

Jeanjean, François

**Conference Paper**

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23rd European Regional Conference of the International Telecommunications Society (ITS), Vienna, Austria, 1st-4th July, 2012

**Provided in Cooperation with:**

International Telecommunications Society (ITS)

*Suggested Citation:* Jeanjean, François (2012) : Incentive to invest in improving the quality in telecommunication industry, 23rd European Regional Conference of the International Telecommunications Society (ITS), Vienna, Austria, 1st-4th July, 2012, International Telecommunications Society (ITS), Calgary

This Version is available at:

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# Incentive to Invest in improving the Quality in Telecommunication Industry

François Jeanjean, France Télécom Orange<sup>1</sup>

June, 14, 2012

## Abstract:

This paper investigates the incentives to invest in improving the quality (as distinguished to investment in a new activity) in telecommunication industry using the empirical example of wireless markets. We highlight that investment incentives are positively related to the potential for technical progress. They also depend on market structure, competition intensity and penetration rate. We show that there is a target amount of investment for each national market that firms strive to achieve. We show that, from a social perspective, this target amount is the best amount that firms are encouraged to invest. Non-achievement of the target amount entails underinvestment, a fall in consumer surplus and welfare and may slow down technical progress. Employing a 30 countries dataset during 8 years, we have empirically found a change in investment behaviour according whether the target amount is achieved or not. A low margin per user may hamper the achievement of the target amount. As a result, the maximum consumer surplus as well as welfare occurs under imperfect competition and not under perfect competition.

## *Keywords:*

Competition, Investment, Investment incentives, Technical Progress, Regulation

JEL Codes: D21, D43, D92, L13, L51, L96, O12

## 1 Introduction

Information technologies are characterized by an exponential and regular growth of data usage exemplified by the famous Moore's law. Telecommunication sector is not an exception and shows an amazing increase in consumption whose annual growth rate often exceeds several tens of percent.

This is made possible, firstly, thanks to the tremendous technological progress of the sector and, secondly, through the regular and ongoing investments of telcos.

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<sup>1</sup> F.J Author is with France Télécom Orange, Economist, 6, place d'Alleray 75015 Paris Cedex (e-mail : [francois.jeanjean@Orange-ftgroup.com](mailto:francois.jeanjean@Orange-ftgroup.com)) (This paper represents the analysis of the author and not necessarily a position of France Telecom)

These investments are essential to enable consumers to benefit from technical progress.

This is the reason why it is crucial for policy makers and competition authorities to ensure that investment incentives as well as investment capacities are sufficient so that investments continue.

This paper investigates telcos' investments in wireless markets from 30 countries around the world from 2002 to 2010.

Empirical evidence shows that in each country, firms try to achieve a target amount of investment that depends on market conditions (competition, standard of living, penetration rate, level of technical advance...) however, only those that generate enough margin succeed. The others invest unless they wish and are thus threatened by the technology gap.

The target amount of investment is the amount that maximizes expected firms' profits. The target amount of investment is highly related to the potential for technical progress. Indeed, a high potential provides more investment opportunities and makes investment more efficient. This increases the target amount.

Investment in improving the quality, which represents a significant part of investments by telecommunication operators, has to be distinguished from investment in a new activity or in a new market. Decision processes are quite different.

Investment in a new activity is expected to provide, eventually, new revenues and new profits. The investment decision is based on the estimation of the Net Present Value and the Return On Investment. Decision of investing in the improvement of the quality of the current service depends more on competition than on the profitability expectations.

Improving the quality means improving network performance for users: (bandwidth, availability, quality and ease of use, customer care...), it leads to increase consumers' willingness to pay.

The operator that improves the more its performance gets a competitive advantage and increases its profits. However, if all competitors improve their performances to the same extent, no one gets any competitive advantage. In practice, competitive advantages are relatively weak because they are difficult to obtain and even more to maintain over time. Indeed, all operators can buy the same equipments and invest in similar conditions. As a consequence, such investments generally do not increase significantly firms' profits; however, they dramatically increase consumers' surplus as well as social welfare.

Competition for improving the quality is even fiercer than the potential for technical progress is high. Indeed, the potential for technical progress increases the profit margin required to achieve the target amount of investment. When the latter is not sufficient, the target amount can not be achieved. The technical progress is then slowed at the expense of consumers and welfare.

We found empirically that this occurs not only in emerging countries but sometimes also in developed countries when price competition is so fierce that it prevents firms from achieving the target amount. A Chow test points out that firms investment behavior varies depending whether they have the means or not, to attain the target amount.

Competition plays a crucial role in investment behavior. More specifically, we have to distinguish between two kinds of competition that have very different impacts: Price competition and competition for quality improvement. The former tends to decrease the margin while the latter tends to increase investment. As long as the margin

remains sufficient to achieve the target amount, competition is sustainable, otherwise it is too fierce and firms underinvest.

There may be a trade off between both kinds of competition. An increase in the potential for technical progress reinforces competition for quality improvement by increasing the target amount of investment and requires a declining adjustment of price competition. Somehow, these two kinds of competition are themselves in competition.

We show that consumer Surplus as well as welfare is maximized for an amount of investment higher than the target amount. Therefore, the tradeoff should be in favor of competition for quality improvement until the target amount is achieved and in favor of price competition otherwise. Indeed, firms will not invest more when the target amount is achieved.

Another key parameter that impacts investment for quality improvement is the users' penetration rate. Investment increases consumer's willingness to pay and thus allows consumers with lower willingness to pay to enter the market. This increases the revenues and the profits of all the competitors even without any competitive advantage. However, that depends on the potential for market growth. When the market is fully covered, there is no more potential for market growth.

We show that investment for quality improvement does not actually increase the profits when the market is close to the full coverage. A granger test shows that investment does not cause margin excepted when the size of the market increases fast enough. By cons, margin always causes investment. The margin, indeed, depends mainly on competition, market structure and standard of living. As a result, the margin has a major influence on the target amount of investment.

Because investment for quality improvement does not affect the margin in a major way, firms can not rely on a future extra margin to finance it, they must generate enough margin. This explains why firms' investment behaviour varies when they do not generate enough margin to attain the target amount. They aim to reach the target amount and when they can not, they try to get as close as possible.

The paper is organized as follow: Part 2 is a literature review on the relationship between competition and investment. Part 3 is a theoretical framework that explains what determines the incentives to invest and the target amount of investment in the specific but particularly relevant case where the market is fully covered. Part 4 states the empirical model. Part 5 is the conclusion and the policy implications.

## **2 Literature review**

The literature on the relationship between competition and investment is quite rich. However, the most part of this literature focuses on the Research and development investment. This literature does not exactly match our topic because R&D investment leads to uncertain outcomes while investment in quality improvement is much more predictable. However, these issues are quite close and the findings quite similar. Two great traditions are conflicting.(Loury, 1979). On the one hand, the "schumpeterian effect" which highlights the negative impact of competition on innovation. Schumpeter emphasized that the monopoly power provides entrepreneurs the best incentive to invest in innovation (Schumpeter, 1942). On the other hand, the "escape effect" which highlights the positive impact of competition on innovation. In a competitive structure, firms are encouraged to innovate to escape competition. Innovation providing them a competitive advantage, restores a part of the monopoly

rent. Adam Smith's "invisible hand" supports the prescription that monopoly should be restrained and competitive market structure should be promoted to foster innovation.

One might wonder if the general tradeoff between Schumpeterian and Escape effect leads to an intermediate degree of competition between monopoly and perfect competition which is optimal. Several empirical and theoretical studies support this view: (Kaminen & Schwartz, 1975) (Dasgupta & Stiglitz, 1980), as well as the famous inverted U relationship between competition and innovation demonstrated by Aghion and al (Aghion, Bloom, Blundell, Griffith, & Howitt, 2005) .

For a relatively low level of competition, the escape effect prevails, after a certain saturation point, the Schumpeterian effect prevails.

This tradeoff between competition and innovation has been extended to the tradeoff between competition and investment (Friederiszick, Grajek, & Röller, 2008) as the concepts of innovation and investment are often closely linked. The inverted U relationship has also been observed between competition and investment (Kim, Kim, Gaston, Kim, & Lestage, 2010) or (Bouckaert, Van Dijk, & Verboven, 2010). However, innovation is closer to the investment in new business, new product or process than in improving the quality. In this latter case, Escape and Schumpeterian effects still exist but act in a somewhat different manner. Escape effect is more regular in this case, because investment never leads to a radical innovation and a competitive advantage is more difficult to obtain. Competition for quality improvement drives firms to invest regularly although that does not significantly increase their profits. However, it always increases consumer surplus as well as social welfare. Schumpeterian effect also works differently. Competition reduces the margin, and that not only reduces the expected benefits, but may also reduce the capabilities to invest. .

This literature has relevant consequences on regulation authorities and policy makers. They have to adjust their decisions depending on whether the Schumpeterian effect or the escape effect prevails.

When the escape effect prevails, a static regulation (Antitrust policy, entry promotion, price competition strengthening, switching costs reduction...) will enhance competition intensity to increase investments. When Schumpeterian effect prevails, a dynamic regulation (regulation vacancy, *laissez faire*...) will lower competition to increase investments. The debate about the trade off between static and dynamic regulation has evolved over time.

Pakes and al have pointed out the positive impact of technological opportunities on the R&D investment.(Pakes & Schankerman, 1984). High technical opportunities improve the effectiveness of investment. It encourages firms to invest more and requires more investment capacities; therefore it moves the balance between escape and Schumpeterian effects in favor of the latter.

In recent years, pure static regulation is increasingly criticized (Audretsch, Baumol, & Burke, 2001), (Valletti, 2003) and (Bauer, 2010). Its main drawback is to consider a framework where demand and market structure are given and steady while telecommunication sector evolves very quickly.

The requirement for heavy investments in telecommunication networks such as Next-Generation-Network is leading regulation authorities to take increasingly into account the issues of investment and dynamic efficiency. Bauer and Bohlin have pointed out this evolution in USA (Bauer & Bohlin, 2008). Furthermore, Cambini and Jiang highlighted (Cambini & Jiang, 2009):

*“Nowadays, the urgency to spread broadband access calls for a large amount of capital expenditure. Therefore more and more regulatory concerns are attracted to the investment issue in the broadband market”*

Dynamic regulation attempts to encourage investments in order to improve the consumers’ appeal and thus their surplus as well as welfare. However, dynamic regulation is not the cure-all for regulation policies. (Salop, 1979), (Gilbert & Newbery, 1982) and (Sutton, 1991) refute this assumption highlighting that dynamic regulation may reduce competition intensity and does not necessarily lead to enhanced consumer welfare.

### **3 Theoretical background**

This section provides a theoretical framework that helps to understand the incentives to invest in quality improvement. In particular, it explains the origin of the target amount of investment and the impact of the different parameters on this target amount.

This model is based on the spokes model as described by (Chen & Riordan, 2007), a competition model with horizontal differentiation among firms.

The model highlights the incentives to invest of telecommunication operators. They invest to improve the quality of their offer and thereby increase consumer’s willingness to pay. On the one hand, this will increase the total number of consumers who purchase and thus the market size. On the other hand, firms that will most improve their quality will gain a competitive advantage, albeit, if all firms improve their quality to the same extent, no one will gain any competitive advantage. Nevertheless, competition will urge them to invest anyway. This is the competition for quality improvement. The amount that firms are encouraged to invest depends on the impact on investment on consumer’s utility. The model shows that there is an amount of investment that maximizes firms’ profits. This is the target amount of investment. Firms invest this amount when they have the capability to do so, otherwise, they do their best but they can not reach the target amount and finally invest less than they would like to.

The model shows that the socially optimal amount of investment is always higher than the maximizing amount that firms seek to invest. As a result, investment is even closer to the socially optimal amount that firms can achieve the target amount.

The model also reviews the best level of margin which maximizes consumer surplus and welfare.

In order to point out the role of competition for quality improvement in the incentives to invest, we are studying the relevant case of the fully covered market. The market size is normalized to 1. When the market is not fully covered, the potential for market growth encourages investment. Here, we want to set aside this issue to focus solely on the impact of competition for quality improvement.

The market is represented by a spoke wheel where consumers are uniformly distributed. Each firm is located at the end of a spoke. The wheel diameter is normalized to 1; the length of each spoke is thus 1/2. Each consumer located within a spoke compares the utility to purchase the offer by the firm located at the end of the spoke and the offer he prefers from among the other firms which have all an equal probability to be chosen. Like all the spokes converge at the centre of the wheel, the

comparison can be made in pairs between all firms. If there are  $N$  firms, there will be  $N(N-1)/2$  comparisons. Each firm is involved in  $(N-1)$  comparisons.

We assume  $v_i$  and  $p_i$  are respectively the consumer's willingness to pay and the price of firm  $i$ 's offer. We will focus on the comparison between firms  $i$  and  $j$ . The length of the two joined spokes is 1. A consumer located at a distance  $x$  from firm  $i$  is located at a distance  $(1-x)$  from the firm  $j$ . His utilities of purchasing firm  $i$ 's and firm  $j$ 's offer are respectively:

$$U_i = v_i - p_i - tx$$

$$U_j = v_j - p_j - t(1-x)$$

With  $t$ , the coefficient of differentiation (transportation cost).

We consider the following two stages game: an investment stage and a competition stage.

In the investment stage, each firm decides the amount of its investment  $I$  per customer which will improve the quality of its offer.

In the competition stage, firms compete in price.

The game is solved by backward induction.

For simplification, we assume that at the beginning of the game, the market is symmetrical<sup>2</sup>.

All firms have the same market share and earn the same profit. In that case,  $\forall i, j \quad v_i = v_j = v$  and  $\pi_i = \pi_j = \pi = t/N$ . Each firm has an equal market share  $\sigma = 1/N$  customers.

The indifferent consumer between  $i$  and  $j$  is located at  $x_{ij} = \frac{v_i - v_j + p_j - p_i + t}{2t}$

Firm  $i$ 's market share is written:

$$\sigma_i = \frac{2}{N(N-1)} \sum_{j \neq i} x_{ij}$$

We assume that all firms incur the same marginal cost  $c$ . The profit of firm  $i$  is:

$$\pi_i = \sigma_i(p_i - c)$$

The first order condition allows us to determine  $p_i$ :

$$p_i = c + t + \frac{(N-1)v_i - \sum_{j \neq i} v_j}{(2N-1)} \quad (1)$$

and hence:

$$\sigma_i = \frac{1}{N} + \frac{(N-1)v_i - \sum_{j \neq i} v_j}{(2N-1)Nt} \quad (2)$$

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<sup>2</sup> The index of asymmetry used in the empirical section, variable IOA, shows that markets are generally not so far from the symmetry. (See descriptive statistics in the appendix). The average IOA is under 15%. Less than 10% of the observations have an index of asymmetry above 30%.

### 3.1 Incentives to invest

We assume that the investment  $I$  per customer at investment stage increases the willingness to pay by  $V(I)$  during the competition stage. Function  $V$  characterizes the impact of investment on consumer's willingness to pay. We assume that function  $V(I)$  is increasing, concave and tends toward a horizontal asymptote. Increasing because the higher is the investment, the higher is the impact. Concave because the marginal increase of investment is less and less efficient. Consumers indeed, following the Weber Fechner law are sensitive to the logarithm of a stimulus (Reichl, Tuffin, & Schatz, 2010). Tends toward a horizontal asymptote, because the impact can not be infinite. These conditions lead to the target amount that firms are encouraged to invest (F. Jeanjean, 2011) As the impact of the marginal investment is decreasing and tends toward zero (horizontal asymptote), there is a threshold above which the cost of investment becomes higher than expected gains. This threshold is the target amount of investment provided the initial marginal investment is lower than expected gains.

Assume that firm  $i$  decides to invest  $I_i$  and improves its consumer's willingness to pay from  $v$  to  $v + V(I_i)$ . At competition stage, firm  $i$  attempts to maximize  $\Pi_i$ , its profit minus the cost of the investment made at the previous stage which depends of the discount rate  $\rho$  :

$$\Pi_i = \frac{1}{Nt} \left( t + \frac{(N-1)V(I_i) - \sum_{i \neq j} V(I_j)}{2N-1} \right)^2 - \frac{1}{N} I_i (1 + \rho) \quad (3)$$

The amount of investment that maximizes equation (3) is  $I^*$ . If all firms play an equal role, they will all invest the same amount  $I^*$ .

The first order condition leads to:

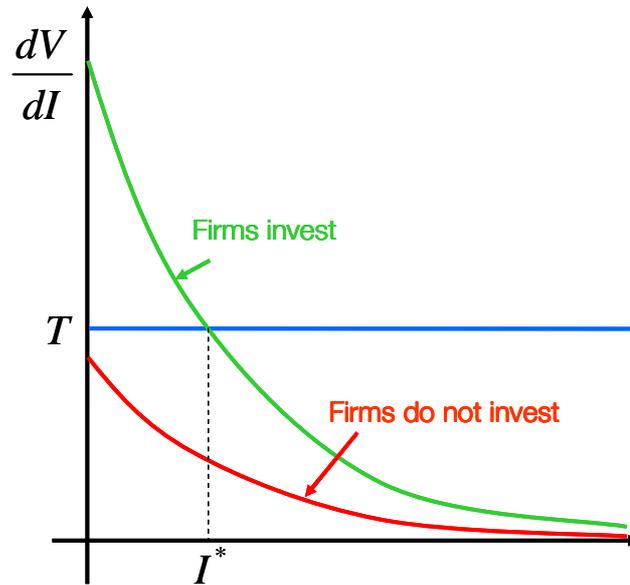
$$\frac{dV(I^*)}{dI} = \frac{(1 + \rho)(2N - 1)}{2(N - 1)} \quad (4)$$

(See proof in appendix)

Let us denote  $T$ , the right side of equation (4). As we can see,  $T$  does not depend on the differentiation between firms, parameter  $t$ . It only depends on the discount rate  $\rho$  and the number of firms,  $N$ . For a given market, when  $\rho$  and  $N$  are fixed,  $T$  does not depend on the amount of investment.

As  $V$  is increasing, concave and the marginal increase of  $V$  tends toward zero,  $dV/dI$  is positive, decreasing, and  $\lim_{I \rightarrow +\infty} (dV/dI) = 0$ . As a result, the higher is  $T$ , the lower is  $I^*$ . If  $dV(0)/dI$  is higher than  $T$ , equation (4) has a solution, and firms are encouraged to invest  $I^*$ . However, if  $dV(0)/dI$  is lower, equation (4) has no solution

and firms decide not to invest as we can see in the graph below (figure.1). As a result  $T$  is the triggering threshold of investment.



**Figure 1: Threshold triggering of investment**

The amount of investment  $I^*$  which maximizes firms profit is obtained when the curve  $dV/dI$  crosses  $T$ . At this point, equation 4 is fulfilled. For a lower amount of investment,  $dV/dI$  is higher than  $T$ , consumer's utility increases faster than the corresponding cost of investment, firms are encouraged to invest more. For a higher amount of investment  $dV/dI$  is lower than  $T$ , consumer's utility increases slower than the corresponding cost of investment. Firms are encouraged to invest less.

The discount rate  $\rho$  tends to reduce investment because investment is more risky or the value of money is higher in the short run.

The number of firms  $N$  tends to increase investment.  $N$  strengthens competition. The difference of quality between competitors, the competitive advantage, becomes more important. The variation of margin per user caused by a higher investment increases with  $N$ .

As the market is symmetric, all firms invest the same amount and as a result, they do not win any competitive advantage, they would have been better off not investing. However, the fear of the competitors urges them to invest anyway. This is a non price competition. This investment benefits more consumers than firms.

### **3.2 Budget constraint and effective amount of investment**

At the end of the game, under symmetrical assumption, firms have all invested the same amount. As a consequence, the market remains symmetrical. Investment has increased quality but neither prices nor profits.

In such a case, firms can not rely on futures profits to finance investment; they must rely solely on self-investment.

Firms try to invest the target amount  $I^*$ . When the profit they earn is sufficient to achieve  $I^*$ , they do invest  $I^*$ , otherwise, although they do their best, they can not achieve the target amount.

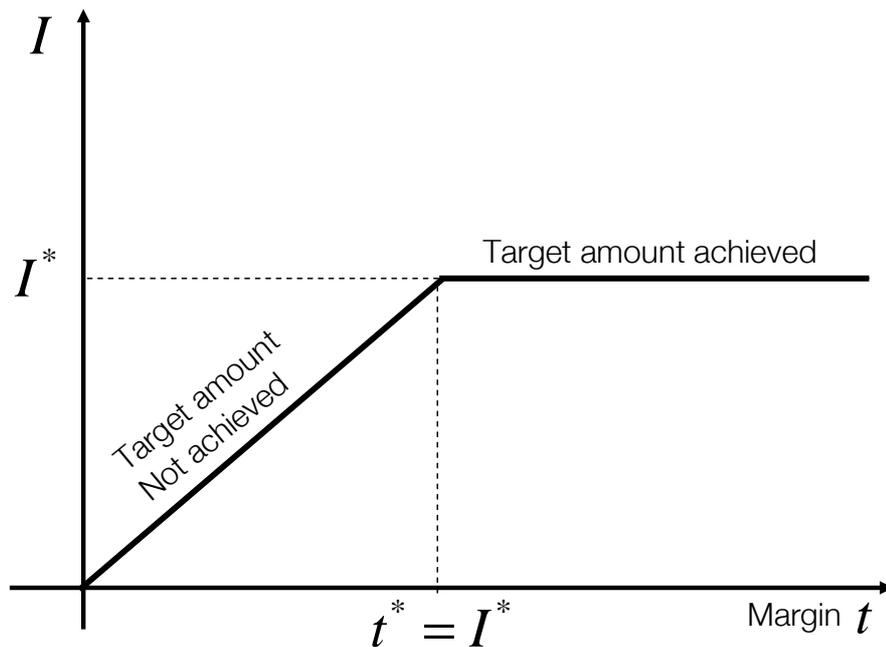
The margin, (Profit per customer), under symmetrical assumption, equals the transportation cost:  $\pi_i/\sigma_i = t$

The relationship between investment and margin is as follow:

When the margin is low, i.e.  $t < I^*$ , firms do not make enough profit to invest  $I^*$ , therefore they invest  $I = t$ .

When the investment capability is high enough, i.e.  $t > I^*$ , firms invest  $I^*$ .

The following graph (figure.2) illustrates the relationship



**Figure 2: Investment according to the margin  $I(t)$**

The budget constraint is the cause of the drop in investment for the low values of the margin. This drop in investment is empirically observed in the next section...

### 3.3 Socially optimal amount of investment

The consumer surplus increases with investment. When the market is symmetrical, all firms benefit from the same willingness to pay  $\forall i, j \in \{1, 2, \dots, N\}, v_i = v_j = v$

$cs = (v - c - \frac{5}{4}t)$  Investment increases willingness to pay by  $V(I)$ , thus

$$cs(I) = (v + V(I) - c - \frac{5}{4}t) \quad (5)$$

(See appendix)

and as a result  $cs(I) - cs = V(I)$

Social Welfare, defined as the sum of consumer surplus and total profit generated on the market writes:  $w(I) = cs(I) + \Pi(I)$

As the market size is normalized to 1, the profit generated on the market is  $\Pi(I) = t - I(1 + \rho)$ . The symmetry of the market encourages all firms to invest the same amount and prevents them to win any competitive advantage. Eventually, investment increases consumer surplus but decreases firms' profits. What is the amount of investment  $I^{**}$  which maximizes welfare?

Welfare writes:

$$w(I) = (v + V(I) - c - \frac{t}{4}) - I(1 + \rho) \quad (6)$$

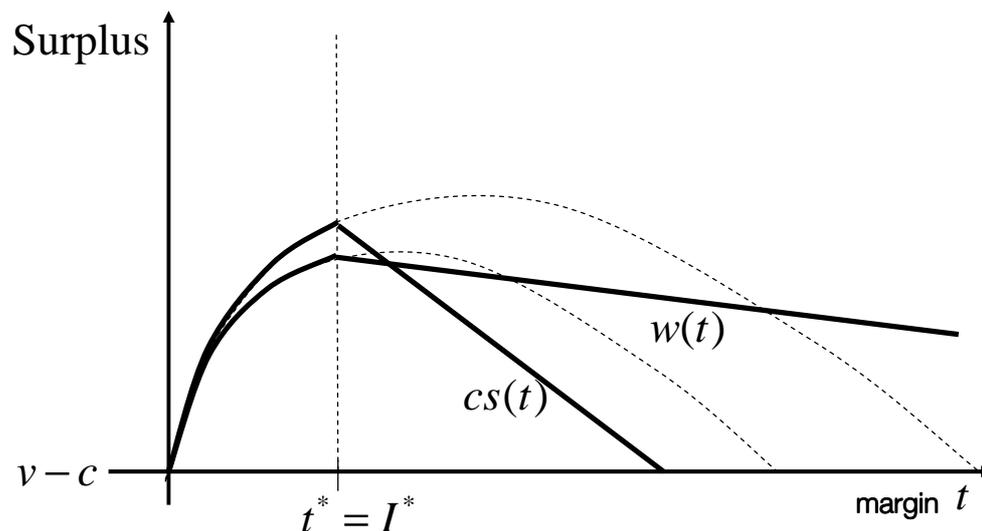
The first order condition leads to the following equation:

$$\frac{dV(I^{**})}{dI} = (1 + \rho) \quad (7)$$

Comparing equation 4 and equation 7 we can observe that  $dV(I^{**})/dI < dV(I^*)/dI$ . As a result,  $I^{**} > I^*$ . The socially optimal amount of investment is always above the investment that maximizes firms' profits. As we have seen in subsection 3.2, firms are never encouraged to exceed the target amount  $I^*$ . As a result, they always invest under the socially optimal level  $I^{**}$ . However, they got closest when they can afford to invest  $I^*$ .

### 3.4 Socially optimal value of margin

Equations (5) and (6) allow to represent consumer surplus and welfare according to the margin  $t$  (figure 3).



**Figure.3: Optimal margin that maximizes consumer surplus and welfare<sup>3</sup>**

<sup>3</sup> The graph is performed under the assumption that the impact of investment on consumers is high enough so that  $dV(I^*)/dI > 5/4 + \rho$ . Consumer surplus and welfare are increasing as long as  $t < t^*$

Derivatives of equation (5) and (6) provide the variations of consumer surplus and welfare according to  $t$ :

$$\frac{dcs}{dt} = \frac{dV}{dI} \frac{dI}{dt} - \frac{5}{4} \quad \text{and} \quad \frac{dw}{dt} = \frac{dV}{dI} \frac{dI}{dt} - \frac{1}{4} - \frac{dI}{dt} (1 + \rho)$$

Figure 2 indicates that investment depends on whether the value of margin is lower or higher than the target amount. If  $t < I^*$ , then  $I = t$  and  $dI/dt = 1$ . If  $t \geq I^*$  then  $I = I^*$  and  $dI/dt = 0$ .

On the one hand, if  $t < I^*$ ,  $\frac{dcs}{dt} = \frac{dV}{dI} - \frac{5}{4}$  and  $\frac{dw}{dt} = \frac{dV}{dI} - \frac{5}{4} - \rho$ , any margin growth is used to invest. As long as the impact of investment on consumers is high enough, in other words, as long as the dynamic effects are higher than static effects: ( $dV/dI > 5/4$  for consumer surplus and  $dV/dI > 5/4 + \rho$  for welfare), the growth of the margin increases consumer surplus as well as welfare.

On the other hand, if  $t \geq I^*$   $dcs/dt = -5/4$  and  $dw/dt = -1/4$ , the growth of margin is no more used to invest. Dynamic effects are stopped, only static effects remain, therefore consumer surplus as well as welfare decrease with the margin.

When dynamic effects are high enough ( $dV/dI > 5/4$  for consumer surplus and  $dV/dI > 5/4 + \rho$  for welfare), the values of margin that maximize consumer surplus or welfare are both strictly positive. That means that the socially optimal value of margin is not equal to zero. The socially optimal situation is not perfect competition. A certain degree of margin  $t$  that reduces market fluidity can be socially efficient. The higher is the potential for technical progress, the higher is the socially optimal value of margin.

Moreover, if  $N \leq 3 + 2\rho$ , then  $dV(I^*)/dI > 5/4 + \rho$ , consumer surplus and welfare are maximum for the same value  $t = t^* = I^*$  (case of figure 3).

Remark: Investment benefits to the telecom sector and mainly to equipment suppliers. As a result, if we consider the welfare without investment, equation (6) becomes:

$$w(I) = (v + V(I) - c - \frac{t}{4}). \quad \text{In that case, welfare is always maximum when } t = t^* = I^* .$$

The competition for quality improvement can be characterized by the target amount of investment  $I^*$  and price competition by the level of margin  $t$  or rather by  $1/t$ , the level of substitutability.

The maximum welfare occurs for  $I^*/t = 1$  which means that the level of competition for quality improvement is inversely proportional to the level of price competition.

## 4 Empirical analysis

This section provides an empirical analysis of the determinants of wireless investment in quality improvement in 30 countries from 2002 to 2010. It points out the causality issue between investment and margin. In our sample, the margin causes investment.

The converse is true, but much less significant. This is explained because the investment considered here is mainly an investment in improving the quality of a service that is already available and not an investment in a new activity. This kind of investment entails a competition for quality improvement which prevents investment to result in a significant increase in the margin. As we have seen in the previous section, there is no increase in profits in symmetrical and fully covered markets.

This section also highlights the existence of a breaking point in the relationship between margin and investment. The investment behaviour of a country firms tends to change when the margin reaches a certain threshold. Below the threshold, investment increases sharply with the margin, and above the threshold, growth is slower. The theoretical model in the previous section predicts this kind of evolution in the case of a symmetrical and fully covered market (figure 2). In that specific case, after the threshold, (the target amount), growth of investment is nil. In not fully covered markets, investment may increase the number of consumers and the profits. This is why, although relatively low, the observed growth of investment is positive. Furthermore, the model highlights the role of other factors as market structure, level of service adoption, level of technology and the standard of living.

## 4.1 Data set

The data set used here is a panel data set for 30 countries (see the list in appendix). It provides annual data per country from 2002 to 2010. The data set should provide 270 observations, however, some data are missing and 29 observations are not available. Thus 241 observations are available. The financial figures: Revenues, Capex, Ebitda, HHI and the number of firms come from Informa “World cellular Information System”. The number of wireless users, the population and the level of technology come from strategy analytics “Broadband cellular user forecasts 2011-2016 (September 2011)”<sup>4</sup>, the standard of living, (GNI per Capita) comes from the World Bank. A table of descriptive statistics is provided in appendix.

The dependant variable in the linear regression model is the yearly Capex per user by country. *CAPU* in US \$. Capex per user is a proxy of investment.

There are two categories of explanatory variables: The financial figures which depend on the wireless market in the country and the country figures which depend on the specificities of each country. A time trend is included *YEAR* which indicates the number of years after 2001. (The value of year in 2002 is 2, and in 2003 is 3 ...) and also a squared time trend. Descriptive statistics are available in the appendix

These variables are presented as follows:

### 4.1.1 Financial figures:

This category of variables aims to evaluate the impact of market on the incentives to invest. First, the margin per user: *MAPU* which is the yearly Ebitda divided by the number of users. Second, the number of firms on the market: *NF*. Third, the index of asymmetry that measures the degree of asymmetry among firms in the market: *IOA*.

This index is obtained as follows:  $IOA = \frac{N(HHI) - 1}{N - 1}$ . *IOA* is comprised between 0

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<sup>4</sup> This report provides not only forecasted data but also previous data from 2002 to 2010.

and 1. Under perfect symmetry  $IOA = 0$ , and  $IOA$  increases with market's asymmetry. Here,  $HHI$ , the Herfindahl index, is expressed in percentage. When the market is absolutely symmetrical, all firms have an equal market share:  $HHI = 1/N$ , thus  $IOA = 0$ . When the market is absolutely asymmetrical, it tends towards the monopoly;  $HHI$  tends towards 1 and thus  $IOA$  tends towards 1 as well. Fourth the potential for market growth:  $PMG$ . It depends on the penetration rate  $q$ , which is the number of users divided by the total population of the country. Assuming that the demand function that expresses the penetration rate according to the price is sigmoid shaped, the potential for market growth is close to its maximum at the middle of market coverage. When  $q$  is low or high, close to 0 or 1, the potential for market growth is low.  $PMG = q(1 - q)$ . The potential for market growth increases with  $PMG$  which seems more relevant than simply  $q$ . The strength of competition is given by  $COMP$  which is defined by  $1 - L$ ,  $L$  is the Lerner index. The Lerner index is calculated yearly by country,  $L$  is the Ebitda divided by the total Revenue of the market.

#### **4.1.2 Countries specific figures:**

This category of variables aims to take into account the specific situation of each country. First the density of population  $DPOP$ , which is the total population, divided by the surface of the country. The density may have an impact on investment. Second, the standard of living given by the Gross National Income per capita  $GNICAP$  expressed in PPP. Finally the level of technical advanced integrated in the network  $3GT$ . this is the proportion of subscriptions using an advanced technology 3G technologies as CDMA 2000 or WCDMA or LTE.

## **4.2 The Econometric Model**

We estimate a system of two equations: The first explains margin per user, the second explains Capex per user. In the margin equation, we expect that margin is positively influenced by GNI per capita and negatively influenced by competition as well as the number of firms. In the investment equation, we expect that margin influences positively investment. The economic literature highlights the non linear influence of competition on investment. We will see whether these results hold and how the number of firms and the potential for market growth influence investment. The subscripts of the variables denote the country  $i$ , at year  $y$ . We also add a date variable in order to capture the time-related effects.

### **4.2.1 Causality issue**

We use the Granger causality test with lagged values of  $MAPU$  and  $CAPU$  per users. This test aims to highlight the non-price competition effect. Escape effect urges firms to invest, but if they all invest to the same extent, no one will obtain any competitive advantage. In the case of a fully covered market, no one increases its profits, and therefore, investment is not expected to granger cause margin. However, when the potential for market growth is high enough, investment will provide, even so, an increase in margin. In that case, investment is expected to granger cause margin. According to the theoretical background, we expect margin granger causes investment

in any cases. The auto regression of CAPU and MAPU are not significant beyond one lag.

Table1:

Granger causality test. Lags:1		Sample 2002-2011		
<b>Null Hypothesis:</b>		<b>obs</b>	<b>F-Statistic</b>	<b>Probability</b>
<b>MAPU does not Granger cause CAPU</b>		211	47,929222	0,000000
<b>CAPU does not Granger cause MAPU</b>			9,314235	0,002570

The two hypothesis have to be rejected which means that MAPU causes CAPU, thus there is a feedback effect: CAPU causes MAPU. However, the first effect is much more significant than the second. Capex per user is widely determined by the margin. Why is the impact of capex per user on margin weaker? In our sample, within the first year studied for each country, the service was available for almost all the population. Therefore, most of investments considered here can be regarded as investments in quality improvement...

The competition for quality improvement among firms reduces the impact of investment on margin. When all firms in a market improve their quality to the same extend, no one acquire a competitive advantage. Global improvement of the quality increases the adoption rate and allows an increase of margin which depends on the potential for market growth. When a market approaches the full coverage, the potential for growth decreases with the coverage and margin no longer increases with investment.

One can check that the feedback effect tends to vanish when the penetration rate is close to the full coverage of the market.

From 2002 to 2006, the average penetration rate increases from 56% to 69% and in 2010 it increases to 79%. The Ganger test on a sample limited from 2002-2006 where the potential for market growth is still high concludes to a feedback effect whereas the Granger test on a sample limited to 2007-2010 where the potential for market growth is lower finds that there is no more feedback effect.

Table2:

Granger causality test. Lags:1		Sample 2002-2006		
<b>Null Hypothesis:</b>		<b>obs</b>	<b>F-Statistic</b>	<b>Probability</b>
<b>MAPU does not Granger cause CAPU</b>		93	26,15652	0,00000
<b>CAPU does not Granger cause MAPU</b>			6,12886	0,01517

The two hypotheses are rejected. MAPU causes CAPU and the feedback effect CAPU causes MAPU.

Table3:

Granger causality test. Lags:1		Sample 2007-2010		
<b>Null Hypothesis:</b>		<b>obs</b>	<b>F-Statistic</b>	<b>Probability</b>
<b>MAPU does not Granger cause CAPU</b>		118	9,96953	0,00203
<b>CAPU does not Granger cause MAPU</b>			0,93663	0,33518

The first hypothesis is rejected but the second is confirmed, CAPU does not cause MAPU.

## 4.2.2 Margin equation

$$MAPU_{iy} = \alpha_0 + \alpha_1 COMP_{iy} + \alpha_2 GNICAP_{iy} + \alpha_3 N_{iy} + \alpha_4 IOA_{iy} + \alpha_5 PMG_{iy} + \alpha_6 3GT_{iy} + \alpha_7 DPOP_{iy} + \alpha_8 YEAR_{iy} + \alpha_9 (YEAR_{iy})^2 + \varepsilon_{iy} \quad (8)$$

The amount of margin results from the combination of two effects: competition and the wealth. As expected, the margin increases with countries wealth and decreases with the competition. The number of firms that reinforces competition has also a negative impact on margin. Index of asymmetry and potential for market growth have no significant impact. The level of technological advance has a positive impact, as expected. By cons, surprisingly, the population density influences margin per user negatively when we would expect the opposite. In fact, the operational expenditure might be more expensive in dense countries because of the real estates prices in urban areas, or the reduction of transmission power due to the suspicion for the electromagnetic waves. These disadvantages could outweigh the economies of scale. Time trend indicates that the margin tends to increase over time however, the squared time trend indicates that this increase slows down. The table below (Table 4) gives the results of those estimations.

Table 4:  
Regression for Margin per user (MAPU)

Independent variable	Coefficient (Standard error)
Constant	183.866 *** (24,891)
Competition intensity (COMP)	-285.296 *** (23,674)
Gross National Income per Capita ,PPP.(GNICAP)	0.00564 *** (0.00025)
Number of firms (N)	-0.917 *** (0,274)
Index of asymmetry (IOA)	37.517 (26.630)
Potential for market growth (PMG)	-11.064 (81.470)
Advanced technologies (3G)	76.354 *** (18.490)
Population density (DPOP)	-0.0165 *** (0.0017)
time trend (YEAR)	14.21 *** (4.688)
time trend squared (YEAR <sup>2</sup> )	-1.949 *** (0.452)
Regression fit (R <sup>2</sup> )	0.83
(adjusted R <sup>2</sup> )	0.82
Number of observations	241

\*Significant at 10%; \*\* significant at 5%; \*\*\* significant at 1%

## 4.2.3 Investment equation

Investment equation provides an analysis of the determinants of wireless investment in quality improvement and emphasizes the difference in behavior of firms according

to the margin. The time trend is not in the investment equation because it is highly correlated with the advanced technologies.

We will estimate three models. The first model uses the following equation:

$$CAPU_{iy} = \beta_0 + \beta_1 MAPU_{iy} + \beta_2 COMP_{iy} + \beta_3 N_{iy} + \beta_4 IOA_{iy} + \beta_5 PMG_{iy} + \beta_6 3GT_{iy} + \beta_7 DPOP_{iy} + YEAR_{iy} + \mu_{iy} \quad (9)$$

The first model takes into account all the 241 observations. The second model uses the same equation, but we removed 3 observations where the Capex seems abnormally high compared to the margin. The second model thus includes 238 observations. The third model uses lagged values of margin to control the endogeneity problem possibly caused by the feedback effect.

$$CAPU_{iy} = \gamma_0 + \gamma_1 MAPU_{iy-1} + \gamma_2 COMP_{iy-1} + \gamma_3 N_{iy-1} + \gamma_4 IOA_{iy-1} + \gamma_5 PMG_{iy-1} + \gamma_6 3GT_{iy-1} + \gamma_7 DPOP_{iy-1} + YEAR_{iy} + \xi_{iy-1} \quad (10)$$

The lag of margin removes one observation per country, 30 observations at all, including the 3 already removed, which leaves 211 available observations. The table below (Table.5) gives the results of those estimations.

Table 5:  
Regression for Capex per user (CAPU)

Independent variable	Model 1 Coefficient (Standard error)	Model 2 Coefficient (Standard error)	Model 3 Coefficient (Standard error)
Constant	0,141 (18.256)	-4.236 (14.192)	-2.777 (14.903)
Margin per user (MAPU)	0.181 *** (0.023)	0.188 *** (0.018)	0.187 *** (0.020)
Competition Intensity (COMP)	43.541 ** (17.618)	27.198 ** (13.750)	23.010 (14.272)
Number of firms (NF)	0,708*** (0.187)	0.814 *** (0.145)	0.532 *** (0.146)
Index of asymmetry (IOA)	5.869 (17.588)	-26.603 * (14.110)	-31.464 ** (14.322)
Potential for market growth (PMG)	63.728 (54.330)	111.246 *** (42.590)	140.635 *** (44.814)
Advanced Technologies (3GT)	59.170 *** (12.336)	57.680 *** (9.595)	66.461 *** (10.979)
Population density (DPOP)	-0.00050 (0.00115)	0.00007 (0.00089)	0.00054 (0.00096)
time trend (YEAR)	-3,894 *** (0,903)	-2,644 *** (0.710)	-3.160 *** (0.790)
Regression fit (R <sup>2</sup> )	0.41	0.55	0.53
(adjusted R <sup>2</sup> )	0.39	0.53	0.52
Number of observations	241	238	211

\*Significant at 10%; \*\* significant at 5%; \*\*\* significant at 1%

Almost all parameters are significant in Model 2 and Model 3 excepted for the density of the population. In Model 1, index of asymmetry and potential for market growth are not significant. The removal of the 3 observations where capex is abnormally high improves the estimation. The adjusted R<sup>2</sup> increases dramatically from 0.39 to 0.53. Indeed, investments in this case do not probably correspond to an investment in improving the quality and are less related to market parameters.

Coefficients between the three models are quite similar excepted for Index of asymmetry and potential for market growth.

Model 2 and Model 3 provide very close coefficients which shows that results are not significantly affected by the endogeneity problem due to the feedback effect.

As expected, margin has a positive impact on investment. Competition has also a positive impact, however, as it decreases margin, its impact could be not monotonic. Economic literature often reports an inverted U relationship. The number of firms reinforces competition and has also a positive impact.

The index of asymmetry has a negative impact. The market asymmetry implies that there is a leader whose market power increases with asymmetry. This market power reduces investment. The potential for market growth impacts positively investment because market growth allows firms to increase their margin. Advanced technology, that improves consumer experience, has a positive impact on investment.

Investment tends to decrease by about 3 \$ per user and per year during the elapsed period. That may be the result of the decline in potential for market growth over time. Indeed, as we have seen in subsection 4.2.1, because most of markets are already highly covered during the period, the potential for market growth tends to decrease with the coverage.

#### **4.2.4 Impact on investment behaviour according to the margin**

It seems that the countries where the margin is very low behave differently than others, in terms of investment. They lack the means to invest as they would like to. In order to check this hypothesis, we will do a Chow test of the previous regression.

The sample is split into two parts according to the amount of margin per user. The Null hypothesis asserts that the two sub-samples have the same estimated coefficients. We made the chow test on Model 2. However, a high correlation appears between 3GT and YEAR in the high margin subsample, 0.739 (see the correlation table in the appendix) . We have chosen to remove the variable YEAR in equation (8) in order to avoid this. We will call this Model 2 bis. The break appears most clearly, i.e. the Chow test statistic is maximum: 7.18, when  $MAPU = 117\$$ , which indicates that the probability of the null hypothesis is  $1.9E-8$ . Therefore, the null hypothesis should be rejected; there is really a break between the two sub-samples.

They do not follow the same model and it is better to have two different regressions depending on whether the margin is low or high. The table below (Table 6) provides the estimated coefficients for the regressions for the two subsamples. The coefficient of determination that corresponds to the fit ( $R^2$ ) obtained between the Capex/user and the estimation of the two subsamples 0.62 is quite higher than that obtained between the Capex/user and the whole sample.0.52. The Chow test and the coefficients are robust for different values of the around the 117\$ break.

Table 6:  
Regressions for Capex per user (CAPU)

Independent variable	Model 2 bis Whole sample Coefficient (standard error)	Low Margin subsample Coefficient (Standard error)	High Margin subsample Coefficient (Standard error)
Constant	-28.302 ** (12.985)	21.914 (24.291)	-39.133 ** (15.243)
Margin per user (MAPU)	0.208 *** (0.018)	0.261 *** (0.090)	0.154 *** (0.026)
Competition Intensity (COMP)	34.679 ** (13.978)	25.892 (21.277)	37.525 ** (16.125)
Number of firms (NF)	0.911 *** (0.147)	0.578 *** (0.146)	2.681 *** (0.575)
Index of asymmetry (IOA)	-31.873 ** (14.427)	2.009 (16.706)	-47.459 * (26.087)
Potential for market growth (PMG)	138.737 *** (43.105)	-124.637 * (69.364)	232.819 *** (61.181)
Advanced Technologies (3GT)	36.530 *** (7.945)	25.877 (31.966)	39.721 *** (8.083)
Population density (DPOP)	0.00059 (0.00090)	0.00056 (0.00167)	-0.00046 (0.00100)
Regression fit (R <sup>2</sup> )	0.52	0.36	0.50
(Adjusted R <sup>2</sup> )	0.51	0.30	0.48
Number of observations	238	82	156

\*Significant at 10%; \*\* significant at 5%; \*\*\* significant at 1%

The coefficients between the two subsamples are quite different. The markets behave differently depending on the amount of the margin.

In the low margin subsample, only three parameters are still significant, the margin, the number of firms and the Potential for market growth. The latter is much less significant. The impact of the margin is crucial for the low margin subsample. The constant, the competition, the index of asymmetry and the level of advanced technologies have no significant impact. The key parameter is the margin.

In the high margin subsample, all the parameters, except the density, are significant. The signs of these coefficients are exactly the same as the whole sample. The values of the coefficients for competition, potential for market growth and advanced technologies are not so far from those of the whole sample.

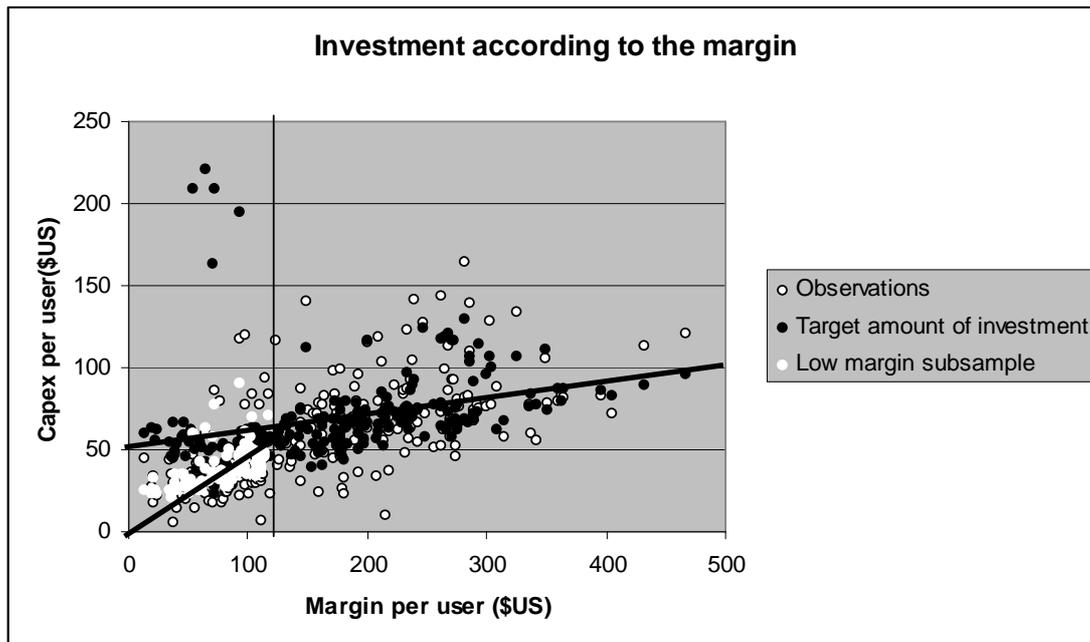
One can suppose that the two subsamples behave differently because the high margin subsample can afford to achieve the target amount of investment, while the low margin subsample can not, like in figure.2.

In the low margin subsample, the main issue is to increase margin to approach the target amount. This is why the margin is the key parameter.

The low margin subsample is less sensitive to the other parameters that impact the target amount of investment because firms do not earn enough margin to achieve it. No matter whether it increases or decreases until it remains beyond the reach. The high margin subsample is much more sensitive to the parameters that impact the target amount because it can achieve it. In this regard it is worth noting the change in sign of the potential for market growth between the two subsamples: Negative in the low margin subsample and positive in the high margin subsample. The potential for market growth tends to decrease the margin and to increase the future profits. Indeed, a high potential indicates high price elasticity and therefore, firms tend to decrease price in order to increase the number of customers. In the same time, a high potential increases the expected future profits and thus incentives to invest. Potential for market growth decreases investment in the low margin subsample by reducing margin, and increases investment in the high margin subsample by increasing incentives to invest.

The high margin subsample could be regarded as representative of the target amount of investment. The extrapolation of the coefficients obtained by the high margin

subsample to the low margin subsample would yield also the target amount of investment, which is not achieved in this case. One can check that this extrapolation provides higher investments than the amount of investment actually observed or estimated. This supports the hypothesis of the non-achievement of the target amount in the low margin subsample because of a lack of resources. The figure 4 below represents the estimation of the target amount of investments (black scatter plot), the estimation of the investment in the low margin subsample (white scatter plot). The high margin estimation is coincident with the target amount which is deemed achieved.



**Figure.4: Estimation of the target amount of investment**

#### 4.2.5 Discussion

Remember in subsection 3.3, the target amount is under the socially optimal level of investment, however, it is the highest amount that firms are encouraged to invest. As a result, the non-achievement of the target amount entails an underinvestment and a fall in consumer surplus and social welfare. A low margin may cause the non-achievement of the target amount. That may be an explanation of the inverted U relationship between investment and competition. As we just have seen, the competition or the number of firms has a positive impact on investment provided the margin is sufficient to achieve the target amount of investment. However, they have also a negative impact on margin. If this latter impact is sufficiently high to decrease the margin under the level able to achieve the target amount of investment, the overall impact may be negative. Otherwise the overall impact remains positive.

## 5 Conclusion and policy implications

Competition for quality improvement leads to a target amount of investment that firms strive to achieve to maximize their profits. This target amount is lower than the

socially optimal amount, and thus the target amount is the socially better amount of investment that firms are encouraged to invest. However, firms need to earn enough margin to achieve the target amount. A lack of resources causes the non-achievement of the target amount and entails a fall in technical progress, in consumer surplus as well as in welfare.

The potential for technical progress increases the impact of investment on quality. As a result, the target amount is even higher than the potential for technical progress is high. This potential is particularly high for information technologies and telecommunications and thus the target amount of investment is particularly high and difficult to achieve. There are many examples where the target amount is not achieved, and not only in emerging countries where the standard of living is low, but also in developed countries when price competition is too fierce.

There is a trade-off between competition for quality improvement which represents the dynamic side of competition and price competition which represents the static side of competition. In some way, these two sides of competition are in competition. Welfare is maximized when the target amount is just exactly achieved. For a given potential for technical progress providing a given target amount of investment and thus a given level of dynamic side of competition, the static side of competition should be adjusted in order to allow the achievement of the target amount.

Sectoral regulator and competition authorities should avoid underinvestment by ensuring that firms are able to achieve the target amount.

In terms of market tools, competition and entry have a positive impact on investment but only when firms can achieve the target amount, otherwise they may have a negative impact.

## Appendix

List of the countries:

Argentina 2004-2010; Australia 2005-2010; Austria 2002-2010; Belgium 2003-2010; Brazil 2002-2010; Canada 2002-2010; China 2005-2010; Colombia 2005-2010; Egypt 2006-2010; France 2003-2010; Germany 2002-2010; Hong-Kong 2002-2010; Hungary 2002-2010; Italy 2002-2010; Japan 2004-2010; Korea 2002-2010; Mexico 2003-2010; Netherland 2003-2010; Norway 2002-2010; Poland 2002-2010; Portugal 2002-2010; Russia 2002-2010; Singapore 2003-2010; South Africa 2002-2010; Spain 2004-2010; Sweden 2002-2010; Switzerland 2003-2008; Turkey 2003-2010; UK 2002-2010; USA 2002-2010.

Descriptive statistics:

	Max	Min	Median	Mean	Standard dev	unit
Capex per User (CAPU)	211	5	61	62	33	US\$/year
Margin per User (MAPU)	467	13	174	173	90	US\$/year
Gross National Income per Capita, PPP (GNICAP)	60 220	4 090	29 950	26 967	13 174	US\$/year
Competition intensity (COMP)	93%	24%	61%	61%	11%	
Number of firms (N)	71	2	4	6	9	
Index of asymmetry (IOA)	52%	0%	12%	15%	11%	
Potential for market growth (PMG)	25%	9%	17%	18%	4%	
Advanced technologies (3GT)	95%	0%	5%	15%	20%	
Population density (DPOP)	6 812	3	108	564	1 582	inh/km <sup>2</sup>
Time trend (YEAR)	9	1	5	5	2	year

**Proof of equation (4):**

$$\frac{d\Pi_i}{dI_i} = \frac{2}{Nt} \frac{(N-1)}{2N-1} \frac{dV}{dI_i} \left( t + \frac{(N-1)V(I_i) - \sum_{i \neq j} V(I_j)}{2N-1} \right) - \frac{1}{N} (1 + \rho)$$

If the market is symmetrical,  $I_i = I_j = I$ ; in that case,  $(N-1)V(I_i) = \sum_{i \neq j} V(I_j)$  and as

a result: 
$$\frac{d\Pi_i}{dI_i} = \frac{2}{N} \frac{(N-1)}{2N-1} \frac{dV(I)}{dI_i} - \frac{1}{N} (1 + \rho)$$

The first order condition  $\frac{d\Pi_i}{dI_i} = \frac{d\Pi_i}{dI} = 0$  leads to

$$\frac{dV(I^*)}{dI} = \frac{(1 + \rho)(2N-1)}{2(N-1)} \text{ equation (4)}$$

**Proof of equation (5) and (6):**

There are  $N$  spokes and  $\frac{N(N-1)}{2}$  different braces  $i,j$ . There are  $q/N$  consumers on

each spoke or  $2q/N$  customer on each brace. Each firm appears in  $(N-1)$  braces.

Let us denote  $cs_{ij}$  the consumer surplus of brace  $i,j$ . Total Consumer surplus is:

$$cs = \frac{N(N-1)}{2} \frac{2}{N} \frac{1}{(N-1)} cs_{ij} = cs_{ij}$$

$$cs_{ij} = \int_0^{x_{ij}} U_i dx + \int_{x_{ij}}^1 U_j dx$$

When market is symmetric,  $v_i = v_j = v$ ;  $x_{ij} = 1/2$

$$cs = cs_{ij} q = \left( \int_0^{1/2} (v - c - t - tx) dx + \int_{1/2}^1 (v - c - 2t + tx) dx \right) = (v - c - \frac{5}{4}t)$$

Welfare is the sum of consumer surplus and profit of the industry

In a symmetrical market, Profit of the industry is  $qt - I(1 + \rho)$ . Welfare writes:

$$w = (v - c - \frac{1}{4}t) - I(1 + \rho)$$

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