Instituto Superior de Economia e Gestão
UNIVERSIDADE TÉCNICA DE LISBOA
DESDE 1911

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ECONOMETRIA APLICADA E PREVISÃO

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DISSERTAÇÃO

ECONOMETRIC STUDY OF ALTERNATIVE OPERATORS'

INVESTMENT DECISIONS

HUGO MIGUEL DE JESUS BRITO

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POR HUGO MIGUEL DE JESUS BRITO

DISSERTAÇÃO APRESENTADA AO INSTITUTO SUPERIOR DE ECONOMIA E GESTÃO/UNIVERSIDADE TÉCNICA DE LISBOA, COMO REQUISITO PARCIAL PARA A OBTENÇÃO DO GRAU DE MESTRE EM ECONOMETRIA APLICADA E PREVISÃO

ORIENTAÇÃO:

PROFESSORA DOUTORA ISABEL PROENÇA

OUTUBRO – 2012

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"*An investment in knowledge pays the best interest*" – Benjamim Franklin

ABSTRACT

The relation between regulation, the alternative operators' investment decisions and the degree of competition in the markets, has been an important policy issue over time. The discussions on this matter are mostly related with the possibility to achieve service-based competition in the short run, without compromising infrastructure-based competition in the long run. The investment ladder theory argues that both goals are achievable by appropriate regulatory intervention.

By using a rich dataset prepared specifically for this study, and taking into account flaws pointed out in other studies, the present study finds reasonable evidence that the Portuguese market's data supports theoretical assumptions of the investment ladder theory: (i) creating conditions for alternative operators entering the market is an important step in creating conditions for investment in infrastructure; (ii) the regulator has the necessary tools to neutralise the opportunity cost for infrastructure investment created by service-based competition profits.

The investment in fibre networks by alternative operators is also taken into consideration, with an evaluation of the investment determinants and their effect on coverage level of alternative operator's fibre networks. Particular attention is given to achieve an appropriate model specification, specifically considering challenges raised by the explained variable – a fractional variable with many zeros. It is concluded that it is preferable to use a two-part model over a one part-model, which provides evidence that the determinants of the decision to invest in a geographical area are not entirely similar to the determinants of the decision on the coverage level in that area.

The present study found that the intrinsic demographic, economic and social characteristics of a given geographical area significantly influence investment decisions of alternative operators. This supports the argument that the regulator must consider these characteristics when defining the obligations to imposed in the market and how to differentiate them per geographical area.

It is undeniable that econometrics represents a valid and very useful decision tool for regulators when deciding which regulation to apply, as well as to provide the "right" investment incentives for alternative operators.

RESUMO

A relação entre a intervenção regulatória, as decisões de investimento dos operadores alternativos e o grau de concorrência nos mercados de comunicações eletrónicas tem sido intensamente discutida. O debate centra-se na possibilidade de obter um compromisso entre concorrência baseada em serviços no curto prazo e concorrência baseada em infraestruturas no longo prazo. A teoria da escada do investimento defende a conciliação destes dois objetivos pela intervenção adequada do regulador.

Usando uma base de dados tão completa quanto o possível, preparada especificamente para o presente estudo e, atendendo às fragilidades apontadas a outros estudos, conclui-se que a informação sobre o mercado português comprova alguns pressupostos teóricos associados à teoria da escada do investimento: (i) a criação de condições para que os operadores alternativos entrem no mercado é um passo importante para que invistam em infraestrutura própria, e (ii) o regulador possui instrumentos regulatórios para neutralizar o custo de oportunidade criado ao investimento em infraestruturas pelos lucros da concorrência baseada em serviços.

O investimento em redes de fibra ótica pelos operadores alternativos é também considerado, avaliando os determinantes deste investimento e o respetivo efeito no nível de cobertura de uma área geográfica. É dada particular atenção à obtenção de uma especificação adequada para o modelo, ponderando os desafios colocados pela variável a explicar: variável fracionária e com muitos zeros. Conclui-se que é preferível utilizar um modelo a duas partes em detrimento de um modelo a uma parte, pois os conjuntos de determinantes da decisão de investir numa área geográfica e da decisão relativa ao nível de cobertura a atingir nessa área não são idênticos.

As características demográficas, económicas e sociais intrínsecas às áreas geográficas influenciam significativamente as decisões de investimento dos operadores alternativos, validando os argumentos dos que defendem a consideração destas características pelo regulador aquando da decisão sobre as obrigações a impor no mercado e a sua segmentação geográfica.

É inegável que a Econometria é um instrumento válido e muito útil para os reguladores quando decidem sobre o tipo de intervenção regulatória que garanta os incentivos de investimento adequados aos operadores alternativos.

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1. INTRODUCTION

Most European (and worldwide) electronic communications markets stem from a monopolistic market structure in which all services were originally provided by a state-owned monopoly. The liberalisation of the European markets marked a milestone for the sector and announced the opening up of markets. This has been developed even further thanks to several European directives on the subject.

One of the principles behind the European regulatory framework is to create conditions for developing effective market competition. Until its development, regulators should promote competition, investment and the European internal market and defend citizen and consumer interests.

Regulators should carry out regular market analysis, defining the markets that should be regulated and the dominant operators upon which obligations should be imposed. Regulators may impose various obligations upon dominant operators, depending on the specific market situation. One of these obligations concerns access to specific network utilities of the dominant operator by alternative operators.

The relation between regulation (especially the access obligation imposition), the operators' investment decisions and the degree of competition in the markets has been an important policy issue. Putting it simply, the discussion is as follows: if NRAs give access to the dominant operator's network, competition is achieved in the short run. However, in the long run, this could lead to less investment in infrastructures both by alternative operators and the dominant operator and therefore compromise infrastructure-based competition.

There are conflicting theories explaining how regulatory decisions might alter operators' investment incentives. One of these theories is called the "investment ladder" which basically defends that regulators should gradually offer different levels of access to the dominant operator's network. If this happens and if the regulator provides the "right" incentives to alternative operators at each moment in time, the theory says that alternative operators will "climb" from the easiest access level (e.g. resale) to other access levels, which implies investment in their network and will develop infrastructure-based competition.

Consequently, the investment ladder theory achieves a compromise between promoting competition (in services) in the short run and promoting investment in the long run (infrastructure-based competition). This theory has been one of the references in the intervention of the Portuguese regulator[1] (and several other European regulators), and has been put forward as an argument for its intervention in the market.

The aim of this paper is firstly to analyse empirically what has happened in the access market in the last decade in Portugal regarding the investment made by alternative fixed operators that entered the market accessing the dominant operator's[2] network and to try to test empirically if what happened in the Portuguese market adheres to the investment ladder theory. We will also look at the types of investment chosen by these operators in the different Portuguese geographic areas and try to identify the determinants of the investment choices made.

Understanding the past may also be important in understanding what is happening now or might happen in the future. The investment in fibre networks is reigniting the discussion as to the way regulatory decisions affect operators' investment decisions. However, there is a significant difference: investments in fibre have yet to be made countrywide. Consequently, the regulators have to consider that, in this case, both alternative and dominant operators may have the option of not investing, while in the copper networks, when the alternative operators entered the market, the dominant operator had already a ubiquitous network.

Considering these differences and how they affect investment decisions and the investment ladder theory, it is important to evaluate the possibility of deployment of fibre networks by alternative operators. The regulator's decisions regarding the imposition of obligations in the dominant operator's fibre network may depend on this possibility.

Accordingly, though it is true that regulatory intervention may influence operators' investment decisions, it is also true that there are other important variables affecting

[1] Autoridade Nacional de Comunicações (ANACOM).
[2] Grupo Portugal Telecom (hereinafter PT Group).

their investment decisions. Especially in investment in fibre, it is essential that the regulator considers these other variables and their influence in investment decisions when defining the obligations and how to differentiate them per geographic area. This study is relevant not only to operators and regulators, but also to other public entities deciding on state aid for investment in specific geographic areas.

Another goal of this paper is therefore to have a better understanding of what is happening regarding the decisions of alternative operators to invest in fibre, namely to estimate how the intrinsic characteristics associated with each geographic area may affect the investment decisions in fibre in that area.

The remainder of the paper is organized as follows. Section 2 provides a short but extensive review of the relevant literature related with the determinants of alternative operators' investment, including regulation. Section 3 describes the main facts characterizing the Portuguese market, while Section 4 presents the data used in the empirical investigation. Section 5 explains the models used and the results achieved in the empirical investigation. Section 6 concludes.

2. LITERATURE REVIEW

This section uses technical terms related with the electronic communications sector which are explained in a simple way in a Technical glossary included in *ANNEX 1*.

2.1 INVESTMENT, REGULATION AND THE INVESTMENT LADDER THEORY

One relevant question the literature considers is the differences between the investment motivations of alternative operators and those of the dominant operator.

According to Cave (2003), the dominant operator enjoys the advantages of usually being the historic monopolist: networks that cover most of the country, established market position, known brand and possible consumer inertia. This author also mentions that the intrinsic characteristics of fixed networks may magnify the differences between alternative and dominant operators[3].

According to Cave (2003), these questions may imply cost advantages for the dominant operator, leading to differences in the risk perception of investments and to a higher

[3] Scale and scope economies lead to lower average costs for dominant operators.

required rate of profit for investment by alternative operators. The author defends that the explained differences may justify the existence of transitory entry assistance by the regulator to minimise the dominant operator's advantages and push alternative operator's investment. The investment ladder theory has its roots in this need for transitory entry assistance.

The basic principle behind the investment ladder consists of gradually offering potential entrants different levels of access to the dominant operator's network. Alternative operators begin by accessing at a level requiring little investment but, as their customer base grows, they are encouraged to invest in the next access level. This sequential and dynamic investment by alternative operators makes them "climb" the investment ladder and boost infrastructure-based competition.

Cave (2006) defends a proactive role of the regulator in promoting alternative operator investment: "forcing" its investment in the next rung of the ladder, but also "choosing" the right time to enhance this investment[4]. Regarding this question, Bourreau *et al* (2010) clarify that this proactive attitude by the regulator is necessary because alternative operators' profits from service-based competition represent an opportunity cost for investments in infrastructure, especially if access prices are low.

In order to clarify, the investment ladder theory does not say that service-based competition is sufficient to achieve facility-based competition. This goal depends on rigorous implementation of the theory by the regulator.

According to Cave (2006), proper implementation of the theory starts by defining the replicable components of the network, non-replicable components of the network and those in an intermediate position. On this issue, Bourreau *et al* (2010) mention that for Cave "replicability is not a simple binary variable, depending on a range of changing factors" (e.g. demand). Cave (2006) concludes that where a regulator finds a replicable asset, regulation should not exist. On the other hand, if the regulator finds an asset that is unquestionably non-replicable, access should be granted, allowing the benefits of service competition. Consequently, the most relevant assets for implementing the

[4] The author defends that the regulator should restrict mandatory access to a limited period and, after this period, access should no longer be available, it should become subject to commercial agreement or the access prices should go up.

investment ladder are those classified as being in an intermediate situation in terms of possible replication.

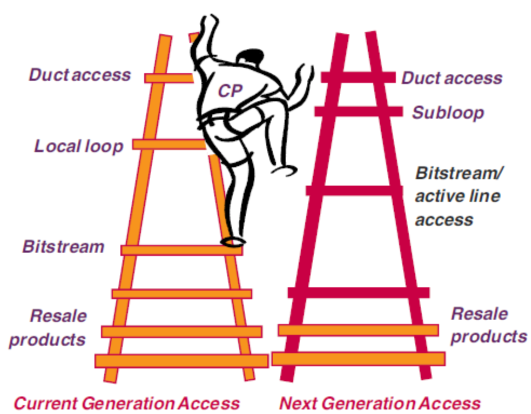
Considering these intermediate assets, Cave (2006, 2010) proposes a 6-step method, involving the determination of the different access levels of the ladder and deciding on the right regulatory tools available to make the alternative operators climb it.

Bourreau *et al* (2010) highlight that there are differences in the way the ladder was defined by Cave and how the theory was implemented by regulators. The original ladder proposed by Cave only foresees one access level available at each moment in time. However, European regulators implemented a ladder in which multiple levels of access are granted to the alternative operators at the same time[5].

Bourreau *et al* (2010) discuss additional problems related to implementing this theory, namely the insufficient information available to the regulator, the information asymmetry between the regulator and the regulated operator(s), the credibility of commitments assumed by regulators, the possible entrance of late entrants and the emergence of Next Generation Access Networks (NGA).

Cave (2010) discusses the main differences between the copper network investment ladder and the NGA investment ladder (Figure 1).

Figure 1. Martin Cave's investment ladder(s)



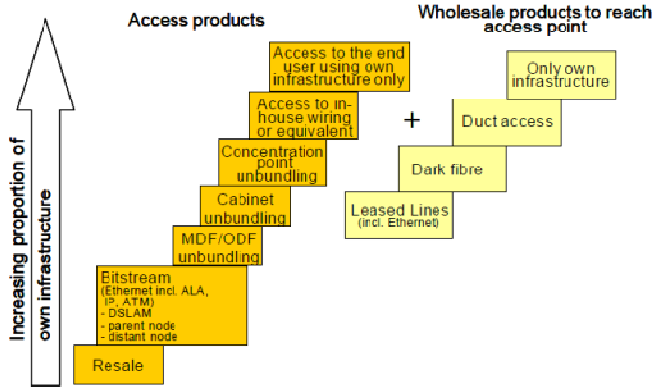
Source: Cave(2010)

Also, BEREC[6] (2010) presents a NGA version of the ladder (Figure 2).

[5] Implementation justified considering (i) the geographical differences in the markets and (ii) the fact that different levels of access may correspond to different business models or phases of market entry.

[6] Body of European Regulators for Electronic Communications.

Figure 2. BEREC's NGA investment ladder



Source: BEREC (2009)

Again, the ladders presented are not identical. The ladder proposed by Cave clearly identifies the differences between the possible access levels in a NGA world and in a copper world. It considers the possible disappearance of local loop unbundling (LLU) at the central exchange and the move of the "new" bitstream access a little closer to the end user. It also highlights the important move that alternative operators must make from the original ladder to the NGA ladder. The ladder presented by BEREC does not tackle this issue. However, it considers wholesale backhaul products that may help alternative operators reach the wholesale access products available. Despite the differences described, both ladders foresee similar access levels to the NGA network.

In this set, Cave (2010) sees two options for alternative operators: (i) go up the new version of the ladder by renting a duct and invest in their own NGA network, or (ii) go down the ladder, moving away from the customers and using the "new" bitstream access product. According to Cave, the ability to go up the new ladder will depend on a variety of circumstances: the state of the ducts, housing density, etc.

If alternative operators must go down the ladder to bitstream access products, Cave (2010) believes that it can be temporary and it is possible that these operators may climb the ladder again after acquiring more fibre clients[7].

Even though there are differences in the NGA investment ladder proposed by Cave and BEREC, both agree that it exists and that regulators can and should continue to use

[7]The author highlights that alternative operators are in a different position compared to what happened in the past because they already have a considerable customer base.

their powers to push operators up the ladder. Consequently, the logic of the investment ladder is not disrupted.

2.2 ALTERNATIVE OPERATORS' INVESTMENT IN FIBRE NETWORKS

The most important difference between fibre access networks and the copper access networks lies in the fact that the first are still not completely developed and, as a result, in some cases, no sunk costs are involved. Consequently, dominant operators (as well as alternative operators) have the option of not investing or delaying the investment. This question and the existence of uncertainty alter the investment decision. Pindyck (2007) argues that, in uncertainty, the opportunity cost of losing the option of investing in the future must be included as part of the total cost of the investment. This creates additional challenges for regulator intervention.

Even though the most deeply discussed issue affecting investment is regulation, it is obviously not the only one. Katz (2008) mentions that, even if regulation is a critical variable in explaining investment, it must be considered to be an intermediate factor in influencing investment decisions. In this regard, Katz defends that unless all the factors affecting investment decisions are understood, it will be difficult to understand the importance of regulation.

Additionally, ERG (2009) and BEREC (2010, 2011) show that alternative operators in different European countries follow different NGA deployment strategies and identify factors that may explain these different strategies: (i) population density and geographic characteristics; (ii) costs of deployment; (iii) existence of demand; (iv) willingness to pay for services; (v) competitive conditions (presence of cable); (vi) potential penetration of NGA networks.

In the following sections the most relevant fibre investment determinants identified in the existing theoretical literature and theoretical models will be presented. These determinants may be classified as (i) cost determinants, (ii) demand determinants, (iii) and (iii) market and regulatory determinants.

2.2.1 COST DETERMINANTS

Access to infrastructure

ARCEP (2007) concludes that, under some assumptions, the existence of access to ducts by operators changes the coverage of Fibre to the Home (FTTH) networks in a specific city[8] from 1% of the area to 21% and the percentage of households covered from 13% to 79%.

Broadband Stakeholder Group (2008) identifies differences in deployment costs of NGA between different areas in the UK and argues that the access to infrastructure may reduce costs by up to 16% for Fibre to the Cabinet (FTTC) and 23% for FTTH. Also Soria & Hernández-Gil (2010), using a theoretical model, conclude that the number of competing operators in the same geographic area grows with the availability of civil infrastructure.

JP Morgan (2006) concludes that duct availability is one of the main determinants of the existence of investment and states that civil works account for 68% of FTTH deployment costs.

Population Density

Haydock *et al* (2012) identifies population density as a key driver in the viability of the investment in fibre and other networks. Hoernig *et al* (2011) also mentions that the viability of investment in access networks strongly depends on subscriber density.

Soria & Hernández-Gil (2010) and JP Morgan (2006) conclude that an increase in population density has a positive effect on investment. JP Morgan specifically mentions that FTTH deployment may be a feasible option for competitors, mainly in metropolitan areas with a high population density, while in low density areas it may not be possible for the alternative operators to invest.

2.2.2 DEMAND DETERMINANTS

Katz (2008) uses an investment model capturing commercial and financial variables to assess financial viability of FTTH deployment and verifies that the results of the models

[8] Clermont-Ferrand

are very sensitive to the percentage of homes that are connected to fibre and the retail ARPU[9].

Also, the studies by Soria & Hernández-Gil (2010) and JP Morgan (2006) expect the increase in ARPU and a higher penetration of the service to have a positive effect on the number of competing networks.

2.2.3 MARKET AND REGULATORY DETERMINANTS

Competition from other infrastructures

Katz (2008) concludes that, in some cases, the operator does not have the chance not to invest due to the pressure from upgraded cable networks. Portugal is mentioned as one of the countries where this happens in some areas.

Hoernig *et al* (2011) concluded that lower profits for copper and fibre will be the result of the existence of cable in the market. The effect of the presence of cable on the dominant operator's incentive to invest in fibre is ambivalent, since it affects both copper and fibre profits.

Price of the wholesale (copper) access

We will focus on the conclusions reached on how wholesale access prices influence alternative operators' decisions to invest in fibre (not dominant operator's or aggregated total investment). Additionally, considering that the Portuguese alternative operators' investment decisions studied in this paper were taken when there were no obligations imposed on fibre networks, we will also focus on the influence of the wholesale copper price alone on investment[10].

Bourreau *et al* (2011) conclude that alternative operators' incentives to invest drop with lower wholesale copper prices due to two effects: (i) replacement effect – when the copper price is low, the alternative operator's opportunity cost of investing in fibre is high; (ii) business stealing effect - if the wholesale copper price is high, the copper retail prices drop and clients will only migrate from copper to fibre with lower and less attractive prices for investment. The other papers considered reach the same conclusion about the way the copper price changes the alternative operators'

[9] Average revenue per user.

[10] The consideration of access conditions on fibre would make both the pricing decisions interdependent.

incentives to invest in fibre[11], The conclusions about the influence of the copper price on the dominant's operator investment decisions seem to be more controversial and may depend on the assumed coexistence period of copper and fibre networks.

2.3 EMPIRICAL ANALYSIS

2.3.1 DIFFICULTIES IN TESTING THE LADDER HYPOTHESIS

Bourreau *et al* (2010) mention that the investment ladder theory relies on two main assumptions: (1) the replacement effect[12] created by service-based competition is neutralised and service-based competition can be a stepping-stone to facility-based entry; and (2) there are regulatory instruments available to neutralise the replacement effect.

The difficulties in testing these assumptions econometrically are mentioned in several papers. Cave (2010) explains the difficulties with the need to consider the effects of a sequence of changing regulatory interventions, while Bourreau *et al* (2010) highlight the difficulties caused by the imperfection in implementing the theory by regulators and criticise the focus of some papers on countries where there is no assurance that the theory has been implemented.

Cambini & Jiang (2009) identify areas in which empirical papers should evolve[13]:

(1) Use longer time-series data to capture the dynamics of the investment in infrastructure and achieve a more robust empirical analysis.
(2) Data at the central exchange level is required for testing the significance of the investment ladder theory.
(3) The use of structural models could provide more rigorous estimations and could also be a relevant instrument in sustaining future policy interventions.

2.3.2 EMPIRICAL WORKS

In this section we will describe papers that studied empirically the effects of regulation and other variables in the operators' investment. We will focus our attention in the description of the goal of the study and on the conclusions achieved. The details about

[11] Cave (2010), Williamson *et al* (2011) and Hoernig *et al* (2011).
[12] The profits from service-based competition act as an obstacle to investments in infrastructure by alternative operators.
[13] The authors also discuss the potential improvements in theory.

the variables, sample, data sources, models and estimation procedures used in the considered papers are presented in *Table 3, ANNEX 2.*

Bouckaert *et al* (2010) concludes that market demographics, in particular demand and investment cost variables, explain differences in broadband penetration levels between countries. Also the different modes of competition explain differences in broadband penetration: inter-platform competition encourages broadband penetration, whereas service-based intra-platform competition is neutral or hinders penetration. The authors consider that these results suggest that the investment ladder theory does not provide the justification to impose access obligations on dominant operators.

The authors use the parameters estimated in the model applied to countries to assess to what extent the determinants of differences in cross-country broadband penetration may also explain regional differences within Belgium. The paper concludes that demographic factors (population density and per capita income) explain most of the regional differences (11% out of 12%). The difference in broadband performance is marginally affected by differences in competition modes.

Distaso *et al* (2009) investigates empirically the investment ladder theory using a data set considering the regulatory intervention adopted in 12 European countries. For each country two graphics were plotted: (i) a "ternary diagram" showing the evolution over time of the shares of bitstream access services, unbundling services and own network used by alternative operators to provide retail access and broadband services; and (ii) the ratio between the percentage changes in the regulated LLU price and the price of bitstream access. The authors conclude that the policies adopted by regulators are broadly consistent with the investment ladder theory.

Waverman *et al* (2008) analyse the impact of access regulation on investment. The authors use econometric methods to test the impact of variations in the price of unbundled local loops on the share of accesses provided through alternative access platforms. The authors estimate that a 10% decline in the LLU price leads to an 18% decline in the share of alternative access in overall broadband and evaluate this effect in terms of value of investment loss.

Waverman *et al* (2008) consider the possibility of endogeneity of regulation: if regulators set LLU prices considering the target levels of penetration or competition, this variable is endogenous and the estimates will be unbiased. Endogeneity tests[14] were performed and the authors conclude that there is no substantial evidence of endogeneity.

Grajek & Röller (2009) study the relation between access regulation and investment incentives. The estimated model includes a policy equation that endogenises access regulation[15], allowing empirical investigation as to whether a regulator is responding differently to investments by dominant operators and entrants. The study concludes that: (i) access regulation discourages investment by dominant and individual alternative operators even as alternative operators' total investment increases; (ii) dominant operators invest more as alternative operators' total investment increases; (iii) access regulation is not affected by alternative operators' investment but it increases when investment by dominant operator increases, suggesting a regulatory commitment problem; (iv) lagged infrastructure and regulation variables are statistically significant and economically relevant, suggesting that there are both short-term and long-term effects affecting these variables.

The study concludes that endogeneity of regulation exists and the results of the models depend on their consideration: a significant impact of regulation on investment is only identified when the regulation is endogenously determined by level of infrastructure investment.

Friederiszick *et al* (2008) analyses the relationship between entry regulation and investment by dominant and alternative operators. The model uses instrumental variables (IVs) to control regulation endogeneity.

The authors reach the following conclusions regarding the fixed sector: (i) a dynamic model controlling for endogeneity provides different results to a static model and without considering endogeneity; (ii) the magnitude of the coefficient on the lagged infrastructure variable is very close to 1, meaning that the stock of infrastructure is highly time-persistent and suggesting that shocks to economic determinants of the

[14] Hausman test using the lagged value of LLU as an instrument.

[15] Intensity of regulation depends on the stock of infrastructure of dominant operators and entrants.

stock of infrastructure have very persistent effects; (iii) entry regulation discourages infrastructure investment by alternative operators and also total investment; (iv) dominant operators change their investment as a result of regulation.

3. MARKET OVERVIEW

To obtain a better understanding of the alternative operator investment decisions being studied it is important to take into consideration the specific characteristics of the Portuguese market (2001-2011) and how it evolved.

Looking at the types of networks used to supply services to end users (*Chart 3, ANNEX 3*), it can be seen that the number of copper accesses suffered a decline during this period[16]. This decline has increased since 2009, probably due to the deployment of fibre networks by the copper operators and the "transfer" of their clients to fibre networks. Cable accesses have increased in the analysed period and show a more stable behaviour. The drop in the total number of accesses does not mean that fewer users are being served. The development of bundled offers may play a role in this decrease[17].

Looking at the market competition through the evolution of the HHI[18,19] concentration index *(Chart 4, ANNEX 3),* it can be seen that, in general, market competition has been on the increase. However, the most recent data shows a more stable pattern in the evolution of the concentration index.

An access in itself has low value for the end user. Its value comes from the services provided in that access. Consequently, it is important to consider how the services that have been the main competition drivers in the retail market have evolved: broadband Internet and pay TV *(Chart 5, ANNEX 3*). The number of television and broadband services provided has been steadily increasing. The current market shares in both services shows *(Figure 4, ANNEX 3*) that these markets are dominated by the PT Group

[16] A decrease of almost 1 million accesses.

[17] E.g. it is possible that clients that had a cable access for receiving television services and a copper access for telephone services now have both services in the same access.

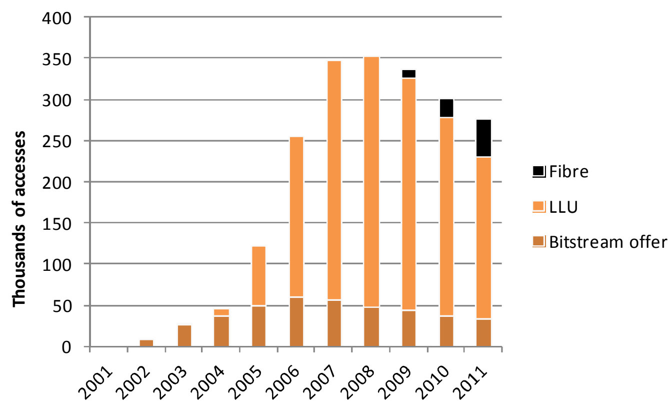
[18] Herfindahl-Hirschman Index: measure of market concentration. It is calculated by squaring the market share of each firm competing in a market, and then summing the resulting numbers.

[19] ZON accesses are always treated as not belonging to the PT Group. Consequently, the effect of the spin-off of ZON from the PT Group (November, 2007) is not observed in the HHI concentration index.

(the dominant operator) and ZON. The alternative operators that have entered the market supported in PT's networks using the access obligations imposed by the regulator (e.g. Optimus and Vodafone) have gained some market share[20] but do not have an important position in these markets.

A simple graphical analysis of the data on the type of accesses in the retail broadband market provided by alternative operators that entered the market by accessing PT Group's network shows us that these operators have in fact "climbed" the investment ladder. These operators entered the market using the wholesale bitstream access offer; they then invested in LLU and, finally, they invested in their own fibre infrastructure (*Chart 1*).

Chart 1. Alternative operators' accesses per rung of the investment ladder



The investments made by the alternative operators in LLU and in fibre networks are concentrated mainly in coastal areas and in the main cities *(Figure 5 – ANNEX 3*).

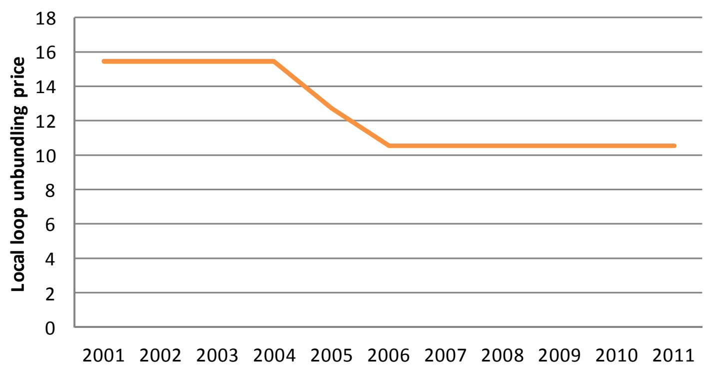
The identification of a "climb" up in the investment ladder by alternative operators does not mean, however, that the investment ladder theory's assumptions were confirmed since (i) it was not showed that the existence of lower rungs in the ladder (e.g. bitstream access) was important to achieve the higher rungs of the ladder (e.g. LLU) and (ii) no causal effect between the regulator's interventions and the investments made by alternative operators was truly identified.

If a causal effect is to be proved between regulatory intervention and the investment made by alternative operators, the regulatory interventions during this period must be analysed. In this paper we will focus our attention on the regulated price of the local

[20] Around 2.5% of the television market and 10% of the fixed broadband market.

loop[21], which is one of the most common regulatory variables used in the studies considered in the literature review and is considered to be one of the most influential regulatory interventions in alternative operators' investment decisions[22] (*Chart 2*).

Chart 2. LLU price (€) evolution



As mentioned in section 2.3.1, one of the flaws of previous econometric studies looking at investment ladder theory assumptions is the use of information from countries where regulators did not assume the goal of achieving its implementation. Addressing this question, it is shown that, during the studied period, the Portuguese regulator aimed to implement the investment ladder theory *(Table 4, ANNEX 4).*

4. THE DATA

Two datasets were prepared specifically for the development of this study. The first dataset uses data at the municipality level and includes yearly observations from 2001 to 2011. The second dataset considers data from 2011 in terms of boroughs[23]. These datasets will be used in two types of models: the first to explain alternative operators' investment type per municipality in the long term (**Model A**) and the latter to explain percentage of households covered by fibre networks deployed by alternative operators in the boroughs (**Model B**)[24].

[21] Installation price divided per 24 months plus the monthly rental price for the local loop.

[22] The dataset prepared additional information about regulatory intervention during the studied period that could be used for future work.

[23] Only the municipalities and boroughs located on the mainland were included in the data sets – Madeira and the Azores not included. It was considered that the investment conditions in these areas would be significantly different from those of the areas located on the main land.

[24] In this model we will also explain the probability of fibre deployment by alternative operators (First part of a two-part model).

The two main information sources are (i) ANACOM, which provided the information about the market situation and the investment made by operators, and (ii) Statistics Portugal[25], which provided the variables characterising the geographic areas demographically, socially and economically. Several variables were specifically created and calculated for this dataset from the available information in order to achieve the most appropriate information. This creation included handling and treating geo-referenced information about the coverage of the networks and geographic information on buildings and population.

With regard to understanding the time period of the dataset used, the use of yearly data from 2001 to 2011 allows the alternative operators' investment pattern to be considered from the moment they entered the markets and conclusions to be drawn on what happened in the Portuguese market during this period regarding these operators' investments.

The variables used in both models are presented[26] in the following sections grouped into different categories: (i) investment (the explained variable), (ii) geographic characterisation variables and (iii) market characterisation variables. The variables related to geographic characterisation will express deployment costs and expected demand, while the market variables will address questions related to competition and regulation.

4.1 EXPLAINED INVESTMENT VARIABLES

Three types of variables expressing the alternative operators' investment (albeit in different ways) will be explained in the models:

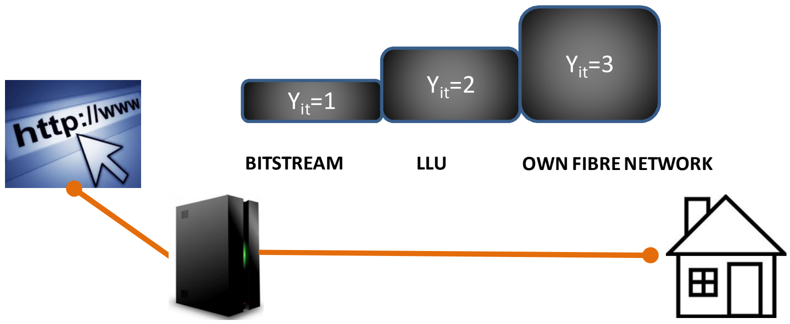
i. The alternative operators' investment type: may be expressed through an "investment ladder" (corresponding to an ordinal variable), considering the wholesale offers used and the deployment of own infrastructure to provide

[25] Instituto Nacional de Estatística.

[26] We will only describe the variables that were used in the models presented. Notwithstanding, the datasets comprehend much more information and are prepared for developing other studies (e.g. investment decisions by the dominant operator or the influence of cable operators in the market) and further work on the issues covered here.

services to end users in each municipality[27]. Figure 3 presents in a very simplified way the representation of the investment ladder achieved using this ordinal variable between 1 and 3.

Figure 3. Investment ladder considering the investment type



ii. The existence or non-existence of alternative operators' investment in fibre networks in each borough (corresponding to a dummy variable);

iii. Percentage of households covered per borough by alternative operators' fibre networks (corresponding to a fractional variable).

Detailed explanation of these variables is presented in *Table 5, ANNEX 4*.

4.2 EXPLANATORY VARIABLES

The decision to invest in a fibre network depends on many complex factors. We produced a rich set of variables, not only to consider all the complexity inherent in alternative operators' investment decisions, but also to avoid endogeneity issues caused by omitted variables.

4.2.1 GEOGRAPHIC CHARACTERISATION VARIABLES

The first group of variables aims to express the specific characteristics of the geographic areas in order to understand the social, demographic and economic environment of the geographic areas. This data will allow the cost of the deployment of a fibre network in the geographic area to be expressed, as well as the expected demand and revenues for the operator.

[27] **1:** If the alternative operator only supplies services to the end user in the municipality using the bitstream access;
2: If the alternative operator supplies services to the end user in the municipality using LLU;
3: If the alternative operator supplies services to the end user in the municipality using its own fibre network

The variables related with the cost of the investment are presented in *Table 6, ANNEX 5,* while the variables related with the demand for the services are presented in *Table 7, ANNEX 5*.

4.2.2 MARKET CHARACTERISATION VARIABLES

Investment is not only "located" in a geographic area. Investment also occurs in a market and the cost and the potential benefits arising from the investment will depend on the market dynamics. Consequently, it is important to characterise the competitive constraints under which the investment occurs. One additional constraint must be considered: regulation, namely how access to the dominant operator's network is regulated.

The variables related with the competition in the market are presented in *Table 8 – ANNEX 4* and the variables expressing the regulatory intervention are presented in *Table 9 – ANNEX 4*.

Regulatory variables are not considered in Model B because: (i) the regulatory intervention in fibre networks is being decided by ANACOM[28]; (ii) the main goal of this model is to consider the motivations for investment decisions without the existence of any obligations applied in fibre networks and (iii) the use of sectional data[29] combined with the national nature of the regulatory intervention in copper access[30] is an obstacle to the consideration of these variables in this model.

Descriptive statistics of all the variables used in Model A and Model B are available, respectively in *Table 10* and *Table 11* in *ANNEX 4*.

5. THE ECONOMETRIC MODELS

5.1 MODEL A - POOLED ORDERED PROBIT MODEL

As explained above, the variable we are explaining is the type of investment alternative operators made in each municipality (between 2001 and 2011). In short, the real level of investment per municipality is not really observed. We only observe

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[28] A draft decision was published in February, 2012. This draft decision foresees the existence of geographic differentiation of the obligations to be imposed to the PT Group's fiber network.

[29] The use of dummy variables to express specific regulatory interventions (in access to ducts, for instance) in time is not possible.

[30] However, in January 2009 two geographic markets were defined by ANACOM in the bitstream offer. One of these geographic markets was considered to be competitive and no obligations were imposed to PT Group in this market.

the type of investment made by the alternative operators, which is, in fact, an indicator of the investment level. The pooled ordered probit model is an appropriate choice for addressing this situation because the ordinal variable (investment type) is observed and can be seen as a form of censored data of the non-observed (latent) variable: investment level performed by alternative operators, verifying:

$$y_{it}^* = x_{it}\beta + e_{it}; \;\; e_{it} \sim N(0,1)$$

$$y_{it} = 1; \quad if\ y_{it}^* \leq \alpha_1$$

$$y_{it} = 2; \quad if\ \alpha_1 < y_{it}^* \leq \alpha_2$$

$$y_{it} = 3; \quad if\ y_{it}^* > \alpha_3$$

where y_{it}^* is the implicit variable expressing investment level; y_{it} is the alternative operators' type of investment in municipality i in year t; x_{it} is a matrix of explanatory variables; β is a vector of the coefficients associated to the explanatory variables and e_{it} the error term.

Considering the normal distribution assumption for the distribution of the error term of the implicit variable, it is possible to calculate the probability of each type of investment conditioned on the explanatory variables used (x_{it}):

$$P(y = 1|x_{it}) = P(x_{it}\beta + e_{it} \leq \alpha_1|x_{it}) = \Phi(\alpha_1 - x_{it}\beta)$$

$$P(y = 2|x_{it}) = P(\alpha_1 \leq x_{it}\beta + e_{it} \leq \alpha_2|x_{it}) = \Phi(\alpha_2 - x_{it}\beta) - \Phi(\alpha_1 - x_{it}\beta)$$

$$P(y = 3|x_{it}) = P(x_{it}\beta + e_{it} > \alpha_2|x_{it}) = 1 - \Phi(\alpha_2 - x_{it}\beta)$$

The probabilities of all the possible investment types will always sum 1.

The parameters α_i and β will be estimated by maximum likelihood (ML) and it will be possible to estimate the marginal effects of each explanatory variable (x_k) in the probabilities of occurrence of each type of investment ($j = 1, 2,3$). For x_k continuous:

$\frac{\partial P(y=j|x)}{\partial x_k} = \{\phi(\alpha_{j-1} - \boldsymbol{x\beta}) - \phi(\alpha_j - \boldsymbol{x\beta})\}\beta_k$, with ϕ being the standard normal probability density function.

If x_k is a dummy variable:

$\frac{\partial P(y=j|x)}{\partial x_k} = P(y = j|x_k = 1, x^*) - P(y = j|x_k = 0, x^*)$; where x^* is the vector of all the regressors except x_k

5.1.1 ENDOGENEITY OF REGULATION

As mentioned in section 2.3.2, the possible existence of endogeneity in the regulatory variables has been addressed in other papers, however, with different approaches. Therefore, it is prudent to consider the endogeneity of regulatory variables as an issue to address. Otherwise there is the risk that the conclusions and results are not valid.

It is important to bear in mind that the possible regulatory endogenous variable used in the model is the regulated price of the LLU. This price has always been defined by the regulator equally for the whole country. Consequently, it did not vary between the municipalities.

Grajek & Röller (2009) identify two main causes for the possible endogeneity of regulatory variables:

(1) Relevant omitted variables correlated with regulatory variables

If the variables related to competition are not considered in the model, they will be in the error term and if the regulator adapts the regulation imposed on the market considering the competition level – more competition leads to less regulation – the model may conclude that less regulation drives alternative operators' investment. However, the positive effect on investment may come from the existence of competition and not from regulation. Therefore, the conclusions of the model will not be valid.

Our model considers a competition variable – alternative operators' market share in broadband services in the municipality – as a control variable which solves the possible endogeneity problems resulting from what is explained above.

There are, however, other possible sources of endogeneity caused by omitted variables. For instance, it is possible that the error term may include alternative operators' expectations about future regulation since this is a non-observable variable and it is to be expected that these expectations will affect investment decisions: if alternative operators expect a lower price in the future, they may have incentives to invest less in the next access level of the rung. It is also probable that the expectations about regulation are correlated with present and past regulation, causing endogeneity.

(2) Simultaneity

If there is investment by alternative operators, the regulator may be in a position to decrease the strength of the regulation (competition will probably increase with investment and less regulation will be needed to accomplish the regulator's targets). Without considering this possible source of endogeneity, it could be said that less regulation leads to more investment, which is not the true causal relation between the variables.

The use of IVs may solve the two possible endogeneity causes discussed above. The inconsistency in the estimation is caused by the endogenous explanatory variable(s) being correlated not only with changes in the explained variable, but also with changes in the error term of the model. Using an instrumental variable (IV) allows only exogenous variation in the endogenous explanatory variable to be generated and unbiased estimations to be achieved.

The main difficulty in implementing estimations by IVs may be getting a valid one:

(1) The IV must be correlated with the endogenous regressor:

This assumption requires that there is some association between the IV and the regulated price of the local loop.

(2) The IV must be uncorrelated with the error term:

The IV cannot be a relevant regressor in the model explaining the type of investment made by alternative operators in each geographic area. This means that our IV can only be associated with changes in the investment made by alternative operators in a specific geographic area due to the influence it has on the LLU price or other variables used in the model (a direct influence is not allowed)[31].

[31] The IV can be correlated with the investment type, but the only source of that correlation can be the indirect path of being correlated with the regulated price of LLU, which affects alternative operator investment.

Considering this, we believe that the use of an IV expressing the total local loops unbundled in the country per year except the local loops unbundled in the municipality ($ivLLUexcept_{it}$) fulfils the conditions of a valid IV:

(1) Regarding the LLU wholesale access, ANACOM defined an access obligation with the LLU price oriented to the cost of providing the service. Consequently, it is expected that the regulator will consider the wholesale LLU cost accounting information to define the regulated price[32]. Considering that these services are characterised by scale economies, it is also expected that the regulated price will be influenced by the total number of unbundled accesses in the country (diminished by the accesses unbundled in the municipality). In this case: $Cov\ (priceLLU_{it}, ivLLUexcept_{it}) \neq 0.$ This assumption was empirically confirmed using the results of the 1st step estimation[33].

(2) It is also assumed that the investment decisions in each municipality do not depend on $ivLLUexcept.$ We believe, as discussed in this paper, that alternative operators' investment decisions mostly depend on the specific characteristic of each geographic area and not on aggregated characteristics of the national market, as proposed by the IV. In this case: $\text{Cov}\ (ivLLUexcept_{it}, e_{it}) = 0.$

5.1.2 ESTIMATION AND RESULTS OF MODEL A

As mentioned above, the pooled ordered probit model is estimated by ML. Additionally, it must be considered that inference in a pooled model needs to control for the expected correlation of the error term over time for the same municipality (within correlation[34]). To solve this question and allow valid inference, the model is estimated using cluster-robust standard errors, which addresses heterokedasticity issues also.

[32] Other information was used according to ANACOM's determinations on this matter: comparison of the prices defined in European countries. A variable constructed using this information could also be a viable option for an IV.

[33] A negative relation between the LLU price and the IV is estimated. The p-value associated to the null hypothesis: Coefficient equals zero is 0.00.

[34] Between Correlation is a matter for future work.

The IV ordered probit estimation was performed considering a system of equations nested by the Conditional (Recursive) Mixed-Process Model (CMP)[35]. The CMP can be applied in two types of models: 1) those in which a recursive data-generating process is assumed; and 2) those in which there is simultaneity, but instruments allow the construction of a recursive set of equations (as in two-stage least squares) that can be used to consistently estimate structural parameters in the final stage. The CMP procedure calculates its estimators from a ML approach over a multivariate normal distribution.

A simple dynamic model was also estimated using as a regressor the lagged investment type made by alternative operators in each municipality. The main purpose of the estimation of this model is to show that alternative operator investment decisions are a dynamic process in which the current type of investment depends significantly on past investment choices. It is obvious that, due to the expected time dependence of investment and of the explanatory variables and the existence of unobserved heterogeneity, the estimation of a dynamic panel data model in these conditions is a matter for further work and improvement.

The resulting coefficients from the estimation of the models discussed are presented in *Table 12, ANNEX 5*.

5.1.3 CONCLUSIONS ON THE AVERAGE MARGINAL EFFECTS (AME)

In this section the AME estimations are discussed and interpreted. Results of AME for using LLU, using own fibre network and using bitstream are presented, respectively in Table 1, Table 2 and *Table 13* (*the latter in ANNEX 5*).

[35] Please see Roodman (2009) for detailed information.

Table 1. AME in Model A – Probability of using LLU

EXPLANATORY VARIABLES	POOLED ORDERED PROBIT – AME – PROB(INVESTTYPE=2)			
	SIMPLE	IV	LAG INVEST	IV+ LAG INVEST
lag.investype	-	-	0.212 (0.000)	0.208 (0.000)
Avrnhh	0.092 (0.000)	0.093 (0.000)	0.023 (0.001)	0.019 (0.001)
Youngindex	0.018 (0.000)	0.018 (0.000)	0.004 (0.000)	0.004 (0.000)
Avrmrevenue	0.038 (0.001)	0.037 (0.001)	0.007 (0.008)	0.008 (0.004)
Altbbmkshare	0.400 (0.000)	0.400 (0.000)	0.044 (0.000)	0.039 (0.001)
priceLLU	-0.065 (0.000)	-0.065 (0.000)	-0.006 (0.000)	-0.003 (0.092)
Ductskmsqkm	0.046 (0.012)	0.046 (0.013)	0.016 (0.001)	0.016 (0.000)
Fibrenear	0.149 (0.000)	0.148 (0.000)	0.014 (0.375)	0.019 (0.247)

Note 1: In parenthesis we report the p-values associated to the null hypothesis: AME equals zero. Significance level=0.05
Note 2: Standard errors calculated using the Delta-Method.
Note 3: The dependent variable is the investment type in the municipality.

Table 2. AME effects in Model A – Probability of using own fibre network

EXPLANATORY VARIABLES	POOLED ORDERED PROBIT – AME – PROB(INVESTTYPE=3)			
	SIMPLE	IV	LAG INVEST	IV+ LAG INVEST
lag.investtype	-	-	0.042 (.000)	0.041 (0.000)
Avrnhh	0.008 (0.007)	0.008 (0.008)	0.005 (0.006)	.004 (0.013)
Youngindex	0.001 (0.002)	0.001 (0.002)	0.001 (0.001)	0.001 (0.002)
Avrmrevenue	0.003 (0.015)	0.003 (0.017)	0.001 (0.029)	0.002 (0.017)
Altbbmkshare	0.033 (0.000)	0.033 (0.000)	0.009 (0.003)	0.008 (0.006)
priceLLU	-0.005 (0.000)	-0.005 (0.000)	-0.001 (0.002)	-0.001 (0.168)
Ductskmsqkm	0.004 (0.041)	0.004 (0.041)	0.003 (0.006)	0.003 (0.004)
Fibrenear	0.012 (0.001)	0.012 (0.001)	0.003 (0.362)	0.004 (0.224)

Note 1: In parenthesis we report the p-values associated to the null hypothesis: AME equals zero. Significance level=0.05
Note 2: Standard errors calculated using the Delta-Method.
Note 3: The dependent variable is the investment type in the municipality.

It is important to highlight that the results and conclusions achieved with the models using an IV to control for endogeneity of the LLU price are not significantly different of the results and conclusions of the models not using an IV. This may mean that the possible endogeneity of the LLU price is not affecting the estimations achieved. In fact, in both static models (with and without IV) it was concluded that the effect on the probability of alternative operators using LLU and fibre networks is opposite to the evolution of the LLU price: lower prices increase the probability of using LLU and fibre networks[36]. The estimation of a negative marginal effect of the LLU price in the probability of alternative operators using its own fibre access network is unexpected taking into account the theory's conclusions described in section 2.3.3. The reason for the difference between the model's result and the theory's conclusions may lie in the fact that the model "catches" the long term effect of the LLU price in the alternative operator's investment in fibre (namely taking into account the influence that the changes in this price had in the investment performed in LLU and "helping" the move to the following step of the ladder – own fibre access) while the theory looks mainly to the present and to the short term effect of the changes of the LLU price.

However, the use of the lagged investment type as a regressor leads to the conclusion that the price of the LLU does not have a significant statistical effect on the probability of using the three ways of serving the clients (when the IV is used). As expected, the investment choices made by alternative operators in a telecommunications network depends greatly on the investment made in the past by these operators[37].

Furthermore, the effect of the existence of neighbouring municipalities where fibre investment has already occurred becomes non-significant when the lagged type of investment is a regressor. In the other cases we can conclude that alternative operators tend to use LLU and fibre in municipalities that are neighbouring municipalities where fibre investments occurred[38]. This may be caused by the existence of economies of density (e.g. the same technical assistance centre can be used to cover more than one municipality).

An increase in the number of households per building leads to an increase in the probability of alternative operators using LLU and fibre networks[39]. This confirms the

[36] The significant marginal effects estimated show that an decrease of 1€ in the monthly LLU price in the municipality increases the probability of alternative operators using LLU by 0.6 percentage points (p.p) in the lagged model and 6.5 p.p in the static model, while it increases the probability of the use of fibre by between 0.1 p.p (dynamic model without IV) and 0.5 p.p (static model).

[37] The significant marginal effects estimated with both dynamic models show that the "rung of the ladder" used in a municipality in the previous period has an effect on the present use of LLU of around 21 p.p. and 4 p.p. in the use of fibre networks.

[38] The significant marginal effects estimated for the static models show that the existence of a municipality where alternative operators have invested in fibre increases the probability of alternative operators using in neighbouring municipalities (distance lower than 25 km) LLU by around 15 p.p and of using fibre by 1.2 p.p.

[39] The significant marginal effects estimated show that an increase of 1 in the average number of households per building in the municipality increases the probability of alternative operators using LLU by around 2 p.p in the dynamic models and 9 p.p in the static model, while it increases the probability of using fibre by around 0,5 p.p in the dynamic models and by 1 p.p in the static models.

expected effect and also the theoretical models considered previously, which conclude that densely-populated areas imply lower costs in fibre deployment.

The probability of investment in LLU and fibre also increases when the proportion of young population in the municipality gets higher[40]. This can be caused by the specific characteristics of this demand segment: higher proficiency and interest in using the internet and the services provided in this market.

As expected, an increase in the average monthly revenue of the municipality's workers also has a positive effect on the probability of an alternative operator investing in the higher rungs of the "ladder"[41]. The same effect is identified with the increase in the alternative operator's market share in the retail broadband market[42]. According to the results, this is the variable that has a higher effect on the alternative operator's investment type.

There is also empirical evidence that the existence of dense networks of ducts in the district where the municipality is located leads to higher investment levels by alternative operators[43]. Again, this empirical conclusion coincides with the theories and models presented in the literature review. The availability of specific data on km of ducts per municipality may lead to a more precise evaluation of the effects of the existence of ducts in the investment decisions per municipality.

It should be remembered that the probability that the investment will occur in all the types of investment must always equal 1. Consequently, if the variables always have the same effects on the probability of investing in LLU and fibre, it is easy to conclude

[40] The significant marginal effects estimated show that an increase of 1 p.p. in the proportion of young population in the municipality increases the probability of alternative operators using LLU by around 0.04 p.p. in the dynamic models and by 0.2 p.p. in the static models, while it increases the probability of using fibre by 0.01 p.p. in both dynamic and static models.

[41] The significant marginal effects estimated show that an increase of 100€ in the average monthly revenue of the municipality's workers increases the probability of alternative operators using LLU by around 1 p.p in the dynamic models and 4 p.p. in the static models, while it increases the probability of using fibre by 0.1 p.p in the dynamic models and by 0.3 p.p. in the static models.

[42] The significant marginal effects estimated show that an increase of 1 p.p. in the alternative operator's broadband market share in the municipality increases the probability of alternative operators using LLU by 4 p.p. in the dynamic models and by 40 p.p. in the static models, while it increases the probability of using fibre by around 1 p.p. in the dynamic models and by 3.3 p.p. in the static models.

[43] The significant marginal effects estimated show that an increase of 1km of ducts per square km in the district where the municipality is integrated increases the probability of alternative operators using LLU by 1.6 p.p. in the dynamic models and by 4.6 p.p in the static models, while it increases the probability of using fibre by 0.3 p.p. in the dynamic models and by 0.4 p.p. in the static models.

that the effect on the other possible type of investment (bitstream access wholesale offer) will always have the opposite signal to those described above.

5.2 MODEL B - FIBRE INVESTMENT PER BOROUGH

5.2.1 FRACTIONAL VARIABLES AND SPECIFICATION

The main goal is to estimate the percentage of households reached by alternative operator fibre networks in boroughs. This variable (i) is restricted to the unit interval (fractional variable) and (ii) the large majority[44] of the observations are zero: none of the households is reached by alternative operators' fibre. These two questions may pose estimation and inference challenges.

The specific characteristics of fractional response variables recently started to be addressed in depth, for instance in the papers by Papke & Wooldridge (1996, 2008). It is also important to mention the paper by Ramalho *et al* (2011), which considers most of the empirical issues that will be dealt with in this paper.

Papke and Wooldridge (1996) defended that one of the solutions for dealing with fractional response variables requires the assumption of a functional form for *y* that imposes the desired constraints on the conditional mean of the dependent variable: bounded in the unit interval.

$$E(y|x) = G(x\theta);\ \ 0 \leq G(x\theta) \leq 1 \qquad (1)$$

Papke and Wooldridge (1996), considering $0 < G(x\theta) < 1$, suggest that any cumulative distribution function could be used as a specification for $G(x\theta)$. These authors also suggest that the model can be consistently estimated by quasi maximum likelihood (QML)[45], namely using a particular QML method based on the Bernoulli log-likelihood function:

$$LL_i(\theta) = y_i log[G(x_i\theta)] + (1 - y_i)log[1 - G(x_i\theta)] \qquad (2)$$

The Bernoulli distribution is a member of the linear exponential family (LEF), making the QML estimator consistent and asymptotically normal, regardless of the true distribution of y conditional on x, provided that $E(y|x)$ is correctly specified. Papke

[44] More than 97.5% of the observations.

[45] It can also be estimated by nonlinear least squares (NLS).

and Wooldridge (1996) also show that, in some cases, the QML estimator is efficient in a class of estimators containing all LEF-based QML estimators[46].

The paper by Ramalho *et al* (2011) mentions two decisions that, in general, must be addressed during empirical work: (i) which functional form to assume for the conditional expectation of *y* and (ii) which method to employ in the estimation. The authors mention that most of the empirical work done chooses the form for the conditional mean of y and the estimation method used without evaluating whether better options were available. These authors argue that test procedures may be employed to assess the best options to adopt regarding the model's specification (including whether to use a one- or a two-part model).

The model described may be used in applications where some portion of the sample is at the extreme values (0 and/or 1). However, this may not be the best option in cases where the number of extreme values is large, as in the present case. As Ramalho *et al* (2011) mention, "for such cases a better approach may be the employment of two-part models, where the discrete component is modelled as a binary or multinomial model and the continuous component as a fractional regression model".

In the case of alternative operators' investment decisions, the first part of a two-part model would explain the existence or non-existence of investment (the probability of investing in fibre in the borough) and the second part of the model would explain the percentage of households covered in the boroughs where investment occurred.

The first part of the model might be expressed as follows:

$$y^* = \begin{cases} 0; & for\ y = 0 \\ 1; & for\ 0 < y \leq 1 \end{cases} \qquad (3)$$

In this case: $\Pr(y^* = 1|x) = E(y^*|x) = F(x\beta_{1P})$ (4)

This part may be estimated by ML using the whole sample.

The second part of the model only applies to the observations where $0 < y \leq 1$:

$$E[y|x; 0 < y \leq 1] = M(x\beta_{2P}) \qquad (5)$$

[46] And weighted NLS estimators.

This part may be estimated by QML, as proposed by Papke & Wooldrige (1996). Consequently:

$$E[y|x] = E[y|x; 0 < y \leq 1] \times Pr(0 < y \leq 1|x) = M(x\beta_{2P}) \times F(x\beta_{1P}) \qquad (6)$$

As explained in Ramalho *et al* (2011), from the previous equation, it is possible to calculate the marginal effects of the continuous explanatory variables.

$$\frac{\partial E(y|x)}{\partial x_j} = \frac{\partial M(x\beta_{2P})}{\partial x_j} \times F(x\beta_{1P}) + M(x\beta_{2P}) \times \frac{\partial F(x\beta_{1P})}{\partial x_j} \qquad (7)$$

The choice between using a one-part model or a two-part model is important and may lead to different empirical conclusions. Deciding upon the "right" model depends on the interpretation given to the observed extreme values (0 or 1): if these values result from a utility maximising decision, a one-part model would seem better but, if a different decision mechanism explains these values, it might be better to use a two-part model.

It is common that theory does not provide inputs about the "right" model to use or even where there are conflicting economic theories that might match the use of a one-part or a two-part model[47]. In these cases, it might be important to use the specification tests for fractional regression models proposed by Ramalho *et al* (2011) to choose which model to use.

In addition to the more common RESET tests and goodness-of-link (GOL) tests, Ramalho *et al* (2011) identify goodness-of-functional-form (GOFF) tests as valid for testing the correct specification of any conditional mean model and they investigate the use of non-nested tests in this framework (P-tests). These tests are also applicable for testing the specification of two-part models and the P-test can be used to evaluate the option of using a one-part versus a two-part model.

These tests evaluate the correct specification of $E(y|x)$ for one-part models and assumptions (4), (5) and (6) in two-part models:

[47] For an example of such a case, see Ramalho *et al* (2011) – section 6 – about the share of debt capital used by SMEs in Portugal

(1) Reset tests: where polynomials in the model's predicted values of the index $x\theta$ are included in the assumed functional form to detect general kinds of functional form misspecification;
(2) GOL tests: based on generalised link functions that incorporate one or more of the links associated with the functions of the competing functional form as particular cases;
(3) GOFF tests: based on generalised functional forms and including the assumed functional form as a special case;
(4) P-tests: where the alternative competing specifications for the assumed functional form are tested against each other and which may also be used for testing the full specification of two-part models.

All these tests may be seen as tests for the omission of a J-dimensional vector z in the model: $E(y|x,z) = G(x\theta + z\gamma)$. Under the null hypothesis (H0: $\gamma = 0$), z is not relevant and $G(x\theta)$ is an appropriate specification for $E(y|x)$. The difference between the tests lies in the composition of the vector z.

As discussed in Ramalho *et al* (2011) the tests for the null hypothesis may be implemented as Lagrange multiplier (LM) tests for omitted variables[48] and have a $\chi^2_{(J)}$ distribution.

Ramalho *et al* (2011) also carried out a Monte Carlo simulation study into the finite-sample performance of estimators and tests when the sample includes zeros and/or ones[49]: (i) QML is, in general, the most attractive estimator in this situation; (ii) estimating the magnitude of partial effects is in general important for choosing the correct specification for the conditional mean of y; and (iii) GOFF tests are the best in terms of size and are among the most powerful tests, while the P-tests, despite over-rejecting the true null hypothesis in some cases, have the best power properties[50].

In this paper we will use the tests discussed by Ramalho *et al* (2011) to test the best functional form to use and also whether to use a one-part or two-part model. These

[48] These tests are calculated using simple artificial regressions. The tests may be evaluated with NLS, QML or ML estimators. Depending on the estimator used, a different artificial regression should be used to compute the tests.

[49] The same kind of study was also developed for when there are no boundary observations.

[50] Where the response variable is symmetrically distributed, GOFF tests exhibit very low power when applied to other symmetric but ill-specified models for the conditional mean of *y*.

tests only apply to cross-sectional fractional regression models when the outcome is univariate and we will apply them in this set.

5.2.2 ESTIMATION AND RESULTS OF MODEL B

Let us first consider the results obtained for the one-part model estimated by QML *(Table 14, ANNEX 6).*

It is important to note that all the four specifications (logit, probit, loglog, cloglog) considered for the functional form of the percentage of households covered in the borough (y), given the regressors, reach the same conclusion about the sign and significance of the regression coefficients. This is no surprise since in Ramalho *et al* (2011) the authors show that the misspecification of the functional form creates significant distortions in the magnitude of partial effects, but does not affect the estimation of their direction.

Regarding the direction of the effect (which is what it is possible to analyse without estimating the marginal effects), it can be said that the increase in (i) the number of retail accesses provided by the alternative operators in the municipality where the borough is included, (ii) the number of households located in the borough, (iii) the population density in the borough and (iv) the percentage of the population in the borough with secondary education or higher leads to an increase in the percentage of households covered. These empirical conclusions are coherent with the conclusions of the theoretical models discussed in section 2.2 and also with some results obtained with model A.

On the other hand, it is concluded that the increase in the proportion of older buildings leads to lower coverage level by alternative operator fibre. This was expected because building *in-house wiring*[51] infrastructure is a relevant component of the costs involved in deploying fibre and it is expected that older buildings will be less prepared for "receiving" fibre in an efficient and cost-free way.

Looking at the estimation results of the two-part models (*Table 15, ANNEX 6*), we can point out some similarities and differences compared to the results of the one-part

[51] Explanation provided in ANNEX 1.

models: (i) the direction of the effect of the regressors in the probability of investing in a borough[52] is the same as that described for one-part models but (ii) in the second part of the two-part model, the retail accesses provided by alternative operators in the municipality where the borough is located and the number of households in the borough are not significant in explaining the percentage of houses covered by alternative operator fibre. Consequently, in the two-part model, it is concluded that the percentage of households covered by alternative operator fibre is only affected by the population density of the borough, the proportion of the population with secondary education or higher and the proportion of older buildings in the borough.

An explanation for these conclusions may lie in the fact that these variables express the most relevant costs and potential revenues involved in covering a borough. The number of accesses and the number of households may express mainly the dimension of the market that operators might capture and the investment risk perception for alternative operators. In this case, it might make sense that these variables are only relevant in explaining the decision of investing or not investing in the borough.

This is an explicit example of the possible different decision mechanisms that can be behind the use of one-part or two-part models. The specification tests performed in the next section may shed some light on the decision mechanism followed by operators.

5.2.3 SPECIFICATION TESTS

The specification tests explained in 5.2.1 were performed[53] in the different models estimated. Regarding the one-part model, the RESET and GOFF tests do not reject the hypothesis of the loglog distribution as a correct specification for $G(x\beta)$ – *Table 14, ANNEX 6*. The same hypothesis is not rejected by the GOL test and the P-test for the cloglog distribution. All the other possible specifications are rejected by all the tests.

[52] We are referring to the first part of the two-part model. Therefore, we are not referring to the percentage of houses covered by fibre, which is only considered in the second part of the model.

[53] Stata Codes used to perform some of the tests were kindly provided by Professor Doutor Joaquim J.S. Ramalho.

So, the loglog and the cloglog distributions will be the two possible specifications. We opt to use the cloglog specification considering the results of the P-tests since these will also be the tests that will be used for choosing between one- and two-part models.

Regarding two-part models, two specifications are always rejected by all the tests *(Table 15, ANNEX 6)*: logit and loglog. According to the GOL test and P-test, the cloglog specification seems the right choice to describe the probability of alternative operators investing in a specific borough.. Regarding the second part of these models, all the specifications considered are not rejected in all the tests, as appropriate for expressing the conditional mean of $E(y|x, 0 < y \leq 1)$.

To choose the specifications that will be tested against the one-part model with cloglog distribution, we use the same criteria as before. Using the P-test results, the chosen specification for the first part of model is the cloglog. Regarding the second part of the model, as mentioned, all the distributions are not rejected by the P-tests in all the tests. Consequently, we choose to test four alternative specifications in the two-part models: the combinations of the cloglog distribution in the first part of the model with all the four possible specifications in the second part of the model.

These four specifications for the two-part model were tested against each other and also against the chosen specification for the one-part model (cloglog). According to the tests – *consider Tables between Table 16 and Table 20 in ANNEX 6, inclusive* –, the best option for explaining the percentage of houses covered by the fibre networks of the alternative operators is to use a two-part model assuming a cloglog distribution for the conditional mean of y in the first part of the model and a loglog distribution in the second part of the model. This specification is not rejected as appropriate in all the P-tests performed against the alternative specifications.

All the P-tests performed in the chosen one-part model against the chosen two-part models indicate that the one-part model is not an appropriate model for explaining the interest variable. There are indications that the alternative operators first choose to invest or not invest in a specific borough and only afterwards, using a different decision mechanism, do they choose the number of households that will be connected to their network in the boroughs in which they have decided to invest.

The estimated AME of the variables used in the selected model is presented in *Table 21, ANNEX 6.*

6. CONCLUSIONS

The empirical analysis performed in Model A provides reasonable evidence that some of the theoretical assumptions behind the investment ladder may apply to what happened in the Portuguese market.

In fact, it was concluded that: (i) the increase in the broadband market share in a municipality leads to an increase in the motivation to go up the ladder in that municipality, and (ii) that going up the ladder in a municipality may lead to other "climbs" in neighbouring municipalities. These results provide evidence that creating the necessary conditions for alternative operators to enter the market (even based on service-based competition) may be an important step in creating conditions for further investments by alternative operators (leading to infrastructure-based competition). Additionally, it was concluded that the regulatory intervention in the LLU price may have enhanced the investments made by alternative operators in higher "rungs of the ladder". This means that the regulator may have the necessary tools to neutralise the replacement effect[54] created by service-based competition.

These conclusions are especially robust because they were achieved considering the flaws pointed out in previous studies: (i) assurance that implementing the ladder was a goal of the Portuguese regulator; (ii) use of dataset of micro data per municipality[55] with a long time series; (iii) control for endogeneity of regulation.

Further work may be done on this model by improving (i) the estimation of dynamic models, (ii) the control and testing for endogeneity and (iii) the effect on investment of other regulatory interventions besides the LLU price (e.g. obligation to give access to ducts). It is also important to consider the effect of regulation, not only on alternative operator investment decisions, but also on all the other operators' investment decisions (e.g. cable and dominant operators) and in the market as a whole.

[54]Profits from service-based competition are an obstacle to investments in infrastructure by alternative operators.

[55]Similarities with the area of the central exchange exist.

Regarding model B, it was concluded that the best specification for explaining the percentage of households covered by alternative operators per borough is to use a two-part model (cloglog + loglog). Consequently, there are indications that alternative operators' first decision concerns in which boroughs to invest and only after that do they decide on the percentage of households to cover in the borough. In this case, all the variables considered in the model influence the decision of the operator investing in a borough. However, only the population density of the borough, the proportion of the population with secondary education or higher and the proportion of older buildings in the borough affect their decision regarding the percentage of households covered by fibre.

The data used in this model comes from the available provisional data from the 2011 census. More detailed and complete information will be available soon, which may allow the estimation to be improved and a better understanding of the alternative operators' underlying investment decision mechanism. It may also be important to consider other possibilities for the models used, namely Tobit models for data censored at the extreme values, even if problems are identified in its use[56]. Future work could also be developed regarding the study of the effect of regulation on fibre[57] in investment decisions.

Both models clearly show that the specific characteristics of the geographic areas significantly affect alternative operators' investment decisions. This supports the arguments that the regulator must consider these specific characteristics and their effect on investment decisions (i) when defining the relevant geographic markets, (ii) when deciding on possible geographic segmentation, and even (iii) when deciding on how the investment ladder should be "constructed" in the different geographic areas.

Looking at the conclusions above, it is undeniable that Econometrics is a valid and very useful decision tool for regulators when deciding which regulation to apply and on providing the "right" investment incentives for alternative operators. In this process it

[56] (i) The two-limit Tobit Model can only be used when there are observations in both extreme values; (ii) Tobit models describe *censored* data in the interval [0, 1] but the observations at the extreme values of a fractional variable result from choices and not of censoring data; (iii) the Tobit model requires normality and homoskedasticity of the dependent variable, prior to censoring.

[57] Regulation of access to infrastructure (e.g. ducts), regulation of copper and future regulation of fibre networks (after the possible imposition of obligations on fibre networks by ANACOM).

is important not only to have the right expertise and apply the appropriate models and estimation techniques, but also to have a proactive role in acquiring the relevant data to achieve the best estimations possible without incurring (or making operators incur) disproportionate costs.

Econometrics and the models used in this paper might also be relevant for other policy decisions taken by the government when choosing and justifying the geographic areas where state aid will be available to enhance investment in NGA, or even for regional administrations to understand whether their decisions will affect the investment of operators in their region and the existence of more competition and different services for the end users.

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ANNEX 1 – TECHNICAL GLOSSARY[58]

Access point: Point in the dominant operator's network where wholesale access is granted to the alternative operators (e.g. duct, building, central exchange). In the case of bitstream access this point can be local, regional, or national.

Backhaul: The intermediate link between the core network and the access network, i.e., the connection between typically distributed access points and more centralised points of presence of alternative operators.

Bitstream Access: Bitstream Access is a wholesale product which consists of an access link to the customer premises and a transmission service to a defined set of access points. It enables alternative operators to differentiate their services by altering a number of technical parameters and/or the use of their own network.

Central Exchange: is a dedicated building in which the access lines serving a particular geographic area terminate in a network's equipment allowing the provision of services to the end users.

Duct: underground pipe or conduit used to house (fibre, copper or coax) cables of either core or access networks.

Fibre to the Cabinet (FTTC): Network that reaches the street cabinet (up to several kilometers away from the customer premises) with fibre, but the final connection is copper or coax.

Fibre to the Home (FTTH): Network that reaches the end-user premises with fibre-optic cables.

In-house wiring: In the context of NGA, in-house wiring relates to the cabling between the basement of a building and each flat, normally inside dedicated cable trays.

Next Generation Access (NGA): wired access networks which consist wholly or in part of optical elements and which are capable of delivering broadband access services with enhanced characteristics as compared to those provided over already existing copper networks. In most cases NGAs are the result of an upgrade of an already existing copper or coaxial access network.

Local Loop Unbundling (LLU): refers to the process in which dominant's operators lease, wholly or in part, the local segment of their access copper or fibre network to alternative operators. With full unbundling the alternative operators take total control of the local loop and can provide subscribers with all services or technologies.

[58] This glossary results from a simplified adaptation of the glossary of terms presented in the BEREC Draft Common Positions on WLA, WBA and WLL.

ANNEX 2 – DETAILS ON THE EMPIRICAL PAPERS CONSIDERED

Table 3. Details on the empirical papers considered

Paper	Dependent variable(s)	Explanatory variables	Sample and Data source	Model and estimation procedure	Conclusions
Bouckaert *et al* (2006)	Total broadband penetration	**Competition variables:** HHI in markets that depend on alternative operator's investment decisions, **broadband service variables** (e.g. price); **market demographics** (e.g. pop. Density); **demand variables** (GDP per capita)	20 OECD countries From December 2003 to March 2008 (quarterly information)	Linear regression model. Estimation using random effects per country (similar results using fixed effects). Estimated static and dynamic models (lagged dependent variable).	Indication that the "ladder of investment" theories might not provide good guidance for regulatory policy.
Waverman *et al* (2008)	Share of alternative access; share of competitor DSL and broadband penetration	Incumbent DSL, ULL Price, Dummy indicating if bitstream access is available, year since ULL implementation; Market's concentration index and share of internet ready cable plant	12 countries 2002 to 2006 (quarterly information) COCOM, European Commission; OECD	Two equations are estimated simultaneously using seemingly unrelated regressions (SUR). One equation is estimated by OLS.	Existence of a trade-off between access regulation and investment by alternative operators. No substantial evidence for endogeneity of regulation.
Friederiszick *et al* (2008)	Firm's tangible fixed assets deflated by the producer price index for telecom equipment	**Demand variables** (e.g. GDP per capita); **Cost variables** (pop. density); **Competition variables** (cable TV penetration); **Regulation variables** (ULL price); **IVs (endogeneity of regulation)**: political variables, near markets	180 operators in 25 European countries over 10 years (around 1000 observations). Source: OSIRIS	Dynamic model (lagged dependent variable). Estimated using fixed effect.	There is a negative effect of regulation on the incentives of entrants to invest.
Distaso *et al* (2009)	No estimations. graphical analysis	No estimations. Graphical analysis.	12 European Countries (semiannual obs. from January 2005 to July 2007) COCOM, OECD.	No estimations. Graphical analysis	The authors conclude that the policies adopted by NRAs are broadly consistent with the investment ladder theory.
Grajek & Röller (2009)	Regulation intensity, Change in Incumbent's and entrant's infrastructure stock	Operator's infrastructure stock, , index of access regulation intensity; dummy variable indicating if there are entrants in the market; Per capita GDP, average index of access regulation in near markets, government's attitude towards regulation; Government's ideological positions	70 fixed operators in 20 countries over 10 years Sources: Amadeus, Plaut Economics; Osiris, World's Bank WDI and political database.	3 equations specified: Regulation intensity; incumbent's investment equation and new entrant's investment. Inclusion of lagged dependent variable and country-specific effects. Correction of potential bias by applying a corrected estimator. Estimation made using OLS and IVs. Use of dummies to achieve fixed effects estimation.	Access regulation negatively affects both total industry and individual carrier investment. Evidence of regulatory commitment problem: higher incumbent's investments encourage provision of regulated access.

ANNEX 3 – MARKET OVERVIEW

Chart 3. Number of active accesses per type of access network

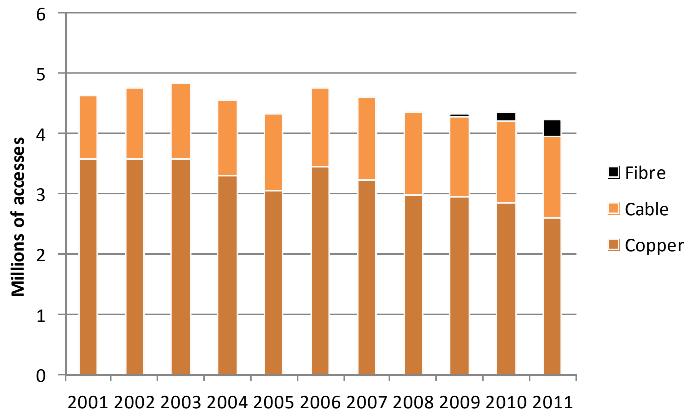

Chart 4. HHI – Retail active accesses

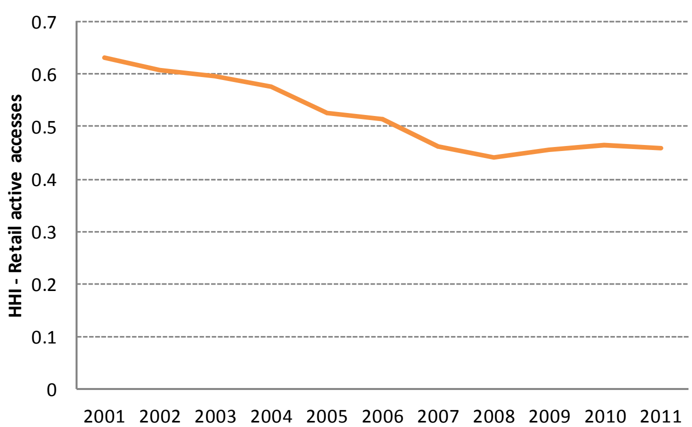

Chart 5. Evolution of the number of broadband and Pay-TV accesses

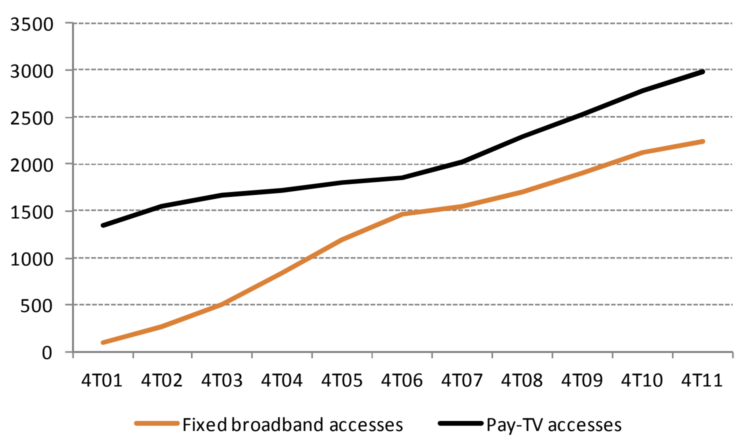

Figure 4. Market share in broadband market and Pay-TV market – End of 2011

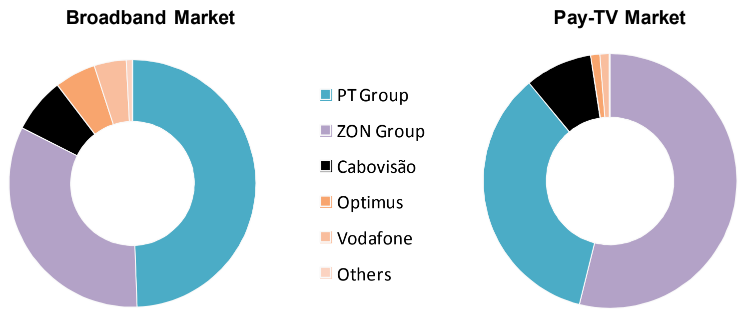

Figure 5. Location of the investments made by alternative operators

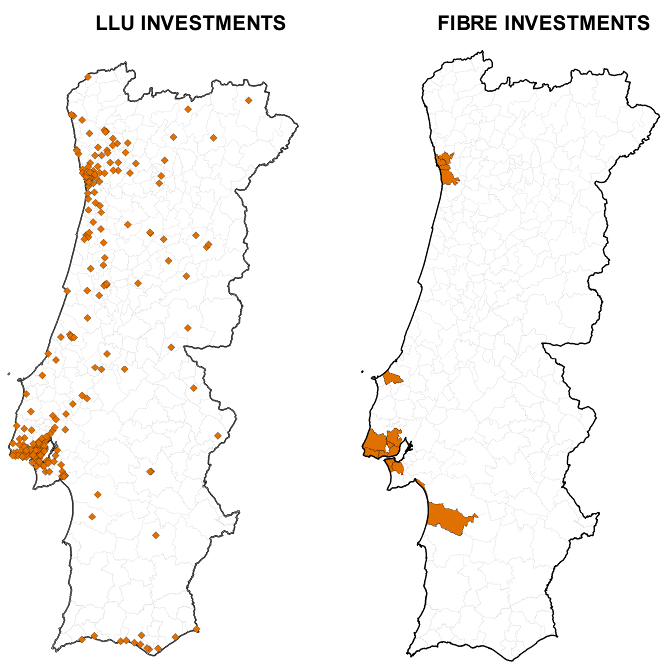

Table 4. ANACOM's references to the investment ladder

YEAR	REFERENCES IN ANACOM'S DOCUMENTS	DOCUMENT
2012	Identifies the three current available rungs on the investment ladder in Portugal: (1) Bitstream access, (2) LLU and (3) Own infrastructure.	ANACOM (2012)
2008	Identifies the LLU as one of the most important rungs on the investment ladder. Mentions that the operators that are located in the bitstream access may use the investment already made to climb the ladder and use LLU.	ANACOM (2009)
2005	Reveals the intention of assuring coherent and complementary wholesale offers, requiring different investments levels by the alternative operators. Mentions that the coherence in prices of the wholesale offers allows alternative operators to climb the investment ladder and add value and flexibility to their offers.	ANACOM (2005a)
2005	States that the regulatory intervention followed by ANACOM aims to promote infrastructure competition and identifies the investment ladder as an important tool in achieving this goal.	ANACOM (2005b)
2005	States that the coherence between the wholesale offer's prices grants alternative operators the opportunity to climb the investment ladder by investing in own infrastructure and adding value to their offers.	ANACOM (2005c)

ANNEX 4 – THE DATA

Table 5. Explained variables

EXPLAINED VARIABLES	DEFINITION	SOURCE
MODEL A – MUNICIPALITIES		
investtype: Alternative operator's investment type in the municipality	**1:** If the alternative operator only supplies services to the end user in the municipality using the bitstream access **2:** If the alternative operator supplies services to the end user in the municipality using LLU **3:** If the alternative operator supplies services to the end user in the municipality using its own FTTH network	ANACOM
MODEL B- BOROUGHS		
investhh: % of households covered by alternative operators' fibre in the borough	Number of households covered by alternative operator fibre networks in a geographic area divided by the number of households in that geographic area	ANACOM and INE
invest: Did alternative operators invest in fibre in the borough?*	**0:** If alternative operators did not invest in fibre in the borough **1:** If alternative operators invested in fibre in the borough	ANACOM

*The goal of Model B is to explain the variable *investhh*. However, the variable *invest* is also explained in the first part of the two-part model used.

Table 6. Geographic explanatory variables

EXPLANATORY VARIABLES	DEFINITION	SOURCE
MODEL A – MUNICIPALITIES		
avrnhh: Average number of households per building in the municipality	Number of households in the municipality divided by the number of buildings in the municipality	INE
ductskmsqkm: Km of PT Group's ducts per square km in the district to which the municipality belongs	Km of PT Group's ducts in the district to which the municipality belongs divided by the area of the district to which the municipality belongs	ANACOM and INE
MODEL B- BOROUGHS		
popdens: Population density in the borough	Residents in the borough (in thousands) divided by the area of the borough (in Km^2)	INE
oldbuilding: Proportion of buildings in the borough constructed before 1945	Number of buildings in the borough constructed before 1945 divided by the total number of buildings in the borough	INE

Table 7. Demand explanatory variables

EXPLANATORY VARIABLES	DEFINITION	SOURCE
MODEL A – MUNICIPALITIES		
youngindex: Proportion of young population in the active population	Number of people aged between 0 and 14 years in the municipality divided by the number of people aged between 15 and 64 years in the municipality	INE
avrmrevenue: Average monthly revenue in the municipality	Hundreds of Euros received by the municipality's workers in average per month	INE
MODEL B- BOROUGHS		
educsec: Proportion of residents with secondary school or higher education	Number of residents in the borough with secondary school or higher education divided by the total residents	INE
households: Number of households in the borough	Total number of households in the borough (in thousands)	INE

Table 8. Market explanatory variables

EXPLANATORY VARIABLES	DEFINITION	SOURCE
MODEL A – MUNICIPALITIES		
***altbbmkshare*: Alternative operators' market share in broadband services in the municipality**	Number of broadband services provided by alternative operators in the municipality divided by the total number of broadband services provided in the municipality	ANACOM
***fibrenear*: dummy indicating if alternative operators have fibre investment in neighbouring municipalities**	**0:** If alternative operators did not invest in fibre in a municipality under 25 km away **1:** if alternative operators invested in fibre in a municipality under 25 km away	ANACOM
MODEL B- BOROUGHS		
***altaccess*: Number of retail access provided by alternative operators**	Thousands of retail accesses provided in the retail market by alternative operators (LLU accesses and own infrastructure accesses)	ANACOM

Table 9. Regulatory explanatory variables

EXPLANATORY VARIABLES	DEFINITION	SOURCE
MODEL A – MUNICIPALITIES		
***priceLLU*: Regulated price of the LLU**	Installation price divided per 24 months + monthly rental price for the local loop (in Euros)	ANACOM

Table 10. Descriptive statistics of variables used in model A

MODEL A – DESCRIPTIVE STATISTICS					
VARIABLES	**OBSERVATIONS**	**MEAN**	**STD. DEV.**	**MIN.**	**MAX.**
Investtype	3058	1.208	0.436	1	3
Avrnrhh	3058	1.390	0.647	1.002	6.066
Youngindex	3058	21.373	3.168	11.6	32.7
Avrmrevenue	3058	7.572	1.477	5.219	16.925
Altbbmkshare	2729	0.112	0.157	0	1
priceLLU	3058	12.543	2.284	10.573	15.462
Kmductssqkm	3058	0.387	0.552	0.0196	2.028
Fibrenear	3058	0.0265	0.161	0	1
ivLLUexcept	3058	126501.8	128028.5	-6763	305244

Table 11. Descriptive statistics of variables used in model B

MODEL B – DESCRIPTIVE STATISTICS					
VARIABLES	**OBSERVATIONS**	**MEAN**	**STD. DEV.**	**MIN.**	**MAX.**
Investhh	4050	0.012	0.904	0	1
Invest	4050	0.025	0.155	0	1
Altaccess	4050	1.325	4.155	0	32.837
Households	4050	0.944	2.025	0.013	24.782
Popdens	4050	0.505	1.707	0.001	29.499
Oldbuilding	4050	0.162	0.135	0	0.966
Educsec	4050	0.169	0.085	0	0.632

ANNEX 5 – RESULTS MODEL A

Table 12. Estimated coefficients in Model A

EXPLANATORY VARIABLES	POOLED ORDERED PROBIT – COEFFICIENTS			
	SIMPLE	IV	LAG INVEST	IV + LAG INVEST
lag.investtype	-	-	3.576 (0.000)	3.601 (0.000)
Avrnhh	0.593 (0.001)	0.598 (0.001)	0.385 (0.002)	0.337 (0.004)
Youngindex	0.114 (0.000)	0.115 (0.000)	0.075 (0.000)	0.068 (0.000)
Avrmrevenue	0.242 (0.001)	0.238 (0.001)	0.119 (0.004)	0.138 (0.001)
Altbbmkshare	2.572 (0.000)	2.570 (0.000)	0.735 (0.000)	0.683 (0.001)
priceLLU	-0.415 (0.000)	-0.420 (0.000)	-0.099 (0.000)	-0.050 (0.089)
Ductskmsqkm	0.298 (0.015)	0.0.297 (0.015)	0.268 (0.001)	0.273 (0.001)
Fibrenear	0.959 (0.000)	0.949 (0.000)	0.244 (0.379)	0.334 (0.254)

Note 1: In parenthesis we report the p-values associated to the null hypothesis: Coefficient equals zero. Significance level=0.05.
Note 2:Estimations with cluster robust standard errors.
Note 3: The explained variable is investtype: Alternative operator's investment type in the municipality.

Table 13. AME in Model A – Probability of using bitstream access

EXPLANATORY VARIABLES	POOLED ORDERED PROBIT – AME – PROB(INVESTTYPE=1)			
	SIMPLE	IV	LAG INVEST	IV+ LAG INVEST
lag.investtype	-	-	-0.026 (0.000)	-0.249 (0.000)
Avrnhh	-0.010 (0.000)	-0.101 (0.000)	-0.027 (0.001)	-0.023 (0.001)
Youngindex	-0.019 (0.000)	-0.019 (0.000)	-0.005 (0.000)	-0.005 (0.000)
Avrmrevenue	-0.041 0.000	-0.040 (0.001)	-0.008 (0.008)	-0.010 (0.004)
Altbbmkshare	-0.432 (0.000)	-0.433 (0.000)	-0.052 (0.000)	-0.047 (0.000)
priceLLU	0.070 (0.000)	0.071 (0.000)	0.007 (0.000)	0.003 (0.101)
Ductskmsqkm	-0.050 (0.004)	-0.050 (0.013)	-0.019 (0.001)	-0.018 (0.000)
Fibrenear	-0.161 (0.000)	-0.160 (0.000)	-0.017 (0.371)	-.0231482 (0.240)

Note 1: In parenthesis we report the p-values associated to the null hypothesis: AME equals zero. Significance level=0.05.
Note 2: Standard errors calculated using the Delta-Method.
Note 3: The dependent variable is the investment type in the municipality.

ANNEX 6 – RESULTS MODEL B

Table 14. Estimated coefficients and Specification tests – One-part model

EXPLANATORY VARIABLES	QML			
	Logit	Probit	Loglog	Cloglog
Altaccess	.0689 (0.000)	.0366 (0.000)	.0349 (0.000)	.0408 (0.004)
Households	.1932 (0.000)	.0914 (0.000)	.0679 (0.000)	.1500 (0.000)
Popdens	.1558 (0.000)	.0784 (0.000)	.0600 (0.001)	.1511 (0.000)
Oldbuilding	-3.0951 (0.002)	-1.6861 (0.000)	-1.6369 (0.000)	-1.8892 (0.021)
Educsec	9.6965 (0.000)	4.5495 (0.000)	3.3084 (0.000)	8.3446 (0.000)
Constant	-8.1761 (0.000)	-3.9896 (0.000)	-2.7224 (0.000)	-7.5596 (0.000)
SPECIFICATION TESTS				
RESET2	0.000	0.007	0.462	0.001
RESET3	0.000	0.006	0.953	0.000
GOL	0.000	0.016	0.036	0.464
GOFF1	0.000	0.008	-	0.009
GOFF2	0.001	0.006	0.940	-
P-TEST				
H1: logit	-	0.002	0.000	0.183
H1: probit	0.001	-	0.002	0.185
H1:Loglog	0.010	0.033	-	0.233
H1: Cloglog	0.028	0.011	0.000	-

Note 1: Below the coefficients we report the p-values associated to the null hypothesis: Coefficient equals zero. Significance level=0.05.
Note 2: Estimations with robust standard errors.
Note 3: For the specification tests we report the p-values for the null hypothesis: the specification is appropriate.
Note 4: Explained variable is *investhh*: % of households covered by alternative operators' fibre in the borough

Table 15. Estimated coefficients and Specification tests – Two-part model

EXPLANATORY VARIABLES	First Part (ML)				Second Part (QML)			
	Logit	Probit	Loglog	Cloglog	Logit	Probit	Loglog	Cloglog
Altaccess	.1734 (0.000)	. 0905 (0.000)	.0860 (0.000)	.1283 (0.000)	-.0152 (0.301)	-.0090 (0.309)	-.0104 (0.281)	-.0089 (0.376)
Households	.2926 (0.000)	.1438 (0.000)	.1060 (0.000)	.2376 (0.000)	.0159 (0.481)	.0099 (0.472)	.0117 (0.454)	.0103 (0.503)
Popdens	.0870 (0.030)	.0463 (0.031)	.0398 (0.109)	.0936 (0.000)	. 1036 (0.008)	.0630 (0.007)	.0691 (0.014)	.0724 (0.002)
Oldbuilding	-5.1680 (0.000)	-2.6465 (0.000)	-2.5151 (0.000)	-3.4874 (0.000)	-1.9722 (0.043)	-1.1994 (0.039)	-1.2613 (0.040)	-1.4755 (0.031)
Educsec	8.9003 (0.000)	3.9919 (0.000)	2.6281 (0.000)	6.7977 (0.000)	4.8104 (0.000)	2.9702 (0.000)	3.5539 (0.000)	3.1644 (0.000)
Constant	-7.4573 (0.000)	-3.6240 (0.000)	-2.3770 (0.000)	-6.7334 (0.000)	-2.0561 (0.000)	-1.2754 (0.000)	-1.1227 (0.000)	-1.7657 (0.000)
TESTS								
RESET2	0.000	0.000	0.000	0.000	0.809	0.798	0.952	0.594
RESET3	0.000	0.000	0.000	0.000	0.690	0.710	0.876	0.526
GOL	0.000	0.000	0.000	0.239	0.900	0.661	0.701	0.216
GOFF1	0.000	0.000	-	0.000	0.823	0.786	-	0.581
GOFF2	0.000	0.000	0.000	-	0.784	0.809	0.958	-
P TEST								
H1: logit	-	0.521	0.000	.312	-	0.842	0.274	0.483
H1: probit	0.000	-	0.000	.312	0.824	-	0.309	0.468
H1:Loglog	0.005	0.123	-	.313	0.286	0.388	-	.465
H1: Cloglog	0.000	0.000	0.000	-	0.349	0.416	0.334	-

Note 1: Below the coefficients we report the p-values associated to the null hypothesis: Coefficient equals zero. Significance level=0.05.
Note 2: Estimations with robust standard errors.
Note 3: For the specification tests we report the p-values for the null hypothesis: the specification is appropriate.
Note 4: Explained variable in the first part of the model is *invest*: Did the operator invest in fibre in the borough?
Note 5: Explained variable in the second part of the model is *investhh*: % of households covered by alternative operators' fibre in the borough

Table 16. Specification tests – Cloglog

	H0: One-part model – Cloglog			
H1: Two-part model	Second Part			
	Logit	Probit	Loglog	Cloglog
First Part: Cloglog	0.000	0.000	0.000	0.000

Note 1: We report the p-values for the null hypothesis: the specification is appropriate. Significance level=0.05.
Note 2: Estimations with robust standard errors.

Table 17. Specification tests – Cloglog + Cloglog

	H0: Two-part model - Cloglog + Cloglog			
H1: One part model: Cloglog	0.109			
H1: Two-part model	Second Part			
	Logit	Probit	Loglog	Cloglog
First Part: Cloglog	0.021	0.046	0.055	-

Note 1: We report the p-values for the null hypothesis: the specification is appropriate. Significance level=0.05.
Note 2: Estimations with robust standard errors.

Table 18. Specification tests – Cloglog + Probit

	H0: Two-part model - Cloglog + Probit			
H1: One part model: Cloglog	0.151			
H1: Two-part model	Second Part			
	Logit	Probit	Loglog	Cloglog
First Part: Cloglog	0.010	-	0.244	0.216

Note 1: We report the p-values for the null hypothesis: the specification is appropriate. Significance level=0.05.
Note 2: Estimations with robust standard errors.

Table 19. Specification tests – Cloglog + Logit

	H0: Two-part model - Cloglog + Logit			
H1: One part model: Cloglog	0.208			
H1: Two-part model	Second Part			
	Logit	Probit	Loglog	Cloglog
First Part: Cloglog	-	0.014	0.912	0.117

Note 1: We report the p-values for the null hypothesis: the specification is appropriate. Significance level=0.05.
Note 2: Estimations with robust standard errors.

Table 20. Specification tests – Cloglog + Loglog

	H0: Two-part model - Cloglog + Loglog			
H1: One part model: Cloglog	0.144			
H1: Two-part model	Second Part			
	Logit	Probit	Loglog	Cloglog
First Part: Cloglog	0.327	0.703	-	0.696

Note 1: We report the p-values for the null hypothesis: the specification is appropriate. Significance level=0.05.
Note 2: Estimations with robust standard errors.

Table 21. AME – Cloglog + Loglog

Variable	AME
Altaccess	.0005
Households	.0011
Popdens	.0009
Oldbuilding	-.0255
Educsec	.05772