Incentives to Invest in Improving Quality in the Telecommunications Industry*

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This paper investigates the incentives of invest in improving quality (as opposed to investments in new activities) in the telecommunications industry, based on the example of wireless markets. What is the impact of competition on incentives to invest, and on capacities to invest? What is the role of the rate of penetration and technical progress? This paper highlights the fact that investment incentives are positively related to potential for technical progress. Investment incentives also depend on market structure, competition intensity, and penetration rate, but not monotonically. This paper consists of a theoretical part which, under assumptions of full market coverage and market share symmetry, shows that for each national market, there is a target level of investment which companies strive to achieve but had not exceeded, and an empirical part that confirms the findings of the theoretical part and explains the differences with the theoretical part by relaxing the assumptions of full coverage and market share symmetry. This target level on the one hand depends on the potential for technical progress and on the other hand, depends on the rate of penetration. From a social perspective, this target level is the best amount that companies are encouraged to invest. Non-achievement of the target level entails underinvestment and a decrease in consumer surplus and welfare and may slow down technical progress. A data set covering 30 countries over a period of eight years is used to empirically prove the existence of a change in investment behavior depending on whether or not the target level is achieved. A low margin per user may hamper achievement of the target level. As a result, maximum consumer surplus and welfare occur under imperfect competition but not under perfect competition.

Keywords: competition, investment, investment incentives, technical progress, regulation, telecommunications

Introduction

Information technologies are characterized by the regular exponential growth of data usage, as exemplified by Moore’s law. The telecommunications sector is no exception, and shows an impressive increase in consumption, with annual growth rates often well into the double digits. This is made possible by the sector’s tremendous technological progress, as well as regular and ongoing investments by operators. These investments are essential to allow consumers to benefit from technical progress.

It is therefore crucial for policy makers and the competition authorities to ensure that investment incentives and capacities are sufficient for investments to continue.

This paper examines telecommunications companies’ investments in wireless markets in 30 countries

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around the world from 2002 to 2010.

It will show empirically that in all studied countries, companies strive to achieve target investment levels based on market conditions (competition, standard of living, penetration rate, technological progress, etc.). However, only companies which generate adequate margins succeed. Companies with lower margins invest only what they can and find themselves threatened by the technology gap.

Target investment levels those which maximize expected corporate profits. They are closely related to the potential for technical progress: high potential provides more investment opportunities and makes investment more efficient, thus increasing the target level.

Investments in quality improvement, which represent a significant portion of telecommunications operators’ investments, must be distinguished from investments in new activities or markets. The decision processes involved differ significantly.

Investments in new activities are expected to ultimately provide new revenues and profits. The decision to invest is based on the estimated net present value and return on investment. The decision to invest in improving the quality of existing services, on the other hand, it depends more on competition than on expected profits. Indeed, this paper shows that when the market is fully covered and symmetrical, investment in improving the quality does not increase profits.

Improving quality means improving network performance for users (bandwidth, availability, quality and ease of use, customer care, etc.) and leads to an increase in consumers’ willingness to pay.

The operator which most improves its performance gains a competitive advantage and increases its profits. However, if all competitors improve their performances to the same extent, none of them creates a competitive advantage. In practice, competitive advantages are relatively weak because they are difficult to obtain and even more difficult to maintain over time. All operators can buy the same equipment and invest under similar conditions, meaning that this type of investment generally does not significantly increase corporate profits; however, these investments do dramatically increase consumer surplus and social welfare.

Competition based on quality improvement grows fiercer as the potential for technical progress increases. An increase in the potential for technical progress increases the profit margin required to achieve the target investment levels. It is impossible to achieve target investment levels if profit margins are too low, thus slowing technical progress at the expense of consumers and their welfare.

Our study revealed that this occurs not only in emerging countries but also in developed countries when price-based competition is so fierce that companies are unable to achieve their target investment levels. A Chow test shows that companies’ investment behavior varies depending on whether or not they have the means to attain their target levels.

Competition plays a crucial role in investment behavior. More specifically, there are two types of competition, which have very different impacts: competition on pricing and competition on quality improvement. The former tends to decrease margins, while the latter tends to increase investments. As long as companies’ margins remain sufficient to achieve their target investment levels, the competition is sustainable; otherwise it is too fierce and companies will underinvest.

A trade-off seems to exist between the two types of competition. An increase in the potential for technical progress encourages competition based on quality improvement by increasing the target investment levels, implying a decrease in price-based competition. In a sense, these two types of competition are in competition with one another.
This paper will show that consumer surplus and welfare are maximized at investment levels which exceed the target. A trade-off should therefore be made in favor of competition based on quality improvement until the target levels are achieved, and in favor of competition based on pricing in other cases. Companies will not invest more once they have achieved their target levels.

Another key parameter which impacts investments in quality improvement is the user penetration rate. Investment increases consumers’ willingness to pay, allowing consumers with lower willingness to pay to enter the market. This increases revenues and profits for all competitors, even without generating a competitive advantage. However, this phenomenon depends on the market’s potential for growth. When a market is fully covered, it no longer offers any growth potential.

It will be shown that investments in quality improvement do not actually increase profits when the market is close to full coverage. A Granger test reveals that investment does not generate margins, except when the size of the market is increasing fast enough. On the other hand, margins always generate investments. Margins mainly depend on competition, market structure, and standards of living, and have a major influence on target levels of investment.

Because investments in quality improvement do not have a major impact on margins, companies cannot rely on future additional margins to finance them, meaning that they must generate an adequate margin. This explains why the corporate investment behavior varies when companies’ margins are insufficient to attain target investment levels. Companies aim to reach their target levels, and try to come as close as possible when reaching their goal is impossible.

Our paper is organized as follows: Part two is a literature review on the relationship between competition and investment. Part three provides a theoretical framework which explains how investment incentives, and target investment levels are determined in the specific and particular relevant case of markets with full coverage. Part four describes the empirical model used, and part five lays out conclusions and discusses its policy implications.

**Literature Review**

The literature on the relationship between competition and investment is quite rich, but mainly focuses on investments in research and development (R&D). These studies differ from ours, since R&D investment leads to uncertain outcomes while investments in quality improvement are much more predictable. The issues are, however, closely related and the findings are very similar. There are two conflicting traditions in the field (Loury, 1979). The first is the Schumpeterian Effect, which highlights the competition’s negative impact on innovation. Schumpeter (1942) emphasized that a monopoly gives entrepreneurs the greatest incentive to invest in innovation. The second is the Escape Effect, which highlights the positive impact of competition on innovation. In a competitive structure, companies are encouraged to innovate in order to escape from the competition. Innovation provides a competitive advantage, thus restoring a portion of their monopoly rents. Adam Smith’s “invisible hand” supports the idea that monopolies should be restrained and competitive market structures promoted in order to foster innovation.

The trade-off between the Schumpeterian and Escape Effects raises the question of whether there is an optimal intermediate degree of competition located somewhere on the spectrum between monopoly and perfect competition. 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 et al. (2005).

The Escape Effect is true for relatively low levels of competition, but the Schumpeterian Effect prevails after a certain saturation point is reached.

The idea of a trade-off between competition and innovation has been extended to the trade-off 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 et al., 2010; Bouckaert, Van Dijk, & Verboven, 2010). The Escape and Schumpeterian Effects also apply to investments in quality improvement, but in a rather different way. The Escape Effect is more prevalent in this case, since investments in quality never lead to radical innovation and a competitive advantage is more difficult to obtain. Competition based on quality improvement drives companies to make regular investments, although these investments do not significantly increase their profits. However, it always increases both consumer surplus and social welfare. The Schumpeterian Effect also works differently in this case. Competition reduces margins, thus decreasing both the expected profits and investment capabilities.

The literature has consequences for regulatory authorities and policy makers, who must adjust their decisions depending on whether the Schumpeterian Effect or the Escape Effect prevails.

When the Escape Effect prevails, static regulation (Antitrust policies, entry promotion, increased price competition, reduced switching costs, etc.) will increase the intensity of competition, thus encouraging investment. When the Schumpeterian Effect prevails, on the other hand, dynamic regulation (regulatory vacancies, laissez faire, etc.) will decrease competition in order to increase investment. The debate surrounding the trade-off between static and dynamic regulations has changed over time.

Pakes and Schankerman (1984) noted the positive impact of technological opportunities on R&D investments. High levels of technical potential improve the effectiveness of investments, encouraging companies to invest more and requiring greater investment capacities. This shifts the balance between the Escape and Schumpeterian Effects towards the latter.

Pure static regulation has come under increasing criticism in recent years (Audretsch, Baumol, & Burke, 2001; Valletti, 2003; Bauer, 2010). Its main drawback is the fact that it is best applied to situations with a very stable demand and market structure, at a time when the telecommunications sector is changing rapidly.

The need for significant investments in telecommunications networks such as the Next Generation Network has led regulatory authorities to increasingly take the issues of investment and dynamic efficiency into account. Bauer and Bohlin (2008) observed this shift in the USA. Furthermore, Cambini and Jiang (2009) note that, “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 seeks to encourage investments in order to improve consumer appeal and surplus, as well as welfare. However, dynamic regulation is not a panacea for regulatory policies (Salop, 1979; Gilbert & Newbery, 1982; Sutton, 1991) refute this assumption and highlight the fact that dynamic regulation may reduce the intensity of competition and does not necessarily lead to improved consumer welfare.

**Theoretical Background**

This section provides a theoretical framework for understanding the incentives to invest in quality improvement. In particular, it explains the origin of the target investment levels and the impact of the different parameters on these levels.
Our model is based on the spoke model described by Chen and Riordan (2007), a competing model with horizontal differentiation among companies.

The model highlights telecommunications operators’ incentives to invest. They invest in order to improve the quality of their offers and increase consumers’ willingness to pay. This boosts the total number of consumers who make purchases, thus expanding the market. Furthermore, the companies which most improve their quality gain a competitive advantage, although if all of them improve their quality to the same extent none of them gains a competitive advantage. Competition will, however, encourage them to invest anyway. This constitutes competition based on quality improvement. The amount that companies are willing to invest depends on their investment’s impact on consumer utility. The model shows that a certain amount of investment maximizes corporate profits. This is the target investment level. Companies invest this amount when they have the ability to do so; otherwise they invest as much as they can but are unable to reach their target and invest less than they would like to.

The model shows that the socially optimal level of investment has been always higher than the financially optimal amount that companies seek to invest. Companies which can achieve their target levels of investment therefore come closest to the socially optimal level.

The model also reviews the ideal margin level, which maximizes consumer surplus and welfare.

The relevant case of a fully covered market has been chosen in order to analyze the role of competition based on quality improvement in investment incentives. The market size is normalized to 1. When the market is not fully covered, its potential for growth encourages investment. This factor should be set aside in order to focus solely on the impact of competition on quality improvement.

The market is represented by a spoke wheel where consumers are uniformly distributed. Each company is located at the end of a spoke. The wheel’s diameter is normalized to 1; the length of each spoke is thus 1/2. Each consumer located within a spoke compares the utility of purchasing an offer from the company located at the end of the spoke and an offer from one of the other companies, which all have an equal probability of being chosen. Since all of the spokes converge at the center of the wheel, the companies can be compared on a one-to-one basis. If there are \( N \) companies, there will be \( N(N - 1)/2 \) comparisons. Each company is involved in \( (N - 1) \) comparisons.

It is assumed that \( v_i \) and \( p_i \) are respectively the consumer’s willingness to pay and the price of company \( i \)’s offer. The focus will be on the comparison between companies \( i \) and \( j \). The combined length of the two spokes is 1. A consumer located at a distance of \( x \) from company \( i \) is located at a distance of \( (1 - x) \) from company \( j \). For the customer, the utility of purchasing company \( i \) and company \( j \)’s offers respectively is:

\[
U_i = v_i - p_i - tx
\]

\[
U_j = v_j - p_j - t(1 - x)
\]

where \( t \) is the differentiation coefficient (transportation cost). Considering the following two-stage game, which comprise an investment stage and a competitive stage:

In the investment stage, each company decides on an investment level \( I \) per customer, which will improve the quality of its offer;

In the competition stage, companies compete on the basis of price. The game is solved by backward induction. In order to simplify the situation, it is assumed that at the beginning of the game, the market is
symmetrical which is not so far from actual markets\(^1\).

All companies have the same market share and earn the same profit. In that case, \(\forall \, i, j \, v_i = v_j = v\) and \(\pi_i = \pi_j = \pi = t/N\). Each company has an equal market share: \(\sigma = 1/N\) customers.

The consumer hesitating between \(i\) and \(j\) is located at \(x_{ij} = (v_i - v_j + p_j - p_i + t)/2t\) Company \(i\)'s market share is written: \(\sigma_i = \frac{2}{n(n-1)} \sum_{j \neq i} x_{ij}\).

It is assumed that all companies incur the same marginal cost \(c\). Company \(i\)'s profit is: \(\pi_i = \sigma_i (p_i - c)\).

The first order condition allows us to determine \(p_i\):

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

and therefore:

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

Investment Incentives

It is assumed that the investment \(I\) per customer at the investment stage increases willingness to pay by \(V(I)\) during the competition stage. Function \(V\) characterizes the impact of investment on consumers’ willingness to pay. It is assumed that function \(V(I)\) is increasing, concave and tends toward a horizontal asymptote: increasing because the greater the investment, the greater its impact; concave because the marginal increase in investment is less and less efficient. According to the Weber Fechner law, consumers are sensitive to the logarithm of a stimulus (Reichl, Tuffin, & Schatz, 2010). It tends toward a horizontal asymptote because the impact of investment cannot be infinite. These conditions define the target amount that companies are encouraged to invest (Jeanjean, 2011). As the impact of the marginal investment decreases and tends to zero (horizontal asymptote), there is a threshold above which the cost of investment is higher than the expected gains. This threshold is the target investment level, provided that the initial marginal investment is lower than expected gains.

Assume that company \(i\) decides to invest \(I_i\) and improves its consumers’ willingness to pay from \(v\) to \(v + V(I)\). In the competition stage, company \(i\) attempts to maximize \(\Pi_i\), its profit minus the cost of the investments made during the previous stage, depending on the discount rate \(\rho\):

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

The level of investment which maximizes equation (3) is \(I^*\). If all companies play an equal role in the market, they will all invest the same amount \(I^*\).

The first order condition leads to:

\[
\frac{dV(I^*)}{dI} = \frac{(1 + \rho)(2N-1)}{2(N-1)}
\]  

(See Proof of equation (4) in Appendix)

Let us denote \(T\), the right side of equation (4). As can be seen, \(T\) does not depend on the difference

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\(^1\) The asymmetry index used in the empirical section, the variable IOA, shows that markets are generally relatively close to symmetrical (see descriptive statistics in Appendix Table A1). The average IOA is under 15% and less than 10% of the markets observed have an asymmetry index above 30%.
between companies, parameter $t$. It depends only on the discount rate $\rho$ and the number of companies $N$. For a given market, when $\rho$ and $N$ are fixed, $T$ does not depend on the level of investment.

As $V$ is increasing, concave and the marginal increase of $V$ tends to zero, $dV/dI$ is positive, decreasing, and $\lim_{I \to \infty} (dV/dI) = 0$. Therefore the higher the value of $T$, the lower the value of $I^*$. If $dV(0)/dI$ is higher than $T$, equation (4) has a solution, and companies are encouraged to invest $I^*$. However, if $dV(0)/dI$ is lower, equation (4) has no solution and companies decide not to invest, as shown in the graph below (see Figure 1). $T$ is thus the triggering threshold for investment.

The amount of investment $I^*$ which maximizes corporate profits is obtained when the curve $dV/dI$ crosses $T$. At this point, equation (4) is fulfilled. For lower levels of investment, $dV/dI$ is higher than $T$, consumer utility increases faster than the corresponding cost of investment, and companies are encouraged to invest more. For higher levels of investment, where $dV/dI$ is lower than $T$, consumer utility increases more slowly than the corresponding cost of investment so companies are encouraged to invest less.

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

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

As the market is symmetrical, all companies invest the same amount, meaning that none of them gains a competitive advantage. They would therefore have been better off not investing but are driven to invest anyway by fear of competition. This is non-price-based competition. This type of investment benefits consumers more than companies.

**Budget Constraints and Effective Investment Levels**

At the end of the game, given the assumption of a symmetrical market, all companies have invested the same amount, so the market remains symmetrical. The investments made have increased quality, but prices and margins remain stable. In a symmetrical market, equation (1) becomes $p_t = c + t$ and industry margin $\pi = t$ which does not depend on investment.

In this case, companies cannot rely on future profits to finance their investments; they must solely rely on
self-investment. Indeed, investment does not increase profits and profits are fully mobilized for investment, thus there remains nothing to repay a loan. Companies try to invest a target amount \( I^* \). When their profits are sufficient to achieve \( I^* \), they invest \( I^* \); otherwise they invest as much as possible but are unable to achieve their target investment levels.

Given the assumption of a symmetrical market, the margin (profit per customer) equals the transportation cost: \( \pi_i / \sigma_i = t \).

The relationship between investments and margins is as follows:

- When the margin is low, i.e., \( t < I^* \), companies do not make enough profits to invest \( I^* \), so they invest \( I = t \).
- When investment capabilities are high enough, i.e., \( t > I^* \), companies invest \( I^* \).

Figure 2 illustrates the relationship.

![Figure 2. Investment according to the margin \( I(t) \).](image)

The drop in investment for low margin is due to budgetary restrictions. This decrease in investment is empirically observed in the next section.

**Socially Optimal Investment Levels**

Consumer surplus increases with investment. When the market is symmetrical, all companies benefit from the same willingness to pay \( \forall i, j \in \{1,2,\ldots,N\}, v_i = v_j = v \).

\[
   cs = (v - \frac{c + 5}{4}t)
\]

Investment increases willingness to pay by \( V(I) \), thus:

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

(See Proof of equation (5) in Appendix)

and as a result \( cs(I) - cs = V(I) \).

Social welfare, defined as the sum of consumer surplus and total profits generated in the market, is written as:

\[
   w(I) = cs(I) + \Pi(I).
\]

The market size is normalized to 1, so the profit generated in the market is \( \Pi(I) = t - I(1 + \rho) \). The market’s symmetry encourages all companies to invest the same amount and prevents them from winning a competitive advantage. Investment ultimately increases consumer surplus but decreases corporate profits. What level of investment \( I^{**} \) maximizes welfare?
Welfare is written as:

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

(6)

The first order condition leads to the following equation (7):

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

(7)

A comparison of equations (4) and (7) shows that

$$\frac{dV(I^{*})}{dI} < \frac{dV(I^{**})}{dI}.$$ As a result, $I^{**} > I^{*}$.

The socially optimal level of investment is always greater than the investment level which maximizes corporate profits. As we saw in subsection 3.2, companies are never encouraged to exceed the target level, meaning that they always invest less than the socially optimal level $I^{**}$. They come closest to achieving $I^{**}$ when they can afford to invest $I^{*}$.

**Socially Optimal Margins**

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

![Figure 3](image)

Figure 3. Optimal margin which maximizes consumer surplus and welfare.

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

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

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

If $t < I^{*}$, $\frac{dcs}{dt} = \frac{dV}{dt} - \frac{5}{4}$ and $\frac{dw}{dt} = \frac{dV}{dt} - \frac{5}{4} - \rho$, any margin growth is used to invest. As long as the impact of investment on consumers is high enough, and so as long as the dynamic effects outweigh the static effects: $(dV/dl > 5/4)$ for consumer surplus and $dV/dl > 5/4 + \rho$ for welfare), the margin’s growth increases both consumer surplus and welfare.

If $t \geq I^{*}$, $\frac{dcs}{dt} = -5/4$, and $\frac{dw}{dt} = -1/4$, however, the margin’s growth is no longer used to make investments. The dynamic effects disappear, leaving only static effects, so both consumer surplus and welfare decrease with the margin.

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2 The graph is based on the assumption that the impact of investment on consumers is high enough that $dV(I^{*})/dl > 5/4 + \rho$. Consumer surplus and welfare increase as long as $t < t^{*}$. 

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

The greater the potential for technical progress, the higher the socially optimal margin value.

Moreover, if \(N \leq 3 + 2\rho\), then \((dV/dl > 5/4 + \rho)\), and consumer surplus and welfare are maximum for the same value \(t = t^* = l^*\) (see Figure 3).

Remark: Investment mainly benefits the telecommunications sector and equipment suppliers. Considering the welfare without investment, equation (6) becomes: \(w(I) = (v + V(l) - c - t/4)\). In that case, welfare is always maximum when \(t = t^* = l^*\).

Quality improvement based competition can be characterized by the target amount of investment \(l^*\) and price-based competition by the level of margin \(t\) or rather by \(1/t\), the level of substitutability.

Maximum welfare occurs in \(l/t = 1\) which means that the level of quality improvement based competition is inversely proportional to the level of price-based competition.

**Empirical Analysis**

This section provides an empirical analysis of the relationship between investment and margin per user for in wireless markets in 30 countries between 2002 and 2010. It highlights the existence of a breaking point in the relationship between margin and investment. Companies’ investment behavior in a country tends to change when their margins reach a certain threshold. Below the threshold, investment increases sharply with the margin, while the increase is slower above the threshold. The theoretical model in the previous section predicts this type of change in a symmetrical and fully covered market (see Figure 2). In that specific case, beyond the threshold (the target level), growth in investment is nil.

Section three addresses the problem in terms of the firm’s problem, however, because the market is assumed to be symmetrical, all firms play the same role. As a result the industry behavior is totally defined by a representative firm. In this section, the analysis is conducted at the industry level and the results could be compared at the theoretical results of section three.

In markets which are not fully covered, investment may increase the number of consumers and profits. The observed growth of investment, although relatively low, therefore remains positive. The model also underscores the role of other factors including market structure, level of service adoption, level of technology, and standard of living.

**Data Set**

The data set used here is a panel data set of 30 countries (cf. list in Appendix, which includes annual data by country from 2002 to 2010). The data set should comprise 270 observations, however 29 observations are unavailable. The data set therefore comprises 241 observations. The financial figures used (Revenue, Capex, Ebitda, HHI, and the number of companies) are drawn from the Informa “World Cellular Information Service”. The number of wireless users, the population, and the level of technology come from the strategy analytics report “Broadband cellular user forecasts 2011-2016 (September 2011)”\(^3\), while the standard of living (GNI per

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\(^3\) This report provides not only forecast data but also data from 2002 to 2010.
Capita) is taken from the World Bank (see Appendix Table A1).

The dependent variable in the linear regression model is the yearly Capex per user by country, \( \text{CAPU} \) in US$. Capex per user is a proxy of investment.

There are two categories of explanatory variables: financial figures, which depend on the wireless market in the country, and country figures, which are based on the specificities of each country. A time trend is included, \( \text{YEAR} \), which indicates the number of years counting from 2001 (the value of year in 2002 is 2, and in 2003 is 3, etc.), as is a squared time trend (see Appendix Table A1).

These variables are presented as follows.

**Financial Figures**

These variables aim to evaluate the market’s impact on investment incentives. First, the margin per user, \( \text{MAPU} \), defined as annual Ebitda divided by the number of users. Second, the number of companies on the market: \( N \). Third, the asymmetry index, which measures the degree of asymmetry among companies present on the market: \( \text{IOA} \). This index is calculated as follows: 
\[
\text{IOA} = \frac{N(\text{HHI}) - 1}{N - 1}
\]
In a perfectly symmetrical market, \( \text{IOA} = 0 \); \( \text{IOA} \) increases with market’s asymmetry. \( \text{HHI} \), the Herfindahl index, is expressed as a percentage. When the market is absolutely symmetrical, all companies have an equal market share: \( \text{HHI} = 1/N \), thus \( \text{IOA} = 0 \). When the market is absolutely asymmetrical, it tends towards a monopoly; \( \text{HHI} \) tends towards 1, so \( \text{IOA} \) tends towards 1 as well. Fourth, the potential for market growth, \( \text{PMG} \). \( \text{PMG} \) depends on the penetration rate \( q \), defined as the number of users divided by the total population of the country. Assuming that the demand function, which expresses the penetration rate according to price, is sigmoid shaped, which is a common assumption in telecommunications (Fildes & Kumar, 2002) 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. \( \text{PMG} = q(1-q) \). The potential for market growth increases with \( \text{PMG} \), which seems more relevant than simply \( q \). The strength of the competition is given by \( \text{COMP} \), which is defined by \( 1-L \), where \( L \) is the Lerner index. The Lerner index is calculated yearly by country; it is defined as Ebitda divided by total revenue on the market.

**Table 1**

<table>
<thead>
<tr>
<th>Descriptive Statistics</th>
<th>CAPU</th>
<th>MAPU</th>
<th>COMP</th>
<th>N</th>
<th>IOA</th>
<th>PMG</th>
<th>3G</th>
<th>DPOP</th>
<th>YEAR</th>
<th>GNICAP</th>
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</thead>
<tbody>
<tr>
<td>Mean</td>
<td>62.24</td>
<td>172.61</td>
<td>60.72%</td>
<td>5.94</td>
<td>14.50%</td>
<td>18.13%</td>
<td>14.88%</td>
<td>564</td>
<td>5.33</td>
<td>26,579</td>
</tr>
<tr>
<td>Standard error</td>
<td>2.10</td>
<td>5.78</td>
<td>0.69%</td>
<td>0.60</td>
<td>0.69%</td>
<td>0.26%</td>
<td>1.29%</td>
<td>102</td>
<td>0.16</td>
<td>810</td>
</tr>
<tr>
<td>Median</td>
<td>60.99</td>
<td>173.55</td>
<td>61.33%</td>
<td>4.00</td>
<td>12.38%</td>
<td>17.20%</td>
<td>5.29%</td>
<td>108</td>
<td>5.00</td>
<td>29,893</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>32.58</td>
<td>89.79</td>
<td>10.76%</td>
<td>9.25</td>
<td>10.76%</td>
<td>3.97%</td>
<td>20.05%</td>
<td>1,582</td>
<td>2.45</td>
<td>12,575</td>
</tr>
<tr>
<td>Variance</td>
<td>1,061.57</td>
<td>8,061.65</td>
<td>1.16%</td>
<td>85.65</td>
<td>1.16%</td>
<td>0.16%</td>
<td>4.02%</td>
<td>2,501,646</td>
<td>6.01</td>
<td>158,135,179</td>
</tr>
<tr>
<td>Kurtosis coefficient</td>
<td>3.12</td>
<td>-0.24</td>
<td>0.94</td>
<td>38.21</td>
<td>1.43</td>
<td>-1.16</td>
<td>2.58</td>
<td>9.41</td>
<td>-1.11</td>
<td>-0.41</td>
</tr>
<tr>
<td>Skewness</td>
<td>1.31</td>
<td>0.44</td>
<td>-0.36</td>
<td>6.05</td>
<td>1.27</td>
<td>0.29</td>
<td>1.67</td>
<td>3.35</td>
<td>-0.12</td>
<td>0.07</td>
</tr>
<tr>
<td>Minimum</td>
<td>5.32</td>
<td>12.92</td>
<td>23.76%</td>
<td>2</td>
<td>0.05%</td>
<td>9.35%</td>
<td>0.00%</td>
<td>2.65</td>
<td>1</td>
<td>4.064</td>
</tr>
<tr>
<td>Maximum</td>
<td>211.11</td>
<td>466.51</td>
<td>93.43%</td>
<td>71</td>
<td>51.99%</td>
<td>25.00%</td>
<td>95.38%</td>
<td>6,812.24</td>
<td>9</td>
<td>68,547</td>
</tr>
<tr>
<td>Sum</td>
<td>15,000</td>
<td>41,599</td>
<td>146</td>
<td>1,432</td>
<td>35</td>
<td>44</td>
<td>36</td>
<td>135,976</td>
<td>1,285</td>
<td>6,405,424</td>
</tr>
</tbody>
</table>
Country-Specific Figures

These variables aim to take into account the specific situation of each country. First, the density of population, DPOP, defined as the total population divided by the country’s surface area. 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 advances integrated into the network, 3GT, defined as the proportion of subscriptions using 3G technologies as CDMA 2000, WCDMA or LTE.

Table 1 represents the descriptive statistics of the variables.

Econometric Model

First the determinants of the margin will be estimated and the impact of investment on future margin will be discussed. The theoretical model shows that in a symmetrical and fully covered market, investment did not increase the margin. However, since markets are neither perfectly symmetrical nor fully covered, it will be seen to what extend investments actually affect margin.

Margin Equation

A panel data regression OLS is used in order to estimate the coefficients of the following equation:

\[ MAPU_{iy} = \alpha + \alpha_{1}X_{iy} + \alpha_{2}Y_{iy} + \epsilon_{iy} \quad (8) \]

where \(X_{iy}\) represents the control variables and \(Y_{iy}\) represents the investment variables:

\[X_{iy} \in \{COMP_{iy}, DPOP_{iy}, GNICAP_{iy}, N_{iy}, IOA_{iy}, YEAR_{iy}\}\]

\[Y_{iy} \in \{CAPU_{iy}, CAPU - 1, CAPU - 1 * PMG_{iy}, CAPU - 1 * IOA_{iy}\}\]

where \(\epsilon_{iy}\) is the error term. \(CAPU\) is the Capex per user \(CAPU\) lagged one year. \(CAPU - 1 * PMG\) and \(CAPU - 1 * IOA\) are the lagged values of \(CAPU\) multiplied respectively by the potential for market growth \(PMG\) and index of asymmetry \(IOA\). These variables aim to assess the impact of the remoteness of assumption of symmetry and full coverage on the margin. The subscripts of the variables denote country \(i\) at year \(y\). The results are presented in Table 2.

The first specification is the regression on the full sample (241 observations). The second specification represents the same model with lagged \(CAPU\), that is why 30 observations are lost (one per country). The results of the second specification are very similar to the first. In this case, Investment seems to have no significant impact on margin. However, three observations show an abnormally high Capex. For those observations, Capex is significantly higher than margin. It is possible that these Capex do not only represent investments in improving the quality or that these values are incorrect. Anyway, in the following columns, these three values are removed leaving 238 observations for \(CAPU\) and 208 for \(CAPU - 1\). In the third and the fourth specification, the investment has a significant impact on margin. There is no significant difference between the coefficients estimated in these two specifications which suggest that an investment remains relatively steady over time. The fifth specification provides both \(CAPU\) and \(CAPU - 1\) in order to compare the respective impact of the past year and current year investment on margin. As expected, although both \(CAPU\) and \(CAPU - 1\) are significant, the impact of the past year is higher and more significant. Consequently, in the following model, the lagged values of investment \(CAPU - 1\) is chosen rather than \(CAPU\). In the sixth specification \(CAPU - 1\) is replaced by the product \(CAPU - 1 * PMG\), and in the seventh \(CAPU - 1\) is replaced by the product \(CAPU - 1 * IOA\). These variables indicate respectively the impact of the Potential for Market Growth \(PMG\) and the asymmetry of the market on the relationship between investment and margin. These two variables have a positive and significant impact on margin. This means that \(PMG\) and \(IOA\) both increase the impact of investment on margin.
This is consistent with section three and the hypothesis of market symmetry and full coverage. Under such hypothesis, \( PMG = IOA = 0 \), Investment has no impact on margin. Therefore, the highlighted impact is caused by the fact that markets are neither fully covered nor symmetrical, even though they often approach close to symmetry and full coverage. \( PMG \) increases profits and thus encourages investment. Indeed, when \( PMG \) is high, investment in quality improvement encourages customers who were not yet in the market to enter. This increases the market size and thus profits. Asymmetry of the market also encourages investment because asymmetry means there are leader firms, and leader firms can expect their investment to provide them a competitive advantage and increase their profits.

The coefficients of control variables are robust to the different specifications. As expected, competition \( COMP \) and the number of firms \( N \) have a negative impact on margin. The density of the population \( DPOP \) and the \( GNI \) per capita have a positive one. The time trend \( YEAR \), indicates a decline of margin over time.

Table 2

<table>
<thead>
<tr>
<th>Variables</th>
<th>MAPU (1)</th>
<th>MAPU (2)</th>
<th>MAPU (3)</th>
<th>MAPU (4)</th>
<th>MAPU (5)</th>
<th>MAPU (6)</th>
<th>MAPU (7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( COMP )</td>
<td>-195.1***</td>
<td>-182.2***</td>
<td>-182.3***</td>
<td>-183.9***</td>
<td>-184.9***</td>
<td>-181.9***</td>
<td>-184.1***</td>
</tr>
<tr>
<td></td>
<td>(25.13)</td>
<td>(25.86)</td>
<td>(24.03)</td>
<td>(24.59)</td>
<td>(24.41)</td>
<td>(24.84)</td>
<td>(24.67)</td>
</tr>
<tr>
<td>( DPOP )</td>
<td>0.0753***</td>
<td>0.0812***</td>
<td>0.0716***</td>
<td>0.0807***</td>
<td>0.0748***</td>
<td>0.0806***</td>
<td>0.0804***</td>
</tr>
<tr>
<td></td>
<td>(0.0254)</td>
<td>(0.0255)</td>
<td>(0.0241)</td>
<td>(0.0239)</td>
<td>(0.0240)</td>
<td>(0.0242)</td>
<td>(0.0240)</td>
</tr>
<tr>
<td>( GNICAP )</td>
<td>0.00458***</td>
<td>0.00489***</td>
<td>0.00426***</td>
<td>0.00455***</td>
<td>0.00450***</td>
<td>0.00461***</td>
<td>0.00399***</td>
</tr>
<tr>
<td></td>
<td>(0.000873)</td>
<td>(0.000885)</td>
<td>(0.000832)</td>
<td>(0.000835)</td>
<td>(0.000829)</td>
<td>(0.000844)</td>
<td>(0.000871)</td>
</tr>
<tr>
<td>( N )</td>
<td>0.0148</td>
<td>-0.288</td>
<td>-0.153</td>
<td>-0.525*</td>
<td>-0.581**</td>
<td>-0.483*</td>
<td>-0.656**</td>
</tr>
<tr>
<td></td>
<td>(0.288)</td>
<td>(0.276)</td>
<td>(0.278)</td>
<td>(0.267)</td>
<td>(0.266)</td>
<td>(0.272)</td>
<td>(0.286)</td>
</tr>
<tr>
<td>( YEAR )</td>
<td>-0.0121</td>
<td>-2.364*</td>
<td>-1.09</td>
<td>-2.684*</td>
<td>-2.579**</td>
<td>-2.171*</td>
<td>-1.837</td>
</tr>
<tr>
<td></td>
<td>(1.220)</td>
<td>(1.255)</td>
<td>(1.162)</td>
<td>(1.189)</td>
<td>(1.181)</td>
<td>(1.211)</td>
<td>(1.215)</td>
</tr>
<tr>
<td>( CAPU )</td>
<td>0.0449</td>
<td>0.223**</td>
<td>0.171*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0740)</td>
<td>(0.0913)</td>
<td>(0.0902)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( CAPU-1 )</td>
<td>0.0374</td>
<td>0.277***</td>
<td>0.253***</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0687)</td>
<td>(0.0924)</td>
<td>(0.0926)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( CAPU-1*PMG )</td>
<td>1.127**</td>
<td>(0.497)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( CAPU-1*IOA )</td>
<td>1.216***</td>
<td>(0.428)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( CONSTANT )</td>
<td>124.0***</td>
<td>121.6***</td>
<td>117.5***</td>
<td>120.5***</td>
<td>116.6***</td>
<td>119.3***</td>
<td>139.0***</td>
</tr>
</tbody>
</table>

Notes: Standard errors are in parentheses. *** \( p < 0.01; ** \( p < 0.05; \) and * \( p < 0.1. \)

**Investment Equation**

The investment equation emphasizes the difference in behavior between companies according to their margins. In order to do so, two hypotheses will be compared: The first hypothesis, \( H0 \) supposes there is no change in firms’ behavior according to their margin. The corresponding equation is as follows:

\[
CAPU_{ly} = \beta_0 + \beta_1 MAPU_{ly} + \epsilon_{ly}
\]  

(9)

The Capex per user \( CAPU \) is explained by the margin per user \( MAPU \). \( \epsilon \) is the error term. The alternative
hypothesis, Ha suppose there is a break in firms’ behavior. Before the break, for the low values of margin, Capex per user follows the equation (9) and after the break, Capex per users follows the following equation:

\[ CAPU_{iy} = \beta_0' + \beta_1'MAPU_{iy} + \beta_2'\Delta MAPU + \epsilon_{iy} \]  

(10)

where \( \beta_0' = \beta_0 + \Delta \text{CONSTANT} \), \( \beta_1' = \beta_1 + \Delta \text{MAPU} \), and \( \beta_2' = \Delta \text{MAPU} \ast \text{PMG} \).

A Chow test will be performed to choose the most likely hypothesis. The model with all the 241 observations will be tested first then the three abnormal observations will be removed like in margin equation. The model for \( \beta_0 = 0 \) which suggests there is no investment when there is no margin will also be tested.

The results are presented in Table 3.

Table 3

<table>
<thead>
<tr>
<th>Investment Equation</th>
<th>CAPU (1)</th>
<th>CAPU (2)</th>
<th>CAPU (3)</th>
<th>CAPU (4)</th>
<th>CAPU (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variables</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MAPU</td>
<td>0.253**</td>
<td>0.502***</td>
<td>0.255***</td>
<td>0.478***</td>
<td>0.478***</td>
</tr>
<tr>
<td></td>
<td>(0.108)</td>
<td>(0.0366)</td>
<td>(0.0868)</td>
<td>(0.0296)</td>
<td>(0.0308)</td>
</tr>
<tr>
<td>Constant</td>
<td>31.30***</td>
<td>52.89***</td>
<td>24.46**</td>
<td>43.96***</td>
<td>38.89***</td>
</tr>
<tr>
<td>( \Delta ) MAPU</td>
<td>-0.357***</td>
<td>-0.606***</td>
<td>-0.303***</td>
<td>-0.526***</td>
<td>-0.331***</td>
</tr>
<tr>
<td></td>
<td>(0.124)</td>
<td>(0.0713)</td>
<td>(0.100)</td>
<td>(0.0586)</td>
<td>(0.0415)</td>
</tr>
<tr>
<td>( \Delta ) MAPU*PMG</td>
<td>1.151***</td>
<td>1.151***</td>
<td>1.016***</td>
<td>1.016***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.271)</td>
<td>(0.274)</td>
<td>(0.221)</td>
<td>(0.224)</td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>21.59**</td>
<td>19.50***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(8.848)</td>
<td>(7.138)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observations</td>
<td>241</td>
<td>241</td>
<td>238</td>
<td>238</td>
<td>238</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.327</td>
<td>0.852</td>
<td>0.438</td>
<td>0.892</td>
<td>0.883</td>
</tr>
<tr>
<td>Chow test</td>
<td>8.46</td>
<td>27.9</td>
<td>8.9</td>
<td>30.27</td>
<td>32.42</td>
</tr>
<tr>
<td>Prob. (H0)</td>
<td>0.00002</td>
<td>0.00000</td>
<td>0.00001</td>
<td>0.00000</td>
<td>0.00000</td>
</tr>
</tbody>
</table>

Notes. Standard errors are in parentheses. ** \( p < 0.01 \); *** \( p < 0.05 \); and * \( p < 0.1 \).

Specifications (1) and (2) use all the 241 observations. Specifications (3), (4), and (5) removed the three abnormal observations.

Specifications (1) and (3) have a coefficient \( \beta_0 \neq 0 \), specifications (2), (4), and (5) have a coefficient \( \beta_0 = 0 \). Those specifications reflect the fact that there should be no investment when there is no margin. The specification (5) has the coefficient \( \beta_2' = \Delta \text{MAPU} \ast \text{PMG} = 0 \) in order to compare the impact of the potential for market growth between specifications (4) and (5).

Removal of abnormal observations does not change significantly the results, however, it improves the accuracy of the model.

The Chow test indicates that in all specifications, the hypothesis H0 is highly unlikely. This means that the alternative hypothesis Ha is confirmed: There is actually a structural change. Under a certain threshold of margin, Capex per user \( \text{CAPU} \) is proportional to the margin per user \( \text{CAPU} \) and follows the equation (9). Beyond the threshold, \( \text{CAPU} \) follows the equation (10). The margin threshold is chosen for the value of \( \text{MAPU} \) that maximizes the fisher’s statistic of the Chow test. This occurs for a value of \( \text{MAPU} = 117$/user/year.\n
Equation (10) does not depend on the initial specification of the coefficient \( \beta_0 \). One can notice that

---

4 This is theoretically exact when the market is symmetrical and fully covered because in that case investment does not provide an increase in profits (see section three).
\[ \beta_0' = \beta_0 + \Delta CONSTANT \quad \text{and} \quad \beta_1' = \beta_1 + \Delta MAPU \] have exactly the same values in specifications (1) and (2) and in specifications (3) and (4).

The structural change in investment behavior according to the margin is consistent with the theoretical framework of section three.

For low margin values (under the threshold), the target amount of investment is not achieved, therefore an increase in margin entails a proportional increase in investment to approach the target amount.

For high values of margin (above the threshold), the target amount is achieved and an increase in margin does not necessarily lead to a higher investment. The value of \( \beta_1' = \beta_1 + \Delta MAPU \) in specification (2), where \( \beta_1' = 0.505 - 0.606 = -0.104 \) and in specification (4), where \( \beta_1' = 0.478 - 0.526 = -0.048 \) is very low (and negative), barely significant in specification (2) and not significant in specification (4). Only the specification (5) indicates a positive and significant coefficient \( \beta_1' = 0.478 - 0.331 = 0.147 \) but this is just because the variable \( MAPU \times PMG \) has not been taken into account. In specifications (2) and (4), the coefficient of this variable \( \beta_2' \), is positive and significant. This variable, indeed, captures all the impacts of the variation of the margin. This means that, beyond the threshold, the impact of margin on investment is positive only if the Potential for Market Growth (PMG) is nonzero. As a result, when the market is fully covered, the margin has no impact on investment, as theoretically stated in section three. However, when the potential for market growth is high, investment increases the market size and future profits, as shown in the margin equation.

Thereby, an increase in margin leads to an increase in investment.

Figure 4 illustrates the relationship between margin and investment.

![Figure 4: Relationship between investment and margin.](image-url)

The linear regression lines in Figure 4, calculated when the three abnormal observations are removed, are quite similar to the theoretical Figure 2. Especially the “\( \gamma (0) = 0 \)” line where \( \beta_0 = 0 \). The break between low margin and high margin values appears clearly from both sides of the margin threshold (\( MAPU = 117\$/year \)). The main difference is the slope of the line due to the potential for market growth. It is noteworthy that when \( \beta_0 = 0 \) (\( \gamma (0) = 0 \) line), the two half-lines are continuous at the breaking point. This is not the case when
\( \beta_0 \neq 0 \). Thus the hypothesis \( \beta_0 = 0 \) is consistent with the trend beyond the threshold. The fact that markets are neither fully covered nor perfectly symmetrical could explain the constant.

Investment behavior is different from either side of the breaking threshold. Before the breaking threshold, margin is too low to achieve the target amount of investment. Thereby, in this case, an increase in margin results in a proportional increase in investment in order to approach the target amount. Beyond the breaking threshold, the target amount is achieved. An increase in margin does not result in an increase in investment if the market is not fully covered. When the market is fully covered, the target amount is achieved and the investment is no more linked to the margin as indicated by equation (4) in the theoretical framework. When the market is not fully covered, target amount depends on the margin. An increase in investment allows an increase in market size and profits, and therefore, margin is reinvested proportional to the potential for market growth.

**Impact of Competition on Investment**

Considering that beyond the margin threshold the target amount is achieved, investment does not exceed this target amount. As a result, it is considered that, in such case, CAPU equals the target amount. The impact of the other variables will now be tested: (\( COMP \), \( N \), and 3G+) on the target amount. Beyond the threshold \( MAPU > 117$/year.\)

\[
CAPU_{iy} = \beta_0 + \beta X_{iy} + \epsilon_{iy}
\]  

(11)

With \( X \), the vector of variables \( X = \{MAPU, MAPU * PMG, COMP, N, 3G+\} \), and \( \beta \) the coefficients to be estimated. The results are presented in Table 4.

<table>
<thead>
<tr>
<th>Table 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Target Amount of Investment</strong></td>
</tr>
<tr>
<td>Variable</td>
</tr>
<tr>
<td>COMP</td>
</tr>
<tr>
<td>(21.45)</td>
</tr>
<tr>
<td>N</td>
</tr>
<tr>
<td>(0.714)</td>
</tr>
<tr>
<td>3G+</td>
</tr>
<tr>
<td>(9.698)</td>
</tr>
<tr>
<td>MAPU</td>
</tr>
<tr>
<td>(0.0659)</td>
</tr>
<tr>
<td>MAPU*PMG</td>
</tr>
<tr>
<td>(0.299)</td>
</tr>
<tr>
<td>Constant</td>
</tr>
<tr>
<td>(16.81)</td>
</tr>
<tr>
<td>Observations</td>
</tr>
<tr>
<td>R-squared</td>
</tr>
</tbody>
</table>

*Note.* Standard errors are in parentheses. *** \( p < 0.01 \); ** \( p < 0.05 \); and * \( p < 0.1 \).

Specifications (1) and (3) use all the 241 observations, specifications (2) and (3) removed the three abnormal observations. Specifications (1) and (2) use the constant term while specifications (3) and (4) do not.

Coefficients of competition \( COMP \) and number of firms \( N \) are positive and significant in all the specifications in Table 4.

Competition has an ambiguous impact on investment. On the one hand, Table 4 indicates that competition tends to increase; however, on the other hand, Table 2 highlights that competition decreases margin.
The overall impact of competition on target amount seems to be positive provided the potential for market growth is not too high, because the variable MAPU, as in equation (10), is not significant. Although variable MAPU*PMG is positive and significant, its impact becomes negligible when market approach the full coverage.

However, when competition is fierce enough to reduce the margin below the threshold, then the target amount is no more achievable. In this case, margin is pushed below the threshold where investment is proportional to the margin. As a result, investment decreases.

In other words, competition has a positive impact on investment as long as the target amount can be reached; otherwise it has a negative impact.

**Discussion**

As discussed in the theoretical model, the target investment level is lower than the socially optimal level of investment, but is the highest amount that companies are encouraged to invest. Non-achievement of the target level thus means underinvestment and a decrease in consumer surplus and social welfare. A low margin may cause non-achievement of the target investment level. This could explain the inverted U relationship between investment and competition. As seen, competition and the number of companies have a positive impact on investment when the margin is sufficient to achieve the target investment level. However, they also have a negative impact on the margin. If this negative impact is strong enough to decrease the margin to a point below the level which makes it possible to achieve the target investment level, the overall impact may be negative. Otherwise the overall impact remains positive.

**Conclusions and Policy Implications**

Competition based on quality improvement leads to a target investment level which companies strive to achieve in order to maximize their profits. This target level is lower than the socially optimal level, meaning that the target level is, in social terms, the best level of investment that companies are encouraged to make. However, companies need to have adequate margins to achieve their target amounts. A lack of resources causes non-achievement of the target level and entails a decrease in technical progress, consumer surplus, and welfare.

The potential for technical progress increases investment’s impact on quality. The target level is thus even higher than the potential for technical progress. This potential is particularly high for information technologies and telecommunications, meaning that the target investment level is particularly high and difficult to achieve. There are many examples where the target level is not achieved, not only in emerging countries where standards of living are low, but also in developed countries when price-based competition is too fierce.

There is a trade-off between competition based on quality improvement, which represents the dynamic side of competition, and competition based on pricing, which represents the static side of competition. These two types of competition can be seen as competitors. Welfare is maximized when the target investment level is exactly achieved. For a given potential for technical progress providing a given target investment level and thus a given level of dynamic competition, the static side of competition should be adjusted in order to allow achievement of the target level.

Regulatory and competition authorities in the sector should avoid underinvestment by ensuring that companies are able to achieve their target levels.

In terms of market tools, competition and entry have a positive impact on investment but only when companies can achieve their target levels, otherwise they may have a negative impact.
References


Appendix

List of countries:
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 therefore:

\[
\frac{d\Pi_i}{dI_i} = \frac{2}{N} \frac{(N-1)}{2N-1} \frac{dV(I)}{dI} \frac{1}{N}(1+\rho)
\]

The first order condition \(\frac{d\Pi_i}{dI} = \frac{d\Pi_i}{dI} = 0\) leads to

\[
\frac{dV(I^*)}{dI} = \frac{(1+\rho)(2N-1)}{2(N-1)} \]

equation (4).

Proof of equations (5) and (6):

There are \(N\) spokes and \(N(N-1)/2\) different \(i, j\) pairs. There are \(q/N\) consumers on each spoke or \(2q/N\) customer for each pair. Each company appears in \((N-1)\) pairs. Let us denote \(cs_{ij}\) the consumer surplus of the pair \(i, j\). Total consumer surplus is:

\[
\frac{N(N-1)}{2} \frac{cs_{ij}}{N(N-1)} = cs_{ij}
\]

\[
\frac{N(N-1)}{2} \frac{cs_{ij} \ x^2}{N(N-1)} = cs_{ij}
\]

When market is symmetrical, \(v_i = v_j = v\); \(x_{ij} = 1/2\):

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

Welfare is the sum of consumer surplus and industry profits.

In a symmetrical market, industry profits are \(qt - I(1+\rho)\). Welfare is written as follows:

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

Table A1

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<th>COMP</th>
<th>N</th>
<th>IOA</th>
<th>PMG</th>
<th>3GT</th>
<th>DPOP</th>
<th>YEAR</th>
<th>GNICAP</th>
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