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Optimal Market Structure in the Mobile Industry*

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Abstract

The optimal market structure in the mobile industry is an important topic in the mobile industry. In this paper, we use two theoretical frameworks and a structural estimation approach to assess the effects of market structure on consumer surplus in symmetric mobile markets. When mobile services are viewed as homogeneous products under Cournot competition, we find that consumer surplus falls with the number of operators. However, when mobile services are considered as differentiated products under Salop competition, we find an inverted-U relationship between consumer surplus and the number of mobile operators. These findings call for a case-by-case analysis of the optimal market structure in the mobile industry.

Keywords: Market structure, Investment, Mobile Telecommunications.

JEL Classification: D21, D22, L13, L40.

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1 Introduction

Finding the optimal market structure in the mobile industry is a timely issue in the current context of mergers, particularly in Europe. Jeanjean & Hounghonon (2016) shows that the optimal market structure involves a trade-off between static and dynamic efficiencies due to a negative relationship between investment and the number of mobile operators. However, it remains to be assessed the balance between the magnitudes of static and dynamic efficiencies. This assessment is not straightforward due to the complexity of consumer preferences and investment decisions in mobile markets. Typically, operators offer a variety of products which are both vertically and horizontally differentiated. Vertical differentiation is driven by quality, which is hardly observable. In addition, investment in quality is likely to include a dynamic aspect due to its effects on subsequent marginal cost of production.

In this paper, we propose two complementary and simplified structural modelings of the effect of market structure on consumer surplus in symmetric mobile markets. First, we consider mobile services as the transmission of electronic signal, homogeneous irrespective of the operator and the actual package sold to the end-users. Under this assumption, operators invest and compete in the volume of signal transmitted. Using data on the volume of traffic, operators market share and investment, we are able to recover their demand elasticity and marginal cost as a function of investment. These parameters have been combined with the findings from Jeanjean & Hounghonon (2016) on the relationship between market structure and investment. It turns out that consumer surplus falls with the number of mobile operators in the average European mobile markets.

Our second approach consider mobile services as horizontally differentiated products sold by single products firms. Using data on operators' accounting profit and operators' market share we are able to recover an estimate of the horizontal differentiation parameter. In addition, the model also provides a value of the parameter which determines the effect of investment on quality. We use these parameters in conjunction with the estimates from Jeanjean & Hounghonon (2016) to simulate the effects of market structure on consumer surplus and social welfare. We find an inverted-U relationship between the number of operators and consumer surplus and social welfare. The optimal number of operators varies between 2 and 5 according to the national markets.

These findings contribute more generally to the literature on the effects of market structure in dynamic frameworks as in Vives (2008) and Schmutzler (2013).

In particular, it provides a piece of evidence to the strand of the literature which investigates the regulation of the mobile industry. Previous papers such as Houn-
bonon & Jeanjean (2016) and Jeanjean & Houn-
bonon (2016) investigate the effects
of competition and more specifically market structure on investment in the mobile
industry, but they do not assess the tradeoff between static and dynamic efficiencies.

The remaining of the paper is organised as follows. Section 2 presents the data
sources and the main variables used in this paper. Sections 3 and 4 present the
structural modelling under the assumption of mobile services as homogeneous and
differentiated products, respectively. Finally section 5 concludes along with some
discussions of the findings.

2 Data

As described in table 1, our data come from three sources. Investment, revenues and
the number of subscribers have been obtained from the World Cellular Information
Services (WCIS), an online database managed by Ovum. Data on consumption
of mobile services, voice and data, come from Analysys Mason. These sources are
proprietary, but widely used in academic research as in Whalley & Curwen (2014),
Kim *et al.* (2011) and Hazlett *et al.* (2014). Finally, socio-demographic data such
as the Gross Domestic Product (GDP) and the population size have been retrieved
from the World Development Indicator database (WDI), a publicly available and
managed by the World Bank. On top of these data, we also rely on estimates from
the paper by Jeanjean & Houn-
bonon (2016). Our sample covered 27 European
mobile markets with 72 mobile operators, observed from 2007 to 2015.

In the sample, investment corresponds to capital expenditures, observed both at the
operator and market level. Capital expenditures is limited to mobile networks, but
may include license fees. As licenses are not purchased every year, change in capital
expenditures due to license fees are expected to be the residual of the econometric
models. Revenues and the number of subscribers include prepaid and postpaid
subscribers. They also include data from the virtual network operators hosted by
mobile network operators. Consumption data are estimates provided by Analysys
Mason on the basis of figures released by national regulators but also on the basis
of their own assessment of the usage of internet contents. The way in which these
data have been used to generate the variables relevant for our analysis is presented
in the appropriate sections below.

3 Mobile services as homogeneous products

This section relies on a Cournot model to analyse the effect of the number of mobile operators on consumer surplus.

3.1 Settings of the model

We consider $N \geq 2$ mobile operators, exogenously given by regulation which supply the transmission of electronic signal between end-users. The electronic signal is physically measured by the byte and corresponds to data services. Irrespective of the operator, bytes are homogeneous. The aggregate demand for bytes is iso-elastic and can be expressed as:

$$Q = P^{-\beta} \quad (1)$$

$Q = \sum_{i=1}^N q_i$ is the aggregate volume of bytes transmitted and q_i denotes the volume supplied by operator i . P is the market price. As such, β corresponds to the absolute elasticity of demand.

Operators experience constant marginal cost of production $c(z)$ which can however be reduced by investment (in new technologies):

$$\frac{\partial c(z)}{\partial z} < 0$$

Due to technological progress, investment lowers marginal cost by allowing more traffic to be conveyed at the same cost. As investment increases the speed at which mobile data can be consumed, it also raises the quality of the mobile data from the perspective of the consumer. However, it is not possible to distinguish the effect of investment on quality from its effect on marginal cost. In this part, we will, therefore, assume that all the effects of investment work through marginal cost reduction.

Operators compete in two stages. At the first stage, they simultaneously choose their investment z_i . At the second stage, they simultaneously choose their output q_i . The profit of operator i writes:

$$\pi_i = [P - c(z_i)]q_i - z_i - F$$

F denotes a fixed cost of entry.

Given investment at the first stage, the first-order condition at the second stage yields:

$$\frac{P - c(z_i)}{P} = \frac{\phi_i}{\beta} \quad (2)$$

Where $\phi_i = \frac{q_i}{Q}$ is the market share of operator i . An equilibrium exists if and only if $\frac{\phi_i}{\beta} < 1$ for all i . In symmetric markets, with the smallest number of operators, that is 2, this condition is equivalent to stating that $\beta > \frac{1}{2}$. In the remaining of the model, we will assume that $\frac{1}{2} < \beta < 1$. Let \hat{P} and \hat{Q} denote the equilibrium price and quantity respectively. They both satisfy equation (2).

Consumer surplus in symmetric markets writes:

$$CS = \int_a^{\hat{Q}} [P(Q) - \hat{P}] dQ \quad (3)$$

Where a stands for a constant which ensures that demand is neither nil. Change in consumer surplus is not sensitive to the choice of this constant which will be set to 1. This choice amounts to assuming that $Q \geq 1$. It can be shown with simple algebra that:

$$CS = \hat{P} - \frac{1}{1 - \beta} \hat{P} \hat{Q} + \frac{\beta}{1 - \beta} \quad (4)$$

Plugging the expression of price from equation (2) into the equation (4), the derivative of consumer surplus writes:

$$\frac{\partial CS}{\partial N} = \frac{\frac{c(z)}{\beta N^2} - \frac{\partial c(z)}{\partial z} \frac{\partial z(N)}{\partial N} (1 - \frac{1}{\beta N})}{\left(1 - \frac{1}{\beta N}\right)^2} (\hat{Q} - 1) \quad (5)$$

Given that $Q \geq 1$, $\hat{Q} \geq 1$ and therefore,

$$\text{sign}\left\{\frac{\partial CS}{\partial N}\right\} = \text{sign}\left\{\frac{c(z)}{\beta N^2} - \frac{\partial c(z)}{\partial z} \frac{\partial z(N)}{\partial N} \left(1 - \frac{1}{\beta N}\right)\right\} \quad (6)$$

Two observations stand out from this equation. First, the sign of the effect of the

number of operators on consumer surplus depends on the number of operators N . Therefore, change in consumer surplus is not necessarily monotonous. Second, this sign is characterized by two terms, one corresponding to a positive market power effect, $\frac{c(z)}{\beta N^2}$, and the other corresponding to a negative effect stemming from investment, $-\frac{\partial c(z)}{\partial z} \frac{\partial z(N)}{\partial N}$. Therefore, the effect of the number of operators on consumer surplus is not theoretically determined. It depends on the magnitude of the elasticity of demand, β , the shape of the marginal cost function, $c(z)$ and $\frac{\partial c(z)}{\partial z}$, and the magnitude of the effect of the number of operators on investment, $\frac{\partial z(N)}{\partial N}(1 - \frac{1}{\beta N})$. The remaining of this section provides empirical estimates for these parameters in order to analyse the effect of the number of operators on consumer surplus.

3.2 Estimation of the demand for mobile services

Following the specification in equation (1), the aggregate demand for mobile services can be estimated on the basis of the following model:

$$\ln Q_{jt} = \alpha - \beta \ln P_{jt} + \varepsilon_{jt} \quad (7)$$

\ln denotes the natural logarithm. Q_{jt} and P_{jt} are respectively the aggregate output and price in market j in year t . ε_{jt} correspond to the unobserved determinants of the demand for mobile services. Due to consumers heterogeneity in terms of income, we need to include a proxy for income into this equation. Let y denotes this proxy. In addition, as suggested by the theoretical settings, price and quantity can be jointly determined by quality, through investment. Therefore, we shall also include a measure of investment into the demand model. Furthermore, time-invariant unobserved market and year specific effects are included into the model. In particular, the unobserved market specific effect is interacted with the price variable in order to obtain market specific elasticity of demand. The resulting model writes:

$$\ln Q_{jt} = \alpha - \beta_j \mu_j * \ln P_{jt} + \delta \ln z_{jt} + \gamma y_{jt} + \mu_t + \mu_{jt} \quad (8)$$

Q_{jt} is measured as the monthly volume of mobile data per user. At this stage, we focus on mobile data as the demand for mobile voice is rather flat. P_{jt} is measured as the price per megabyte of mobile data. It corresponds to the ratio of aggregate mobile data revenues to the aggregate volume of mobile data consumption. z_{jt} is the capital expenditures per user and y_{jt} is the monthly estimate of GDP per capita.

μ_j is a set of dummy variables for each market in our sample and μ_t is set of yearly dummies. Table 2 presents the summary statistics of the main variables.

OLS estimates of equation (8) would be biased due to unobserved horizontal differentiation. We implement a Generalized Method of Moments estimator using the lagged price of mobile data and the lagged of investment as the instruments. Serial autocorrelation statistics are presented to test the validity of these lags as instruments. The estimation relies on 243 observations from 26 European markets from 2007 to 2015. Due to the use of lags the final sample includes 175 observations. The outcome of the estimation is presented in table 5. Demand elasticities are all negative as expected. As discussed in section 3.3 below, the market specific demand elasticities will be useful for the estimation of marginal cost. The average demand elasticity is -0.814 . It will be used in the simulation of the effect of the number of operators on consumer surplus.

3.3 Estimation of the marginal cost of production

In this section, we assume that investment is already chosen in the first stage. Hence, the marginal cost of mobile services will be recovered from the first-order condition of the Cournot equilibrium in the second stage. This condition corresponds to equation (2) in the theoretical section. With a knowledge of market-specific demand elasticities from the previous section and price per megabyte and the market share from the data, marginal cost can be calculated using the following formula:

$$c(z_{ijt}) = p_{ijt} * \left(1 - \frac{\phi_{ijt}}{\beta_j}\right) \quad (9)$$

This formula yields estimates of the marginal cost experienced by each mobile operator under the assumption that they compete in output. We can now use these estimates in conjunction with operators' investment in order to determine the marginal cost function $c(z)$. As the effect of market structure on consumer surplus depends on the nature of this function we first employ a non-parametric strategy to identify the functional form and then estimate the parameters of this function.

■ Non-parametric identification of $c(z)$

We employ the locally weighted scatterplot smoothing (Lowess), a non-parametric algorithm proposed by Cleveland (1979). This algorithm traces a curve through the

scatterplot of two variables, from locally fitted curves identified by regressing one variable over the other. The algorithm runs as follows:

First, it derives the residuals of the regressions of the marginal cost and investment on operator's fixed effects. This procedure follows from the Frish-Waugh Theorem (Frisch & Waugh, 1933), which basically states that a regression between two variables with additional controls is equivalent to regressing their residuals obtained from their regressions on the controls. Let's c_k^r and z_k^r denotes the residuals of marginal cost and investment respectively.

For a given investment z_k^r , let's define a bandwidth b around this point. This bandwidth determines a subset of pairs (c_l^r, z_l^r) such that $z_{k-\frac{b}{2}}^r \leq z_l^r \leq z_{k+\frac{b}{2}}^r$. The corresponding *Lowess* smoother of the marginal cost c_k^r is the predicted value of the following weighted OLS regression:

$$c_l^r = \sigma * w_l * z_l^r + \mu_l \quad (10)$$

$$l \in [k - \frac{b}{2}; k + \frac{b}{2}].$$

w_l is a weight attached to the observations indexed by l . Several kernel weighting functions can be used. The non-parametric smoothing relies in particular on the tricube weighting function, a robust kernel widely used in the literature on non-parametric modelling.¹

The *Lowess* smoother of marginal cost associated with the investment z_k^r is determined as:

$$\hat{c}_k^r = \hat{\sigma} * w_l * z_k^r$$

The same procedure is replicated for all k , that is, for all observations of investment. The Lowess smoother is a graphical representation of the set of points (\hat{c}_k^r, z_k^r) . Figure 1 presents the outcome of the non-parametric algorithm. It shows a downward sloping relationship between marginal cost and investment.

¹The tricube weighting function is defined as follows:

$$K(u) = \frac{70}{81}(1 - u^3)^3 \quad (11)$$

For all u such that $|u| \leq 1$, $u = l - k$.

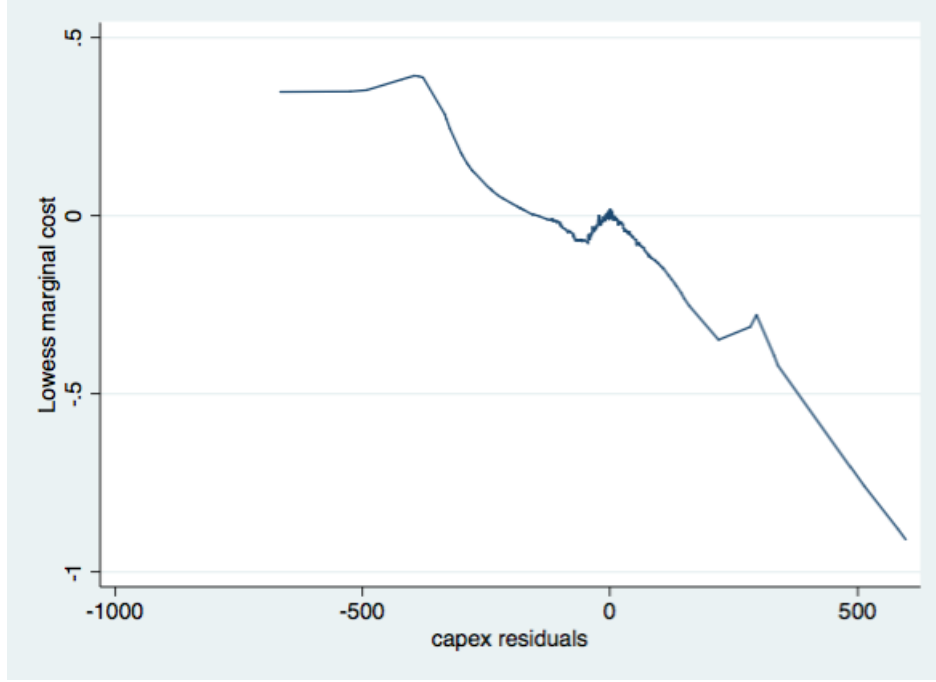


Figure 1: Non-parametric marginal cost curve

■ Parametric identification of $c(z)$

In order to get an estimate of the magnitude of the effect of investment on marginal cost, we formulate the following equation that provides the best statistical fit to the relationship between marginal cost and investment.

$$\ln c(z_{ijt}) = \alpha' - \beta' z_{ijt} + \gamma' y_{jt} + \nu_i + \nu_t + \nu_{ijt} \quad (12)$$

$c(z_{ijt})$ are estimated from equation (9). z_{ijt} is investment, measured by capital expenditures, of operator i in market j at time t . y_{jt} is an estimate of the monthly GDP per capita. ν_i is a set of operators dummy variables. ν_t corresponds to year-specific effects, which are dummy variables. Finally, ν_{ijt} is the residuals. Table 3 presents the summary statistics of the main variables.

OLS estimate of β' can be biased due to the unobserved horizontal differentiation parameters or time variant efficiency parameters. As a result, equation (12) is estimated by the Generalised Methods of Moments with instrumental variable strategy. We use population size as an instrument for investment, the intuition being that investment per operator is higher in more populated markets, whereas population size is exogenous.

The outcome of the estimation is presented in table 5. It turns out that investment in mobile network significantly reduces marginal cost of mobile data. The magnitude is such that one million more investment reduces marginal cost by 0.3 per cent, on average.

3.4 Simulation outcome

This section presents the outcome of a simulation exercise of the effects of market structure on consumer surplus in a representative European mobile market. This representative market has the average characteristics of all European mobile market and is symmetric. One missing ingredient is the relationship between market structure and investment, that is $z(N)$. Ideally, we would like to model the investment decision and derive $z(N)$ from the theoretical model. This could actually be done if the marginal cost function $c(z)$ was fully specified. However, our goal is to make the least theoretical hypotheses and focus on the empirical facts stemming from the data. This is particularly the case for investment given that previous works predict ambiguous relationship between market structure and investment. Fortunately, we are going to rely on the empirical findings from the paper by Jeanjean & Houngebonon (2016) to specify $z(N)$.

In this paper, investment is expressed as a log-linear function of the number of operators N , the asymmetry in terms of market share and additional market and operators characteristics. The model also account for the adjustment cost of investment by introducing the lagged investment as an explanatory variable.

$$\ln z_{ijt} = \alpha + \theta N_{jt} + \rho \ln z_{ijt-1} + \delta \Delta_{ijt} + \lambda X_{ijt} + \epsilon_i + \epsilon_t + \epsilon_{ijt} \quad (13)$$

With $\Delta_{ijt} = \sigma_{ijt} - \frac{1}{N_{jt}}$ represents the difference between operator i 's market share and the average market share. In symmetric markets $\Delta_{ijt} = 0$. X_{ijt} represents the control variables, ϵ_i the operators fixed effects, ϵ_t the time fixed effects and ϵ_{ijt} the residuals. The derivative according to the number of operator provides $\frac{(\partial z_{ijt}/\partial N_{jt})}{z_{ijt}} = \theta + \delta \frac{\partial \Delta_{ijt}}{\partial N}$

For a symmetric market, this provides: $\frac{\partial z_{jt}}{\partial N_{jt}} = \theta z_{jt}$. In the long run, $\frac{\partial z_{jt}}{\partial N_{jt}} = \frac{\theta}{1-\rho} z_{jt}$

The simulation relies on the estimates of θ and ρ from Jeanjean & Houngebonon (2016). $\hat{\theta} = -0.158$ and $\hat{\rho} = 0.609$. Therefore, the long run effect of one additional operator on investment is -0.404 .

This estimate provides the second row of table 4, showing that investment per operator falls with the number of operators. The estimates of equation (12) in conjunction with the simulated investment yields the simulated marginal cost in the third row of table 4. As expected, marginal cost increases with the number of operators. It tends to double with each additional entry but at a lower pace.

We use the average demand elasticity and the simulated marginal cost to recover the corresponding price per GB of mobile data. The formula writes:

$$P(N) = \frac{c[z(N)]}{1 - \frac{1}{N*\beta_j}} \quad (14)$$

It turns out that market power reduction effect of an additional entry is not strong enough to compensate the dynamic effect stemming from investment. As a result, price per unit rises with the number of operators. As shown in the fourth row of table 4, price per gigabyte rises from 3 dollars with two operators to 8 dollars with five operators. Correspondingly, the monthly data consumption per user decreases. And as a result consumer surplus falls with the number of operators.

4 Mobile services as differentiated products

This section provides a complementary approach to the Cournot framework by considering mobile services as differentiated products.

4.1 Settings of the model

In this section we use the Salop model developed in Jeanjean & Hounghonon (2016). In this model, N operators compete in price. Profit of operator i writes:

$$\pi_i = [p_i - c_i]q_i - z_i - F$$

Where p_i , c_i , q_i and F denote respectively price, marginal cost, quantity and fixed cost of entry.

The equilibrium price of operator i , p_i is written:

$$p_i^* = c_i + \sigma_i h$$

Where σ_i is the market share of operator i and h , the transportation cost which represents the differentiation between operators.²

Equilibrium profit is written:

$$\pi_i^* = \sigma_i^2 h \quad (15)$$

Market share of operator i is written:

$$\sigma_i = \frac{1}{N} + \frac{1}{h} \left(\sum_{j=0}^{\lfloor N/2 \rfloor} \gamma_j \beta_j (d_{i+j} + d_{i-j}) \right)$$

where $\lfloor \cdot \rfloor$ is the floor function.

$$\lfloor N/2 \rfloor = \begin{cases} \frac{N}{2} & \text{if } N \text{ is even} \\ \frac{N-1}{2} & \text{if } N \text{ is odd} \end{cases}$$

$$\gamma_j = \begin{cases} \frac{1}{2} & \text{if } j = 0 \text{ or } j = \frac{N}{2} \\ 1 & \text{otherwise} \end{cases}$$

with coefficient $\beta_0 = 1 - \frac{(2+\sqrt{3})^N + 1}{\sqrt{3}[(2+\sqrt{3})^N - 1]}$ and $\beta_j = -\frac{(2+\sqrt{3})^{N-j} + (2+\sqrt{3})^j}{\sqrt{3}[(2+\sqrt{3})^N - 1]}$ for $j \neq 0$

The incentive to invest z_i to improve quality d_i is written:

$$\frac{\partial z_i}{\partial d_i} = 2\beta_0 \sigma_i \quad (16)$$

Change of consumer surplus and welfare following a change in the number of operators in a symmetric market are written:

$$\frac{\partial CS}{\partial N} = \frac{\partial d}{\partial N} + \frac{5h}{4N^2} = \frac{\partial d}{\partial z} \frac{\partial z}{\partial N} + \frac{5h}{4N^2} \quad (17)$$

and

²The notation h has been chosen rather than t , generally used for the transportation cost, in order to avoid confusion with the time denoted t .

$$\frac{\partial W}{\partial N} = \frac{\partial d}{\partial z} \frac{\partial z}{\partial N} (1 - 2\beta_0) - z - F + \frac{h}{4N^2} \quad (18)$$

These equations show a trade-off between static and dynamic effects. Terms with $\frac{\partial d}{\partial N}$ are the dynamic effects. $\frac{\partial d}{\partial N}$ is negative and represents the decrease in quality caused by an increase in the number of operators, as investment per operator decline with the number of operators. Terms with h are the static effects, they represent the decrease in consumers transportation costs caused by a higher number of operators. As transportation costs have a negative impact on consumer surplus and welfare, its reduction has a positive one, hence the positive sign.

4.2 Optimal number of operators

The effect of market structure on consumer surplus depends on the size of the transportation cost h , the value of $\frac{\partial z}{\partial N}$ and $\frac{\partial d}{\partial z}$. In symmetric markets, $\frac{\partial d}{\partial z}$ can be derived from equation (16):

$$\frac{\partial d}{\partial z} = \frac{N}{2\beta_0}$$

Regarding the effect of market structure on investment, we know from equation (13) that:

$$\frac{\partial z}{\partial N} = \frac{\theta}{1 - \rho} z$$

Therefore,

$$\frac{\partial d}{\partial N} = \frac{\theta z N}{2(1 - \rho)\beta_0}$$

Finally, transportation cost h can be estimated by using the industry profit, calculated on the basis of equation (15):

$$\sum_{i=1}^N \pi_i^* = HHI \cdot h$$

where HHI is the Herfindahl-Hirschmann Index defined as: $HHI = \sum_{i=1}^N \sigma_i^2$

The industry profit is proxied by sum of the ebitda (earnings before interest, taxes, depreciation, and amortization) of all the operators. Therefore, h is estimated as:

$$h_{jt} = \frac{\sum_{i=1}^N ebitda_{ijt}}{HHI_{jt}}$$

As a result, equation(17) can be written:

$$\frac{\partial CS}{\partial N}(N) = \frac{\theta_{lr} z_s N}{2\beta_0} + \frac{5h}{4N^2}$$

and equation(18):

$$\frac{\partial W}{\partial N}(N) = \frac{\theta_{lr} z_s N}{2\beta_0} - (\theta_{lr} N + 1) z_s + \frac{h}{4N^2} - F$$

$\theta_{lr} = \frac{\theta}{1-\rho}$ and z_s is the symmetric equivalent of operators' investment.

We can easily check that $\frac{\partial^2 CS}{\partial N^2}$ and $\frac{\partial^2 W}{\partial N^2}$ are negative, as a result, $\frac{\partial CS}{\partial N} = 0$ or $\frac{\partial W}{\partial N} = 0$ at the maximums of consumer surplus and social welfare. The number of operator which is the closest respectively from $\frac{\partial CS}{\partial N} = 0$ or $\frac{\partial W}{\partial N} = 0$ is thus the one that maximizes respectively consumer surplus or welfare.

As the dynamic term includes zs and the static one includes h , the ratio h/zs seems to be a good measure of the trade-off between static and dynamic effects.

$$\frac{\partial CS}{\partial N} = 0 \implies \frac{h}{zs} = \frac{-2\theta_{lr} N^3}{5\beta_0}$$

In the database, we do not observe the fixed cost F incurred by operators to enter the market which has a decreasing impact on welfare. Neglecting F leads to overestimate the number of operators which maximizes welfare.

$$\text{neglecting } F, \frac{\partial W}{\partial N} = 0 \implies \frac{h}{zs} = \frac{-2\theta_{lr} N^3(1-2\beta_0)+4\beta_0 N^2}{\beta_0}$$

4.3 Simulation outcome

Figure 2 below represents the values of h/zs that maximize consumer surplus and welfare (neglecting F).

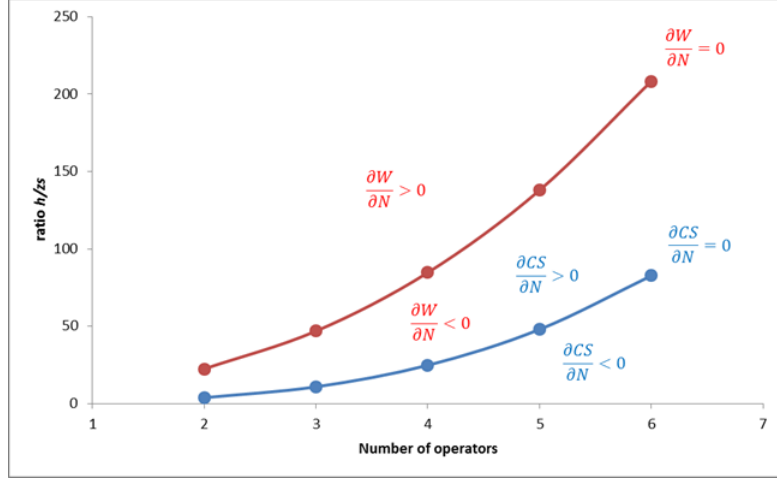


Figure 2: ratio h/zs maximizing consumer surplus and welfare

For all the countries in the sample and each year, we can calculate the ratio $\frac{h}{zs}$ and compare it to $\frac{-2\theta_{lr}N^3}{5\beta_0}$ and $\frac{-2\theta_{lr}N^3(1-2\beta_0)+4\beta_0N^2}{\beta_0}$.

When $\frac{h}{zs} > \frac{-2\theta_{lr}N^3}{5\beta_0}$ then $\frac{\partial CS}{\partial N} > 0$, in such case, if $\frac{h}{zs}$ is closer from $\frac{-2\theta_{lr}(N+1)^3}{5\beta_0}$ than from $\frac{-2\theta_{lr}(N)^3}{5\beta_0}$, then the current number of operator is below the number of operator that maximizes consumer surplus. Otherwise it is the one that maximizes consumer surplus.

And same manner when $\frac{h}{zs} < \frac{-2\theta_{lr}N^3}{5\beta_0}$ then $\frac{\partial CS}{\partial N} < 0$, if $\frac{h}{zs}$ is closer from $\frac{-2\theta_{lr}(N-1)^3}{5\beta_0}$ than from $\frac{-2\theta_{lr}(N)^3}{5\beta_0}$, then the current number of operator is greater than the number of operator that maximizes consumer surplus. Otherwise it is the one that maximizes consumer surplus.

Similar reasoning shows whether the current number of operator is greater than, equal to or below the one that maximizes the welfare (neglecting F).

5 Concluding remarks

Our analysis shows that consumer surplus tends to fall with the number of operators in the mobile industry. This finding suggests that dynamic effects stemming from investment tend to outweigh static effects on average. However, when horizontal differentiation is introduced, static effects tend to dominate dynamic effects at lower level of competition. Therefore, the effect of market structure on consumer surplus in the mobile industry is sensitive to consumer preferences. In addition, market specific analysis of the relationship between market structure and consumer surplus is required.

This analysis is conducted for symmetric markets and in the long run. While it is clear that our findings underestimate the optimal number of mobile operator in the short run, the effect of asymmetry on the optimal number of mobile operators is less clearer. Asymmetry affects both the static and dynamic component of surplus in an ambiguous way. Smaller level of asymmetry can increase the industry investment while higher level of asymmetry decreases it. In addition, More asymmetry increases market power of some firms while reducing it for others.

Another limitation of this analysis is the fact that we only account for differentiation across operators, assuming that operators are single product firms. Yet, in practice operators are multiproduct firms and consumers preference for variety as well as the way in which change in market structure affects operators product line is not clear-cut. Future works need to deal with these issues.

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A Appendix

Table 1: **Datasets and variables**

Original variables	Comments	Unit of observation	Data source
Capital expenditures	in millions US dollars	operator level	WCIS, Ovum
Ebitda		operator level	WCIS, Ovum
Mobile data revenue	in millions US dollars	market level	WCIS, Ovum
Subscribers		operator level	WCIS, Ovum
Mobile data market share		operator level	WCIS, Ovum
Mobile data traffic	in Terabytes	market level	Analysys Mason
Gross domestic product	in thousands US dollars	market level	WDI
Population size	in million	market level	WDI

WCIS: World cellular Information Services by Ovum,

WDI: World Development Indicators. All variables are observed at the year level.

Table 2: **Summary statistics for the demand estimation**

	Obs	Mean	Std. Dev.	Min	Max
lnadatpu	175	7.80	1.42	3.59	11.01
lnprice	175	-3.95	1.18	-6.64	-0.61
lninvpu	175	3.70	0.60	2.28	5.74
gdppcpm	175	1940.84	1091.93	459.36	5386.31

Table 3: **Summary statistics for the marginal cost estimation**

	Obs	Mean	Std. Dev.	Min	Max
lncost	366	-4.11	1.43	-9.00	0.28
capex__	366	292.42	376.93	1.05	2665.57
gdppcpm	366	1.99	1.09	0.45	5.38
pop	366	26.27	27.54	1.32	82.21

Table 4: **Simulation results**

Number of operators	2	3	4	5
Yearly investment per operator (million US dollars)	786.86	525.30	350.68	234.11
Marginal cost per GB (US dollars)	1.15	2.53	4.27	6.06
Price per GB (US dollars)	2.99	4.29	6.17	8.04
Monthly data traffic per user (MB)	113.35	84.63	62.93	50.73
Variation in consumer surplus (US dollars)		-0.12	-0.13	-0.10

Table 5: **Estimation results**

	Log. MB per user	Log. marg. cost
Average elasticity	-0.814	
lninvpu	2.608 (9.461)	
gdppcpm	-0.000 (0.002)	-1.761*** (0.553)
capex		-0.003** (0.001)
Operators FE		✓
Year FE	✓	✓
_cons	-7.406 (33.325)	3.390** (1.615)
<i>N</i>	175	366
Instruments	28	1
hansenp		
ar2p	0.80	
ar3p	0.79	
ar4p	0.95	
weak id. test		45.99