

Houngbonon, Georges Vivien; Jeanjean, Francois

Conference Paper

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25th European Regional Conference of the International Telecommunications Society (ITS): "Disruptive Innovation in the ICT Industries: Challenges for European Policy and Business", Brussels, Belgium, 22nd-25th June, 2014

Provided in Cooperation with:

International Telecommunications Society (ITS)

Suggested Citation: Houngbonon, Georges Vivien; Jeanjean, Francois (2014) : Is there a level of competition intensity that maximizes investment in the mobile telecommunications industry?, 25th European Regional Conference of the International Telecommunications Society (ITS): "Disruptive Innovation in the ICT Industries: Challenges for European Policy and Business", Brussels, Belgium, 22nd-25th June, 2014, International Telecommunications Society (ITS), Calgary

This Version is available at:

<https://hdl.handle.net/10419/101384>

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Is there a level of competition intensity that maximizes investment in the mobile telecommunications industry?*

Georges Vivien Hounghonon [†]Francois Jeanjean [‡]

30th May 2014

Preliminary version, comments are welcome

Abstract

This paper empirically assesses the impact of the intensity of competition on investment in new technologies within the mobile telecommunications industry. Using firm level panel data and an instrumental variable estimation it finds an inverted-U relationship between competition intensity and investment. The intermediate level of competition intensity that maximizes investment stands at 62 percent, whereby competition intensity is measured by 1-Lerner index at the firm level. This means that the maximal level of investment is reached, on average, when the operating profit represents 38 percent of total revenue. This result is rationalized through a theoretical model that yields an inverted-U relationship between competition and investment. It shows that the potential technological progress, measured by the impact of investment on the reduction of marginal cost, is the main determinant of the investment maximizing intermediate level of competition. The higher the potential technological progress, the lower the level of competition intensity that maximizes investment.

Keywords: Competition, Investment, Mobile Telecommunications.

JEL Classification: D21, D22, L13, L40.

*The usual disclaimer applies.

[†]Paris School of Economics & Orange, gvivienh@gmail.com

[‡]Orange, Regulatory Affairs, francois.jeanjean@orange.com

1 Introduction

The relationship between competition and investment is one of the most important issues in economics. Although the debate is lively for many decades, it has not yet reached a clear conclusion. There are two opposite views about the direction of the relation. The Schumpeterian view highlights that large firms in low concentrated markets are more likely to invest, and the school of Harvard's view highlights the virtues of competition that stimulates investment to escape competition. One of the significant contributions to this debate is the findings by Aghion, Bloom, Blundell, Griffith, and Howitt (2005) of an inverted-U relationship between competition and investment in R&D. While these findings raise a caution about the relevance of perfect competition as a policy objective, they do not identify the level of competition which maximizes investment, as this level may depend on each industry.

The goal of this paper is to assess empirically whether there is a level of competition that maximizes investment in infrastructures within the mobile telecommunications industry. It takes advantage of the availability of firm level panel data for mobile telecommunications operators to identify the causal impact of competition on investment. Competition is measured at the firm level as 1-Lerner index and investment is the yearly expenditures in tangible and durable assets. The identification strategy is an instrumental variable estimation that relies on the role of spectrum policy in determining the number of operators and their year of entry into the mobile telecommunications market. It turns out that there is an inverted-U relationship between competition and investment. That is, investment is maximal for an intermediate level of competition between monopoly and perfect competition. The intermediate level of competition that maximizes investment is found at 62 percent. This means that the maximal level of extensive investment is reached, on average, at 38 percent of profit margin. Put it differently, more competition raises investment in the mobile telecommunications industry as long as a firm's gross profit is greater than 38 percent of its revenue. Below this level, more competition decreases investment. This result is robust to the functional specification of the relationship between competition and investment. It is also robust with respect to the difference in willingness to pay across markets, market dynamics such as entry, merger and exit, extreme values, and alternative instruments.

Nonetheless, this empirical evidence cannot be generalized to other sectors. Actually, the mobile telecommunications industry is characterized, like the whole information technologies sector, by a very high rate of technological progress, more than 20%

for more than a century according to Koh and Magee (2006a). To highlight the role of technological progress in driving the shape of the relationship, we propose a theoretical model in which investment in a new technology generates a stream of monopoly profit for the investing firm over a certain period. However, this period is reduced by competition. Technical progress shifts downward the marginal cost of production. Provided that technological progress is high enough, the model yields a non-monotonous relationship, particularly an inverted-U, between competition and investment, consistently with the empirical findings for the mobile industry. In addition, technological progress reduces the intermediate level of competition that maximizes investment. More generally, we show that the inversion of the curve is more likely to occur under high technological progress as observed in the mobile telecommunications industry.

This theoretical model embeds both the positive and negative effects of competition on investment, respectively the escape competition and Schumpeterian effect. In short, fiercer competition increases the escape competition effect, due to lower ex-ante profit. This effect generates greater incentive to invest. However, fiercer competition also decreases the period over which a firm enjoys the escape competition effect. As a result, the escape competition effect is superior at lower level of competition; but is overtaken by the Schumpeterian effect above a certain level of competition if the technological progress is high enough.

The rest of the paper is organized as follows. Section 2 provides a summary of the related literature, section 3 describes the industry, the dataset and the variables, section 4 presents the empirical evidence and section 5 provides a theoretical framework that gives the insight of the inverted-U shaped curve for a highly innovative industry. The final section discusses the results and provides some concluding remarks.

2 Related Literature

Most of the papers dealing with the relationship between competition and investment focus on investment in R&D (innovation). This feature of the literature differs from this paper which rather focuses on investment in quality improving technologies and infrastructures. However, as emphasized by Mathis and Sand-Zantman (2014), once we abstract from property rights issues, there is no difference between investment in R&D and in other types of assets. Therefore, this literature review shall mainly

rely on the findings from the literature on the impact of competition on innovation.

Actually, as reviewed by De Bondt and Vandekerckhove (2012), the relationship between competition and investment is a long standing debate owing to the critical role of investment for economic growth. Two conflicting views reside at the core of this debate. On the one hand, the Schumpeterian view pioneered by Schumpeter (1942) points out the role of firm size, financial constraints and more specifically the incentive of the monopoly to invest more than a firm in a competitive market. This latter is driven by the *efficiency effect* as epitomized by the paper of Gilbert and Newbery (1982). On the other hand, the Arrow's view developed by Arrow (1962) emphasizes that the monopolist has less incentive to innovate due to what Tirole (1988) terms the *replacement effect*.

Several theoretical and empirical papers have been proposed to settle this debate. From the abundant theoretical literature, it turns out that the relationship between competition and investment can be of any type (Schmutzler, 2013). It actually depends on the theoretical parameterization of competition, the mode of competition and the nature of investment. This conclusion is strongly supported by the multitude and somehow contradictory empirical findings. For instance, using data of British firms, Blundell, Griffith, and Van Reenen (1999) found that larger firms innovate more; while firms in more concentrated markets innovate less. Likewise, Kraft (1989) found a negative relationship between the number of competitors and the percentage of sales attributable to new products, whereas Nickell (1996) identified a positive relationship between competition and innovation for British firms. In his paper, competition is measured by the number of competitors and the Lerner index, and innovation is measured by productivity and productivity growth of British firms.

In this unsettled debate, the path-breaking paper of Aghion, Bloom, Blundell, Griffith, and Howitt (2005) provided both a theoretical and empirical evidence of an inverted-U relationship between competition and innovation. In their paper, the measure of competition is based on the Lerner index and innovation is measured by the citations weighted patents counts of British firms between 1968 and 1997. The underlying mechanism of the inverted-U stems from the reconciliation between the escape-competition effect, corresponding to the Arrow's view, and the Schumpeterian effect whereby laggards firms have no incentive to invest due to a lower incremental profit from catching up with the leader. The Arrow's effect plays out at lower level of competition; whereas the Schumpeterian effect dominates above a certain level of competition; yielding an inverted-U relationship between competition and investment. The central force driving the inverted-U relationship is the techno-

logical gap between firms within each industry. These findings have been confirmed by several subsequent empirical papers ; though they emphasize their limitation in terms of causal identification.¹

Currently, there are two important issues that emerge from the literature. First, the lack of robustness in the theoretical results requires a focus on specific industries to identify the actual level of competition which maximizes investment. Second, the interaction between competition and the technological gap across firms play an important role in determining the impact of competition on investment. Both of these issues pose a great deal of challenges to the empirical identification of the nature of the relationship between competition and investment. To the best of our knowledge, there is so far no empirical paper tackling these two issues, probably due to the lack of the required data.

Indeed, most of the cross-industries studies are plagued with the unobserved difference in the presence of basic scientific knowledge (technological opportunities) across industries (Kamien and Schwartz, 1975). To the extent that technological opportunities drives both investment and competition, the empirical estimation of the relationship between competition and investment is biased by the difference in technological opportunities across industries. In addition, the need to focus on specific industries requires panel data on firms from a given industries across several countries. Although many firm level databases have been assembled very recently, they are still hardly accessible to researchers. When they are, the issues of unobserved efficiency and collusion, as well as the reverse causality running from investment to competition require additional information to implement a robust identification strategy.

In this study, we take advantage of the availability of firm level panel data on mobile network operators (MNO) and the specific role of spectrum policy in determining the intensity of competition to identify the causal impact of competition on investment. The empirical evidence is supported by a simple theoretical model that yields the inverted-U and suggest the level of technological progress as the main driver of this relationship.

¹See the special issue of the Journal of Industry, Competition and Trade for a list of papers.

3 Background, Dataset and Variables

This section presents the key features that makes the mobile telecommunications industry suitable for the identification of the relationship between competition and investment. It also describes the available information and the main variables that will be used throughout this paper.

3.1 Industry background: The role of spectrum policy and technological progress

There are mainly two features that make the mobile telecommunications industry suitable for identifying the causal impact of competition on investment. The first is the significant role of spectrum policy in determining the intensity of competition in the mobile telecommunications market. Indeed, electromagnetic spectrum is a key input for the provision of mobile telecommunications services. However, due to their properties in terms of coverage and propagation, the range of spectrum bands that can be used for communications purposes is limited. In addition, there is a risk of interference when similar or neighboring frequency bands are used for different communication purposes. As a result, the electromagnetic spectrum is managed by the government.²

So often, the governments release additional frequency bands according to their own assessment of the intensity of competition.³ Each frequency band is split into several spectrum licenses according to the number of network operators that the government is willing to accommodate in the market. Typically, the 2100 MHz frequency band can be split into four spectrum licenses in a market with initially three operators in order to allow the entry of a fourth operator, like in Europe for instance. Unlike the number of spectrum licenses, the number of frequency bands allocated by the government does not depends on the firms' behavior. It rather directly affects the intensity of competition in the market. As its allocation depends on the assessment of competition by the government, pro-competitive governments are much more

²At the global scale, the World Radiocommunication Conference (WRC) allocates the range of frequency to each region of the World. Thereafter, each country in a given region sets up a government agency which assigns the allocated frequency range to radio-navigation, maritime mobile, broadcasting and land mobile telecommunications.

³As of December 2012 at the global scale, the following frequency bands have been assigned to mobile network operators: 1500, 2100, 800, 1600, 1700, 1900, 2500, 2600, 1800, 2300, 3400, 3500, 410, 450, 700 and 850 MHz.

likely to release more frequency bands into the mobile telecommunication market at an earlier date.

Another reason why the governments may decide to grant additional frequency bands is to respond to the demand for larger bandwidth as new applications appear and require faster data transmission. This is currently the case in most of the developing countries where an increasing traffic over the internet is generated on mobile devices (Pepper, 2013). Frequency bands allocated under these circumstances can generate more competition in the market. As the demand for larger bandwidth is driven by technological progress, which can be viewed as exogenous at a country level, the number of frequency bands is an exogenous shifter of competition in the mobile market.

It turns out that competition in the mobile market is partly driven by the allocation of frequency bands by the governments because of their own assessment of competition and the rate of technological progress. This feature makes the number of frequency bands allocated before a given year a good instrumental variable for the intensity of competition in the mobile telecommunication market.⁴ In addition to the number of frequency bands, the spectrum management policy determines exogenously the exact year of entry of a firm into the market: network operators decide upon their entry into the market and the year of entry is determined by the government through the process of granting the spectrum license.

The second feature of the mobile telecommunications industry is the significant rate of technological progress which drives regular investment in the adoption of new technologies. Each year, equipment providers innovate and release new technologies of mobile telecommunications on the market. The new technology can be a radical change in the provision of telecommunications services or a mere improvement in the transmission of traffic over the network. Radical innovations commonly referred to as a new generations of network, are characterized by a shift in the speed or the protocol of data transmission. So far, there have been four overlapping generations of mobile telecommunications networks (Analog, 2G, 3G and 4G). The overall outcome is a continuous progression of performances.

As a result, mobile network operators need to invest regularly in order to update their network and keep in the race for technology adoption. In addition, innovations in the mobile ecosystem are strongly normalized allowing different network operators to invest in the adoption of the same technology. The investment takes the form

⁴The validity of the instrumental variable is presented in the result section.

of the purchase of new spectrum license or new equipment necessary to adapt the existing infrastructures to the new technology and also to subsidise new generations of devices adapted to the new network technology.

3.2 Dataset

We build a new dataset by aggregating information from several sources. The first source is the World Cellular Information Services (WCIS) database provided by *Infoma Telecom*. This database provides quarterly accounting information on mobile network operators worldwide. This information includes firms' revenue, profit and investment. We aggregate them over the year in order to avoid measurement errors.⁵ Within a market, information is not always available for all firms and over all years. Thus, we only select those firms and years for which full and consistent information on revenue, profit and investment are available.⁶

The dataset is complemented by information from the Wireless Intelligence online database. This information includes the launching years of commercial services based on a specific frequency band. Therefore, we are able to identify the year of entry of each firm into the market as well as the number of frequency bands released for mobile telecommunications services as of a given year. We also use the World Broadband Information Services database to identify mobile networks operators that also operate the fixed network. Additional information on the GDP per capita, population density and the size of the active population have been added to the dataset from the World Development Indicator online database managed by the World Bank.

The compilation of this information yields an unbalanced panel of 187 firms over ten years, from 2003 to 2012. These firms have been selected from 77 national markets covering all the regions of the World. The total number of observations is 940.

⁵Actually, most of the operators provide annual information but the managers of the database divide them by four as an estimate of the quarterly data.

⁶This selection may raise some issues about the sample selection bias if the determinants of a firm inclusion into the sample is jointly correlated to its investment and competition. Actually, the omission of a firm is generally due to missing observations about its investment. For most of the firms, we check that the average margin from the sample (39%) is closed to the estimated global average margin of 36.12% between 2003 and 2012 (GSMA, 2014). Hence, we do not consider the issue of sample selection.

3.3 Description of the Variables

The measure of competition is derived from the Lerner index of monopoly power. Its computation requires information on firms' revenue and operating profit. We use total revenue as a measure of firm's revenue. According to the methodology and definition guide accompanying the WCIS database, the total revenue is the sum of revenue generated through the provision of wireless communications services during a year and the revenue generated from the sales of mobile devices or other equipment sold by the operator during the year. The revenue from the provision of wireless communications services includes revenue from voice and data services over the mobile network, roaming charges, revenue from international direct dialing and interconnection revenue.⁷

The earnings before interest, tax, depreciation and amortization (EBITDA) is used as a measure of operating profit. It is the difference between total revenues and operating expenditures, excluding portions arising through tax, interest payment, depreciation and amortization of assets.

From these two variables we are able to derive a measure of competition intensity in the market based on the Lerner index of monopoly power. Hence, competition is broadly defined in this study as any market interactions that reduce the Lerner index. In the remaining of the paper, we will use the term "competition" as equivalent to the intensity of competition when there is no risk of confusion. If $Comp_i$ denotes the intensity of competition faced by the firm i , the following equation provides the formula for computing the intensity of competition:

$$Comp_i = 1 - \frac{Ebitda_i}{Revenue_i}$$

Regarding the investment, it is measured by the capital expenditures (CAPEX). They include the investment in the acquisition of tangible (fixed) assets and the investment in the maintenance of the existing tangible assets with a useful lifetime that extends beyond the taxable year. The investment as measured by the CAPEX does not include spectrum licences fees. Although the CAPEX can be affected by the accounting standards of each firm, capital expenditures as recorded in the financial report, is used in the economic literature as a reliable measure for investment

⁷Actually, the service revenue is a better measurement as it only includes revenue from the provision of access to the mobile network. However, it is not generally available and over the period of this study the revenue from the sales of mobile devices typically accounts for less than 1 percent of the total revenue.

(Grajek and Roller, 2012). In order to smooth out the scale and the large variation in investment across firms and years, we use the natural logarithm of investment throughout the remaining of the paper.

Consistently with the discussion on the role of spectrum policy and technological progress, two variables have been used as the main instruments of competition; namely the number of frequency bands allocated to mobile communications services and the year of entry into the market. In order to avoid the possibility that some frequency bands might be granted as a response to low investment we use the number of frequency bands allocated before 2005 (excluded) as the exact definition of the first instrument. As such, the spectrum policy is determined before competition and investment take place. Similarly we will restrict the sample to firms that enter the market before 2003 in order to avoid accounting for endogenous entry into the market. The lagged variable of competition, as well as the incumbency of the firm will also be used as complementary instruments for competition.

Firms' characteristics such as market share, the operation of the fixed network have been used to ensure comparability across firms. The operation of the fixed network is represented by a dummy variable indicating whether or not a mobile network operator also operates a fixed network.

Investment and competition in the mobile telecommunications industry can be affected by production cost and demand parameters. For instance, investment and competition may be stronger in more developed countries where the demand for telecommunications services is larger. Similarly, more investment is needed in those markets with larger size. We use the GDP per capita, regional dummies and the size of the active population as demand shifters. Each regional dummy represents a given region of the World (Africa and Middle East, Western Europe, Eastern Europe, Asia-Pacific, Latin America and North America). Population density is used as a cost shifter.

The panel structure of the sample implies that market dynamics such as entry, merger and exit can occur between 2003 and 2012. These dynamics are likely to affect both the intensity of competition and the level of investment. For each type of market dynamics, we build a dummy variable taking the value 1 when it occurs at a given year on the market.

3.4 Descriptive statistics

Table 1 in appendix presents the summary statistics of these variables. Competition varies between 1 and 97 percent, corresponding to a range from 99 to 3 percent of profit margin (Lerner index). The logarithm of investment is spread between 0.46 and 9.9 with an average of 5.24; corresponding to 188.7 millions of US dollars. This suggests that the yearly investment by mobile network operators is large. Although the firms have been selected according to the availability of data, figures 2 and 3 in appendix shows that the Kernel density graph of competition and investment are almost normal. In addition, the sample is made of 35 incumbent fixed network operators out of 187 firms, representing 19 percent of the sample of mobile network operators.

Regarding the allocation of frequency bands, information is missing for one country in our sample (Kosovo). According to table 1, between 1 and 6 frequency bands were allocated to MNO before 2005; with an average of 2.6 frequency bands. Until 2012, figure 4 shows that there have been several waves of frequency bands allocation, corresponding to the emergence of a new generation of mobile network. Three waves stand out from this figure. The first two waves span over the period 1981 and 2005, corresponding to the upper limit defining our instrument. The third wave occurs between 2006 and 2012.

In terms of market dynamics, figure 5 shows that most of the entries occur before 2003. More specifically; there were 162 MNOs that entered into the market before 2003 in the countries selected into the sample. Between 2003 and 2012, 181 additional MNOs entered the market; but we only observe 25 of them. The remaining were not observed because of missing values particularly on their investment. Most of the entries occur in Brazil, Canada, Nigeria and Ukraine; particularly in 2003, 2007 and 2008. There were 58 mergers, typically in Brazil in 2006. Only 8 exits occur particularly in 2011 and 2012. These dynamics generally concerns small firms at the regional level within a country. Typically, there were many entries at the regional level in Brazil followed by several mergers of these regional mobile network operators afterwards. Therefore, we do not expect that in our sample, the specific events related to market dynamics (entry, merger, exit) would have any significant impact on our empirical analysis.

Table 2 in appendix presents the pair-wise correlation between the variables. These correlations were computed on the pooled sample of 940 observations. Several interesting insights stand out from this table. First, there is no significant correlation

between competition and investment. Second, firms in richer countries face more competition and invest more than firms in poorer countries. This correlation suggests that demand parameters such as the willingness to pay play an important role in the relationship between competition and investment. Third, firms in larger markets invest more; but do not face a significantly different intensity of competition than firms in smaller markets. Hence, market size will improve the precision of the relationship between competition and investment without affecting the point estimates of competition. Fourth, incumbent fixed network operators enter earlier, undertake more investment, has higher level of the Lerner index and operate in richer countries that released more frequency bands. Given the correlation between the firm incumbency status and the main instruments, it cannot be used as an additional instrument in order to check the robustness of the results.

4 Empirical Evidence

Before going into the econometric modeling, we first provides a preview of the non-parametric relationship between competition and investment. Figure 6 presents the scatter plot of the measure of competition and the logarithm of investment. To the extent that the descriptive statistics suggest no linear correlation between competition and investment, we directly examine a quadratic fit. Overall, it turns out that there is an inverted-U relationship between competition and investment.

However, there are several identification issues that preclude us from drawing any causal conclusion from this figure. First, as suggested by the descriptive statistics, this relationship omits some variables that are jointly correlated with investment and competition. Among these omitted variables, some of them are observables or can be proxied by exogenous variables. Specifically, the market size and production cost can be proxied by the size of active population and population density respectively. Others are unobservable; namely unobserved efficiency across firms, unobserved collusion and willingness-to-pay across markets. Second, there may be a reverse causality running from investment to competition. For instance investment can be undertaken as barrier to entry. A third identification issue is related to extreme values which could drive the tails of the quadratic fit. The following empirical model and the identification strategy are designed to deal with these issues in order to uncover the causal relationship between competition and investment.

4.1 Empirical model and identification strategy

From a theoretical perspective, the equilibrium investment should be a function of some parameters characterizing competition, demand, and production cost: $Y = f(\theta, D, C)$.⁸ In order to fit this equilibrium investment with the data, we need to account for some control variables X such that the equilibrium investment writes: $Y = f(\theta, D, C, X)$.

The first parametric assumption is about the functional form of f . As suggested by the preliminary results, we assume that f can be written as a quadratic function of competition and linear in the other variables. Hence, the general statistical model to be estimated writes:

$$Y_{it} = \alpha + \beta_1 \theta_{it} + \beta_2 \theta_{it}^2 + \gamma X_{it} + \delta D_t + C_{it} + \epsilon_{it} \quad (1)$$

Where the subscripts i and t describes firm and year respectively. Y_{it} stands for the investment of firm i at year t , θ_{it} is a measure of competition faced by firm i at year t . X_{it} is a set of control variables including time dummies. Countries specific effects are not included because there are few variations within country. Their inclusion would deteriorate the precision of the point estimates.⁹ D_t is the demand shifter, typically the willingness-to-pay which is unobservable and will be proxied by regions specific effects assuming constant preferences over time. C_{it} is the cost parameter. It can be decomposed into a firm specific effect capturing the unobserved efficiency across firms and a common, market-based, component capturing the cost of deploying the network. This latter is proxied by the population density.

We first choose the appropriate model by identifying the relevant observable controls, excluding the extreme values and controlling for market dynamics. The relevant observable variables are identified by their statistical significance in the regression. Following the shape of the density function of competition as presented in figure 2, we build a confidence interval for the competition variable. This confidence interval

⁸We do not consider the type of game that is played on the market, neither do we specify any equilibrium concept. This expression tells what should be expected in general from any theoretical model relating competition to investment. By doing so we are able to identify the key determinants of investment on top of competition.

⁹The inclusion of all the countries fixed-effects into the model removes the competition variable from the regression outcomes, confirming the little within-country variation in the data. When we include a subset of the country fixed-effects into the model, the intermediate level of competition that maximizes investment varies between 57 percent and 62 percent. This interval accords well with the confidence interval found in the main estimation results.

is built as the median of competition plus/minus twice the standard deviation as computed from the sample. Observations for which the intensity of competition is outside this interval are deemed extreme values. The dummy variables *Entry*, *Merger*, and *Exit* are used as controls for market dynamics. Of course, these variables are not exogenous with respect to competition and investment. Their coefficients cannot be interpreted as causal effects of market dynamics on investment.

Second, we identify the causal impact of competition on investment by implementing an instrumental variable approach based on the Generalized Method of Moment (GMM) estimation (Hansen, 1982). In the empirical model, the endogenous variables are competition and its square. We therefore need at least two instruments to identify the causal impact of competition on investment. As presented in the section on the industry background, the spectrum policy is a strong and exogenous predictor of competition in the market. The identification strategy relies on the fact that some governments might be more pro-competitive than others and release more frequency bands earlier. They shall also grant the spectrum license at a date that does not depend on market conditions, but will affect the intensity of competition faced by the entering firm.

The exogeneity of the instruments can be jeopardized by government reaction to the level of competition and investment in the market. To ensure the exogeneity, we use the number of frequency bands assigned to the mobile network operators before 2005. We expect that the more frequency bands assigned before 2005, the stronger the intensity of competition faced by firms in the market between 2003 and 2012.¹⁰ The year of entry of a firm into the market is chosen for firms that enter before 2003. This date is determined by the government such that the later a firm enters into the market, the more intense competition it faces. Figure 7 depicts the causal chain running from the instruments to competition and then to investment.

While the instruments are exogenous, they may be weak; meaning that they do not capture a significant part of exogeneity from the competition variables. The weakness of the instruments can be strengthened by the fact that both of them are strongly correlated. As shown in table 2, firms generally enter earlier in those countries that release more frequency bands before 2005. We implement the weak instruments test using the instrumental variables stata routine proposed by Baum, Schaffer, and Stillman (2007). The Kelibergen-Paap Wald rank F-statistics are compared to the critical values tabulated by Stock and Yogo (2002) to test the weakness

¹⁰The results are robust to restricting the sample to observations between 2005 and 2012 at the cost of losing little precision.

of the instruments. In addition, this Stata routine allows controlling for heteroskedasticity and serial correlation.

The GMM estimation yields efficient estimates of β_1 and β_2 , that are robust to heteroskedasticity and serial correlation. The quadratic model is validated over the data when these two coefficients are significantly positive and negative respectively. In that case, the optimal level of competition that maximizes investment is estimated as:

$$\hat{\theta} = -\frac{\beta_1}{2\beta_2} \quad (2)$$

The confidence interval of this threshold is estimated using the delta method. An estimation algorithm is developed in Stata by Hole (2007).

4.2 Results

Table 3 presents the estimation results leading to the selection of the appropriate model. The first three columns show the result of OLS estimation. The estimation of a simple linear model yields no statistically significant relationship between competition and investment. Column (2) thus estimates a quadratic model controlling for year and regions fixed effects. Only the quadratic term is significant at 10%; suggesting an inverted-U relationship between competition and investment with an optimal level of competition at 62 percent. The point estimates of competition (β_1 and β_2) in this quadratic model are more precisely estimated when controlling for population density, population size and firm's status (incumbent FNO) in column (3). The inverted-U relationship is still confirmed but the optimal level of competition falls down to 57 percent, probably due to the fact that both competition and investment are higher in larger markets (See table 2). The lack of significance of population density and firm's status is because they are correlated and the population density is also correlated with the market size. Hence, the logarithm of active population, as a proxy for market size, is a better control for the regression between investment and competition than population density and firm's status.

While these results might be plagued with endogeneity issues, the next three columns show the results from the instrumental variable GMM estimation. Using the number of frequency bands and the year of entry into the market as instruments for both competition and its square, the outcome of the IV regression in column (4) validates

the inverted-U relationship between competition and investment.¹¹ However, the slopes of both sides of the inverted-U shaped curve are steeper; suggesting that the impact of competition on investment was underestimated by the OLS estimation. Consequently, the optimal level of competition was also underestimated by the OLS regression. It rises from 57 to 60 percent, and is more precisely estimated. The exclusion of extreme values from the sample in column (5) yields more precise estimates of the coefficients of the regression. It also increases the steepness of the relationship between competition and investment. To improve the definition of the second instrument (year of entry into the market), column (6) restricts the sample to firms that enter into the market before 2003 and includes market dynamics variables into the model. It turns out that the inverted-U relationship is still validated. However, its steepness is lower, and the optimal level of competition is slightly higher, up to 63 percent. The precision of the estimates decreases probably due to the fall in the sample size. None of the market dynamics variables is significant. In addition, these variables are potentially endogenous, as entry, merger or exit may occur according to determinants of the intensity of competition. Note that the years fixed effects are not significant in any of the regressions.

As a result, the appropriate model only controls for the market size (size of active population) and regions fixed effects. It is similar to the model estimated in specification (6) of table 3; but without the variables which are not significant. Its estimation relies on the sample of firms that enter into the market before 2003, excluding extreme values. The first column of table 4 presents the estimation results of this model. This model corrects for heteroskedasticity in the residuals as well as autocorrelation of order 1. The results of this estimation confirm an inverted-U relationship between competition and investment. The optimal level of competition is between 58 and 66 percent with an average level of 62 percent. The first stage regression in table 6 shows that the instruments have the good signs and significantly explain the intensity of competition. More specifically, an additional frequency bands is predicted to increase the intensity of competition by 2 percentage points, while a firm that enters 10 years later faces an intensity of competition which is 1 percentage point higher than its rivals. These results are confirmed by the underidentification test as shown in table 4. In addition, the Kleibergen-Paap's test rejects the null hypothesis of weak instruments, as the value of the F-Statistics (8.1) is higher than the critical value of 7.03 from the table provided by Stock and Yogo (2002). In addition, the F-statistics of the first stage are 15.46 and 15.53 re-

¹¹The missing observations on the number of frequency bands allocated in Kosovo explains the drop in the number of observations from 940 to 937.

spectively for competition and its square, well above the rule of thumbs value (10). Therefore, the point estimates of the model can be interpreted as the causal impact of competition on investment.

We provide complementary results on the relationship between competition and revenue, investment and revenue, as well as the impact of competition on the intensive investment; that is, the ratio of investment over revenue. The results from the second column of table 4 yields an inverted-U relationship between competition and revenue. This relationship is much steeper than the one between competition and investment. In addition, the optimal level of competition for maximal revenue is slightly higher than the optimal level for maximal investment (63 percent). However, we do not know whether or not this difference is significant. The OLS estimation of a linear relationship between revenue and investment is highly significant, suggesting that a 1 percent increase in investment is associated with 0.9 percent increase in revenue. Contrary to the relationship between competition and the extensive investment, the relationship between competition and the intensive investment, defined as the ratio of investment over revenue, is rather an U-Shaped. The minimal level of intensive investment is reached at 62 percent of intensity of competition, very close to the optimal level of competition for maximal extensive investment.

Actually, the U-shaped relationship between competition and intensive investment stems from the high correlation between investment and revenue. Their inverted-U shaped curves have almost the same maximum, close to 62 percent. As the revenue's curve is steeper than the investment's one, the resulting curve of intensive investment is decreasing on the left-hand side and increasing on the right-hand side. Hence the minimum of the intensive investment curve is also close to 62 percent. In short, for lowest or highest intensity of competition, investment is low, but revenue is also low such that intensive investment turns out to be high. For an intermediate intensity of competition, close to the maximum of inverted-U curves, investment is high but revenue is higher and, as a result, intensive investment turns out to be low.

4.3 Robustness Checks

In order to check the robustness of the main results, we implement a non-parametric estimation of the relationship between competition and investment. We also check the outcome of the model under alternative instruments.

4.3.1 Non-parametric estimation of the relationship between competition and investment

Generally, the quadratic fit does not necessarily reflect the actual relationship in the data. This is because the parametric estimation assumes beforehand a quadratic relationship. On the contrary, a non-parametric estimation can reveal the actual relationship between competition and investment as suggested by the data. We use two non-parametric methods, namely the local polynomial smoothing (Lpoly) and the locally weighted scatter plot smoothing (Lowess). The Lpoly method approximates each data point by a polynomial function of the neighboring points weighted accordingly by a given kernel function. The lowess method implements a weighted linear regression on data from the neighborhood of each data point. Then, the actual observation is replaced by the predicted value of this regression. It uses a tricube function as the weighting function. Both methods should yield similar results; but the lowess generally best accounts for the slope of the overall curve at the neighborhood of each point than the local polynomial smoothing at the cost of introducing some parametric modeling into the approach through the use of local OLS regression.

Given the significance of the size of the market as a determinant of investment, we first partial out the effect of market size from the logarithm of investment and competition. This is done by using the residuals from the OLS regression of both variables on the size of the active population. The non-parametric estimation of the relationship relies on these residuals. The outcomes of these non-parametric methods are presented on figures 8 and 9. They show that the inverted-U relationship, as identified from the parametric estimation, is consistent with the actual relationship in the data. Moreover, the optimal level of competition is around 62 percent which is very close to the one obtained from the parametric estimation. However, the slopes of the curves are flatter; probably due to the endogeneity biases stemming from unobserved efficiency across firms, unobserved collusion and reverse causality which are still present in the non-parametric estimation.

4.3.2 Exogeneity and power of the instruments

The overlapping between the instrument "number of frequency bands allocated before 2005" and the period of observation might cast some doubt on the exogeneity of this instrument. This lack of exogeneity may bias the impact of competition on investment due to policy reaction to the level of investment and competition in the

market. Thus we restrict the sample to observations from 2005 to 2012. The results in column (1) of table 5 suggest that the optimal level of competition is not much affected. It falls by 2 percentage points, down to 60 percent. However, the point estimates of the competition variables increases, suggesting a steeper curve than what we obtain for the full sample (2003-2012).

Another concern is about the power of the instrument which might be affected by the heterogeneity in willingness to pay across countries. For instance, consumers in richer countries typically have higher willingness to pay for communications services. These countries might experience fiercer competition and release more frequency bands earlier than poorer ones. Thus the inclusion of a measure of willingness to pay, the GDP per capita for instance, can weaken the power of the instrument. This concern is somehow supported by the first stage estimation result in column FS(2) of table 6. The number of frequency bands is no longer a significant predictor of the intensity of competition, when we control for GDP per capita. However, the point estimate of GDP per capita is not significant in the IV estimation results in column (2) of table 5. Actually, the GDP per capita is by itself an endogenous variable which should not be included in the regression. The inclusion of the region fixed effects, which differ in terms of their level of GDP per capita, is a better proxy for the heterogeneity in willingness to pay, and it is indeed exogenous with respect to investment and competition.

4.3.3 Alternative instruments

We also consider alternative instruments such as the lagged variable of competition and the firm incumbency status. Typically, the current level of competition is explained by the previous year level of competition; but current level of investment is not determined by the previous year intensity of competition. However, this instrument may fail to be exogenous if the current level of investment is determined by the intensity of competition of the previous years.

Likewise, the control of the fixed network may confer a competitive advantage to a mobile network operator and therefore determine the intensity of competition it faces. Meanwhile, since the incumbency is determined by history, it is not correlated with any other determinants of investment. It can therefore be used as a valid instrument for competition along with the year of entry into the market. The interest in testing these two instruments is that they accommodate well the inclusion of the GDP per capita as a control variable into the regression.

Columns (3) and (4) of table 5 present the results of the estimation replacing the number of frequency bands released before 2005 by the lagged variable of competition and the firm incumbency status respectively. Both regressions yield an optimal level of competition very similar to the one obtained from the main regression, 58 and 59 percent respectively. However, the point estimates of the competition variables are smaller; suggesting an overestimation of the impact of competition on investment from the main regression. Yet, the exogeneity of the lagged of competition as an instrumental variable can be questioned though it is not a weak instrument according to the statistical tests. To the extent that investment is serially correlated, previous year level of competition should affect the current level of investment irrespective of the current level of competition. Hence, the presence of time dependence in the investment invalidates the exogeneity of the lagged variable of competition as an instrument. Regarding the incumbency status, the results in column FS(4) of table 6 show that it has the good sign. Its exogeneity is not questioned; but rather it is a weak instrument as confirmed by the Kleibergen-Paap test in column (4) of table 5.

5 A theoretical model to explain the inverted-U shaped

In this section, we present a simple theoretical model to show the role of the potential for technological progress in driving the inverted U shaped relationship between competition and investment. This potential for technical progress is not a parameter of the econometric model that we have tested because our dataset only consider the mobile market where all firms have roughly access to the same technologies. As a result, there is not enough difference between firms or countries to test it as one of the underlying mechanism of the inverted-U. However, technological progress is particularly high in mobile telecommunication sector. Koh and Magee (2006b) found a 20 to 30 percent rate of technological progress for information technologies for more than a century. This is far above most of other sectors like energy where technological progress is close to 6 percent, and far above the rate of global productivity growth often under 5 percent. This is probably one of the reasons why the relationship between competition and investment is inverted U-shaped in mobile telecommunication industry.

In the literature, the main model rationalizing the inverted-U is the one provided

by Aghion, Bloom, Blundell, Griffith, and Howitt (2005) (ABBGH). This model does not help explaining our empirical evidence as it is derived from an endogenous growth model. It is therefore a general equilibrium model in which the main feature driving the inverted-U is the technological gap between firms within the industries. In addition, when the technology is normalized and available to all firms within an industry, there is hardly a technological gap between them.

This model encloses both the escape-competition and the Schumpeterian effects like in the ABBGH's model. However, while the modeling of the escape competition effect is alike, the Schumpeterian effect, which decreases the incentive to invest with the intensity of competition, is modeled as a reduction in the duration over which a first mover enjoys its investment. This is not the same as in the ABBGH model, whereby the Schumpeterian effect is driven by the technological gap. By doing so, we are able to emphasize the technological progress as the main driver of the inverted-U relationship within an industry.

5.1 Settings of the model

Consider a symmetric Bertrand duopoly with differentiated goods, produced at constant marginal cost c . The differentiation parameter $\theta \in [0, 1]$ stands for the intensity of competition. When $\theta = 0$ the goods are independent and each firm enjoys a monopoly over its product. When $\theta = 1$ goods are perfect substitutes, in which case the Bertrand competition yields the perfect competition outcome. Typically, an increase in θ implies a rise in competition.

We consider an infinite horizon over which innovation occurs once. This horizon is split into three periods during which firms first invest and then compete in the product market.

Period 0: Symmetric market

During this period there is no innovation and both firms incur the marginal cost \bar{c} and earn the duopoly profit $\pi^d(\bar{c}; \theta)$.

Period 1: Innovation and the first mover's investment

At the beginning of period 1, an exogenous innovation occurs; providing a new technology which is available to both firms. The cost of this technology is decreasing over time and investment in the new technology reduces the marginal cost of production from \bar{c} to \underline{c} , with $\bar{c} > \underline{c}$.

Given the innovation, one of the firms invest in the new technology; this is the first-mover. Then, they both compete in price to supply the differentiated good until the end of this period.

During this period, the reduced form of the profit of the first mover writes: $\pi^1(\underline{c}; \theta)$ and the profit of the second firm writes $\pi^1(\bar{c}; \theta)$. As such, the intensity of competition is not affected by the investment in the new technology.

Period 2: The follower's investment

The second firm, the follower, invests in the new technology at the beginning of period 2. As a result, both firms now incur the marginal cost \underline{c} and earn the duopoly profit $\pi^d(\underline{c}; \theta)$.

The lag between periods 1 and 2 represents the reaction time of the follower to the investment of the leader. This duration is denoted T and assumed to be exogenous. We assume that the more the products are substitutes, the quicker the reaction of the follower; that is, T is a decreasing function of θ : $T'(\theta) < 0$. In particular, T tends to infinity when θ tends to zero.

Note that the settings of the model accord well with the investment and competition in the mobile telecommunications industry.

Now that the settings of the model are in place, our goal is to show how the potential for technological progress, measured by the impact of the innovation on marginal cost of production and denoted $\tau = \bar{c} - \underline{c}$, affects the relationship between investment and the intensity of competition. More specifically, we first determine the nature of the relationship between the intensity of competition and investment by relying on the incentive to invest in the new technology. This incentive is characterized by the additional flow of profit generated by investment over the whole period. Then, we study how the relationship is affected by the potential for technological progress τ .

Let's f and g denote this instantaneous and constant additional flow of profit over the first and second periods respectively:¹²

$$f(\theta) = \pi^1(\underline{c}, \theta) - \pi^d(\bar{c}, \theta) \text{ and } g(\theta) = \pi^d(\underline{c}, \theta) - \pi^d(\bar{c}, \theta)$$

$f(\theta)$ and $g(\theta)$ are respectively increasing and decreasing function of θ .

¹²The expression of the instantaneous profit over the second period stems from the fact that the duration $T(\theta)$ is exogenously determined by the intensity of competition. Should the timing of investment chosen by firm, then $g(\theta) = \pi^d(\underline{c}, \theta) - \pi^1(\underline{c}, \theta)$.

The total incremental flow of profit generated by investment by the first mover writes:

$$V(\theta) = \int_0^T e^{-rt} f(\theta) dt + \int_T^\infty e^{-rt} g(\theta) dt$$

This is equivalent to:

$$V(\theta) = \frac{1}{r} [\phi(\theta) f(\theta) + (1 - \phi(\theta)) g(\theta)]$$

With r , the discount rate and $\phi(\theta) = 1 - e^{-rT(\theta)}$.

Although we do not know the explicit expression of $V(\theta)$, we are able to derive the shape of its curve by studying the sign of its derivative at the extreme of the intensity of competition. This derivative writes:

$$\frac{\partial V}{\partial \theta} = \frac{1}{r} \left[\frac{\partial \phi}{\partial \theta} (f(\theta) - g(\theta)) + (1 - \phi(\theta)) \frac{\partial g}{\partial \theta} + \phi(\theta) \frac{\partial f}{\partial \theta} \right] \quad (3)$$

5.2 The inverted-U and the role of the potential for technological progress

Given that $T(\theta)$ is decreasing, so is the derivative of $\phi(\theta)$: $\frac{\partial \phi}{\partial \theta} < 0$. In addition, $f(\theta) - g(\theta) \geq 0$ because the efficient duopolist's profit is higher than the profit of the symmetric duopoly. Therefore, the first term within the bracket is negative; that is $\frac{\partial \phi}{\partial \theta} (f(\theta) - g(\theta)) \leq 0$.

Moreover, given that $f'(\theta) \geq 0$, $g'(\theta) \leq 0$ and $0 \leq \phi(\theta) \leq 1$, we have that $(1 - \phi(\theta)) \frac{\partial g}{\partial \theta} \leq 0$ and $\phi(\theta) \frac{\partial f}{\partial \theta} \geq 0$.

The sign of the derivative of $V(\theta)$ at the extreme of the intensity of competition turns out as follow;

■ When $\theta = 0$, the products are independent and both firms are monopolists in each product's market. In this case, $f(0) = g(0)$ and $\phi(0) = 1$. As a result, $\frac{\partial V}{\partial \theta} = \frac{1}{r} \frac{\partial f}{\partial \theta} > 0$. The derivative of the incentive to invest is positive when the market is monopolistic.

■ When $\theta = 1$, the positive term in the brackets of equation (3) is lower than the negative terms and $\frac{dV}{d\theta} < 0$, only if $\phi(1)$ is sufficiently small. This condition

means that the duration of the first mover's advantage is sufficiently small under perfect competition. Under this condition, the derivative of the incentive to invest is negative at the perfect competition.

It turns out from these two results that $V(\theta)$ is locally increasing at $\theta = 0$ and locally decreasing at $\theta = 1$, when $\phi(1)$ is sufficiently small. Therefore, there can be a value θ^* in the interval $[0,1]$ that maximizes $V(\theta)$ and therefore an inverted-U relationship between competition and investment can arise. Otherwise, if $\phi(1)$ is large, the positive term can be higher than the negative ones and $\frac{\partial V}{\partial \theta} > 0$. In that case, investment is maximized under perfect competition.

A first note from this result is that the duration of the first mover's advantage under perfect competition determine whether or not relationship between competition and investment is inverted-U. Indeed, this duration is a decreasing function of the potential for technological progress τ . Hence, the potential for technological progress decreases the incentive to invest because of a lower duration of the first mover advantage under high intensity of competition. This effect is similar to the Schumpeterian effect. On top of this effect, we can observe that the difference $f(\theta) - g(\theta)$ represents the magnitude of the first mover advantage. It is an increasing function of the potential for technological progress τ . This is the escape-competition effect.

The Schumpeterian effect tends to reduce the positive term of equation (3); whereas the escape-competition effect tends to raise the negative ones. As a result, the larger the potential for technological progress, the more likely is the inverted-U. This is precisely because the first mover enjoys higher rent from investing; but over a smaller period.

5.3 An illustration with the Singh and Vives' demand function

The inverse demand function of firm i writes: $p_i = 1 - \frac{1}{1+\theta}q_i - \frac{\theta}{1+\theta}q_j$, where $0 \leq \theta \leq 1$ (See(Singh and Vives, 1984)). If c_i and c_j denote respectively the constant marginal cost of production of firm i and j , the Nash-equilibrium of the Bertrand competition with differentiated products yields:

$$p_i(\theta) = \frac{(2 - \theta^2) + 2 * c_i - \theta(1 - c_j)}{(2 - \theta)(2 + \theta)}$$

$$\pi_i(\theta) = \frac{[(2 - \theta^2)(1 - c_i) - \theta(1 - c_j)]^2}{(4 - \theta^2)^2(1 - \theta)}$$

Before investment in the new technology, the market is symmetric and both firms incur the marginal cost \bar{c} and earn the profit:

$$\pi^d(\bar{c}, \theta) = \frac{(1 - \theta)(1 - \bar{c})^2}{(2 - \theta)^2}$$

The first-mover invest in the new technology and decreases its cost from \bar{c} to \underline{c} and earns the asymmetric profit which writes:

$$\pi_i^1(\underline{c}, \theta) = \frac{[(2 - \theta^2)(1 - \underline{c}) - \theta(1 - \bar{c})]^2}{(4 - \theta^2)^2(1 - \theta)}$$

At date T, the follower reacts and the market becomes symmetrical again. Then, each firm incurs the cost \underline{c} and earns the symmetric profit:

$$\pi^d(\bar{c}, \theta) = \frac{(1 - \theta)(1 - \underline{c})^2}{(2 - \theta)^2}$$

The instantaneous profits before and after the reaction of the follower writes:

$$f(\theta) = \frac{(2(1 - \bar{c})\tau + \tau^2)(2 - \theta^2)^2 - 2\theta(2 - \theta^2)(1 - \bar{c})\tau}{(4 - \theta^2)^2(1 - \theta)}$$

$$g(\theta) = \frac{(1 - \theta)(2(1 - \bar{c})\tau + \tau^2)}{(2 - \theta)^2}$$

We choose an arbitrary duration of the $\phi(\theta) = 1 - \lambda\theta$, with $0 \leq \lambda \leq 1$. This function is decreasing in the intensity of competition θ and yields the required properties for the reaction time $T(\theta)$.¹³

The graphical illustration of the relationship between competition and investment based on this model is presented below:

¹³Theoretically, $\phi(\theta) = 1 - e^{-rT(\theta)}$. Thus, the corresponding reaction time is $T(\theta) = -\frac{\ln(\lambda\theta)}{r}$ and it is decreasing in the intensity of competition.

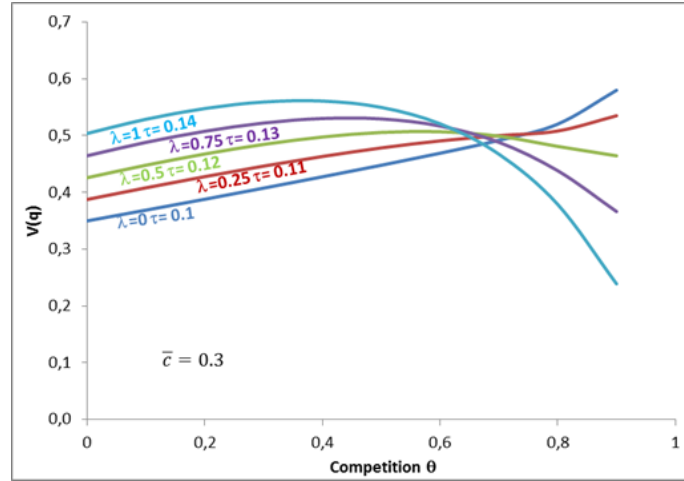


Figure 1: Competition and investment using Singh and Vives' demand function

6 Conclusion

This paper uses firm level panel data and an instrumental variable estimation to identify the causal relationship between competition and investment in the mobile telecommunications industry. The intermediate level of competition which maximizes investment stands at 62 percent, corresponding to 38 percent of profit margin. With a probability of 95 percent, the intermediate level of competition lies between 58 and 66 percent. This result is robust to the functional specification of the relationship between competition and investment. It is also robust with respect to the difference in willingness to pay across markets, market dynamics such as entry, merger and exit, extreme values, and alternative instruments.

To explain this result, we derive a simple model that embeds both the escape competition effect and the Schumpeterian effect. Provided that the level of technical progress is high enough, this model yields an inverted-U relationship between competition and investment, consistently with the empirical findings. That is, at low level of competition, the escape competition effect dominates over the Schumpeterian effect. However, above certain intermediate level of competition, the escape competition effect is overtaken by the Schumpeterian because of the smaller duration over which any first mover enjoys the monopoly rent generated by investment. One of the key features of this model is the fact that the inversion of the curve depends on the intensity of the technological progress. The model implies that the investment maximizing intermediate level of competition is higher in industries with lower rate of technological progress. Therefore, the significance of technological progress in the mobile telecommunications industry, as found in the literature, is at the root of the inverted-U. Otherwise, a strictly increasing relationship would be more likely to emerge.

While this explanation relies on a theoretical model, a further research would be to assess the investment maximizing intermediate level of competition across several industries with different rate of technological progress. This type of research would help to confirm the technological progress as one of the main determinant of the intermediate level of competition that maximizes investment. Additional researches includes the role of market and technological leadership in influencing the relationship between competition and investment. Finally, it would be interesting to distinguish between investment in network coverage and investment in quality improving technologies.

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A Appendix

A.1 Descriptive and Summary Statistics

	Obs.	Mean/Share	Std. Dev.	Min	Max
Competition (1-L)	940	0.61	0.13	0.01	0.97
Log(investment)	940	5.24	1.48	0.46	9.90
Incumbent FNO	187	0.19		0	1
# frequency bands	76	2.66	1.10	1	6
Year of entry	187	1996.46	5.73	1979	2009
Log(GDP/capita)	770	8.69	1.50	5.34	11.12
Log(density)	770	4.24	1.21	0.95	8.83
Log(active pop.)	770	16.20	1.41	12.93	20.71

Incumbent is a dummy variable referring to the incumbent fixed network operator. # frequency bands refers to the number of frequency bands released before 2005.

Table 1: Summary statistics

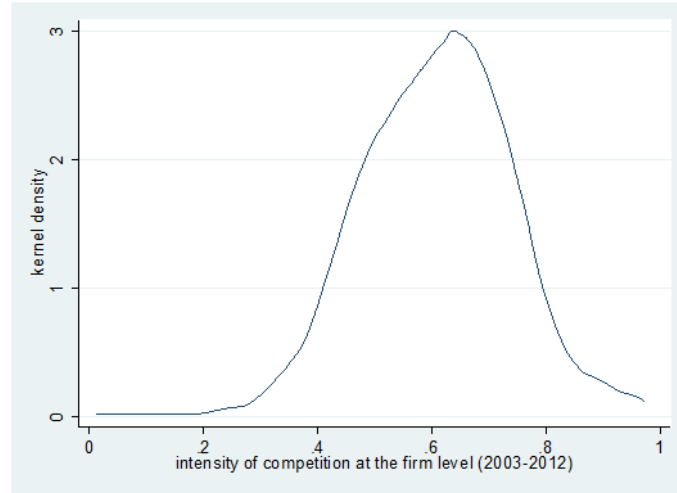


Figure 2: Kernel density of the intensity of competition at the firm level for the pooled data

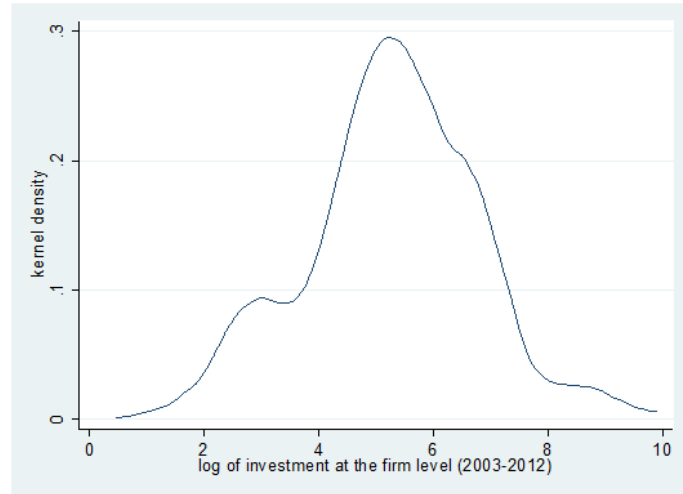


Figure 3: Kernel density of the log of investment at the firm level for the pooled data

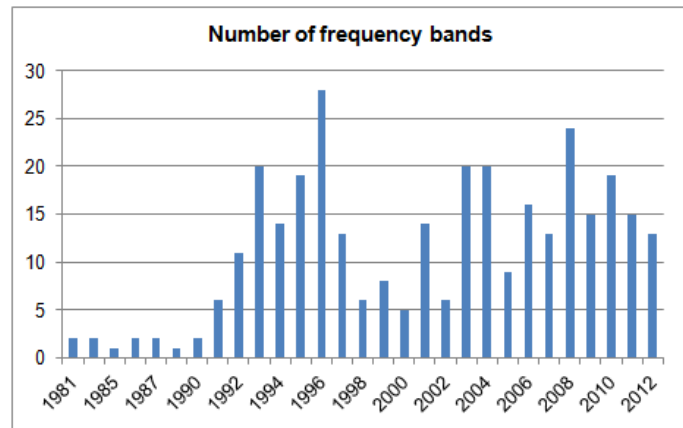


Figure 4: Number of frequency bands released for mobile communications services

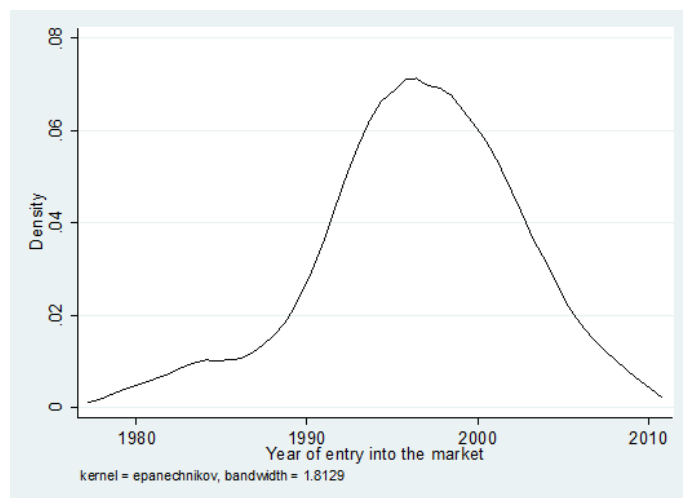


Figure 5: Kernel density of the years of entry into the market

	Log(invest)	competition (1-L)	# frequency bands	Year of entry	Log (GDP/capita)	Log(density)	Log(active pop.)
Log(investment)	1						
competition (1-L)	0.02	1					
# frequency bands	0.14*	0.20*	1				
Year of entry	-0.22*	-0.01	-0.33*	1			
Log(GDP/capita)	0.23*	0.35*	0.52*	-0.39*	1		
Log(density)	0.15*	0.02	0.16*	-0.15*	0.15*	1	
Log(active pop.)	0.78*	0.02	0.02	0.01	-0.08*	0.11*	1
Incumbent FNO	0.41*	-0.04*	0.18*	-4.36*	0.39*	-0.27*	0.08
Entry	0.04	-0.02*	-0.02	-0.26	-0.32*	-0.12	0.16
Merger	-1.09	-0.03	-0.01	0.44	0.03	-0.25	0.43
Exit	0.18	0.05	0.12	1.41	-0.09	-0.33	-0.80

Significant at 1% (*). For the dummy variables 'Incumbent, Entry, Merger, Exit' the table reports the difference in mean of the column variable. For instance, on average, the incumbent FNO invest more than the non-incumbent, the difference in investment (0.41) is significant at 1%.

Table 2: Par-wise correlation table

A.2 Preview of results and identification strategy

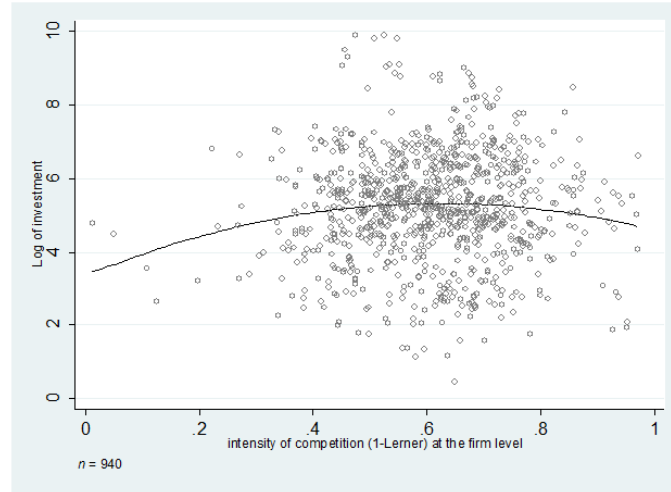


Figure 6: Competition and Investment

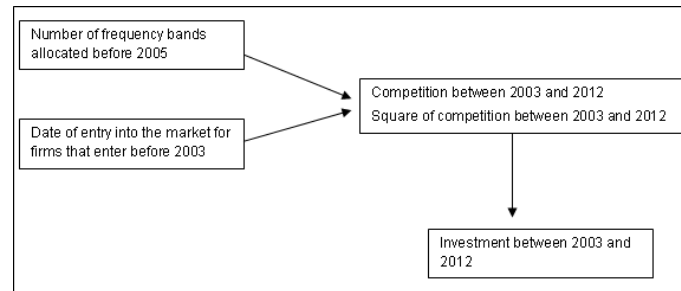


Figure 7: Causal chain linking the instruments to competition and then investment

A.3 Econometric estimation results

	Log of investment					
	(1)	(2)	(3)	(4)	(5)	(6)
Competition	0.302 (0.837)	5.883* (3.061)	6.520*** (1.560)	53.67*** (10.43)	82.76*** (16.56)	67.41*** (13.51)
Squared of competition		-4.780** (2.273)	-5.727*** (1.217)	-44.84*** (9.163)	-69.94*** (14.71)	-53.64*** (11.87)
Log of population density			0.015 (0.056)	-0.061 (0.039)	-0.005 (0.045)	-0.056 (0.038)
Log of active pop.			0.744*** (0.050)	0.783*** (0.051)	0.738*** (0.058)	0.838*** (0.044)
Incumbent			0.226* (0.119)	0.287 (0.200)	-0.132 (0.192)	0.104 (0.190)
Entry						-0.197* (0.107)
Merger						0.133 (0.208)
Exit						-0.183 (0.244)
Regional effects	No	Yes	Yes	Yes	Yes	Yes
Year fixed effects	No	Yes	Yes	Yes	Yes	Yes
Constant	5.053*** (0.522)	3.142*** (0.962)	-8.647*** (0.999)	-22.34*** (3.021)	-30.05*** (4.443)	-28.37*** (3.840)
Observations	940	940	940	937	894	815
R-squared	0.001	0.028	0.698			
Optimal level of competition:						
Lower bound		0.45	0.51	0.55	0.56	0.58
Mean		0.62	0.57	0.60	0.59	0.63
Upper bound		0.78	0.63	0.64	0.63	0.68

Significant at 1% (***), 5% (**) and 10% (*). OLS estimation in specifications (1), (2) and (3). Instrumental variable estimation using the Generalized Method of Moment in specifications (4), (5) and (6). Robust standard errors are in parentheses, clustered at the country level for the OLS estimation.

Specifications (1) to (4) rely on the full sample. Specification (5) drops extreme values from the original sample. Specification (6) drops extreme values and restricts the sample to firms that enter into the market before 2003. Competition is measured as the complement to one of the Lerner index of monopoly power. This latter is measured as the ratio of profit over revenue.

The endogenous variables "Competition" and the "squared of competition" have been instrumented by i) the number of radio spectrum allocated to mobile telecommunications services before 2005 (excluded) in a given country and by ii) the date of entry of a given firm into the mobile telecommunications market.

The optimal level of competition and its confidence interval are estimated using the "delta method".

Table 3: Selecting the appropriate empirical model

	Log (invest)	Log(revenue)	Log(revenue)	Invest./Revenue
	IV-GMM (1)	IV-GMM (2)	OLS	IV-GMM (3)
Competition	71.00*** (14.57)	114.5*** (19.07)		-7.837*** (2.023)
Squared of competition	-57.04*** (11.88)	-90.93*** (15.53)		6.273*** (1.612)
Log of investment			0.874*** (0.037)	
Log active pop.	0.822*** (0.045)	0.752*** (0.063)	-0.008 (0.037)	0.015** (0.007)
Region fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	No	No	Yes	No
Observations	815	815	815	815
R-squared			0.881	
Optimal level of competition:				
Lower bound	0.58	0.59		0.57
Mean	0.62	0.63		0.62
Upper bound	0.66	0.67		0.68
Underidentification test (H0: model is underidentified)				
Kleibergen-Paap rk LM statistic (Chi2)	14.11***	14.12***		14.12***
Weak identification test (H0: weak instrument)				
Kleibergen-Paap Wald rk F-stat	8.14	8.14		8.14
Weak-instrument-robust inference (H0: Endogenous regressors are not jointly significant)				
Anderson-Rubin Wald test F-stat	18.20***	49.93***		12.67***
Endogeneity test (H0: comp and comp2 are exogenous)				
Chi-squared statistics	25.51***	57.19***		18.27***

Significant at 1% (***), 5% (**) and 10% (*). Standard errors in parenthesis are robust to heteroskedasticity and auto-correlation of order 1. Auto-correlation is corrected for by using the Newey-West kernel function.
The sample includes all firms that enter into the market before 2003, excluding outliers.

Table 4: The impact of competition in the market on investment

	Log of investment			
	(1)	(2)	(3)	(4)
Competition	91.25*** (20.79)	-70.25 (143.1)	41.29*** (15.80)	42.26* (22.00)
Squared of competition	-76.15*** (18.36)	43.95 (101.8)	-35.35*** (12.91)	-35.58** (17.02)
Log of active pop.	0.744*** (0.0720)	0.940*** (0.0570)	0.950*** (0.0266)	0.930*** (0.0258)
AMEA	-0.349 (0.244)			
Asia-Pacific	-0.133 (0.209)			
Eastern Europe	-1.105*** (0.291)			
Latin America	-0.276 (0.362)			
Log of GDP per capita		1.045 (0.852)	0.385*** (0.0429)	0.371*** (0.0886)
Constant	-32.93*** (5.614)	6.122 (40.23)	-25.44*** (4.608)	-25.47*** (6.302)
Observations	767	815	670	815
Optimal level of competition:				
Lower bound	0.56	0.34	0.56	0.53
Mean	0.60	0.80	0.58	0.59
Upper bound	0.64	1.26	0.61	0.65
Underidentification test (H0: model is underidentified)				
Kleibergen-Paap rk LM statistic (Chi2)	13.65***	0.5	18.60***	8.85***
Weak identification test (H0: equation is weakly identified)				
Kleibergen-Paap Wald rk F statistic	7.3	0.3	10.0	3.9
Weak-instrument-robust inference (H0: Endogenous regressors are not jointly significant)				
Anderson-Rubin Wald test F-statistic	21.42***	7.38***	33.31***	8.79***
Endogeneity test (H0: comp and comp2 are exogenous)				
Chi-squared statistics	31.05***	8.11***	14.12***	5.62*

Significant at 1% (***), 5% (**) and 10% (*). Standard errors in parenthesis are robust to heteroskedasticity and residual auto-correlation of order 1. Auto-correlation is corrected for by using the Newey-West kernel function.
Specification (1) tracks firms that enter into the market before 2005 from 2005 to 2012 in order to ensure the exogeneity of the instrument "number of radio spectrum released before 2005".
Specification (2) includes the GDP per capita into the regression. Specification (3) uses previous year competition as an instrument for current year competition. Specification (4) uses the "fixed network incumbency" as an instrument for competition.

Table 5: Robustness Checks Results

	FS (1)		FS (2)		FS (3)		FS(4)	
	Comp	Comp^2	Comp	Comp^2	Comp	Comp^2	Comp	Comp^2
# Spectrum	0.019*** (0.004)	0.022*** (0.004)	0.003 (0.004)	0.003 (0.005)				
Year of entry	0.001* (0.0008)	0.002** (0.001)	0.003*** (0.0008)	0.005*** (0.001)	-0.0001 (0.0004)	0.0005 (0.0005)	0.002** (0.0008)	0.003*** (0.001)
Competition (t-1)					0.801*** (0.021)	0.978*** (0.027)		
Incumbent FNO							-0.050*** (0.008)	-0.061*** (0.011)
Log(GDP/capita)			0.037*** (0.004)	0.044*** (0.005)	0.005** (0.002)	0.006** (0.003)	0.038*** (0.003)	0.046*** (0.004)
Log active pop.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Regional effects	Yes	Yes	No	No	No	No	No	No
Constant	-1.978 (1.623)	-4.302** (2.045)	-6.514*** (1.625)	-9.591*** (2.048)	0.297 (0.810)	-1.335 (0.996)	-3.743** (1.736)	-6.202*** (2.178)
Observations	815	815	815	815	670	670	815	815
R-squared	0.108	0.107	0.157	0.151	0.792	0.789	0.185	0.179
F-Statistics	15.46	15.53	31.63	30.21	445.35	431.74	39.62	38.64

*Significant at 1% (***), 5% (**) and 10% (*). FS(1) represents the first stage of the main econometric results (IV-GMM (1)). FS(2), FS(3) and FS(4) correspond respectively to the first stage of robustness checks results in columns (2), (3) and (4).*

Table 6: First stages results of the main specifications

A.4 Non parametric estimation results

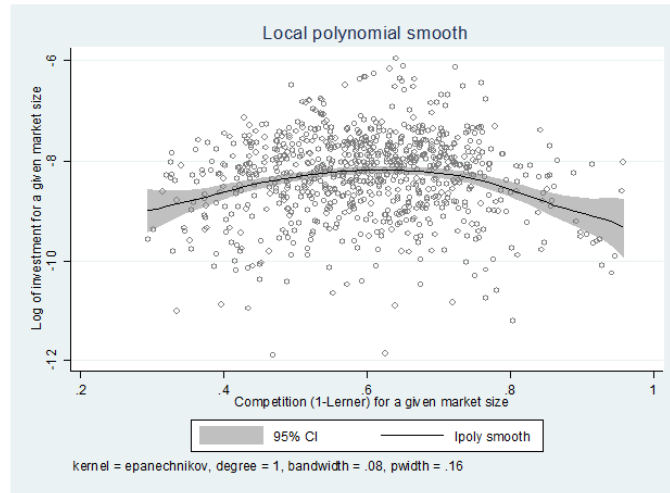


Figure 8: Local polynomial smoothing

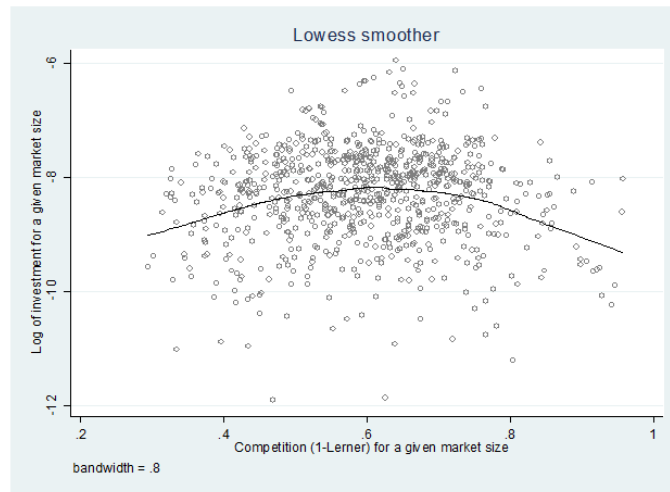


Figure 9: Locally weighted scatterplot smoothing