling decision, and show that they account for a relatively small fraction of overall incentives to unbundle. We finally use simulation results to provide welfare analysis under alternative regulations.

1 Introduction

This paper develops and estimates a structural model of competition in a regulated industry: the French broadband industry. The focus on this industry makes economic sense. The social benefits from use of the Internet, in particular consumer benefits, have been largely documented in the literature (Morton (2005)). The focus on the French experience is also of great interest considering the recent evolution of the high-speed Internet industry in this country [1]: before

*For their constructive and helpful comments, we would like to thank Nicolas Coeurdacier, Cecile Gaubert, David Spector, Jean Tirole as well as seminar participants at the IDEI/Bruegel Conference on Competition in Network Industries. We would also like to thank the ARCEP, and in particular Bertrand Vandeputte for providing us with and guiding us through the data. This paper reflects solely the opinions of the two authors.

[1]See Sraer (2007) for a more detailed accounts of these trends

2002, France was desperately lagging behind the United States, Japan or the average OECD country in terms of broadband penetration rate ; since 2005, it is by and large ahead of these countries, as one can see from figure 1. Because the industry began to be severely regulated in the 2000-2002 period, practitioners have been attributing this success to regulation. This paper tries to shade theoretical and empirical lights on the interplay between regulation and market structure in this industry.

High-speed Internet access in France is essentially delivered through the DSL technology. Cable represents less than 5% of the access to Internet. Other alternative technologies (satelite, Wimax, dial-up...) are marginal. The DSL technology is based on standard telephone lines: using a Digital Subscriber Line Access Multiplexer (DSLAM), it delivers high-speed data transmission over existing copper telephone lines[2]. DSL thus requires access to the local telephone network (the local loop), which belongs to the incumbent operator. Because this local loop is considered an essential facility (i.e. it would be too costly to be reproduced), the incumbent has been compelled by the regulator to lease to entrants its copper pair between the telephone exchange and the customers home. To serve consumers, alternative operators must then install their own high-speed access equipment on the incumbents premises (mostly DSLAM), and connect the site to their own backhaul network. There is an alternative for potential entrants to "local loop unbundling": alternative operators can also use so-called bitstream wholesale offers. In that case, the incumbent activates the end customers copper pair with its own access equipment, then routes the Internet flows to the closest delivery point between its backhaul network and that of the alternative operator. Regulation consists essentially in the setting of two access charges: (1) the fee an alternative operator must pay in order to gain access to the local loop and (2) the price of bitstream wholesale offer.

We lay down a simple two stage model of competition in the broadband market that incorporates the various features of the French regulation. In the first stage, potential entrants decide, for each local market, on local loop unbundling: they can invest in network construction and unbundle the local loop, which allow them consequently to operate at near-zero marginal cost; or they can decide to save on the fixed cost and and use the bitstream offer. The trade-off involved is thus one between high fixed costs but low marginal costs on the one hand vs. low fixed costs but high marginal costs on the other hand. In the second stage, each firm compete locally in price. Demand is derived from a LOGIT choice model and thus exhibit imperfect substitutability between firms. Our model is thus similar in spirit to a classical game of investment a la Fudenberg and Tirole (1984) with ex ante investment and ex post price competition.

We solve the model theoretically using a standard sub-game perfect Nash equilibrium concept. Turning to the data, we prove that the model is identified. Quite surprisingly, the identification of demand parameters does not rely on the observation of local prices, but is obtained through the knowledge of regulated prices (i.e. the pair of access charges set by the regulator). The main intuition for this result is that the difference in these access charges approximates the difference in entrants' marginal costs between "unbundled" markets and "bitstream" markets. Therefore, using the first-order conditions associated with profit maximization, we can infer information on prices at the local level by just observing unbundling decisions and knowing this

[2]Basically, a DSLAM separates the voice-frequency signals from the high-speed data traffic and controls and routes digital subscriber line (xDSL) traffic between the subscriber's end-user equipment (router, modem, or network interface card [NIC]) and the network service provider's network.

difference in regulated price. Using a revealed preferences argument, we parametrically identify fixed cost parameters by observing local unbundling decisions. Turning to the estimation of the model, we are confronted with the traditional endogeneity bias of demand estimation (Berry (1994)): prices (or unbundling decisions in our case) can be correlated with the unobserved heterogeneity of demand. Going back to each company's history, we define instrumental variables that provide us with exogenous shocks to the fixed costs associated with local loop unbundling. We show that our instruments are strong and provide I.V. estimates of the demand structural parameters.

As is standard in models of investment a la Fudenberg and Tirole (1984), our model exhibits strategic externalities: because local loop unbundling (1) makes entrants more efficient and (2) directly decreases the incumbent's revenue, it makes second-stage price competition tougher. We show that in our model, entrants have thus natural incentives to adopt a "puppy dog" strategy and "under-unbundle" in order to soften second stage price competition. Our structural approach allows us to compute quantitatively the intensity of these "puppy dog" effects. We find that competitive externalities are empirically small: the potential impact of local loop unbundling on price competition explains, on average, less than 1% of the incentives of a firm to unbundle. In other words, we find that the price elasticity of demand is too low to induce significant deviations in unbundling strategies from a world where firms simply don't anticipate that unbundling has an impact on price competition[3]. To our knowledge, this is the first attempt at exploring quantitavely the importance of such competitive externalities. Considering how popular the Fudenberg and Tirole taxonomy is among both academics and practitioners, we believe this is an important result.

The last part of the paper is devoted to welfare analysis. We investigate the question of optimal regulation from a utilitarian perspective. There again, this is only possible thanks to our structural approach. We simulate the model keeping every parameter constant except the regulated prices. We then look at the welfare response to various changes in these access charges. One potential caveat is that, as is classical with model of entry and perfect information, our model potentially involves multiple equilibria in unbundling decisions. While this is not problematic from the estimation point of view (as observing one equilibrium is sufficient to provide identification), this becomes an issue when one try to simulate the model. Rather than refining the equilibrium using an arbitrary criterion, we derive all the potential equilibria and are thus only able to provide bounds on welfare. [**DISCUSS HERE THE RESULTS OF SIMULATION**]

Related Literature

The rest of the paper is organized as follows. Section 2 briefly summarizes the characteristics of the broadband industry and highlights the French specificities. Section 3 provides a detailed description of the data we use in this paper. Section 4 presents the model and its resolution. Section 5 shows identification of the model and details the estimation procedure. Section 6 performs the welfare analysis by simulating the model. Finally, section 7 concludes the paper.

[3] This world is referred to as an "open loop equilibrium" (Fudenberg and Tirole (1984)

2 A Brief Overview of the French Broadband Industry

Both the incumbent and alternative operators propose high-speed DSL offers on the copper pair to households and businesses on the retail market. The incumbent uses its own copper local loop, which it deployed in the 1970s and 1980s for telephony needs. Alternative operators use part of the incumbents network to propose their own high-speed offers on the residential and professional markets. The incumbent leases out its infrastructures and copper pairs to the alternative operators, which complete the link with their own equipment and services before selling their offers to end customers. The offers by which the incumbent provides alternative operators with a variable part of its network are called wholesale offers. Some of these offers are regulated by ARCEP. There are two major families of wholesale offers purchased by alternative operators from the incumbent to create their offers on the retail market.

The best-known wholesale offer is called local loop unbundling, where the incumbent leases to alternative operators its copper pair between the telephone exchange and the customers home. The alternative operator has to install its own high-speed access equipment (essentially DSLAM) on the incumbents premises, and connect the site to its own backhaul network. This involves important cost in terms of civil and mechanical engineering. Once it has installed its own equipment in a distribution frame for local loop unbundling (the distribution frame is said to be unbundled), an operator can order two types of unbundling for its subscribers: (1) shared access, which involves providing high frequencies on the copper pair: users keep their switched line subscription (2) full unbundling, which involves providing the entire copper pair: users no longer pay a separate telephone subscription. Before 2005, i.e. for the period that interests us, full unbundling was not yet introduced: shared access was the only unbundling option an entrant could consider.

For sites which are too small or too far from their networks, alternative operators can use so-called bitstream wholesale offers. The incumbent activates the end customers copper pair with its own access equipment, then routes the Internet flows to the closest delivery point between its backhaul network and that of the alternative operator. On the wholesale market, this offer is more expensive than simply leasing the copper pair, as the incumbent is involved on a greater share of the technical production chain. This offer lets alternative operators propose retail offers to households and businesses located in areas where they have not installed broadband access equipment. The bitstream offer is proposed at the regional level, and delivered to the main regional cities. The operator wanting to buy wholesale bitstream access from France Tlcom must therefore connect to the delivery points on the incumbent's network. On the one hand, the

retail residential and professional broadband market is not regulated by ARCEP. Each operator, including the incumbent, is therefore free to set its own fees and determine the content of its offers, as long as it respects the legislation in force. On the other hand, the wholesale market is regulated by the regulation 2887/2000 that was enacted December 18th 2000 by the EU commission. Thanks to this regulation, ARCEP has set in the last quarter of 2001 the prices of the two main wholesale offers. These prices have remained constant until 2006.

At the end of September 2006, i.e. one year after our sample period, the incumbent was leasing 5.50 million wholesale accesses to third party operators under local loop unbundling and bitstream offer. This total covers all DSL accesses sold by alternative operators on the professional and residential broadband retail markets. These 5.50 million accesses can be broken down as follows: (1) 3.5 millions unbundled access (2) 2 millions bitstream access. Close to 99% of telephone lines are now connected to the incumbent's high-speed network, making almost each consumer eligible to a broadband offer.

As shown in figure 2, the broadband market is dominated by the incumbent and three main operators (Free, Neuf Telecom and Cegetel), who accounted for more than 96% of the market share at the beginning of 2005, i.e. the year covered by our data. The seven other operators represents only a "residual" share of the market. As one can observe from figure 2, the distribution of market share is extremely skewed: Cegetel, the smallest operator in terms of market share among the three major alternative operator, has a market share more than 3.4 times larger than that of Tiscali, the largest operator among these residual operator; the average aggregated market share of these "residual" operators represents only 1.9%.

3 The Data

The dataset used in this paper was collected in the beginning of 2006 by the ARCEP during a standard administrative investigation led at France Telecom's headquarter. It provides detailed demand-and-supply informations on a sample of central offices (CO) in France. A central office (CO) is the central office to which subscribers are connected, by a line interface module: in the incumbent's tier system, this is the lowest ranking exchange on the network.

Our sample of central office consists of (1) the entire set of COs where at least one alternative operator was using unbundling access at the end of 2005 (which amounts to 951 COs) and (2) the 549 largest COs (in terms of end-user lines) where all alternative operators use bitstream access. Overall, the dataset comprises 1,500 COs, which represent about 20 Million telephone lines, i.e. more than 70% of the population. For each CO and for each 2005's quarter, we know (1) the overall number of lines served by the CO (2) the number of firms that operate in the CO through full unbundling and the date at which they installed their own equipment in the CO (3) the number of lines served by each firm present in the CO and the nature of their Internet access (i.e. through unbundled or bitstream access) and (4) the date at which the incumbent installed its own DSL equipment. The ARCEP also provided us with information on whether a cable operator was present in the CO.

The other source of data we are using in the paper comes from the "geographical files" of INSEE, the French Statistical Office, . These files provide us with demographic and economic variables and includes data on income, age structure, occupation structure, housing density, unemployment rate and fraction of residential lines . These data are defined at the *commune* level. The *commune* is the French administrative division which is the closest in size to the CO. A potential issue is that *communes* and COs are not perfectly matched: a COs may serve lines on several *communes* and several COs may be located on the same *commune*. In all the following regression analysis, we will thus make sure that observations are clustered at the *commune* level.

Table 1 provides summary statistics on the sample broken down into two categories: (1) COs where at least one operator has unbundled the local loop and (2) COs where all operators buy bitstream access. A quick glance at this table shows that there is quite a strong heterogeneity between these two categories. Unbundled COs are in much larger and more dense *communes*, indicating that they mostly represent large, urban areas. On the other hand, income or age distribution appears quite similar in both type of COs. Table 1 is a first indication that local market characteristics have an impact on unbundling decisions.

4 The Model

4.1 Model Set Up

We consider a model of local loop unbundling and competition in the broadband market. Our model is a model of local loop unbundling and not one of entry *per se*. We thus consider a fixed market structure, where there are only four active firms in all local markets: 3 Entrants ($i \in \{1, 2, 3\}$, "Neuf Telecom", "Cegetel" and "Free") and an Incumbent ($i = 0$, "Wanadoo"). As we already noted in section 2, this assumption of exogenous participation is motivated by the extreme skewness of market shares observed in figure 2.

The national market for high speed Internet is divided into M=1,500 local markets of size K_m, indexed by $m \in [1, 1500]$. This 1,500 markets corresponds to the 1,500 largest central offices in France, i.e. those for which data were made available to us by ARCEP. Note that we do have a perfect measure of market size as we know exactly the number of telephone lines in each central office. This is a clear advantage of our data compared to other paper where measuring market size is a challenge.

We model competition as a two stage game. In the first period, each entrant i ($i \in \{1, 2, 3\}$) decides on unbundling the local loop in each market m.

Unbundling the local loop in market m implies a fixed investment $I_m^i + \omega_m^i$; it allows the Entrant to operate under marginal cost

$$\gamma_{1m} = c^i + \beta^i + t_1.$$

Let us briefly comment the different terms in these costs: (1) c^i is the part of the marginal cost that does not depend on the entrant's unbundling choice (it represents, e.g., administrative expenses associated with online services, billing, etc...) (2) β^i stands for the marginal costs associated with entrant i operating its own network (e.g. network maintenance, CO maintenance, DSLAM acquisition – note that this is indeed marginal cost as the size of a DSLAM depends on the number of lines connected in the CO etc...)[4] (3) t_1 is the access charge, set up by the regulator, and required to access the incumbent's local loop: it has been set to 2.9 euros per access per month (4) ω_m^i is a random shock on the cost of investment and is supposed to be i.i.d. across firms and markets, it is public information and revealed at the beginning of the game, before the investment decision.

Opting for the bitstream option requires no investment but entrant i then faces a higher marginal cost, which is given by:

$$\gamma_{0m} = c^i + t_0,$$

[4]These costs β^i could be market-dependent because of cross-market variability in broadband traffic: In this case, information flows could be measured by the demographics characteristics X_m and we would have to include a βX_m term in the entrant's marginal cost.

where c^i is, as before, the non-network marginal cost of the entrant and t_0 is the access charges associated with the bitstream offer. t_0 has been set to 15.5 euros per access per month. The reader should bear in mind that this price is also regulated.

We make two important assumptions at this point. First, we assume that regulated prices t_1 and t_0 are exogenous for each firm, i.e. entrants do not internalize the impact of their decisions on regulation. Second, we assume that regulation is constant through time, i.e. that there is no regulation uncertainty. Both these assumptions are reasonable: regulated prices were fixed in 2001, and did not move until the end of 2006, which is, we believe, a strong indication of both the stability of regulation and of its "exogeneity".

As for the incumbent, we first make the assumption that it has already invested to build the local loop and that its fixed costs have entirely been repaid. It therefore operates only under marginal cost $\gamma^0 = c^0 + \beta^0$. As before, c^0 stands for the overall part of the marginal costs, while β^0 represents the marginal costs associated with network ownership.

In the second stage, firms compete in price. Demand is given by a LOGIT choice model which is detailed in section 4.2. The equilibrium concept we use to solve this model is subgame perfect Nash equilibrium. Finally, we assume that all these marginal costs are common knowledge across all market participants.

4.2 Demand Function

The demand function is specified as a LOGIT model (for a general presentation of the LOGIT demand function, see Anderson et al. (1992)). More specifically, we assume that consumer k in market m derives utility u^i_{km} from buying broadband to company i, with:

$$u^i_{km} = \xi^i + \xi_m - \alpha p^i_m + \epsilon^i_m + \eta^i_{km} \tag{1}$$

ξ^i is a firm fixed effect: it can be interpreted as the goodwill associated with consuming broadband from firm i. ξ_m is a central office fixed effect: it corresponds to the propensity of consumer in central office m to buy broadband. α is the price elasticity of consumer utility. p^i_m is the price set by company i for central office m. ϵ^i_m represents a local demand shock, e.g. a shock to the local image of firm i. We assume that these shocks are independently and identically distributed across firms and markets, and they are perfectly observed by all firms before their unbundling decision. Finally, η^i_{km} is a random utility term distributed according to an extreme value distribution.

We should stress here that we make the crucial assumptions that (1) prices are not observable and (2) prices are set at the market level. First of all, observing real prices is particularly complicated when it comes to broadband as pricing scheme used by operators are often non-linear, involving upfront discount, ex-post penalty and sometimes even variable monthly fees. Moreover, anecdotal evidence tend to show that both entrants and the incumbent have many ways to make prices local: rebates on initial subscription, local promotional offers, inclusion of the modem in the subscription, and more generally, local constraints on flows are various instruments at the disposal of operators that (1) we cannot observe and (2) make prices vary locally.

Finally, we normalize the utility associated with the outside option to 0, so that when consumer k decides not to buy broadband service, he simply gets utility:

$$u_{km}^{\varnothing} = \eta_{km}^{\varnothing} \tag{2}$$

Integrating over the random utility term, one can show, as in Berry (1994), that the market share s_m^i of firm i in market m is given by:

$$s_m^i(p_m; a_m) = \frac{D_m^i(p_m; a_m)}{K_m} = \frac{e^{\xi^i + \xi_m - \alpha p_m^i + \epsilon_m^i}}{1 + \sum_{l=0}^{3} e^{\xi^l + \xi_m - \alpha p_m^l + \epsilon_m^l}}, \tag{3}$$

where $p_m = (p_m^0, (p_m^l)_{l \in \{1,2,3\}})$ is the price vector and $\epsilon_m = (\epsilon_m^0, \epsilon_m^1, \epsilon_m^2, \epsilon_m^3)$ is the shock vector.

Using the fraction $s_m^{\varnothing}$ of consumers buying the outside option, this model generates the traditional linear equation for all firms $i \in 0, 1, 2, 3$:

$$\ln(s_m^i) - \ln(s_m^{\varnothing}) = \xi^i + \xi_m - \alpha p_m^i + \epsilon_m^i \tag{4}$$

As mentioned earlier, we do not observe local prices p_m^i. Thus, we cannot estimate directly equation 4. Instead, we need use first-order conditions associated with firms' profit maximization in order to get rid of these local prices. We do that in the next section 4.3

4.3 Solving the Model

As previously mentioned, for each market, the timing of the game is as follow. In a first stage, firms decide simultaneously to enter or not and if they want to unbundle the local loop. In a second stage, firms compete in prices.

The equilibrium concept is Perfect Nash Equilibrium. We solve the model backward and first look for the price equilibrium.

4.3.1 Second Stage: The price equilibrium

We note (a_m^i) the unbundling decision of firm i in market m. a_m^i equals 1 when firm i decides to unbundle the local loop in market m in the first stage. Firm i's profit in market m can be written as:

$$\Pi_m^i(p_m^i, p_m^{-i}; a_m) \quad = \quad D_m^i(p_m; a_m)\left(p_m^i - a_m^i \gamma_{1m}^i - (1 - a_m^i)\gamma_{0m}^i\right) - a_m^i \left(I_m^i + \omega_m^i\right)$$

The profit function of entrant i is quasi concave in price p_m^i (see Appendix A for a proof). Given the price p_m^{-i} of its competitors, firm i 's best response is thus defined by the following first order condition:

$$p_m^i - a_m^i \gamma_{1m}^i - (1 - a_m^i)\gamma_{0m}^i = \frac{1}{\alpha}\frac{1}{1 - s_m^i} \tag{5}$$

We can use this last equation 5 to replace local prices p_m^i in equation (4). Noting $\zeta^i = \xi^i - \alpha(c^i + t_0)$, we obtain for all $i \in \{1,2,3\}$ the following "demand" equation:

$$\ln(s_m^i) - \ln(s_m^\varnothing) + \frac{1}{1-s_m^i} = \zeta^i + \xi_m - \alpha\left(t_1 - t_0 + \beta^i\right) a_m^i + \epsilon_m^i \tag{6}$$

Because we observe unbundling decisions and the regulated prices, we can estimate equation 6. Note however that ξ^i and c^i are not separately identified. When a firm has a strong demand, it is not possible to distinguish, using our identification strategy, whether this is due to lower marginal costs or to a "higher goodwill", i.e. fixed effect.

We now turn to the Incumbent's (i.e. firm 0) profit function in market m. The Incumbent derives profit from two sources: first, it has direct revenues from selling broadband to its own consumer; secondly, it receives the proceeds from the wholesale market, either through the local loop access charges if the entrant is unbundling or through bitstream access charges.

$$\begin{aligned}\Pi_m^0(p_m^0, p_m^{-0}; a_m) &= = D_m^0(p_m; a_m)\left(p_m^0 - c^0 - \beta^0\right) \\ &\quad + \sum_{i=1}^{3}\left(t_1 a_m^i + \left(t_0 - \beta^0\right)\left(1 - a_m^i\right)\right) D_m^i(p_m; a_m)\end{aligned}$$

This program is also quasi concave in p_m^0 (see proof in appendixA), so that the incumbent's price should respect the following first order condition:

$$p_m^0 - c^0 - \beta^0 = \frac{1}{\alpha}\frac{1}{1-s_m^0} + \sum_{i\in\{1,2,3\}}\left(t_1 a_m^i + (t_0 - \beta^0)(1 - a_m^i)\right)\frac{s_m^i}{1-s_m^0} \tag{7}$$

The reader should pay attention to the fact that, while the entrants only bear the marginal costs β^i associated with network ownership when unbundling the local loop, the incumbent always operates under marginal costs β^0. As we did for the entrants, using this expression to replace p_m^0 in equation 4 and noting $\zeta^0 = \xi^0 - \alpha c_0 - \alpha\beta^0$, we obtain the last "demand" equation which does not contain any local prices:

$$\begin{aligned}\ln(s_m^0) - \ln(s_m^\varnothing) + \frac{1}{1-s_m^0} &= \zeta^0 + \xi_m - \alpha\left(t_0 - \beta^0\right)\underbrace{\left(\sum_{i\in\{1,2,3\}}\frac{s_m^i}{1-s_m^0}\right)}_{=V_m^0} \\ &\quad -\alpha\left(t_1 - t_0 + \beta\right)\underbrace{\left(\sum_{i\in\{1,2,3\}}\frac{s_m^i}{1-s_m^0}a_m^i\right)}_{=W_m^0} + \epsilon_m^0\end{aligned} \tag{8}$$

The expressions V and W have a simple interpretation. Because the proceeds from the access charges are increasing with entrants demand, the incumbent has incentive to soften price competition to boost entrants demand: thus at equilibrium, the higher the entrants demand, the lower the entrant market share should be; this is the V expression. However, the incumbent's incentive to soften price competition are lower the more entrants have been unbundling the local loop, as access charges are then lower. This is the W expression. The more efficient the incumbent (i.e. the lower β^0), the higher $V - W$ should be, as lower marginal costs increase the incumbent's preference for bitstream vs. unbundling access.

Equation $s_m^{\varnothing} + s_m^0 + \sum_{i=1}^{3} s_m^i = 1$ combined with equations 6 and 8 define the Nash equilibrium of our second stage pricing game. The solution $s_m^*(a_m, \epsilon_m) = (s_m^{0*}(a_m, \epsilon_m), ..., s_m^{N*}(a_m, \epsilon_m))$ of this nonlinear system of equations corresponds to the equilibrium market shares. The vector of equilibrium prices, $p_m^*(a_m, \epsilon_m)$, can be easily recovered using demand equations 5 and 7.

Using the first order condition, the equilibrium profit function of firm i writes:

$$\Pi_m^{i*}(a_m) = \frac{K_m}{\alpha} \frac{s_m^{i*}}{1 - s_m^{i*}} - I_m^i a_m^i \tag{9}$$

while the equilibrium profit of the Incumbent writes:

$$\Pi_m^{0*}(a_m) = \frac{K_m}{\alpha} \frac{s_m^{0*}}{1 - s_m^{0*}} + K_m \sum_{i=1}^{3} \left(t_1 a_m^i + (t_0 - \beta^0)(1 - a_m^i)\right) \frac{s_m^{i*} s_m^{0*}}{1 - s_m^{0*}} \tag{10}$$

4.3.2 First Stage: The unbundling equilibrium

We now turn to the ex ante investment decision: each firm has to decide if it wants to unbundle the local loop in each market. We rule out the possibility of mixed strategies and thus constrains a_m^i to be either 0 or 1. We also drop the index m when unnecessary. We consider Nash-equilibria of the unbundling game. Let $a_m^* = (a_m^{0*}, a_m^{1*}, a_m^{2*}, a_m^{3*})$ be the equilibrium vector of unbundling decisions. Because a_m^{i*} is the optimal unbundling decision for firm i, it must necessarily satisfy the following condition (omitting the ϵ dependence of equilibrium prices and using obvious notations):

$$\Pi^i \left(p^{i*}(a^{i*}, a^{-i*}), p^{-i*}(a^{i*}, a^{-i*})\right) \geq \Pi^i \left(p^{i*}((1 - a^{i*}), a^{-i*}), p^{-i*}((1 - a^{i*}), a^{-i*})\right)$$

Therefore, entrants i decides to unbundle the local loop if and only if:

$$\begin{aligned} & D^i \left(p^{i*}(1, a^{-i*}), p^{-i*}(1, a^{-i*})\right) \left(p^{i*}(1, a^{-i*}) - \gamma_1^i\right) - D^i \left(p^{i*}(0, a^{-i*}), p^{-i*}(0, a^{-i*})\right) \left(p^{i*}(0, a^{-i*}) - \gamma_0^i\right) \\ & \qquad \geq I^i + \omega^i \\ \Leftrightarrow \; & \underbrace{D^i \left(p^{i*}(1, a^{-i*}), p^{-i*}(1, a^{-i*})\right) \left(p^{i*}(1, a^{-i*}) - \gamma_1^i\right) - D^i \left(p^{i*}(0, a^{-i*}), p^{-i*}(1, a^{-i*})\right) \left(p^{i*}(0, a^{-i*}) - \gamma_0^i\right)}_{\text{Open Loop Equilibrium}} \\ & + \underbrace{\left(p^{i*}(0, a^{-i*}) - \gamma_0^i\right) \left(D^i \left(p^{i*}(0, a^{-i*}), p^{-i*}(1, a^{-i*})\right) - D^i \left(p^{i*}(0, a^{-i*}), p^{-i*}(0, a^{-i*})\right)\right)}_{\text{Strategic Effect (``Puppy Dog'')}} \\ & \qquad \geq I^i + \omega^i \end{aligned} \tag{11}$$

As one can see from equation 11, the trade-off associated with the unbundling decision involves three terms: (1) the cost of investment (2) the direct overall effect on marginal cost and own pricing decision of unbundling (this would be the only effect in an open loop equilibrium (see Fudenberg and Tirole (1984)), i.e. in an equilibrium where the entrants would fail to acknowledge that pricing decisions are made contingent on unbundling decisions[5] (3) a strategic effect coming from the variation in other firms' prices in response to the unbundling decision.

As we show in appendix C, the direct effect is positive: each firms experience a direct gain from unbundling as unbundling lower their marginal costs. However, the last term (i.e. the "strategic effect") is negative in our context: the entrants has incentives to under-invest in order to make both other entrants and the incumbent "softer" in the second stage price competition. This is simply because unbundling makes firms tougher and prices are strategic complement in our LOGIT model. Therefore, each entrant has the incentive to adopt a *puppy dog* strategy with respect to unbundling: relative to an equilibrium with no anticipation of strategic effect, the entrants opt for a less aggressive unbundling policy in order to make second-price competition softer.

Finally, let us remark that our unbundling game might give birth to multiple equilibria. This is a classical feature of games of simultaneous decisions with perfect information (see for instance Berry (1992)). We don't use any refinement that could restrict the scope for these multiple equilibria. As it turns out, the presence of multiple equilibria is not problematic as far as the estimation of the model is concerned. It can however becomes an issue once we simulate the model, as it is then impossible to provide a unique welfare assessment. In section 6, when we simulate the model, we shall content ourselves with providing only bounds for the welfare.

5 Estimation and Identification

The estimation of our model is fairly direct and proceeds in two stages. In the first stage, we estimate the structural demand parameters of our LOGIT model. In a second stage, using these parameters and the equilibrium profits computed in equations 10 and 9, we are able to compute, for each market m and each potential market structures (i.e. the eight different unbundling vector) firms' profit. Using the local first order conditions in firms' unbundling decisions (equation 11), we derive a simple PROBIT model of unbundling the local loop.

5.1 First Stage Estimates

From equation 6 and 8, which are the first order conditions associated with firms' profit maximization in the second stage (as a function of market shares), we derive a system of linear equations which don't involve observability of local prices (i.e. (p_m^i)). This is similar to traditional demand equations as in Berry (1994) in the case where we don't observe prices but know part of firms' marginal costs.

$$\begin{cases} \ln(s_m^i) - \ln(s_m^\varnothing) + \dfrac{1}{1-s_m^i} = \zeta^i + \xi_m + \alpha\left(t_0 - \left(t_1 + \beta^i\right)\right) a_m^i + \epsilon_m^i \\ \ln(s_m^0) - \ln(s_m^\varnothing) + \dfrac{1}{1-s_m^0} = \zeta^0 + \xi_m - \alpha\left(t_0 - \beta^0\right) \times V_m^0 + \alpha\left(t_0 - \left(t_1 + \beta^0\right)\right) \times W_m^0 + \epsilon_m^0 \end{cases} \tag{12}$$

[5] Note that the effect of unbundling on one own pricing scheme appears in our discrete context but would not appear in a more continuous model (thanks to the envelop theorem)

where $V_m^0 = \sum_{i\in\{1,2,3\}} \frac{s_m^i}{1-s_m^0}$ and $W_m^0 = \sum_{i\in\{1,2,3\}} \frac{s_m^i}{1-s_m^0} a_m^i$ have been defined in section 4.3.

In order to obtain the most precise estimates (in particular for the CO fixed effect), we combine the equations in system 12 into a single joint equation:

$$\begin{aligned}\ln(s_m^i) - \ln(s_m^{\varnothing}) + \frac{1}{1-s_m^i} &= \zeta^i + \xi_m + \alpha\left(t_0 - \left(t_1 + \beta^i\right)\right) \mathbb{1}_{\{i\in\{1,2,3\}\}} a_m^i - \alpha\left(t_0 - \beta^0\right) \mathbb{1}_{\{i=0\}} V_m^i \\ &\quad + \alpha\left(t_0 - \left(t_1 + \beta^0\right)\right) \mathbb{1}_{\{i=0\}} W_m^i + \epsilon_m^i, \quad \forall i. \end{aligned} \tag{13}$$

where $a_m^0 = 0$ and $V_m^i = W_m^i = 0$ for $i \in \{1,2,3\}$.

As in Berry (1994), the estimation of equation 13 is problematic as it is potentially plagued by endogeneity issues. As it turns out, the model's structure is such that a_m^i, firm i's unbundling decision in market m and ϵ_m^i, the unobserved heterogeneity of firm i's demand in market m are not independent: unbundling decisions clearly depend on all demand shocks, and in particular on ϵ_m^i. In particular, firms should unbundle more, *ceteris paribus*, in markets where the unobserved heterogeneity of their demand is high, leading to an upward bias in the estimation of the unbundling coefficients $\alpha\left(t_0 - \left(\hat{t_1} + \beta + \gamma\right)\right)$. The model also suggests that both V and W should be correlated with ϵ^0: V and W are a function of the firms prices, which are themselves a function of the unobserved heterogeneity of the incumbent's demand. Note however that this last endogeneity source seems *a priori* to be less obvious than that on the unbundling decisions. Nevertheless, we need to find instrumental variables for unbundling decisions a_m^i as well as for variables V_m and W_m in order to provide robust and consistent estimates of equation 13. The next section presents in detail such instrumental variables.

5.1.1 Instrumental Variables and first stage equation.

We first look for variables credibly instrumenting unbundling decisions, i.e. which are correlated with unbundling decisions but are not correlated with unobserved heterogeneity in each operator's demand. The historical development of two of the main operators in France provides us with such an instrument.

First of all, Neuf Telecom[6] was created (and still is) as an affiliate to the Louis-Dreyfus group. This long-lived business group (which was created in 1851) was first specialized in the trading and worldwide processing of bulk agricultural commodities. Influenced by these core activities, the group diversification in the beginning of the 19th century lead Louis-Dreyfus to engage in shipping activities and to become one of the world's 10 leaders in the bulk carrier industry. In particular, the group developed an important fleet of cable laying vessels. When Louis-Dreyfus decided to become an active player in the telecommunication industry in 1998 with the creation of Neuf Telecom, it instantaneously decided to roll-out a national fiber optic network. In order to do so, Neuf Telecom naturally used the *savoir faire* of the Louis-Dreyfus group in laying cables in canals, so that the major part of their backbone network simply followed the geography of waterways within France. Being close to such a waterway therefore increases the expected proximity to the Neuf Telecom's backbone network. As unbundling costs are decreasing with the distance to the backbone network, a CO distance to a waterway should be a good predictor

[6]A detailed account of the Louis-Dreyfus group history can be found on the group's web site at `http://www.louisdreyfus.com`

of the probability of being unbundled by Neuf Telecom. Moreover, it is not likely that the distance of a particular CO to a waterway should be correlated with demand shocks, as these waterways were build decades before the apparition of telecommunication technologies. Also, we should stress that our regressions will include central office fixed effects[7], so that the distance to a waterway is not going to be just a proxy for some unobserved CO characteristics.

The second instrument we use exploits the fact that SNCF, the French historical railway monopole and also the major shareholder of Cegetel, developed at the end of the 90s a company, "Telecom Developpement", which owned and leased an optic fiber network. Obviously, to reduce the civil engineering costs, this company used the infrastructure at its disposal, i.e. the major railways across France, to develop its optic fiber network. It is also interesting that part of this network was already installed by SNCF for internal purposes (mainly to develop their internal information system). Therefore, a CO's distance to a railway should be a good predictor of the probability that Cegetel unbundled this particular central office. Once again, this variable (distance to the major railways) appears quite exogenous as railways were constructed more than a hundred years ago for reasons which should be quite exogenous to demand unobserved heterogeneity (they were mostly designed so as to join major cities). The same disclaimer on the use of CO fixed effects in our regressions apply to this instrument.

Finally, our last instrument takes advantage of the fact that at the end of the 90s, most French highway companies decided to renovate their infrastructure. During these renovations, these companies decided to lay down optic fibers along their highways in order to lease them to telecommunication operators, as the added cost in terms of civil engineering was almost negligible. While Neuf and Cegetel decided to build a network in-house, Free opted for leasing solution, signing numerous IRU (Indefeasible Rights of Use) contracts with network owning companies. In particular, because of the low cost of their network, many such IRU contracts were signed with freeway operators. The distance of a CO to a freeway should thus be a valid instrument for the probability that the CO is unbundled by Free.

We also look for variables instrumenting the variables V and W. V can be rewritten as: $1 - \frac{s^{\varnothing}}{1-s^0}$. The distance of a CO from either a railway, a motorway or a highway will decrease the probability of unbundling by the entrants and will therefore increase the outside option market share, thus decrease V. Of course, there is no reason to imagine that the distance to infrastructure is related in any way to ϵ^0. Similarly, W is increasing with entrants aggregate unbundled market share: the more likely a CO is to be unbundled (i.e. the closer to an infrastructure), the higher should W be, for reasons exogenous to ϵ^0.

Let us call $Z_m = (Z_m^1, Z_m^2, Z_m^3)$ our vector of instrument. Because it is not possible to include directly CO and firm fixed effects in the first stage, we instead consider a within version of equation 13, and instrument this equation. Averaging over COs and firms, equation 13 becomes, using the traditional notation and letting $Y_m^i = \ln(s_m^i) - \ln(s_m^{\varnothing}) + \frac{1}{1-s_m^i}$[8]:

[7] These fixed effects are going to be identified, because our instruments are defined at the CO/firm level, i.e we use a different CO-level instrument for each firm.

[8] Of course, it is necessary to assume that $\epsilon_{\cdot}^i = \epsilon_m^{\cdot} = \epsilon_{\cdot}^{\cdot} = 0$, which is a condition for identification of the fixed effects.

$$
\begin{aligned}
(Y^i_m - Y^\cdot_m) - (Y^i_\cdot - Y^\cdot_\cdot) &= \alpha\left(t_0 - (t_1 + \beta^i)\right)\left(\mathbb{1}_{\{i\in\{1,2,3\}\}} - \frac{1}{4}\right)(a^i_m - a^i_\cdot) - \alpha\left(t_0 - \beta^0\right)\left(\mathbb{1}_{\{i=0\}} - \frac{1}{4}\right)(V^i_m - V^i_\cdot) \\
&\quad + \alpha\left(t_0 - (t_1 + \beta^0)\right)\left(\mathbb{1}_{\{i=0\}} - \frac{1}{4}\right))(W^i_m - W^i_\cdot) + \epsilon^i_m, \quad \forall i. \qquad (14)
\end{aligned}
$$

Because Z^j is a valid instrument for $\mathbb{1}_{\{i=j\}}a^j_m$, $\left(\mathbb{1}_{\{i\in\{1,2,3\}\}} - \frac{1}{4}\right)(Z^i_m - Z^i_\cdot)$ is a valid instrument for $\left(\mathbb{1}_{\{i\in\{1,2,3\}\}} - \frac{1}{4}\right)(a^i_m - a^i_\cdot)$, and similarly, $\left(\mathbb{1}_{\{i=0\}} - \frac{1}{4}\right)(Z_m - Z_\cdot)$ is a valid instrument for both $\left(\mathbb{1}_{\{i=0\}} - \frac{1}{4}\right))(V^i_m - V^i_\cdot)$ and $\left(\mathbb{1}_{\{i=0\}} - \frac{1}{4}\right))(W^i_m - W^i_\cdot)$. The first stage regressions we are interested in are thus:

$$
\begin{cases}
\left(\mathbb{1}_{\{i=1\}} - \frac{1}{4}\right)(a^1_m - a^1_\cdot) = \rho\left(\mathbb{1}_{\{i=1\}} - \frac{1}{4}\right)(Z^1_m - Z^1_\cdot) + \eta^i_m \\
\left(\mathbb{1}_{\{i=2\}} - \frac{1}{4}\right)(a^2_m - a^2_\cdot) = \rho'\left(\mathbb{1}_{\{i=2\}} - \frac{1}{4}\right)(Z^2_m - Z^2_\cdot) + \eta^{i'}_m \\
\left(\mathbb{1}_{\{i=3\}} - \frac{1}{4}\right)(a^3_m - a^3_\cdot) = \rho\left(\mathbb{1}_{\{i=3\}} - \frac{1}{4}\right)(Z^3_m - Z^3_\cdot) + \eta^{i''}_m \\
\left(\mathbb{1}_{\{i=0\}} - \frac{1}{4}\right))\left(V^i_m - V^i_\cdot\right) = \kappa\left(\mathbb{1}_{\{i=0\}} - \frac{1}{4}\right)(Z_m - Z_\cdot) + \upsilon^0_m, \\
\left(\mathbb{1}_{\{i=0\}} - \frac{1}{4}\right))\left(W^i_m - W^i_\cdot\right) = \kappa'\left(\mathbb{1}_{\{i=0\}} - \frac{1}{4}\right)(Z_m - Z_\cdot) + \upsilon^{0'}_m
\end{cases} \qquad (15)
$$

Table 2 presents OLS estimations of first-stage equations 15. The first comment from Table 2 is that our instruments do have a strong predictive power on the endogenous variables, i.e. the unbundling decisions and V and W. The influence of the instrument is also of the predicted sign: an increase of the distance to the relevant infrastructure leads to (1) a decrease in the probability to unbundle and (2) a decrease in both V and W. The magnitude of the influence of the instrument on the endogenous variables is economically significant: A one standard deviation increase in the distance to a waterway (resp. railway) decrease the probability of unbundling by Neuf (resp. Cegetel) by around 11 percentage points (resp. 9 percentage points), which is approximately 37% (resp. 28%) of the operator unbundling dummy standard deviation. Finally, we remark that each first stage F statistic indicates that our instruments are strong. This conforts us in our IV approach.

5.1.2 IV estimation

Our IV estimation relies on a simple two stage least square strategy. We simply recover the expected value of the endogenous variables from Table 2 and then uses them as explanatory variables in the second stage "within" equation. We then recover the value of the CO and the firm fixed effects with the usual method. Table 3 presents the results of this 2SLS estimation of equation 13 using a simple OLS estimation (Column 1) and our 2SLS strategy (Column2). From these estimates (we note $\widehat{\mathbb{1}_{\{i\}}a_m}$, $\widehat{V}$, $\widehat{W}$ the estimates of the coefficients associated with each of the unbundling dummy, V and W in equation 13), it is easy to recover the structural parameters $\widehat{\alpha}$, $\widehat{\beta^i}$ and $\widehat{\gamma}$:

$$\begin{cases} \widehat{\alpha} = -\dfrac{\widehat{V} + \widehat{W}}{t_1} \\ \widehat{\beta^0} = t_0 + \dfrac{\widehat{V}}{\widehat{\alpha}} \\ \widehat{\beta^i} = t_0 - t_1 - \dfrac{\widehat{\mathbb{1}_{\{i\}} a_m^i}}{\alpha} \end{cases} \tag{16}$$

These structural parameters are also reported in table 3. Their standard errors are recovered using simple delta methods (Oehlert (1992)). Let us briefly comment this table. First, one immediately notice that the sign of the estimated coefficients are as expected from the theory. In other words, the basic constraints from the model are not rejected by the data: we do find a negative price elasticity of demand, as well as positive marginal costs. Second, endogeneity issues are not too stringent in the estimation of equation 13: the coefficients obtained from the IV regression are not statistically different from the coefficients retrieved from the OLS estimation. Given that our first stage regressions in Table 2 proved that our instruments are strong, this might just indicate that the magnitude of these firm/CO demand shocks are small compared to CO or firm fixed effect and/or fixed cost variables, so that they do not play an important role in entrants' unbundling decisions.

Quantitatively, we find that unbundling does have quite a strong causal positive impact on entrant's market share, which is interpreted as a sign of a strong, negative, price elasticity of demand. However, there is quite an heterogeneity in the entrants market share reaction to unbundling. For instance, Cegetel's market shares are not significantly stronger in COs where it has unbundled the local loop, while a one standard deviation increase in the probability of unbundling leads Neuf to a 50% standard deviation increase in $\ln(s_m^i) - \ln(s_m^{\varnothing}) + \frac{1}{1-s_m^i}$. The interpretation is simply that there is quite an heterogeneity in entrants efficiency: an efficient entrant can significantly decrease its local prices and therefore increase its demand. As it turns out, Cegetel marginal costs are more than 2 euros/month/consumer those of Neuf. We also find that the incumbent marginal cost is fairly high, and in the same order of magnitude than that of the other entrants. This is simply so because we do not find in the data a strong difference in the incumbent's market share in COs where entrants have massively unbundled relative and in COs where entrants have not unbundled. However, because of the difference in access charges $t_0 - t_1$, the incumbent should be willing to increase its price in "bitstream" COs relative to unbundled COs, unless its marginal cost β^0 associated with network ownerhsip high to partly compensate for the gain $t_0 - t_1$. As it turns out, W, once instrumented, is no longer significant: while this may be just due to the large variance of IV estimators, it is nevertheless a sign that β^0 is not very different from $t_0 - t_1$.

5.2 A Quantitative Look into Strategic Externalities

In this section, we are interested in using demand estimates from Table 3 in order to quantify the importance of strategic externalities in the unbundling decisions of entrants. The way to do so is to use the parameter estimates from table 3 and, for each LE in our dataset, to compute the vector of profits for the 8 potential market structures (i.e. the 2^3 combination of unbundling decisions among entrants). The procedure is fairly straightforward. Consider first a given unbundling strategy (a_m^1, a_m^2, a_m^3) for a LE m. Conditional on such an unbundling strategy, the second stage equilibrium market share of entrants $s_m = (s_m^k)_{k=0,1,2,3}$ must be given by the following first order condition:

$$\begin{cases} \ln(s_m^i) - \ln(s_m^{\varnothing}) + \dfrac{1}{1-s_m^i} = \widehat{\zeta}^i + \widehat{\xi_m} - \widehat{\alpha}\left(t_1 - t_0 + \widehat{\beta}^i\right) a_m^i + \widehat{\epsilon_m^i} \\ \ln(s_m^0) - \ln(s_m^{\varnothing}) + \dfrac{1}{1-s_m^0} = \widehat{\zeta}^0 + \widehat{\xi_m} - \widehat{\alpha}\left(t_0 - \widehat{\beta^0}\right)\left(\displaystyle\sum_{i\in\{1,2,3\}} \frac{s_m^i}{1-s_m^0}\right) - \alpha\left(t_1 - t_0 + \widehat{\beta}\right)\left(\displaystyle\sum_{i\in\{1,2,3\}} \frac{s_m^i}{1-s_m^0} a_m^i\right) + \widehat{\epsilon_m^0} \\ s_m^{\varnothing} + s_m^0 + \displaystyle\sum_{i=1}^{3} s_m^i = 1 \end{cases} \tag{17}$$

As we show in Appendix B, this system has a unique solution, $s_m^{\star}(a_m)$, which we can easily compute numerically and which provides us with the equilibrium market shares associated with the unbundling vector a_m. Using the first-order conditions 5 and 7, we can then infer the corresponding markups $p_m^i - a_m^i\gamma_1^i - (1-a_m^i)\gamma_0^i$, as they are solely a function of the equilibrium market shares. However, the reader should bear in mind that in our model, it is not possible to entirely identify the entrant's cost structure: indeed, c^i, entrant's i network-unrelated marginal cost, is not separately identified from entrant's i fixed effect ξ^i. Therefore, it is not possible to infer i's price in market m, as we cannot compute its overall marginal cost. Yet, this does not prevent us from computing the two terms in equation 11, i.e. the equation that allows us to quantify the relative role played by competitive externalities in the decision to unbundle (i.e. how large the price response of other operator to entrant i's unbundling decision is). Consider the "puppy-dog" term in equation 11:

$$A_1 = \left(p^{i*}(0, a^{-i*}) - \gamma_0^i\right)\left(D^i\left(p^{i*}(0, a^{-i*}), p^{-i*}(1, a^{-i*})\right) - D^i\left(p^{i*}(0, a^{-i*}), p^{-i*}(0, a^{-i*})\right)\right) \tag{18}$$

The first term $(p_m^{i*}(0, a^{-i*}) - \gamma_0^i)$ is easily determined from the first order condition 5 associated with market structure $a = (0, a^{-i*})$ and can therefore be expressed as a function of $s_m^{\star}(0, a^{-i*})$. Similarly, the last expression $D^i\left(p^{i*}(0, a^{-i*}), p^{-i*}(0, a^{-i*}\right) = K_m \times s_m^{\star}(0, a^{-i*})$ is directly inferred from the solution of the system 17 using $(0, a^{-i*})$ as a market structure. The only potentially problematic term is therefore $D^i\left(p^{i*}(0, a^{-i*}), p^{-i*}(1, a^{-i*})\right)$, as it include prices from different market structures. We come back to the LOGIT specification:

$$D^i\left(p^{i*}(0, a^{-i*}), p^{-i*}(1, a^{-i*})\right) = K_m \frac{e^{\xi^i + \xi_m - \alpha p^{i*}(0, a^{-i*}) + \epsilon_m^i}}{1 + e^{\xi^i + \xi_m - \alpha p^{i*}(0, a^{-i*}) + \epsilon_m^i} + e^{\xi^{-i} + \xi_m - \alpha p^{-i*}(1, a^{-i*}) + \epsilon_m^{-i}}}$$

But using the first order conditions, we know that:

$$\begin{cases} \dfrac{s_m^{\star,i}(0, a^{-i*})}{s_m^{\star,\varnothing}(0, a^{-i*})} = e^{\xi^i + \xi_m - \alpha p^{i*}(0, a^{-i*}) + \epsilon_m^i} \\ \dfrac{s_m^{\star,-i}(1, a^{-i*})}{s_m^{\star,\varnothing}(1, a^{-i*})} = e^{\xi^{-i} + \xi_m - \alpha p^{-i*}(1, a^{-i*}) + \epsilon_m^{-i}} \end{cases}$$

Note that the two ratios $\frac{s_m^{\star,-i}(1, a^{-i*})}{s_m^{\star,\varnothing}(1, a^{-i*})}$ and $\frac{s_m^{\star,i}(0, a^{-i*})}{s_m^{\star,\varnothing}(0, a^{-i*})}$ can be computed as we know from solving equation 17 each of the market share associated with each potential unbundling vector. Therefore, the last expression is computed as:

$$D^i\left(p^{i*}(0,a^{-i*}),p^{-i*}(1,a^{-i*})\right)=K_m\frac{\frac{s_m^{\star,i}(0,a^{-i*})}{s_m^{\star,\varnothing}(0,a^{-i*})}}{1+\frac{s_m^{\star,i}(0,a^{-i*})}{s_m^{\star,\varnothing}(0,a^{-i*})}+\frac{s_m^{\star,-i}(1,a^{-i*})}{s_m^{\star,\varnothing}(1,a^{-i*})}}$$

Thus, the expression 18 can be entirely inferred from our estimation. We now only need to compute the overall difference in profit for entrant i, i.e. its incentives to unbundle. This difference in profit is given by the following expression:

$$A=D^i\left(p^{i*}(1,a^{-i*}),p^{-i*}(1,a^{-i*})\right)\left(p^{i*}(1,a^{-i*})-\gamma_1^i\right)-D^i\left(p^{i*}(0,a^{-i*}),p^{-i*}(0,a^{-i*})\right)\left(p^{i*}(0,a^{-i*})-\gamma_1^i\right)$$

Because it only corresponds to equilibrium market structure, it can be alsco computed using the equilibrium values of profit given by equation 9. This provides us with a simple way to compute equilibrium profits for a given unbundling vector using the equilibrium market share associated with this unbundling vector (and that are computed by solving the system 17.

We have therefore retrieved empirically the ratio $\frac{A_1}{A}$: it provides us with a measure of the importance of the strategic "puppy dog" effect in entrants unbundling decisions. Figure 3 is eloquent: it provides for each entrant, the distribution of the ratio $\frac{A_1}{A}$ across COs. The average ratio across entrants and COs is .005, i.e. that the decrease in profit when unbundling associated with other firms being more aggressive in the price competition accounts only for 0.5% of the overall increase in marginal profits when unbundling. In other words, strategic effects in our context is responsible for less than .5% of the overall incentives to unbundle. Anticipating on the results of section 5.3, we can look empirically at the number of COs that are not unbundled because of these strategic effects: using the estimated fixed costs, we can simply compute the equilibrium decisions of unbundling if entrants omit this A_1 term. We find that omitting these effects do change any of the unbundling decisions observed in our strategic framework: these effects really are second-order in the decision process of the entrants.

5.3 The Unbundling Equilibrium: PROBIT model

Using equation 9 and 10, we can recover the profit function associated with the 3-tuple (a_m^1, a_m^2, a_m^3), ie $(\widetilde{pi}_m^i(a_m))$. We are now interested in estimating the cost of unbundling for each of the entrant. As we already mentioned in section 5.1.1, the specific CO/firm cost characteristic depends mostly on the distance of the CO to the main infrastructures. We thus decompose the firm/CO fixed cost I_m^i into (1) a *région* fixed effect[9] (2) firm fixed effect and (3) the distance of the CO to the firm's backbone network approximated by the distance to the relevant infrastructure. Therefore, let us write for a CO m in *région* r: $I_{m,r}^i+\omega_m^i=\zeta_r+\zeta^i+\chi^i Z_m+\omega_m^i$. Let us also assume that $\omega_m^i\sim N(0,\sigma)$. We then have, for all entrant i:

$$\tilde{a}_m^i=a_m^i\Leftrightarrow\underbrace{\tilde{\pi}_m^i(a_m^i,a_m^{-i})-\tilde{\pi}_m^i(1-a_m^i,a_m^{-i})}_{\text{difference in profit between } a \text{ and } 1-a}+(1-2a_m^i)\left(\zeta_r+\zeta^i+\chi^i Z_m\right)\geq(2a_m^i-1)\omega_m^i \quad (19)$$

Equation 19 is nothing but a simple probit model. Indeed, noting $\Delta\pi_m^i=\tilde{\pi}_m^i(1,a_m^{-i})-\tilde{\pi}_m^i(0,a_m^{-i})$, equation 19 simply states the following unbundling rule:

[9]The *région* is the largest geographical division in France. There are 26 such *région* over the territory. Note that we do not include CO fixed effect as this would lead us to add 1,500 variables in our Probit estimation, which would make the estimation unconsistent (Greene (2002)).

$$a_i^m = \mathbb{1}_{\{\omega_m^i \leq \Delta\pi_m^i - \zeta_r - \zeta^i - \chi^i Z_m\}} \tag{20}$$

Note that, using our estimated demand parameters and solving system 17, we are able to compute, for each entrant and each CO the $\Delta\pi_m^i$ expression: this is the difference in variable profits induced by unbundling, conditional on other entrants' equilibrium unbundling strategy[10]. The estimation of equation 20 is reported in Table 4. Note that in equation 20, identification comes from imposing a coefficient 1 in front of $\Delta\pi_m^i$, which pins down the variance of ω_m^i. In Table 4, we have estimated equation 20 but have imposed that the variance of the residual is equal to 1, so that the estimated variance of ω_m^i is actually the inverse of the coefficient in front of $\Delta\pi_m^i$.

As predicted by the model, entrants tend to unbundle COs where the "marginal" part of the profit from unbundling is stronger. We also see, as in Table 2 that our instruments have a strong predictive power on the unbundling decisions of entrants, which we believe is a confirmation that they capture firm/CO-level heterogeneity in fixed costs associated with unbundling. Another observation from Table 4 is that, conditional on the "marginal profit" from unbundling, Neuf and especially Cegetel have on average lower fixed costs than Free. Finally, we can recover from Table 4 the expected fixed costs at the CO/entrant level. To do so, we first recover the observed part of the fixed cost: $\zeta_r + \widehat{\zeta^i + \chi}^i Z_m$. We the infer, using the gaussian assumption, the expectation of the error term conditional on unbundling decisions, i.e. $\mathbb{E}[\omega_m^i | \omega_m^i < \Delta\pi_m^i - \zeta_r - \zeta^i - \chi^i Z_m]$ and $\mathbb{E}[\omega_m^i | \omega_m^i > \Delta\pi_m^i - \zeta_r - \zeta^i - \chi^i Z_m]$. We then use as fixed cost for entrant i in market m the following estimation:

$$\widehat{I_m^i} = \zeta_r + \widehat{\zeta^i + \chi}^i Z_m + \mathbb{E}[\omega_m^i | a_m^i] \tag{21}$$

Figure 4 shows, for each entrant, the distribution of these fixed costs across markets. As evident from figure 4, there is a quite a strong heterogeneity in these fixed costs. Note that the cross-entrant within CO variability in our data comes from the distance to the relevant infrastructures and from the unobserved heterogeneity in investment costs ω. Actually, as can be seen from Table 4, the estimated standard deviation $\widehat{\sigma}$ is fairly large (around 250, while the overall standard deviation of estimated investment is 277), so that a good chunk of this heterogeneity might just come from this unobserved part. This might be a sign that our PROBIT model of unbundling is not precise enough, and should include more geographical variables at the CO level. We plan to do so in future versions of the paper. A last remark on these estimated fixed costs: in less than 9% of the case, these estimated fixed costs are negative.

This achieves the identification and the estimation of the model. The next section presents the methodology used for simulation and discuss simulation results.

[10] As we already said in section 5.2, we can compute the equilibrium vector of profit for each potential market structure by solving system 17. The $\Delta\pi_m^i$ expression is just the difference between profits from $a = (1, a^{-i})$ and the profit from $a = (0, a^{-i})$.

6 Simulation

6.1 Methodology

We are interested in simulating the model using alternative scenarios for regulated prices (t'_0, t'_1). The methodology to do so is quite simple. Using the demand parameters, we can easily solve system 17 using the new regulated prices (t'_0, t'_1) to determine the equilibrium market shares associated with all potential unbundling vector under the alternative regulation. Using our estimates for CO/firm fixed costs $\widehat{I^i_m}$ determined in equation 21, we can thus compute the vector of profit $\pi(a; t')$ for each firm and each unbundling vector a, under the new regulation t'. It is then quite easy to determine the Nash equilibrium of the unbundling games, as it involves only a $2 \times 2 \times 2$ matrix of payoff.

Two issues might come up at this stage. First, there might be no pure-strategy equilibrium. In such a case, we should use mixed-strategies to find the appropriate equilibrium. It can also be the case that there are multiple equilibria. Our approach is not to refine the equilibria in such a case but rather to compute the entire set of equilibria, and to provide bounds on welfare.

Welfare is then easily computed. First, we know the equilibrium firms' profits, and in particular the fixed costs of unbundling, so the firms' surplus is easy to recover. Then, consumers' surplus can be computed going back to the LOGIT specification of utility. As we show in appendix D, the aggregate utility of consumers in CO m is given by the simple expression:

$$\Delta S_C = -K_m \times ln(s^{\varnothing}_m) \tag{22}$$

6.2 Welfare Analysis

7 Conclusion

References (to be completed)

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A Concavity of the Profit function

B Existence of a unique solution for system 17

C Comparative statics of the model

We note $p^{i*}(a)$ the equilibrium prices as a function of the vector of unbundling decisions, $a = \left(a^0, a^1, a^2, a^3\right)$. The equilibrium prices are defined by the following first order conditions:

$$\begin{cases} \pi_i^i(p^{0*}(a), p^{1*}(a), p^{2*}(a), p^{3*}(a); a^i) = 0 \ \ \forall i \in 1,2,3 \\ \pi_0^0(p^{0*}(a), p^{1*}(a), p^{2*}(a), p^{3*}(a); a^1, a^2, a^3) = 0 \end{cases}$$

We can differentiate these first order conditions in a^1 to get to the comparative statics in a^1. Consider the matrix M defined as: $M = (\pi_{ij}^i)_{(i,j)\in\{0,1,2,3\}^2}$. We have:

$$\underbrace{\begin{bmatrix} \pi_{00}^0 & \pi_{01}^1 & \pi_{02}^2 & \pi_{03}^3 \\ \pi_{10}^1 & \pi_{11}^1 & \pi_{12}^2 & \pi_{13}^3 \\ \pi_{20}^2 & \pi_{21}^1 & \pi_{22}^2 & \pi_{23}^3 \\ \pi_{30}^3 & \pi_{31}^1 & \pi_{32}^2 & \pi_{33}^3 \end{bmatrix}}_{=M} \times \begin{bmatrix} \frac{\partial p^{0*}}{\partial a^1} \\ \frac{\partial p^{1*}}{\partial a^1} \\ \frac{\partial p^{2*}}{\partial a^1} \\ \frac{\partial p^{3*}}{\partial a^1} \end{bmatrix} = \begin{bmatrix} -\frac{\partial \pi_0^0}{\partial a^1} \\ -s\frac{\partial \pi_1^1}{\partial a^1} \\ 0 \\ 0 \end{bmatrix}$$

Thanks to the stability conditions, we know that M is invertible, and that $det(M) > 0$ as all its eigenvalues are negative and M is a $(4,4)$ square matrix. Using Cramer's identity, we can sign the vector consisting of the derivatives of prices in a^1.

$$\begin{aligned}
\underbrace{\frac{1}{det(M)}}_{>0} \times \frac{\partial p^{3*}}{\partial a^1} &= \begin{vmatrix} \pi_{00}^0 & \pi_{01}^1 & \pi_{02}^2 & -\frac{\partial \pi_0^0}{\partial a^1} \\ \pi_{10}^1 & \pi_{11}^1 & \pi_{12}^2 & -\frac{\partial \pi_1^1}{\partial a^1} \\ \pi_{20}^2 & \pi_{21}^1 & \pi_{22}^2 & 0 \\ \pi_{30}^3 & \pi_{31}^1 & \pi_{32}^2 & 0 \end{vmatrix} \\
&= (-1)^{4+1}\left(-\frac{\partial \pi_0^0}{\partial a^1}\right) \begin{vmatrix} \pi_{10}^1 & \pi_{11}^1 & \pi_{12}^2 \\ \pi_{20}^2 & \pi_{21}^1 & \pi_{22}^2 \\ \pi_{30}^3 & \pi_{31}^1 & \pi_{32}^2 \end{vmatrix} + (-1)^{4+2}\left(-\frac{\partial \pi_1^1}{\partial a^1}\right) \begin{vmatrix} \pi_{00}^0 & \pi_{01}^1 & \pi_{02}^2 \\ \pi_{20}^2 & \pi_{21}^1 & \pi_{22}^2 \\ \pi_{30}^3 & \pi_{31}^1 & \pi_{32}^2 \end{vmatrix} \\
&= \underbrace{\frac{\partial \pi_0^0}{\partial a^1}}_{<0} \times \underbrace{\begin{vmatrix} \pi_{10}^1 & \pi_{11}^1 & \pi_{12}^2 \\ \pi_{20}^2 & \pi_{21}^1 & \pi_{22}^2 \\ \pi_{30}^3 & \pi_{31}^1 & \pi_{32}^2 \end{vmatrix}}_{>0} - \underbrace{\frac{\partial \pi_1^1}{\partial a^1}}_{<0} \times \underbrace{\begin{vmatrix} \pi_{00}^0 & \pi_{01}^1 & \pi_{02}^2 \\ \pi_{20}^2 & \pi_{21}^1 & \pi_{22}^2 \\ \pi_{30}^3 & \pi_{31}^1 & \pi_{32}^2 \end{vmatrix}}_{<0} \\
&< 0
\end{aligned}$$

In determining the sign of the previous expression, we used the fact that the stability condition of the equilibrium must hold for each market structure (duopoly, etc...), so that for all $(i \neq j) \in \{0,1,2,3\}^2$, we must have:

$$\pi_{ii}^i \pi_{jj}^j - \pi_{ij}^i \pi_{ji}^j > 0$$

We also used the fact that the cross-derivative of profit π_{ij}^i are positive for all $(i \neq j) \in \{0,1,2,3\}^2$ and that the profit functions are quasi-concave, ie $\pi_{ii}^i < 0$ for all $i \in \{1,2,3\}$. So for instance:

$$\begin{aligned}
\begin{vmatrix} \pi_{00}^0 & \pi_{01}^1 & \pi_{02}^2 \\ \pi_{20}^2 & \pi_{21}^1 & \pi_{22}^2 \\ \pi_{30}^3 & \pi_{31}^1 & \pi_{32}^2 \end{vmatrix} &= (-1)^4 \pi_{30}^3 \times \left(\underbrace{\pi_{01}^1 \pi_{22}^2 - \pi_{21}^1 \pi_{02}^2}_{<0}\right) + (-1)^5 \pi_{31}^1 \left(\underbrace{\pi_{00}^0 \pi_{22}^2 - \pi_{20}^2 \pi_{02}^2}_{>0}\right) + (-1)^6 \pi_{32}^2 \left(\underbrace{\pi_{00}^0 \pi_{21}^1 - \pi_{20}^2 \pi_{01}^1}_{<0}\right) \\
&< 0
\end{aligned}$$

Using similar proofs, one can show that:

$$\forall (i,j) \in \{0,1,2,3\} \times \{1,2,3\}, \qquad \frac{\partial p^{i*}}{\partial a^j} < 0$$

More unbundling by any of the entrants induce all other firms to be more agressive in the price competition (because prices are complement and investment makes the entrants more efficient and therefore makes it price more aggressively itself).

Using the notation of equation 11, we thus have:

$$D^i\left(p^{i*}(0,a^{-i*}), p^{-i*}(1,a^{-i*})\right) \leq D^i\left(p^{i*}(0,a^{-i*}), p^{-i*}(0,a^{-i*})\right),$$

as $p^{-i*}(0,a^{-i*}) \geq p^{-i*}(1,a^{-i*})$ and demand for firm i in increasing in $-i$'s prices.

The first term in equation 11 is positive as, using the definition of p^{i*}:

$$\begin{aligned} D^i\left(p^{i*}(1,a^{-i*}), p^{-i*}(1,a^{-i*})\right)\left(p^{i*}(1,a^{-i*}) - \gamma_1^i\right) &\geq D^i\left(p^{i*}(0,a^{-i*}), p^{-i*}(1,a^{-i*})\right)\left(p^{i*}(0,a^{-i*}) - \gamma_1^i\right) \\ &\geq D^i\left(p^{i*}(0,a^{-i*}), p^{-i*}(1,a^{-i*})\right)\left(p^{i*}(0,a^{-i*}) - \gamma_0^i\right) \quad \text{as } \gamma_1 > \gamma_2 \end{aligned}$$

D Computation of consumres' welfare

E Figures and Tables

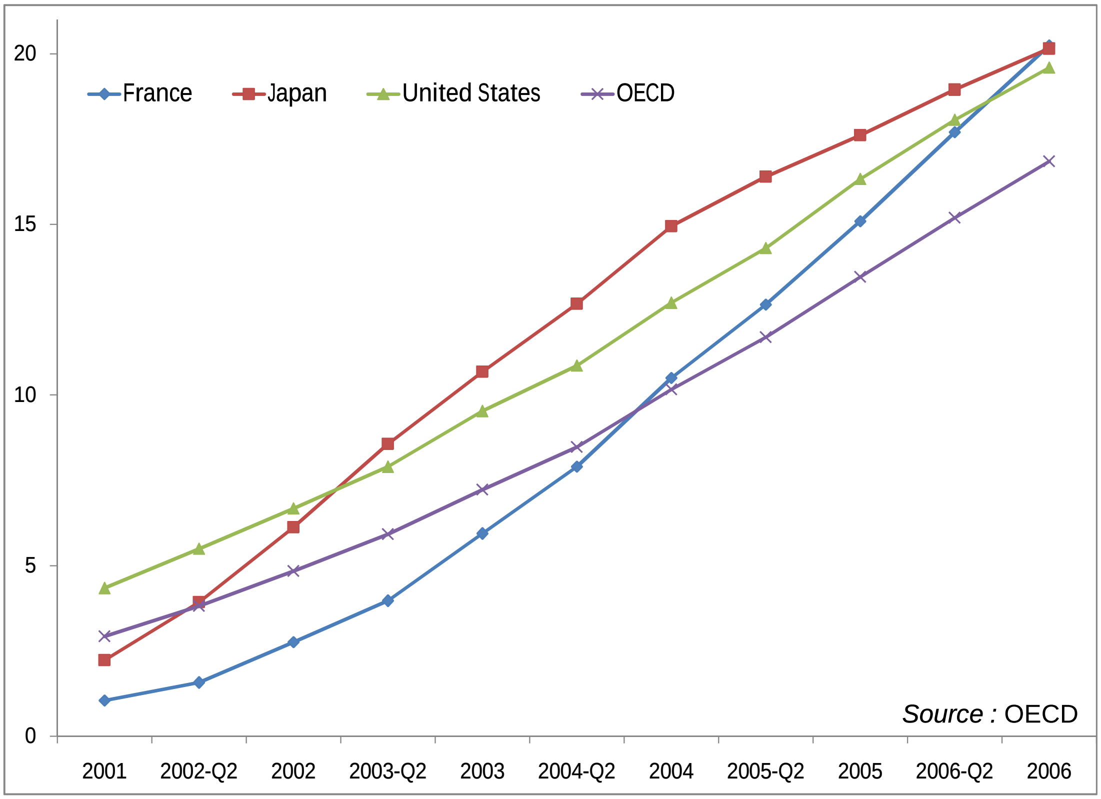

Figure 1: Trends in Broadband Penetration (Source: OECD)

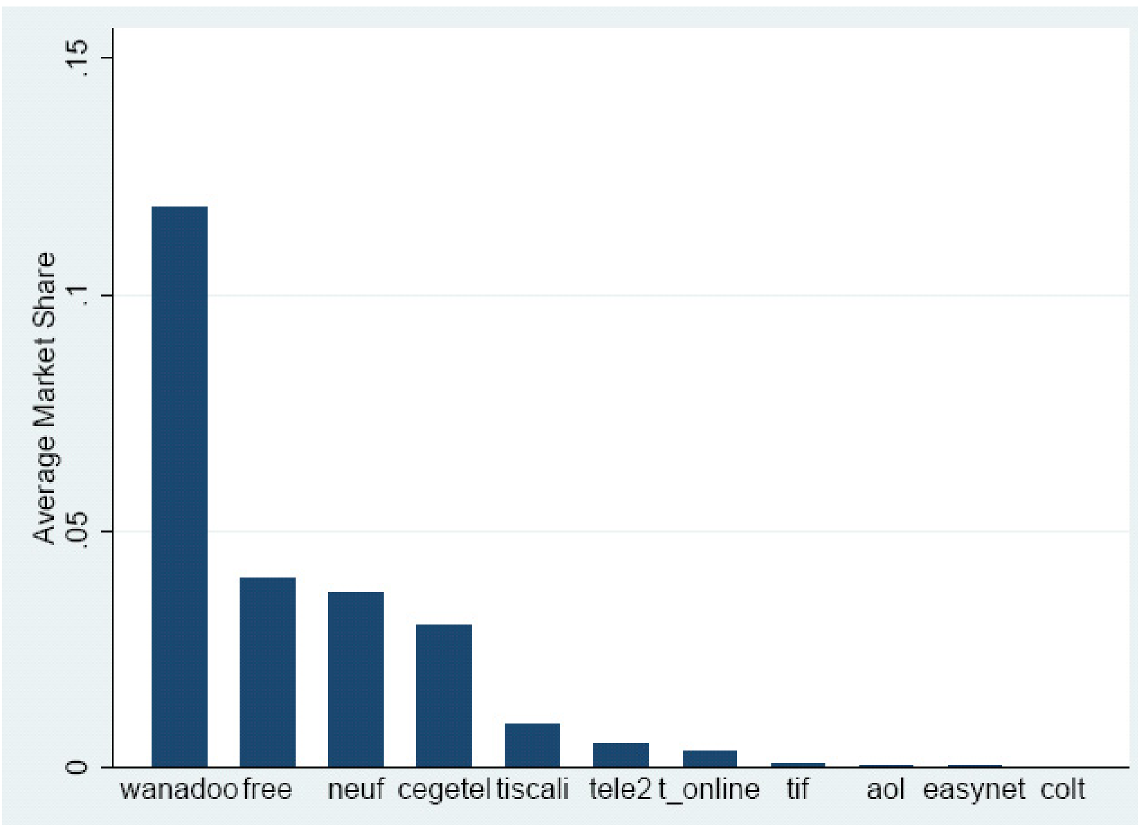

Figure 2: Average Market Shares of all Broadband Operators as of March 2005

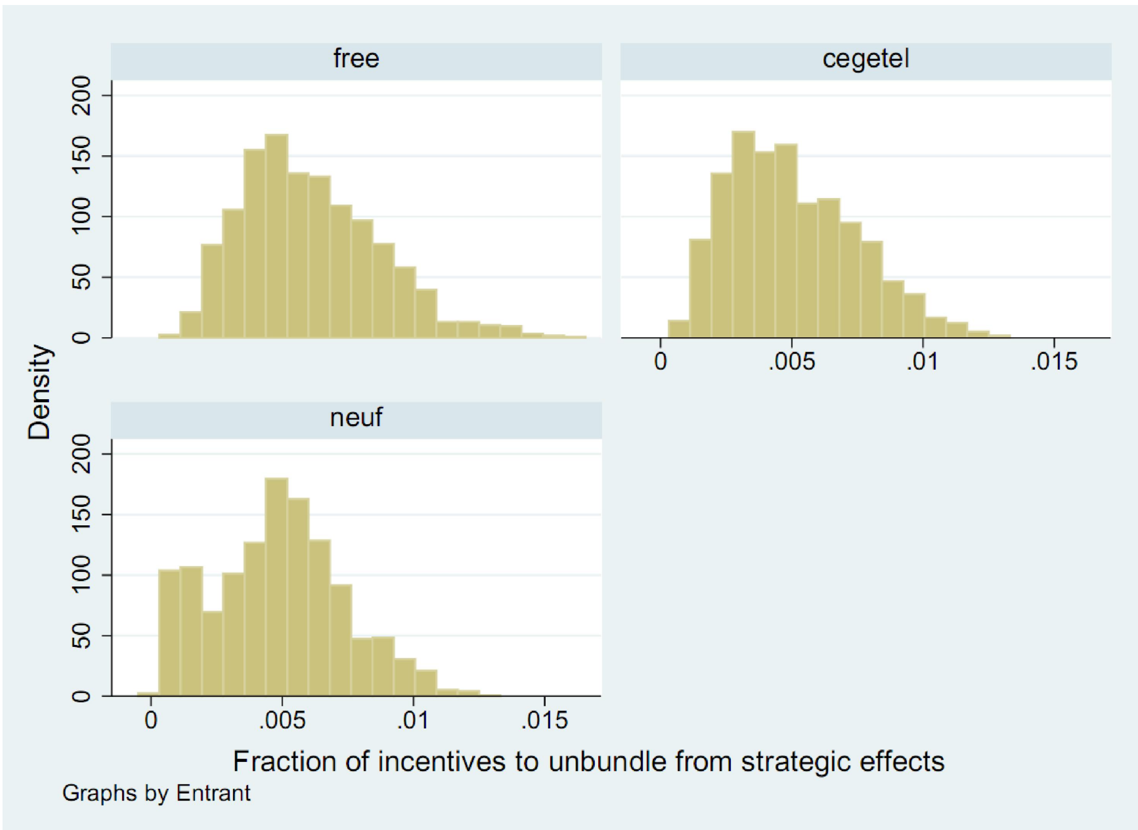

Figure 3: Fraction of incentives to unbundle coming from strategic effects ($\frac{A_1}{A}$) across COs.

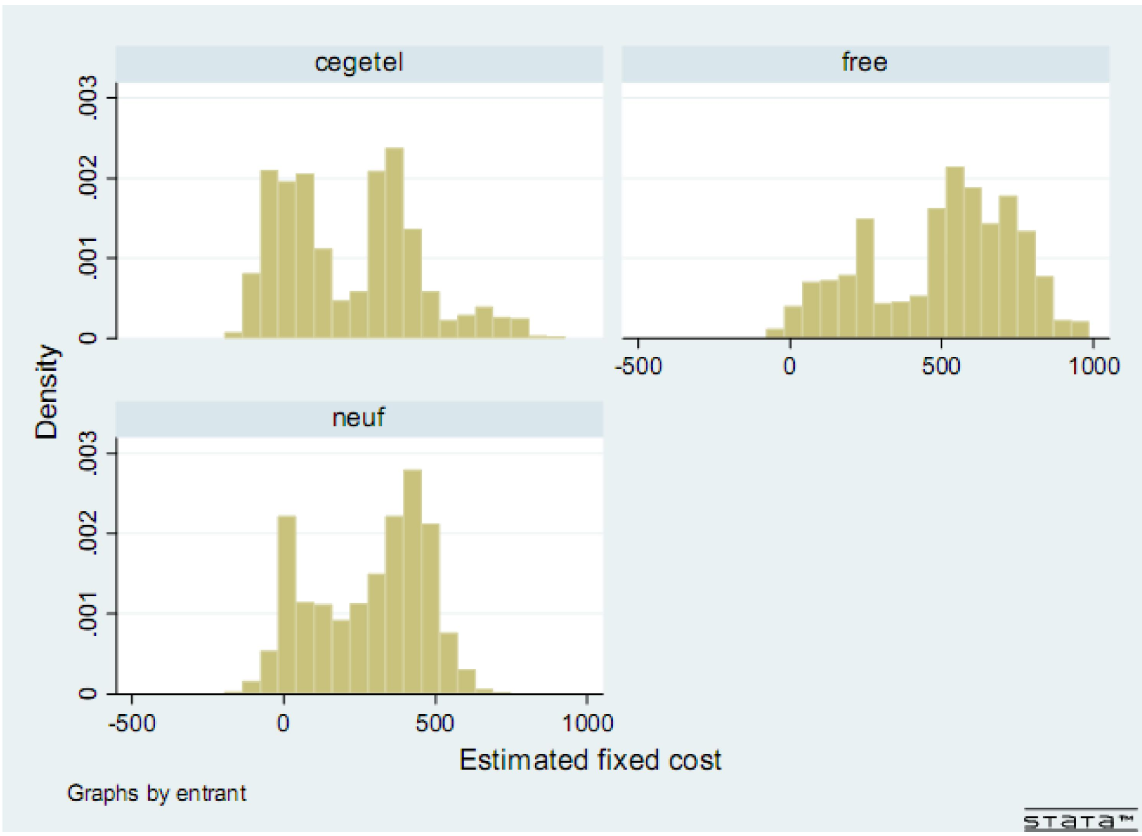

Figure 4: Distribution of estimated fixed costs across COs.

Table 1: Descriptive Statistics : Unbundled vs. Bitstream Areas

Bitstream COs	Observations	Mean	Std. Dev.	Min	Max
Number of Lines	469	6,206	2,112	4,176	19,088
Housing Density (Log)	469	322	380	20	4,181
Pop≤19	469	.24	.04	.134	.40
20≤ Pop≤39	469	.26	.03	.17	.42
40≤ Pop≤65	469	.26	.025	.18	.35
Log(Avg. Income)	469	9.5	.19	8.89	10.21
Fraction of Residential Lines	469	.92	.035	.53	.99
Unemployment Rate	469	.17	.07	.04	.40

Unbundled COs	Observations	Mean	Std. Dev.	Min	Max
Number of Lines	907	17,553	12,315	689	95,616
Housing Density (Log)	907	1,777	3,152	17	26,517
Pop≤19	907	.24	.03	.14	.38
20≤ Pop≤39	907	.30	.04	.18	.46
40≤ Pop≤65	907	.25	.03	.18	.37
Log(Avg. Income)	907	9.6	.26	9.0	11.0
Fraction of Residential Lines	469	.93	.02	.71	1
Unemployment Rate	469	.17	.07	.04	.55

Notes: This table presents descriptive statistics of the sample, broken down into bitstream and unbundled CO (an unbundled CO is defined as a CO in which at least one of the alternative operator has unbundled the local loop). Number of Lines is the number of telephone lines covered by the central office. Housing density is measured as the ratio of numbers of people living in the *commune* divided by the *commune*'s surface. *Pop* represent the age structure of the population living in the *commune*. Fraction of Residential lines is the ratio of telephone lines held by individuals to telephone lines held by companies in the *commune*. Unemployment rate is the *commune*'s unemployment rate.

Table 2: First Stage Estimates

	$\mathbb{1}_{\{i=Neuf\}}a_m^i$	$\mathbb{1}_{\{i=Cegetel\}}a_m^i$	$\mathbb{1}_{\{i=Neuf\}}a_m^i$	$\mathbb{1}_{\{i=0\}}V_m^i$	$\mathbb{1}_{\{i=0\}}W_m^i$
$\mathbb{1}_{\{i=Neuf\}}\times$ Waterway Distance	-.024***	-	-	-	-
	(.002)	-	-	-	-
$\mathbb{1}_{\{i=Cegetel\}}\times$ Railway Distance	-	-.034***	-	-	-
	-	(.002)	-	-	-
$\mathbb{1}_{\{i=Free\}}\times$ Highway Distance		-	-.036***	-	-
	-	-	(.001)	-	-
$\mathbb{1}_{\{i=0\}}\times$ Waterway Distance	-	-	-	-.002***	-.003***
	-	-	-	(.003)	(.003)
$\mathbb{1}_{\{i=0\}}\times$ Railway Distance	-	-	-	-.001***	-.002***
	-	-	-	(.0003)	(.0003)
$\mathbb{1}_{\{i=0\}}\times$ Highway Distance	-	-	-	-.006***	-.006***
	-	-	-	(.0002)	(.0003)
Observations	5,596	5,596	5,596	5,596	5,596
R^2	.54	.50	.46	.85	.59
F stats	171	129	123	171	171

Source: Proprietary data and INSEE local database. Note: this table presents the first stage estimations 15 associated with second stage equation 15. The dependent variable is the unbundling dummy a_m^i interacted with a dummy equal to 1 when entrant i is Neuf (column 1), Cegetel (column 2) and Free (Column 3), and the variables V_m (Column 4) and W_m (Column 5) defined in equation 8. Waterway, Railway and Highway distance are distance of central office m to the closest major infrastructure measured in Km. These regressions control for CO and firm fixed effects and allow for autocorrelation of the residuals within a CO. F stats is an F statistic testing that the instruments are equal to zero in each first stage regression. *, **, and *** means statistically different from zero at 10, 5 and 1% level of significance.

Table 3: Estimation of Demand Parameters: OLS and IV estimates

	$\ln(s_m^i) - \ln(s_m^{\varnothing}) + \frac{1}{1-s_m^i}$	
	OLS	IV
$\mathbb{1}_{\{i=Free\}} \times a_m^i$	.95***	1.4***
	(.035)	(.48)
$\mathbb{1}_{\{i=Cegetel\}} \times a_m^i$	.25***	.27
	(.03)	(.41)
$\mathbb{1}_{\{i=Neuf\}} \times a_m^i$	1.7***	2.2***
	(.036)	(.44)
V	-6.8***	-7.3***
	(.32)	(2)
W	3.4***	4.5
	(.25)	(3.2)
Free Fixed Effect	-2.3***	-2.4***
	(.029)	(.13)
Neuf Fixed Effect	-3***	-3.2***
	(.039)	(.14)
Cegetel Fixed Effect	-2.2***	-2.2***
	(.028)	(.14)
CO Fixed effect	Yes	Yes
Observations	5,596	5,596
R^2	.84	.81
Structural Parameters		
$\widehat{\alpha}$	1.19***	.96
	(.07)	(.76)
$\widehat{\beta^0}$	9.75***	7.92
	(.26)	(6.5)
$\widehat{\beta^{Free}}$	11.8***	11.1***
	(.06)	(1.6)
$\widehat{\beta^{Neuf}}$	11.2***	10.3***
	(.097)	2.2
$\widehat{\beta^{Cegetel}}$	12.4***	12.3***
	(.03)	(.65)

Source: Proprietary data and INSEE local database. Note: This table provides a joint estimation of the set of equations 12. Column 1 provides OLS estimates; Column 2 provide 2SLS estimates using table 2 as a first stage regression. All regressions allow autocorrelation of the residual within a CO. *, **, and *** means statistically different from zero at 10, 5 and 1% level of significance.

Table 4: Probit model of Unbundling

	a_m^i
$\Delta\pi_m^i$	.004***
	(.0002)
$\mathbb{1}_{\{i=Neuf\}}\times$ Waterway Distance	-.05***
	(.006)
$\mathbb{1}_{\{i=Cegetel\}}\times$ Railway Distance	-.17***
	(.02)
$\mathbb{1}_{\{i=Free\}}\times$ Highway Distance	-.09***
	(.017)
Region Fixed Effect	Yes
Cegetel Fixed Effect	1.32***
	(.11)
Neuf Fixed Effect	1.0***
	(.13)
Observations	4,314

Source: Proprietary data and INSEE local database. Note: This table provides an estimation of the probit model of unbundling derived in equation 20. $\Delta\pi_m^i$ corresponds to the difference of profits made by firm i if, conditional on others' equilibrium strategy, it was to change its first period unbundling decision. The regression allows for *region*, as well as firm fixed effects and autocorrelation of the residual within a CO. *, **, and *** means statistically different from zero at 10, 5 and 1% level of significance.