Dynamic Competition in the Mobile Market, Subsidies and Collusion

Jérôme Bezzina[(a),(b),*] and Thierry Pénard[(a),(c),†]
[(a)] ENST Bretagne, [(b)] IDATE, [(c)] CREREG
FRANCE

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Abstract

These few last years, the breathtaking growth of mobile subscribers has been associated with increasing competition and pricing innovations by cellular operators. Our paper proposes a dynamic model of pricing competition on outgoing and incoming calls where the operators are horizontally differentiated. We find that fixed-to-mobile call revenues influence pricing strategies and the level of connection and package subsidies. The lower these revenues, the higher the access price and monthly charges. Another interesting result is that for decreasing revenues on fixed-to-mobile calls, collusion becomes more easily sustainable. Thus, a regulation which attempts to improve pricing efficiency can enhance the incentives to collude on the mobile market.

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1 Introduction

In the last decade, mobile usage has been booming in all developed countries. In Finland, the penetration rate (number of mobile subscribers over the total population) had passed beyond[1] 65% on February 2000. In France, the penetration rate reached 36% by the same date compared with a level of 19% and 10% in December 1998 and 1997 respectively.

In this context, mobile operators tend to innovate in their pricing policies. They have multiplied the tariff schemes for the connection, monthly rental and

*jbezzina@idate.fr

†thierry.penard@univ-rennes1.fr, CREREG, University of Rennes I, 7 place Hoche 35 065 Rennes Cedex, France,

[1] Besides Finland, the highest penetration rates of mobile equipment are in Sweeden (57.9%), Norway (62.7%) and Iceland (63.4%) . See Gruber and Verboven [200] for the explanatory factors of mobile diffusion.

calls. Their pricing strategies are generally characterized by handset subsidies: the operators agree to lose money on the sale of equipment to attract new subscribers. This practice has been enhanced with the progressive introduction of packages which allow a bundling of services : handset, access and communications. In fixed telephony, even quite recently, such a cross subsidization of access was common and theoretically justified by social gains resulting from network externality : for the former public telecommunication operators, it was an efficient mean to reach the critical mass of users and to provide an universal diffusion of telephony services. But in mobile markets, access subsidies are offered competitively and consequently expose the operators to commercial risks. Indeed, a consumer can breach his contract before the operator recovers the cost of access. Churning or subscribers disconnection may generates large financial losses. However, these practices are restricted by the fact that contracts have a minimum fixed length (12 months usually) and are often tacitly renewed, one or two months before the term. Besides, switching costs tend to be high in the absence of portability, which is the possibility to keep the same phone number when switching to another operator.

Mobile operators also compete in non price dimensions. Valetti and Cave [1998] underline the possibility of vertical differentiation in mobile markets. Through its network coverage, an operator determines its quality of service. Similarly, the network capacity is a key parameter and a lack of investment is associated with severe congestion problems. The technologies can also be a differentiation factor. During the eighties, two technological standards were successively introduced in the market : GSM 900 MHz and GSM 1800 MHz. Finally, operators can increase a vertical or horizontal differentiation through advertising and marketing .

However, few papers have dealt with competition in mobile markets, if we except Armstrong [1997] and Valetti [1999]. The former analyses the issues of access subsidies and incoming charges in the UK market. The latter studies the strategic choice of network coverage in a model of vertical differentiation.

Our paper proposes a dynamic model of competition on access, outgoing and incoming calls. Contrary to Valetti [1999], we do not focus on quality as a strategic variable. We opt for a framework of horizontal differentiation because the quality parameters of mobile services are usually set by the regulator. The operators must respect or comply with some obligations of coverage and capacities. Moreover even if some differences can still exist, customers are hardly aware of them when they select their carrier. Rather mobile operators tend to create horizontal differentiation through marketing, advertising and variety of services.

As Arsmstrong [1997] has suggested, a particularly pregnant pricing and regulatory issue is the treatment of incoming traffic of calls from the Public Switched Telephone Network [PSTN] and from the international to the mobile network. It is known that access subsidies and outgoing traffic are endured by fixed consumers who generally bear excessive fixed-to-mobile charges. In Western Europe, the way to price calls from fixed to mobile operators has involved debates between the National Regulatory Authority, mobile and fixed operators and consumer groups. In 1998, the European Commission worried about the level of incoming calls and analyzed the degree to which the fixed-to-mobile termination charges of various European mobile network operators vary from a "best practice" benchmark[2]. The Commission also questionned the rigidity of fixed-to-mobile charges, contrasting with the donward pressure on prices of mobile connection and outgoing calls. For example, in France, fixed-to-mobile charges have been typically identical among operators and very stable until a recent regulatory decision in July 1999. Moreover, these charges were set by the french mobile operators[3] until november 2000, whereas in other countries these charges depend on the fixed operators.

The pricing structure and level of incoming calls are legitimated by operators in the name of user mobility. In that sense, the difference between fixed-to-mobile charges and associated costs generate a premium that accurately measures a value added service: i.e. the possibility of issuing a call instantly from the PSTN wherever the mobile user is. Another reason sustaining the asymmetry between incoming and outgoing call charges is the necessity for mobile operators to cover operating losses. Indeed, the revenue received by operators for providing call termination represents a large proportion of their overall revenues.

But the similarity and high level of incoming call prices, as well as the relative stability of market shares in some european mobile markets, raise suspicions about possible pricing agreements between mobile operators [4]. This question is theorically and empirically relevant. First, mobile markets present enough features to suspect such a behavior : perfect information, high degree of concentration, regulatory barrier to entry, dispersed demand. These structural factors are well-known to facilitate collusive conduct (see Scherer and Ross [1990] or Jacquemin and Slade ,[1989])[5]. Besides, Parker and Röller [1997] and Busse [2000] empirically examined the US mobile market in the eigthies and found evidence of collusive pricing that is enhanced by multimarket contacts.

In this paper, we want to analyse pricing strategies on mobile markets and to determine the impact of fixed to mobile revenues on competition intensity

[2]Best practice rates were calculated and three mobile operators with the lowest average termination charges were selected : Eircell (Ireland), Esat Digfone (Ireland) and Vodafone (UK). The Commission then computed the variance from best practices and expressed it as a range in which a given termination rate differs from the first and third lowest rates.

[3]The transfer payments among operators were as follows: the fixed local operator charged the retail incoming price set by the mobile operator and at the same time retained a part of that retail revenue (corresponding to the conveyance cost of calls on the fixed local network and to billing and cash collection costs) before transfering the differential to the mobile operator.

[4]For example, in France, the impressive growth of mobile subscribers contrasts with a relative stability in the market shares. For two years, the market shares have been stabilised at 48 % for France Telecom mobile, subsidiary of the Public Telecommunication Operator, 35 % for SFR and 17 % for Bouygues.

[5]On the other hand, further factors as asymmetries between operators, are typically opposite to the idea of collusion. For example, the former public operator, still monopolist on the local loop, has often a licence on the mobile market, and its incentives to respect the collusive terms are normally less strong than those of its competitors : lower incoming prices would contribute to increase traffic between fixed to mobile network and so increase revenues for the fixed local operator.

between mobile operators. May incoming revenues and access subsidies increase the incentives to collude ? This issue is important and has many regulatory implications. Should the fixed-to-mobile charges be regulated and cost-oriented ? Otherwise who should set these charges ? the mobile or fixed operators ? And how should the revenues be shared between operators ?

In this paper, we find first that revenues from fixed-to-mobile calls play an important role in the design of access and package subsidies. The lower these revenues, the higher the access price and monthly charges.Thus the subsidies increase with the incoming revenues. Another interesting result is that the incoming charges and revenues have a negative influence on the incentives to collude. For decreasing revenues on fixed-to-mobile calls, collusion becomes more easily sustainable . In other words, a regulation which tries to improve pricing efficiency (i.e. to reduce subsidies) can enhance the incentives to collude. Also, we show that tacit collusion is usually more stable in the starting phase of the market.

The remainder of the paper is organized as follows. Section 2 presents the dynamic model of horizontal differentiation. Section 3 characterizes equilibrium strategies in prices. Section 4 establishes the conditions of stability for tacit collusion and presents some simulations.

2 The theoretical framework

2.1 The parameters

We consider a mobile market with m competitors. Each mobile operator $i = 1, ...m$ must set a subscribing price for its service, at each period t. We suppose that the operators offer *rental packages* which include the rental fee and a fixed volume of calls per month (a volume in hours). The customers sign a contract with the operator for a period (for example, one year) and have the possibility of renewing or terminating it freely at the end of that period. In our model, we restrict price competition to a unique *package* providing the same volume of communications. $f_{i,t}$ is the package price fixed by the operator i for the period t. Moreover, the customers have to acquire a handset before choosing an operator. We suppose that each operator provides an *access package* which includes the handset and linked services like the allocation of a phone number. The price of this package is denoted $a_{i,t}$.

In this model, there is no pricing discrimination on *rental packages* between new and current subscribers. A new subscriber pays $a_{i,t} + f_{i,t}$ for the first period. Then he just has to pay $f_{i,t}$ for the ensuing periods if he renews his contract or f_{jt} if he switches to another operator $j \neq i$. Implicitly we assume that the handsets included in the access package are compatible between mobile operators. In case of incompatibility, the behavior of current subscribers should be analysed as a choice between staying on the market of current subscribers and switching to the market of new subscribers[6].

[6] In the context of technological progress, it may be a profitable strategy for a current

We suppose that the cost of providing an access package is c_0: this includes the cost of the handset and advertising costs. Moreover, we define c_1 as the costs of the *rental package* : this includes administrative costs and exploitation costs of the mobile network,... The access is subsidized if a_{it} is lower than c_0. Similarly, $f_{it} < c_1$ implies rental subisidies.

The mobile market follows a dynamic path of diffusion. At each period, new customers enter the market. We define N_t as the number of new subscribers at period t. At the beginning of period t, the current or existing subscribers are $\sum_{j=0}^{t-1} N_j$.

2.2 The market shares

The operators compete in two distinct markets : the market of new subscribers and that of current subscribers. In the former market, the price competition has two dimensions : the access price $a_{i,t}$ and the package price $f_{i,t}$. On the latter, the operators compete only in the package price $f_{i,t}$. We denote $\alpha_{i,t}$ ($\alpha'_{i,t}$) as the market shares of the operator i at the period t of new subscribers (on current subscribers). These market shares are determined by a model of horizontal differentiation *à la Salop* [1979]. We consider two unit circles that respectively represent the markets of new subscribers and current subscribers.

On the first circle, the new subscribers are uniformly distributed. Moreover, each operator i is located in l_i on this circle with $l_1 = 0$ and $l_1 \leq l_2 \leq ... \leq l_i \leq ... \leq l_m \leq 1$. The location of a subscriber corresponds to his ideal operator. Consequently customers have a disutility to subscribe to a distant operator. This disutility increases with the distance between the subscriber and the operator. The customer located in θ chooses the operator i which minimizes

$$a_{i,t} + f_{i,t} + k\,|\theta - l_i| \tag{1}$$

where k measures the disutility to subscribe to an operator different from his ideal operator. The higher k, the stronger the market power of an operator over its close customers. We define $\overline{f}$ as the willingness-to-pay for subscribing to a mobile package. We suppose that $\overline{f}$ is identical for all customers. Moreover, we restrict our analysis to a complete coverage of the circle. This implies that the willingness to pay is high enough[7]. Finally, for convenience, we restrict the theoretical framework to a symmetric location of the operators. Thus the distance between two neighbor operators is $1/m$. These assumptions ensure that all the operators are active and have a positive market share.

For an operator i, its market shares are defined by :

$$\alpha_{i,t} = \frac{1}{m} + \frac{a_{i+1,t} + a_{i-1,t}}{2k} - \frac{a_{i,t}}{k} + \frac{f_{i+1,t} + f_{i-1,t}}{2k} - \frac{f_{i,t}}{k} \tag{2}$$

subscriber because he can obtain an handset of higher quality and benefit from new services. Otherwise, in the absence of innovation, switching to the market of the new subscribers is costly and source of disutility.

[7]We will give the minimum value of $\overline{f}$ in the next section, after having determined the equilibrium prices.

We can notice that the operator's market shares decrease with its own access and subscribing charges, and increase with the prices of its direct competitors :

$$\begin{cases} \frac{\partial \alpha_{i,t}}{\partial a_{i,t}} = \frac{\partial \alpha_{i,t}}{\partial f_{i,t}} = -\frac{1}{k} \\ \frac{\partial \alpha_{i,t}}{\partial a_{j,t}} = \frac{\partial \alpha_{i,t}}{\partial f_{j,t}} = \frac{1}{2k} \qquad \text{with} \quad j = \{i-1, i+1\} \end{cases} \tag{3}$$

Now we have to define the market shares on the second market or circle of current susbcribers. We assume that the mobile operators have the same location on both markets. Moreover, the current subscribers are uniformly distributed on the unit circle. The only difference comes from the absence of an access price, since a current subscriber always has the opportunity of reusing his handset in the following periods. His handset is compatible with the services provided by the other operators, without switching cost. Thus a current subscriber located in θ chooses the operator i which minimizes

$$f_{i,t} + k\left|\theta - l_i\right| \tag{4}$$

We obtain directly the market shares of the operator i

$$\alpha'_{i,t} = \frac{1}{m} + \frac{f_{i+1,t} + f_{i-1,t}}{2k} - \frac{f_{i,t}}{k} \tag{5}$$

Its market shares decrease with its own subscribing charges and increase with the prices of its direct competitors.

2.3 The fixed-to-mobile calls

The rental and access charges are not the only revenues for mobile operators. Fixed-to mobile calls also constitute an important part of their revenues[8]. Let us define $e_{i,t}$ as the price for a call from the fixed network to the mobile network i at the period t. The quantity of fixed-to-mobile calls received by a given subscriber is defined by a function of demand $D\left(e_{i,t}\right)$ with $D^{'}\left(e_{i,t}\right) < 0$ and $D^{''}\left(e_{i,t}\right) \leq 0$. On each fixed to mobile call, the mobile and fixed operators support a constant cost equal to c_2 and w respectively. We suppose that the fixed operator collects the revenue from the fixed-to-mobile calls. Then it gives a part of this revenue to the mobile operators which terminate the calls. This monetary transfer is a function of the cost supported by the mobile operator, but it can also be based on the price of the fixed-to-mobile call. Let $r\left(e_{i,t}\right)$ be the transfer price per call. The retail charges for fixed-to-mobile calls $e_{i,t}$ can be set by either the mobile operators or the fixed operators, depending on the regulatory environment. In the first case, $e_{i,t}$ is a strategic variable for the mobile operators. In the other case, the incoming charges and revenues are exogeneous.

[8]In this model, we ignore mobile to mobile calls.

From this, we can give the expression of mobile operator profit i at period t :

$$\begin{aligned}\Pi_{i,t}\left(a_{i,t},f_{i,t},e_{i,t}\right) &= \alpha_{i,t}N_t\left[\left(a_{i,t}-c_0+f_{i,t}-c_1\right)+\left(r\left(e_{i,t}\right)-c_2\right)D\left(e_{i,t}\right)\right] \\ &\quad +\alpha'_{i,t}\sum_{j=0}^{t-1}N_j\left[\left(f_{i,t}-c_1\right)+\left(r\left(e_{i,t}\right)-c_2\right)D\left(e_{i,t}\right)\right] \qquad (6)\end{aligned}$$

The first term corresponds to the revenues from new subscribers, and the second term to the revenues from current subscribers whether they renew their contract or come from a rival operator.

In the following section, we determine the equilibrium prices on rental, access and fixed-to-mobile calls.

3 The results

Mobile operators choose their prices simultaneously and periodically. Their objective is the maximization of their intertemporal profit. The first order conditions on the access charge and the rental charge are given for all i and t by :

$$\frac{\partial\Pi_{i,t}}{\partial a_{i,t}}=-\frac{1}{k}N_t\left[a_{i,t}-c_0+f_{i,t}-c_1+\left(r\left(e_{i,t}\right)-c_2\right)D\left(e_{i,t}\right)\right]+\alpha_{i,t}N_t=0$$

$$\begin{aligned}\frac{\partial\Pi_{i,t}}{\partial f_{i,t}} &= -\frac{1}{k}N_t\left[a_{i,t}-c_0+f_{i,t}-c_1+\left(r\left(e_{i,t}\right)-c_2\right)D\left(e_{i,t}\right)\right]+\alpha_{i,t}N_t \\ &\quad -\frac{1}{k}\sum_{j=0}^{t-1}N_j\left[f_{i,t}-c_1+\left(r\left(e_{i,t}\right)-c_2\right)D\left(e_{i,t}\right)\right]+\alpha'_{i,t}\sum_{j=0}^{t-1}N_j=0\end{aligned}$$

Moreover, if the mobile operators are responsible for the price of fixed-to-mobile calls, we have a supplementary first order condition :

$$\frac{\partial\Pi_{i,t}}{\partial e_{i,t}}=\left(\alpha_{i,t}N_t+\alpha'_{i,t}\sum_{j=0}^{t-1}N_j\right)\left[\left(r\left(e_{i,t}\right)-c_2\right)D'\left(e_{i,t}\right)+r'(e_{i,t})D\left(e_{i,t}\right)\right]=0 \qquad (7)$$

We can notice that this last condition is independent of the two previous conditions. For the resolution of the model, we proceed sequentially: we first determine the prices $(a_{i,t},f_{i,t})$, then we discuss the different solutions for the prices of incoming calls.

3.1 Rental and access charges

As the choice of the access and rental charges is simultaneous, we have to solve a system of $2m$ equations and $2m$ unknowns, where m is the number of mobile operators. The price of incoming calls is given and identical for all mobile networks. We denote $\pi(e)$ as the revenues per subscribers that the mobile operators obtain from these calls. The first order conditions become :

$$\left\{\begin{array}{l} -\frac{1}{k}N_t\left[a^*_{i,t}-c_0+f^*_{i,t}-c_1+\pi(e)\right]+\alpha_{i,t}\left(a^*_{1,t},...,a^*_{m,t},f^*_{1,t},...,f^*_{m,t}\right)N_t=0 \\ -\frac{1}{k}\left[N_t\left(a^*_{i,t}-c_0\right)+\sum_{j=0}^{t}N_j\left[f^*_{i,t}-c_1+\pi(e)\right]\right] \\ +\alpha_{i,t}\left(a^*_{1,t},...,a^*_{m,t},f^*_{1,t},...,f^*_{m,t}\right)N_t+\alpha'_{i,t}\left(f^*_{1,t},...,f^*_{m,t}\right)\sum_{j=0}^{t-1}N_j=0 \end{array}\right. \tag{8}$$

3.1.1 The symmetric case

Since the operators are symmetrically located, the equilibrium prices are necessarily symmetric. The solution has the following form :

$$\left\{\begin{array}{l} a^*_{i,t}=a^*_t \\ f^*_{i,t}=f^*_t \end{array}\right. \quad \forall i,\forall t \tag{9}$$

and the equilibrium market shares are equal to $\alpha^*_{i,t}=\alpha^{*\prime}_{i,t}=\frac{1}{m}$. The first order conditions can be simplified :

$$\left\{\begin{array}{l} -\frac{1}{k}\left(a^*_t-c_0+f^*_t-c_1+\pi(e)\right)+\frac{1}{m}=0 \\ -\frac{1}{k}\left[N_t\left(a^*_t-c_0\right)+\sum_{j=0}^{t}N_j\left(f^*_t-c_1+\pi(e)\right)\right]+\frac{1}{m}\sum_{j=0}^{t-1}N_j=0 \end{array}\right. \tag{10}$$

When we solve this system, we obtain a two-part equilibrium.

Proposition 1 *When $c_1+\frac{k}{m}-\pi(e)>0$, the equilibrium prices and profits are, respectively, defined by :* $\left\{\begin{array}{l} a^*_t=c_0 \\ f^*_t=\frac{k}{m}+c_1-\pi(e) \quad \forall \quad t \\ \Pi^*_t=\sum_{j=0}^{t}N_j\frac{k}{m^2} \end{array}\right.$

Conversely, when $c_1+\frac{k}{m}-\pi(e)\leq 0$, the equilibrium prices and profits are now defined by : $\left\{\begin{array}{l} a^*_t=c_0+c_1+\frac{k}{m}-\pi(e) \\ f^*_t=0 \\ \Pi^*_t=N_t\frac{k}{m^2}+\sum_{j=0}^{t-1}N_j\frac{[-c_1+\pi(e)]}{m} \end{array}\right. \quad \forall \quad t$

When $c_1+\frac{k}{m}-\pi(e)>0$, the handset is not subsidised. The operators tariff the access at its cost. For the rental charge, some subsidies can appear $\left(f^*_t<c_1 \Longleftrightarrow \frac{k}{m}<\pi(e)\right)$. This situation is more likely when the operators do not have a high market power (k is low), when the number of operators is high (more intensive competition) or when the fixed to mobile revenues are huge. The higher these revenues, the more incentives the operators have to decrease the rental fees. The rental charge can even become free if $\pi(e) > c_1 + \frac{k}{m}$. In this case, the handset is also subsidized ($a_t^* = c_0 + c_1 + \frac{k}{m} - \pi(e) < c_0$). Therefore, we can notice that for new subscribers the second situation is not as favorable as for current subscribers. They always have to pay $c_0 + c_1 + \frac{k}{m} - \pi(e)$ which obviously decreases with $\pi(e)$. The fixed network subscribers subsidize the mobile users, mostly current users. We have the same logic as with sound advertising that some mobile subscribers accept in exchange for free calls: here, the subsidies come from the advertisers[9].

3.1.2 Market coverage

Initially, we supposed that the market was covered. This hypothesis is satisfied only if all the subscribers obtain a positive surplus, in particular those who are distant from the operators (especially subscribers located at an equal distance between the two operators) :

$$\overline{f} > \frac{k}{2m} + f_t^* + a_t^* \tag{11}$$

After substitution, we have :

$$\overline{f} > c_0 + c_1 + \frac{3k}{2m} - \pi(e) \tag{12}$$

The coverage of the market increases with the revenue of fixed-to-mobile calls and with the intensity of competition.

Given the importance of the fixed-to-mobile revenues on the equilibrium charges paid by the mobile subscribers, we have to scrutinize the price-setting of the fixed-to-mobile calls and the sharing of the induced revenues. Obviously, the fixed to mobile revenues will always be higher when the mobile operators are responsible for fixing the price. Consequently, the rental and access prices should increase when we transfer this right from the mobile operator to the fixed operator. Similarly, the handset subsidies should diminish when the fixed operator itself chooses the price of fixed to mobile calls.

3.2 The price-setting of fixed-to-mobile calls

According to proposition 1, the profits of mobile operators increase with the incoming revenues.Thus if mobile operators were responsible for setting the retail charges of fixed-to-mobile calls, they would choose the price that maximises the incoming revenues per subscriber. In fact, there is no strategic rivalry over the fixed-to mobile calls between mobile operators. An operator cannot gain more subscribers or increase its market shares by decreasing its price on fixed to mobile calls. Hence each mobile operator benefits from a local monopoly over

[9] Internet provides many, many examples of free services subsidized by other indirect revenues.

the fixed network subscribers who wish to contact its own customers and the non-cooperative equilibrium should be characterized by monopolistic incoming charges, identical for the m mobile operators As long as the mobile operators are symmetrically located and have the same constant costs, the prices of fixed-to-mobile calls have no reason to vary between operators and throughout the periods.

If the price-setting comes under the fixed operator, then the incoming charges should remain identical whatever the network termination. But we can expect that the incoming revenues for the mobile operators will be lower than in the previous regulatory frame. And we should observe lower prices for mobile access and outgoing calls in the european countries that let mobile operators set retail charges of fixed-to-mobile calls. In the appendix, we also compare the level of retail charges that will be chosen by the mobile operators and a fixed operator. These charges depend on the sharing methods of the incoming revenues between mobile and fixed operators. We find that mobile operators always tend to set a lower price than the fixed operator. Transferring the responsibility for price-setting from the mobile operator to the fixed operator could imply a rise of retail charges on the fixed-to-mobile calls[10].

4 Mobile market and tacit collusion

Tacit collusion between mobile operators could allow them to relax or soften price competition and reduce subsidies on access. As price agreement is forbidden by the antitrust law, collusion must be tacit and self-enforceable. Enforcement of the agreement can only come from the incentives of the operators.

Firstly, we determine the maximum profit that operators can expect from tacit collusion. Then, we give the profit that an operator can obtain by breaching the agreement. Finally, we consider the conditions of a collusive equilibrium when operators apply trigger strategies. These strategies designed by Friedman (1971) involve in cooperating as long as all the partners cooperated in the previous period, and in triggering infinite punishments if one of the operators cheated in the past. These punishments correspond to an infinite return to the competitive equilibrium.

4.1 Collusive profits

If the operators decide to agree on prices, they will attempt to maximize their joint profits :

$$N_t \left[(a_t - c_0 + f_t - c_1) + \pi(e) \right] + \sum_{j=0}^{t-1} N_j \left[(f_t - c_1) + \pi(e) \right] \tag{13}$$

[10] However it should no longer be the case if fixed subscribers can select the local or long distance carrier for its fixed-to-mobile calls. Competition between fixed operators should lead to significant price undercutting.

We notice that operators are always well advised to fix their prices as high as possible, because the penetration of mobiles (the number of new subscribers at each period) is independent of the access and rental prices. The different special offers on the handsets are assumed to have no accelerating effect on the diffusion rate in our model[11]. The only constraint for the operators is the willingness-to pay of the subscribers which imposes an upper bound on the prices of the handset and of the packages. However, the operators have stronger incentives to raise the rental charges than the access price. In the case of tacit collusion, an optimal strategy involves fixing the access at its lowest level ($a^c = 0$) and the rental charge at its highest level. Obviously, this upper price depends on the willingness-to-pay of the subscribers ($\overline{f}$). We can show that the operators will raise the rental charge up to the threshold where distant subscribers agree to pay for a mobile service.

Proposition 2 *In tacit collusion, the optimal pricing strategies are defined by* $\begin{cases} a^c = 0 \\ f^c = \overline{f} - \frac{k}{2m} \end{cases}$

Proof. The subscribers located at equal distance between two operators always obtain the lowest utility from using a mobile service. Their utility is positive only if $\overline{f} - f^c - \frac{k}{2m} \geq 0$. If the operators want to cover the market entirely, they must fix their price at $f^c = \overline{f} - \frac{k}{2m}$.

We can notice that operators have no incentive to fix a price lower than f^c : they would obtain no additional subscribers and their revenue per subscriber would decrease. The only strategy which might be profitable involves setting a rental charge higher than f^c. For such a price, the coverage is partial. Let s be the part of the unit circle covered by an operator when it announces a rental charge $f > f^c$:

$$s = 2\frac{(\overline{f} - f)}{k} < \frac{1}{m} \tag{14}$$

Then the operators maximize the following joint profit :

$$2m\frac{(\overline{f} - f)}{k}\left(\sum_{j=0}^{t} N_j\left[f_t - c_1 + \pi(e)\right] - c_0 N_t\right) \tag{15}$$

and the optimal rental charge is :

$$f^{nc} = \frac{\overline{f} + c_1 - \pi(e)}{2} + \frac{N_t}{\sum_{j=0}^{t} N_j}\frac{c_0}{2} \tag{16}$$

[11]In future developments, we will remove this hypothesis to analyse the pricing strategies on access more finely.

If we compare prices f^c and f^{nc}, normally we must check that $f^c < f^{nc}$. This is equivalent to

$$\overline{f} - \frac{k}{2m} < \frac{\overline{f} + c_1 - \pi(e)}{2} + \frac{N_t}{\sum_{j=0}^{t} N_j}\frac{c_0}{2} \tag{17}$$

After rearrangement :

$$\overline{f} < \frac{N_t}{\sum_{j=0}^{t} N_j} c_0 + c_1 + \frac{k}{m} - \pi(e) \tag{18}$$

But, we assumed previously that the market is covered at the competitive equilibrium, i.e. :

$$\overline{f} > c_0 + c_1 + \frac{3k}{2m} - \pi(e) \tag{19}$$

As we have $c_0 + c_1 + \frac{3k}{2m} - \pi(e) > \frac{N_t}{\sum_{j=0}^{t} N_j} c_0 + c_1 + \frac{k}{m} - \pi(e)$, it is impossible to have $f^c < f^{nc}$. We can conclude that the optimal collusive strategies for mobile operators involve fixing the price f^c and covering all the market. ■

In tacit collusion, the access is free, but rental charge is not subsidized by the fixed users. The collusive rental package only depends on the willingness-to-pay of the customers and on the degree of market competition (m and k). It is also interesting to notice that access subsidies can be compatible with collusive conducts as well as with competitive behaviours. The presence of access subsidies does not constitute in itself evidence of collusion or competition.

From proposition 5, the collusive profit is given by :

$$\Pi_t^c = \frac{1}{m}\left(\sum_{j=0}^{t} N_j \left[\overline{f} - \frac{k}{2m} - c_1 + \pi(e)\right] - N_t c_0\right) \tag{20}$$

We can check that this profit is higher than the equilibrium profit Π_t^* defined in the previous section.

4.2 The stability of collusion

At any period, an operator may decide to quit the tacit agreement and to follow an independent pricing strategy. Indeed there is no binding contract between operators which can force them to respect the agreement. Only the threat of future punishments can deter them from cheating.

Consider the optimal pricing of a cheating operator. Its best strategy involves decreasing its rental charge slightly in order to attract the subscribers of its competitor. At the same time, it maintains the access free of charge. With such a strategy, the cheater i can expect to increase its market shares defined by :

$$\alpha_{i,t} = \alpha'_{i,t} = \frac{1}{m} + \frac{f^c}{k} - \frac{f_{i,t}}{k} > \frac{1}{m}$$

with $f^c > f_{i,t}$. The cheating price is determined by maximizing the profit :

$$\Pi^d_{i,t} = \left(\frac{1}{m} + \frac{f^c}{k} - \frac{f_{i,t}}{k}\right)\left(\sum_{j=0}^{t} N_j \left[f_{i,t} - c_1 + \pi\left(e\right)\right] - N_t c_0\right) \tag{21}$$

We obtain the following solution :

$$f^d_t = \frac{k}{4m} + \frac{\overline{f} + c_1 - \pi\left(e\right)}{2} + \frac{N_t}{\sum_{j=0}^{t} N_j}\frac{c_0}{2} \tag{22}$$

We can verify that $f^d_t < f^c$: the cheating operator obtains a larger market share than $1/m$, to the detriment of its nearest rivals. It can even attract all the subscribers of its neighbors and reach a market share higher than $2/m$. For convenience, we assume that all the operators maintain their activities and keep a positive market share. This condition implies that :

$$f^d_t + \frac{k}{m} \geq f^c \tag{23}$$

This condition means that a customer always prefers subscribing to his ideal operator (no disutility) rather subscribing to a distant cheating operator, even if the cheater has largely undercut its prices. After rearrangement, we obtain a condition on the willingness-to-pay of the subscribers :

$$\overline{f} < \frac{N_t}{\sum_{j=0}^{t} N_j} c_0 + c_1 + \frac{7k}{2m} - \pi(e) \tag{24}$$

If this willingness-to-pay is higher than the threshold given by the right hand term of (24), then a cheating strategy is more profitable and collusion might be less sustainable.

If condition (24) holds, the cheating profit has the following expression :

$$\Pi^d_t = \frac{\sum_{j=0}^{t} N_j}{k}\left(\frac{k}{4m} + \frac{\overline{f} - c_1 + \pi\left(e\right)}{2} - \frac{N_t}{\sum_{j=0}^{t} N_j}\frac{c_0}{2}\right)^2 \tag{25}$$

From the collusive and cheating profits, we can deduce the conditions of stability. Let Φ be the discount factor which measures the preference of the operators for future gains, and consider an infinite horizon. After the period

$2t^*$, we can notice that repeated competition is stationary, since the number of subscribers becomes constant.

For a scheme of reprisals which involves returning infinitely to the competitive equilibrium, an operator is never incited to cheat if for any period t we have :

$$\sum_{s=0}^{\infty} \Phi^s \Pi_{t+s}^c \geq \Pi_t^d + \sum_{s=1}^{\infty} \Phi^s \Pi_{t+s}^* \tag{26}$$

The left hand term of (26) represents the discounted value of a collusive strategy from period t to the infinity. The right hand term corresponds to the gain of a cheating strategy followed by reprisals. The discounted value of the punishment is $\sum_{s=1}^{\infty} \Phi^s \Pi_{t+s}^*$. Condition (26) means that respecting collusion is always profitable for all the mobile operators.

This condition depends crucially on the period t. Indeed, we can notice that when t rises, then the number of subscribers $\left(\sum_{j=0}^{t} N_j\right)$ increases and influences the cheating profit Π_t^d positively. Consequently, collusion may be more sustainable in the first period and the incentives to cheat should increase with the saturation of the market (after $t < t^*$, the number of new subscribers decreases). We undertook some simulations to confirm this intuition.

4.3 Simulations

For the simulations, we have to specify a dynamic path for mobile diffusion. Thus, w assume that the number of new subscribers are defined by :

$$N_t = Max\left\{\beta t\left(2t^* - t\right), 0\right\} \tag{27}$$

At the period t^*, the number of new subscribers reaches a peak. Then, the number of new subscribers decreases and after the period $2t^*$, the mobile market is saturated.

Then, for some given values of the variables $\left(k, m, \overline{f}, c_0, c_1, \pi\left(e\right), \beta, t^*\right)$, we determine the minimum threshold of the discount factor below which collusion is not sustainable. This minimum threshold should be a function of the periods t. The simulations can be easily interpreted: the lower the threshold of the discount factor, the more collusive is the market.

We find that the threshold of the discount factor always increases through time and with the size of the market. So tacit collusion is more sustainable in the early periods of market growth. We notice that the threshold increases with the intensity of the competition, measured by the number of mobile operators (Figure 1). By licensing a supplementary mobile operator, the regulator reduces the probability of collusion. When the number of operators rises, the competitive and cheating profits diminish. The incentives to collude are strengthened since the punishments are more severe. But this pro-collusive effect is more than counterbalanced by the decrease in collusive profits.

Insert Figure 1 here: The impact of the operators (3 or 4) on the discount factor threshold. Simulations for $k = 3000$, $\overline{f} = 3600$, $c_0 = 1000$, $c_1 = 2000$, $\pi(e) = 1000$, $\beta = 0.2$, $t^* = 5$.

Finally, the probability of collusion decreases with the revenues from the fixed-to-mobile calls (Figure 2). This result can be interpreted as follows: when the revenues from incoming calls are huge, competitive profits increase and the punishments which sustain the collusion are less severe. The incentives to collude are weakened when competition is relaxed .

Insert Figure 2 here: The impact of the incoming call revenues ($\pi_e = \{800, 1000, 1200, 1500\}$) on the discount factor threshod. Simulations for $k = 2500$, $\overline{f} = 3300$, $c_0 = 1000$, $c_1 = 1500$, $m = 3$, $\beta = 0.2$, $t^* = 5$.

5 Conclusion

This model of mobile competition has underlined the importance of incoming revenues in the tariff schemes and operator's conduct. We have shown that when the revenues from incoming calls are huge, competitive profits increase and the punishments or reprisals that could sustain collusion are less severe. Thus the incentives to collude are weakened. In other words, a regulator that tries to improve pricing efficiency, by reducing cross-subsidies or imposing cost-oriented charges, can enhance the likeliness of collusion on mobile markets.

If we consider the French market, the importance of access subsidies could be explained by the fact that mobile operators were responsible for setting prices of fixed to mobile calls. From November 2000, as the fixed operators are now setting these charges, we can expect a decrease of these revenues for mobile operators and we should observe a reduction of access subsidies and a rise of rental fees. But we could also face a collusion in which mobile operators agree to maintain access subsidies.

A possible critic of this model is the absence of churning at the equilibrium. It can be explained by the stationnary environment of the model. But in the real life, mobile operators do not enter into the market simultaneously. After the entry of a new operator, some current susbscribers cand find this entrant closer to their ideal operator and decide to switch to it. Moreover even without new entrant, mobile operators are likely to change their location and thus can stimulate churning behaviours. Finally, mobile services could also be an experience good : some current subscribers could revise their first choice after experimenting mobile usage. All these factors can positively influence the churn rate on mobile markets.

Regulation can also play an important role. The absence of number portability is a significant source of switching costs. Number portability enables consumers to keep the same phone number when switching to another operator. The regulatory obligation of number portability could stimulate competition on telecommunications markets[12]. But such a decision might also reduce access subsidies and enhance the incentives to cooperate among mobile operators.

An other important issue is the uncertainty about the market of the third generation mobile. The European Commission has pressed member countries into allocating UMTS licences no later than 2001 : some countries have opted for an auction mechanism (Germany, UK) others for a beauty contest (France, Spain). But in many european countries mobile operators have been complaining about the excessive amount of licence fees. Some operators fear for their future profitability and predict a chain of bankruptcies and exit for the weaker operators (Gruber [2000]). In the line of our model, the other alternative is a loosening of competition. The large requested licence fees are likely to enhance tacit collusion on the market of the third generation mobile.

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6 Appendix : Pricing methods for Fixed-to-Mobile calls

We consider different methods of payment for call terminations. The transfer schemes have two components. The first component corresponds to the cost supported by mobile operators to terminate the call (i.e. c_2). The second component is the extra revenue that the mobile operator receives for each incoming call. This extra revenue can be 1) a payment proportional to the margin on each call, 2) a payment proportional to the turnover on fixed-to-mobile calls or a lump-sum on each call. For these three schemes, we compare the retail charges for fixed-to mobile call ($e_{i,t}$) depending on whether this decision is taken by the fixed or mobile operators.

6.1 A payment proportional to the margin

The overall margin on each fixed-to-mobile call is equal to $(e_{i,t} - c_2 - w)$. The sharing of these revenues results from a bilateral negotiation between the fixed and the mobile operators and depends on many variables like the relative force of each operator . We do not explicitly model this bargaining. We just suppose that the fixed and mobile operators are forced to interconnect their networks. More precisely, they must find an agreement Let δ be the share of the fixed operator on the fixed-to-mobile margin. Consequently, a mobile operator receives a payment equal to $r_{i,t} = (1-\delta)(e_{i,t} - c_2 - w) + c_2$ for each call and its profit on these calls is given by :

$$\pi(e) = \left(\alpha_{i,t} N_t + \alpha'_{i,t} \sum_{j=0}^{t-1} N_j \right) (1-\delta)(e_{i,t} - c_2 - w) D(e_{i,t}) \tag{28}$$

Let e^* be the price which maximizes this profit. e^* is defined by :

$$(e^* - c_2 - w) D'(e^*) + D(e^*) = 0 \tag{29}$$

We can compare this price with the price that the fixed operator would have chosen. We suppose that it does not practice any pricing discrimination. The fixed subscribers pay the same price e_t, whatever mobile network they call. e_t is determined by maximizing the following profit function:

$$\Pi_{f,t}\left(e_t\right)=\sum_{j=0}^{t}N_j\delta\left(e_t-c_2-w\right)D\left(e_t\right) \tag{30}$$

Proposition 3 *If e^* is the price set by the mobile for fixed-to-mobile calls and e^{**} the price set by the fixed operator, then for a payment proportional to the global margin, we have $e^*=e^{**}$.*

Proof. The first order condition for the fixed operator is given by :

$$\frac{\partial\Pi_{f,t}}{\partial e_t}=\delta\sum_{j=0}^{t}N_j\left[\left(e_t-c_2-w\right)D'\left(e_t\right)+D\left(e_t\right)\right]=0 \tag{31}$$

From (29), we find that e^* satisfy this condition. ■

The fixed and mobile operators have a similar interest in fixed-to-mobile calls. Transferring the responsibility for price-setting from the mobile operator to the fixed operator does not modify the level of retail charges and the level of revenues for the operators.

6.2 A payment proportional to the turnover on fixed-to-mobile calls

When the payments are proportional to the overall revenues received by the fixed operator on fixed-to-mobile calls, then the monetary transfer per call is equal to $r_{i,t}=\mu e_{i,t}+c_2$ where $\mu\in[0,1]$ reflects the bargaining conditions[13]. The profit of the mobile operator is as follows :

$$\pi(e)=\mu\left(\alpha_{i,t}N_t+\alpha'_{i,t}\sum_{j=0}^{t-1}N_j\right)e_{i,t}D\left(e_{i,t}\right) \tag{32}$$

If this price is set by the fixed operator, then its function of profit is :

$$\Pi_{f,t}\left(e_t\right)=\sum_{j=0}^{t}N_j((1-\mu)e_t-c_2-w)D\left(e_t\right) \tag{33}$$

Proposition 4 *If $\widehat{e}$ is the price set by the mobile operator for fixed-to-mobile calls and $\widehat{\widehat{e}}$ the price set by the fixed operator, then for a payment proportional to the revenues we have $\widehat{e}<\widehat{\widehat{e}}$*

Proof. From (32), the optimal retail charges $\widehat{e}$ for the mobile operator is given by :

$$\widehat{e}D'\left(\widehat{e}\right)+D\left(\widehat{e}\right)=0 \tag{34}$$

[13]The higher μ, the larger the share of mobile operators on the fixed-to-mobile revenues.

and from (33), the optimal charges $\widehat{\widehat{e}}$ for the fixed operator satisfies :

$$((1-\mu)\widehat{\widehat{e}} - c_2 - w)D'\left(\widehat{\widehat{e}}\right) + (1-\mu)D\left(\widehat{\widehat{e}}\right) = 0 \quad (35)$$

As we have $\widehat{\widehat{e}}D'\left(\widehat{\widehat{e}}\right) + D\left(\widehat{\widehat{e}}\right) = \frac{(c_2+w)}{(1-\mu)}D'\left(\widehat{\widehat{e}}\right) < 0$, from (34), we infer that $\widehat{e} < \widehat{\widehat{e}}$. ■

When mobile operators obtain a payment proportional to the overall turnover on fixed-to-mobile calls, then they have incentives to set a lower price than the fixed operator.

6.3 A lump-sum

In a lump-sum scheme, the mobile operators receive $r_{i,t} = c_2 + \Delta$ per call. Their profit on fixed-to-mobile calls has the following expression :

$$\pi(e) = \left(\alpha_{i,t}N_t + \alpha'_{i,t}\sum_{j=0}^{t-1}N_j\right)\Delta D\left(e_{i,t}\right) \quad (36)$$

It is in the interest of mobile operator to set the fixed-to-mobile price as low as possible. Given the different relevant costs, the price will be fixed at $\widetilde{e} = c_2 + \Delta + w$.

If the fixed operator has the responsibility for setting the fixed-to-mobile price, then its decision $\widetilde{\widetilde{e}}$ is determined by :

$$\left(\widetilde{\widetilde{e}} - c_2 - \Delta - w\right)D'\left(\widetilde{\widetilde{e}}\right) + D(\widetilde{\widetilde{e}}) = 0 \quad (37)$$

Proposition 5 *If $\widetilde{e}$ is the price set by the mobile operator for fixed-to-mobile calls and $\widetilde{\widetilde{e}}$ the price set by the fixed operator, then for a lump-sum scheme we have $\widetilde{e} < \widetilde{\widetilde{e}}$*

Mobile operators have more incentives to fix a lower price on the fixed-to-mobile calls than the fixed operator when they obtain a flat payment or a fixed mark-up on each call. We have the opposite result if the fixed mark-up is for the fixed operator and the mobile operators receive the differential.